From Mechanistic to Organismal Biology

E. S. Russell

We continue here our effort to "resurrect" some of the remarkably prescient writings from scientists before the modern era of molecular biology—a scientist in this case whose criticisms of the early development of genetic theory sound like they could have been written today. The following text is excerpted from Chapters 9 and 10 of E. S. Russell's The Interpretation of Development & Heredity: A Study in Biological Method, *published originally in 1930. For some notes about Russell, see "When Holism Was the Future" in* In Context #22 *(http://natureinstitute.org/pub/ic/ic22/russell.htm).*

The Process of Abstraction

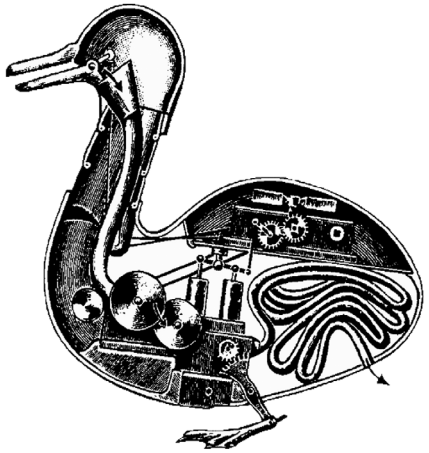
If we consider the various ways in which, for the purposes of science, abstraction is made from the living reality of the organism, we shall see how the different theories of development have arisen, and how their character has been determined by the mode of abstraction they adopt.

Biology occupies a unique and privileged position among the sciences in that its object, the living organism, is known to us not only objectively through sensory perception, but also in one case directly, as the subject of immediate experience. It is therefore possible, in this special case of one's own personal life, to take an inside view of a living organism.

When we conceptualize this living experience, we arrive at a definition of organism which, though it is abstract and schematic as compared with the experienced reality, is yet rich in content as compared with the still more schematic representations commonly employed in biology. The concept of organism which we derive from a study of direct experience is that of a continuing psycho-physical unity or individuality, which acts as a whole in relation to its environment.

The first stage of abstraction from the concrete reality of organism as experienced is the concept of organism as a psycho-physical unity or individuality.

The second step along the path of abstraction—namely, the elimination of the psychical—is one which nowadays is almost universally taken as a matter of course. It is a step of immense importance, for it introduces at once a dualism of matter and mind, and creates between them a dividing line which can never be crossed. To reintroduce mind into living things, to reconstitute the living unity, it is necessary to have recourse to such lame expedients as psycho-physical parallelism or psycho-physical interaction, or to adopt some form of dualistic vitalism. With the psychical aspect eliminated, the organism becomes a material system, similar in nature to, though more complex in structure than, other material bodies.



The complexity and variety of organization naturally provoke investigation, and give rise on the one hand to the science of organic form, in which types of structure are distinguished and their variants classified (morphology), and on the other hand to the study of the functioning of the different types (physiology). Morphology tends to remain a formal and abstract science, until it is revivified by the study of function; physiology develops very soon the concept of the organism as a complicated mechanism. Here two somewhat diverse points of view emerge—the teleological and the dynamical.

A machine is definitely a teleological construction, and the working of its parts can be fully understood only if their relation to one another and to the action of the whole be realized and grasped. The same view can be applied to the organism, which may be regarded as a teleological mechanism or machine, albeit of extreme complexity. The teleological point of view has undoubtedly great heuristic value in biology, and is in fact much used.

But the progress of physico-chemical study applied to the living thing has shown that the organism cannot be separated from its environment, with which it maintains the closest relations of interchange of matter and energy. Hence the conception arises of the organism as a physico-chemical system, standing in closest connexion with its

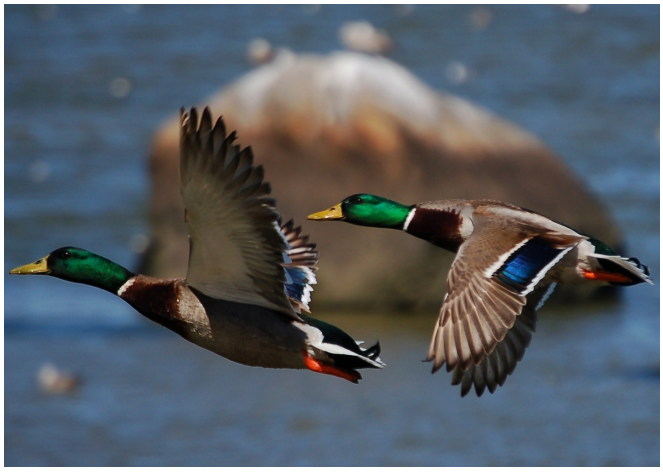
physico-chemical environment. The simple concept of the organism as a formed machine is then replaced by the more general concept of it as a dynamical system. From this to the application to the organism of the general philosophical concept of material determinism there is only a step, and the organism tends then to become merged in, and hardly distinguishable from, the general flux of material events.

Abstraction from the living reality of organism reaches of course its highest degree in the mathematical or statistical treatment of living things. Here the organism is regarded merely as a numerical value—a number, a weight, a dimension. Mathematical laws of growth, for instance, may be worked out, in which the organism is treated simply as a quantity which increases in accordance with a certain formula. Clearly such formulation gives only the most general and abstract account of the process, highly useful though it may be within strict limits.

To recapitulate the main stages of abstraction from the organism as a whole—we get from the *living reality* as *experienced*, which is our ultimate standard, *first,* the primary abstraction or conceptualization as *psycho-physical unity* or *individuality*, from which may be developed the organismal theory of living things, and *second*, by abstraction from this of the psychical aspect, the ordinary 'scientific' conception of the organism as a *machine*, or more generally a *physico-chemical system*.

Of Wholes and Parts

The use of analysis is characteristic of science generally. Given a complex body, the chemist proceeds immediately to resolve it into its elements, to determine their relative proportions, and in some cases their architectonic arrangement. The same tendency is shown very clearly in biology. Given an organism, the morphologist's first thought is to discover its structure in minutest detail, to resolve it into its constituent organs and cells and their arrangement. The same process of analysis is applied to what appears to be the ultimate vital unit, the cell; this is decomposed into its constituent parts, nucleus, cytoplasm, chromosomes, mitochondria, and so on, and each of these elements is further resolved as far as may be into smaller parts, as for instance chromomeres, linin threads, and granules of all kinds. The process is even extended beyond the limits of microscopical vision, and hypothetical units, such as biophors, bioblasts, and genes, are freely invented to fill the gap between the just visible units and the complex colloidal molecules which make up the bulk of living matter. The method of morphological analysis leads then to a biological atomism, analogous to the atomism of the chemist.



From the physiological side also there starts a similar process of analysis or decomposition. The physiologist studies for choice isolated organs or organ-systems – the properties of a muscle-nerve preparation, for example, or the functions of the isolated heart. Even when he studies a major organ-system as a whole, the nervous system for instance, his method remains analytical; he resolves the action of the nervous system into the action of reflex arcs in their interconnexion with one another.

Now this analytic method, employed both in the study of form and in the study of function, is quite indispensable in biological research, and has yielded extremely valuable results. It is essential also for organismal biology. But we must note that it necessarily entails abstraction. The initial step which leads to abstractness of treatment is of course the isolation and definition of parts and part-processes as such. To define is to separate, and to separate is to ignore or to disregard in some measure the relations with other parts and with the whole. In the living thing there are in actuality no separate parts, no separate processes, for no part can be adequately characterized save in terms of its relations to the whole.

By the process of morphological analysis we can, for instance, resolve the organism into its component cells, but the cells so distinguished are abstract morphological units, characterized statically, in terms of structure. Actually the living tissue-cell is indissolubly linked up, by reason of its functional activity, with the neighbouring cells, and, through the *milieu interne* and the nervous system, with the general activities which the whole organism is pursuing. The tissue-cell takes part in the activity of the whole, and it is dependent for its own continued existence as a living part upon its manifold functional relations with the whole. If we distinguish it as an independent unit or component we necessarily abstract from its full reality; we disregard its functional connexions or relations with the whole, and form a simplified and static conception of it.

In the living thing there *are* no completely separable or independent parts; if we distinguish separate units or components it is at the cost of artificially simplifying our definition of them by abstracting from their continuing relations with the activity of the organism as a whole. It is primarily because the parts or constituents so distinguished are to a large extent abstract that it is impossible fully to reconstitute from them the whole from which they are themselves derived by the process of analytical abstraction. This is true even if we characterize them physiologically.

Contrast in this respect a machine. The machine has separate parts; it can be taken to pieces and put together again; its parts can be adequately characterized in terms of their own structure, apart from their relations to the machine as a whole. This is not the case with the organism. Here the parts can be adequately characterized only in terms of their functional relations to the organism as a whole. These relations, which are manifold and subtle, involve time and process, a taking part or merging in the total activity of the continuing unity which is organism.

The unity of the organism is accordingly not decomposable without loss, and cannot be resynthesized in its original completeness from the abstract components distinguished by analysis. We may sum this up in the following cardinal law of biological method: *The activity of the whole cannot be fully explained in terms of the activities of the parts isolated by analysis, and it can be the less explained the more abstract are the parts distinguished.*

Since analysis is necessary for biological science we must accept the fact that our biological results will be to a certain extent abstract and schematic, and we must strive to correct this abstractness as far as possible by distinguishing only such elements as are concrete and biological, not physico-chemical and abstract, and by carrying out as complete a reconstitution or reintegration of such elements as may be possible.

It follows from what we have said that the parts cannot be understood save in relation to the whole, and so we arrive at our second law of biological method: *No part of any living unity and no single process of any complex organic activity can be fully understood in isolation from the structure and activities of the organism as a whole.* To regard any process or structure by itself without relating it to the general activity of the organism is to deal with something which is in large measure abstract and unreal. To re-invest it with some degree of concrete reality it is necessary to re-integrate it into the whole. Its isolation by analysis should be provisional only, and after analysis there should always follow re-integration. We know that the reconstitution of the original unity will be incomplete, but we must make it as complete as possible.

Particulate Theories

There is, however, a misuse of analytical or disintegrative method which leads to disastrous consequences. The organism is by this method resolved into cells, cells into their constituent parts, and the substance of the cell into hypothetical units, to which are attributed many of the essential vital functions. This fractionalization is a method of approach to the problems of heredity and development which has become traditional and habitual, so that nowadays any other way of looking at these problems is rarely considered, and it is of course the basal method underlying all particulate theories. It is generally, though not invariably, coupled with the idea that some at least of these ultimate units represent and give rise to, or at the least co-operate in the formation of, particular parts or characters of the organism. This idea of representative particles is, we have seen, a very old one, dating back at least to the Greeks, and revived again by Bonnet, Darwin, and Weismann. It derives some of its force and verisimilitude from the fact that certain characters appear to behave as units in inheritance—a particular lock of white hair, for example, may recur from one generation to another.

From facts of this kind it is easy, but illogical, to conclude that all characters of the organism are separable in inheritance, that the organism is, as it were, a bundle of separate characters, represented separately in the germ, which can be shuffled about, so that some of the offspring get one set, some another, and so on indefinitely. It may be remarked that to distinguish separate characters at all in the organism has necessarily something artificial and abstract about it. Obviously the number of characters that can be distinguished is infinite, but yet none of them is in reality separate from the rest. The lock of hair, for instance, clearly cannot arise apart from the organism which manifests it. Separate or separable characters are therefore to a very large extent abstractions. But the idea that the organism is a composite of separate characters, each of which is represented in the germ by a separate vital unit, seems to have a perennial fascination for the human mind.

The attempt to find an internal formative mechanism as the cause alike of heredity and development, which is characteristic of nearly all modern theories, results necessarily in this separation of agent and material, just as the attempt of the vitalists to reintroduce life into the mechanistic abstraction that stands for organism results in a dualism or opposition between the immaterial agent and the material mechanism which it in some way controls. In either case one arrives at a *Deus ex machina.* The nuclear organization, the germ-plasm, or the gene-complex of modern theories, is accordingly invested with semi-magical powers of control.

The organism is regarded as a collocation of subordinate parts, of units of diverse degree, but the problem of 'composition', organization, or wholeness is ignored, and attention is concentrated on the lowest grade of these units. These are supposed to represent the parts or the characters of the developed organism, and in some way, which always remains mysterious, to give rise to them in the course of development. (The hereditary units being the purest of abstractions, it is of course natural that their relations with the characters they determine should remain obscure.)

Hereditary units and 'determinants' of all kinds are pure abstractions; the process of analysis has been carried so far that it is impossible to reconstitute from these purely abstract elements the activities of the cell or the organism as a whole. All that is left then to the theorists is to smuggle back into the determinants or other 'parts' the powers and functions which belong rightly to the organism as a whole, and have inevitably been dropped out during the process of analysis. The concept of the organism as a whole, which has been destroyed by unrestrained analysis, is reintroduced surreptitiously, and the qualities and powers of the organism as a whole attributed to certain abstract and subordinate *parts* of it, just as to entelechy are ascribed powers and capabilities which properly belong only to the whole organism.

The Organismal Perspective

It is perfectly possible to frame a working conception of organism which shall be less abstract than that of mechanism and shall do less violence to the essential facts. Let us see if we can formulate such a conception. In the first place, the functional unity of the living thing must be emphasized. The activities of the parts work together for the good of the whole; the meaning of any functional activity can be understood only if its relation to the activity of the whole is known. It is not really possible to study adequately any one function, e.g. excretion, without taking into account its relations to other functions and conditions, as assimilation, circulation, the composition of the internal medium, and so on, and without determining what part it plays in the economy of the whole.

This teleological conception can, however, be applied also to a machine; this also is a unity, in which each part has a definite role to play in relation to the functioning of the machine as a whole. But a machine can properly be analysed into constituent and independent parts, whereas in the living organism separate parts can be distinguished only by the artifice of abstraction, and its unity is not decomposable without loss. The organism differs from the machine also in another respect, in that all its functions are directed to one or other of three great ends, namely the development of specific form and activities, the maintenance or restoration of such typical form and activities, and the reproduction of specific type. None of these broad characteristics of living things is shared by any machine.

We must therefore add to our first point – that the organism is a functional unity – the further characteristic that the functional activities of the living thing are essentially related to the ends of development, maintenance, and reproduction. Implied in this fuller definition are certain temporal relations of vital activities which are fundamental for our conception of organism. The organism is *not,* like a machine, a static construction, but a constantly changing organization of functional activities, which tends towards some end, and in such tendency is influenced by its past. Its activity is related both to its past and to its future.

That these are not vague general assertions made to bolster up a preconceived notion of the organism is made clear if we consider fairly and with an open mind the general activities of living things. That in development there is a definite progression to an end or goal, i.e. a reference to the future, cannot be denied. That the course of development is essentially influenced by the past history of the race is likewise difficult to deny, and we sum up such facts of the historical background of development in the laws of heredity and recapitulation. The reference to past and future is clear also in all cases of restitution or regeneration, and it is so obvious in behaviour as to need no pointing out. Reproduction too is essentially a preparation for the future, and its course is determined and defined by what, for want of a better word, one might call the organic tradition handed down by countless ancestors.

Let it be made quite clear that this reference to past and future is not necessarily or usually (so far as we know) a conscious reference on the part of the organism. It is, for example, necessary for description and understanding of the bald facts that we use the word 'end' in considering the phenom-

ena of development, but it is not implied that the developing organism is conscious of the end or purpose which appears *to us* to be embodied in its development. Whether the organism makes conscious reference to the past and the future is really a point of minor importance; what is important to realize is that organic activities are objectively of such a character that we cannot fully understand them unless we consider them in relation both to the past and to the future of the organism.

When in an embryo there is formed an eye long before it can function, when we see the germ-cells segregated early and slowly coming to maturity, when we watch the mother-bird building a nest for eggs that are not yet laid, we must, if we are to understand these actions at all, take into consideration their essential reference to the future. When we see in the development of the frog the reproduction of stages passed through by its ancestors near and remote, the formation and destruction of organs which had significance is some distant past and now have none, when we see the mature eel setting forth on its dangerous journey to spawn thousands of miles away in the depths of the Atlantic, we must in accounting for these facts bear in mind their essential relation to the past history of the race; they can be understood only on the hypothesis that in some way or other the past of the organism and of its ancestors still influences its present activities.

Time then enters as an essential element into our definition of organism. The living thing at any one moment of its history must be regarded as merely a phase of a life-cycle. It is the whole cycle that is the life of the individual, and this cycle is indissolubly linked with previous life-cycles—those of its ancestors right back to the dawn of life. This is what we mean by the continuity of life. And the activities of the organism at any stage of its career can be understood only if they are reintegrated in the individual and the evolutionary life-cycles.

There is yet another characteristic to add to our concept of organism before it can be regarded as reasonably complete, and that is a characteristic belonging to the functions and activities themselves. The action of the whole has a certain unifiedness and completeness which is left out of account in the process of analysis. This unifiedness of response can best be illustrated by reference to one's own experience of living—one's actions for example in playing tennis are unified responses of one's whole physical and mental being at the time, and an analysis of them into their constituents would inevitably miss out the essential point, namely their accurate co-ordination and applicability to the situation arising. In our conception of the organism we must then take account of the unifiedness and wholeness of its activities. This is the more necessary since we have seen that the activities of the organism all have reference to one or other of three great ends, and that both the past and the future enter into their determination. Such characteristics can belong only to actions possessing a concrete reality which is not wholly exhausted by analysis into constituent elements or parts.

We have now sketched, in the very broadest outline, a conception of organism which is completely free from any mechanistic assumption, and seems on the face of it to fit the main facts reasonably well. Let us summarize our conclusions. We agree that biology is essentially the study of individual living organisms, that the individual organism, whether unicellular or multicellular, is the unit to which all biological concepts and laws must relate. The organism is essentially a *continuing* unity, and all its activities are directed towards the ends of development, maintenance, and reproduction; these have reference to the future and to the past of the organism, and cannot be understood unless these temporal relations are taken into account; its activities have a certain unifiedness and wholeness which makes them irreducible to processes of lower order; the action of the organism as a whole is therefore not completely explicable in terms of the actions of the parts, and still less in terms of physical and chemical action.

We cannot claim for organismal biology anything like complete adequacy, or a close approach to full understanding of the living thing. The full secret of life will always elude a purely scientific treatment; it may be experienced, imagined, and felt, but never completely pinned down and explained. Something will always escape definition and measurement. Nevertheless we may rightly claim that the organismal method gives us a biology less remote from the truth than the abstract and schematic account to which the materialistic assumptions would limit us. It gives us a unitary biology, in which the abstractness and excessive analysis of the materialistic method are avoided; it allows us to look upon the living thing as a functional unity, disregarding the separation of matter and mind, and to realize how all its activities — activities of the whole, and activities of the parts, right down to intra-cellular unities — subserve in co-operation with one another the primary ends of development, maintenance, and reproduction.