In Dispraise of Reductionism

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Thinking of Biology

In dispraise of reductionism

In my long career I have often met other scientists—chemists, physicists, biologists—who declared themselves steadfast reductionists. When I asked, naively, what this meant, I usually got the answer that a reductionist holds the strong belief that all phenomena of life are governed by nothing but the laws of physics and chemistry. Later, becoming aware that reductionism was a much broader term, employed in philosophy, sociology, politics, and other disciplines, I came upon a shrewd remark by the philosopher Roger Scruton, pointing out that the idiom of reductionism included, as a favorite expression, this very "nothing but."

Dangers of premature simplification

Among several definitions of the term "reductionism," the supplement of the majestic Oxford English Dictionary (Vol. 3) offers the following definition (p. 1139): "The practice of describing organic processes in terms of the physico-chemical reactions which underlie them." Actually, biological reductionism does more than describe the life processes on that basis. After all, you can describe the life of the Pharaohs in terms applicable to the French Court of the Bourbon, although that will not get you far. Reductionism claims that life is reducible to, that it is "nothing but," physics and chemistry. It is a normative, fundamentalist creed, driving generalization to an unwholesome peak. It would certainly be foolish to maintain that Louis XIV was nothing but a French Cheops. What is distinctive about each is surely more important than what they have in common.

I cannot say that I look with great favor on people carrying a descriptive label, as it were, on their foreheads, proclaiming their adherence to one of the many sects and doctrines whose names end with -ism: hedonism, monetarism, Darwinism, and so on. I prefer unclassified and, indeed, unclassifiable human beings. I would not even want, therefore, to describe myself as an antireductionist. There has, incidentally, occurred a curious change of sectarian tags: One used to speak of vitalists, of whom there were many, believing in the existence of an as yet unidentified life force, *vis vitalis*, and of antivitalists, a timid bunch, denying the reality of such a force. Now the "anti" has been affixed to the other party, and a small group of antireductionists is facing a vast crowd of fervent biomachinists. This switch in proportions and labels testifies not only to the enormous advances that inductive science has made in the last 60 years, but also to a change in the character of the people choosing science as their profession.

When, in the old days, the practitioners of science approached such a formidable problem as "What is life?" most of what was said when thoughtful and cautious scientists talked together certainly never saw print. What must have awakened the attention of many was the existence of entire families practicing a craft, a skill, or even a high art with great distinction and in several generations. I am thinking of such painter families as the Cranach and the Carracci or of musicians' families, such as the Bach. To my mind, the Mozart family does not belong to that illustrious list. And yet, when the sperm of Leopold Mozart fertilized the egg of his wife, former Anna Maria Pertl, and there appeared, in due course, the seventh child, Johann Chrysostomus Wolfgang Theophilus, was that not a true miracle never to be explained by those nothing buts? (I know, in science "never" is a long word.)

Actually, the scientists that I imagined talking about such matters in the old days managed to combine their materialism with a form of deism; they took the givenness of life for granted and did not try hard to reconcile the "inconceivable mystery of life" (Hegel1) with what they knew of physics and, later, of chemistry. There were exceptions, but those tended to be found among philosophers and writers rather than among practicing scientists. Readers of Diderot's *Le Rêve de d'Alembert* or Holbach's *Le Système de la Nature* and especially of that silly book *L'Homme Machine* by La Mettrie will realize how "unscientific" speculations about life could still be in the eighteenth century. We are now wont to include microorganisms, plants, animals, and men in the realm of life, but those ancient materialists had learned from Descartes that animals were automata, whereas human beings belonged to a different, unique class. The revival of the feeling of how great a mystery life really is came only later, with the onset of the Romantic Era.

It was during the Victorian Era that scientific research began in a form that we can still recognize today. The various scientific disciplines were established and sanctioned through the creation of corresponding university chairs and departments. The advance in knowledge was orderly, and it occurred with a speed to which the human mind could adapt itself. This state continued until the Second World War, when a hectic acceleration and intensification

by Erwin Chargaff

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1Hegel speaks, in his *Jenenser Logik* (II, 416) of life as "ein unbegreifliches Geheimnis" (an inconceivable mystery).
took place simultaneous with, and probably caused by, the entrance, on a large scale, of the United States on the scientific scene. So far as the biological sciences are concerned, one could claim that their modern phase began around 1945. If I place the emphasis on biology, of which the medical sciences are an application, it is because that is where the fallacy of reductionism becomes evident.

**Provisional character of scientific definitiveness**

It seems that the greatest gift that God, Providence, Darwin, or the National Institutes of Health bestowed on the sciences is the preliminary character of scientific research. The very survival of science is vouchsafed by the provisional nature of its findings and its claims. It can never be certain. Otherwise, it would long have come to an end, as does an edifice that has reached its roof. (Only a New York builder would retort that the air rights over the sciences have not yet been assigned.)

The certainty of that uncertainty seems, however, to have dwindled in our times. An observer of present-day scientists and scholars will find only a few who appear to be aware that even their firmest supports must carry an expiration date. The majority clearly are imbued with the conviction that they have reached the peak of attainable perfection. If, at a certain period, they seem engaged, on the contrary, in opening undreamed-of vistas before us, those belong to the realm of fund-raising and publicity rather than to that of reality.2

I do not believe that there will be much objection to the claim that biology, in its struggle to become an exact science, has made enormous advances in the last 50 years. To make them, biology has had, however, to abjure its very name—that is, to be the science of life. The more exact it became, the more distant from the state of living—an appraisal that is certain to be rejected by all practitioners of what has become a new scientific discipline, molecular biology, whose very name strikes me as something like ambrosia with garlic. Molecular biology is a medley into which enter many established sciences: not only chemistry and physics but also biochemistry, microbiology, virology, immunology, genetics, and a few others. The difficulty of becoming competent in any one of these venerable and established disciplines may explain the unavoidably amateurish flavor of many publications in this relatively young science.

It is perhaps not surprising that it is from molecular biology that one hears the loudest assertions of reductionist fanaticism. Practitioners of this discipline are forced to use many half-understood techniques, yielding many results that they are not really competent to evaluate. This fact does not keep them from agreeing on one thing, namely, that they all know what life is.

**Explanation is not understanding**

I am not at all persuaded that the phenomena of living can be explained by the presently known laws of physics and chemistry, but even if life were explicable, is it also comprehensible? Did Hegel speak of life as the "inconceivable mystery" only because in his time the exact sciences were not developed sufficiently, whereas now we know most of what can be known (or at least all that has to be known, so as to "explain" life)? Actually, I do not think that we even can do the latter in a form that would render unnecessary the quotation marks that I have used here.

It would be easier to make clear to a layman than to a scientist that the words "to explain" and "to understand" are not necessarily communicating vessels, as it were. For me, in fact, the opposite often seems to be the case: The more I get explained by the experts, the less I understand what they are talking about. Indeed, sometimes I suspect that the experts do not understand it either. Consider a simple machine at rest: One may, by inspecting the parts and contemplating how they fit and work together, be able to explain the manner in which it produces motion, exerts force, or whatever. But only after seeing it do actual work will one begin to understand it. Only then shall we also recognize the source of the energy that it requires, be it steam, electricity, or another source, and be able to describe the fruits of its labor. Pull out the plug, and the machine stops; put back the plug, and the machine resumes work. When we deal with a living organism, to pull out the plug is easy: The synonym is to kill the organism. But where is the socket to which one could return the plug? At the end, even Lazarus was dead.

There may be objections to my simile of a plain machine, which, like most similes, is not entirely superposable on reality. One may point out that if one or the other part is broken or bent in my machine while it is disconnected, then it, too, will not resume work after being reconnected. Identify and replace the part that was damaged when the plug of life was pulled out, the objector will say, and you will be able to resurrect Lazarus as often as you wish. Such a notion sounds stupid to me; after all, a machine at rest does not rot.

In denying that a living cell is a mere collage of chemical compounds, and in questioning the reducibility of life to the laws of physics and chemistry, I am faced with the question: Are all relevant laws already known? It was this very question that led the great theoretical physicist Erwin Schrödinger to reflect on the nature of the state of living and that made him write his small and influential book *What Is Life?,* which appeared in 1945. The impact that Schrödinger's book had on my thinking I have described in *Heraclitean Fire* (1978). Here is one of the conclusions to which the eminent physicist came:

Living matter, while not eluding the laws of physics as established to date, is likely to involve other
laws of physics hitherto unknown which, however, once they have been revealed, will form as integral a part of this science as the former.

One can see that Schrödinger was an antireductionist until further notice. I doubt that he would have changed his point of view, were he still alive. The less so, as no further laws of physics pertaining to the mystery of life appear to have come forward in the ensuing 50 years; nor should I have expected it because, if pertinent patterns are to be revealed, such norms would hardly belong to the realm of present-day exact science. The noisy celebrants of instant scientific glory will shout: "Fifty years is long enough, there are no more laws of physics relating to the specific nature of life to be discovered. We know all that is worth knowing."

Schrödinger was a physicist, so he gave his book the subtitle The Physical Aspect of the Living Cell. Had he been a chemist, he would, of course, have addressed himself to the chemical aspects of the living cell. Such a book—especially if written after, say, 1965—would have been a very fat book indeed. A great deal has been learned in the last 50 years about biochemistry, the science that is concerned with the chemical properties and abilities of the living cell.

In 1987, when the centenary of Schrödinger's birth was to be celebrated, many articles were written that praised the achievements of this great man. There were also several unusually venomous pieces in which the importance of his thoughts about biology was denied. He was taken to task for thinking that it was likely that additional laws of physics and chemistry remained to be discovered, rules as yet unknown that would permit us to understand the workings of a living cell. This as yet unrealized hope belongs precisely to the area of life in which the fallacies of reductionism become evident.

Humans apprehend the occurrences of nature by way of the intellect, and the intellect is surely a faculty of the living organism. To my mind, there exists a real difficulty with respect to deciding whether the scientific method is fully applicable to understanding life. Many of life’s attributes can, no doubt, be so investigated, for instance, the chemistry and physiology of the reactions of the living cell. But is such knowledge sufficient for an understanding of life? Valid scientific conclusions must rest on the availability of an adequate number of premises. I admit that I consider it extremely doubtful that we shall ever be able to draw valid conclusions, because in no other case is science confronted with so enormous, so overwhelming a phenomenon as that of life—a phenomenon whose very contours cannot even be delineated, except through reductionist light-mindedness; and a phenomenon, moreover, whose investigators cannot afford to step back from it because the object of their research is itself a condition of their being able to function. Can life investigate itself?

Life is never “nothing but”

"Copper is nothing but copper"—a harmless, meaningless statement whose validity would not be impaired by the discovery of a few unknown properties of the element. But “life is nothing but the supreme realization of the entelechy of matter"; "life is nothing but a machine for the transformation of inorganic into organic matter"; and "life is nothing but the expression of the urge of a DNA to make more of itself." How ridiculous such statements are! Life is never "nothing but."

Excessive reductionism is, I believe, doing much harm in biology. It has become a subterfuge, an expedient through which researchers can increase their importance by claiming to be studying the problem of life. In reality, they are only scraping around the outworks. A real understanding of life would be comparable to the Second Coming. We should not wait for it.

I may be told that the biological sciences have reached the point at which they can explain the state of living. I deny even that assertion. Biologists can enumerate some of the conditions, but the dark and solemn moment at which life is conferred on a cell or a complex of cells will remain opaque forever. Even the languages refuse to supply us with suitable vocabularies; talk about the concepts of God, life, and death turns almost automatically into prattle.

There remains, besides, a great difference between explaining and understanding. Explanation concerns only human reason, understanding involves the heart. We understand things that we cannot explain, and vice versa. Those who are open to them may understand great works of art, even if they are unable, and feel no desire, to explain them. On the other hand, we can explain the working of an enzyme, a hormone, a receptor; but to understand their meaning, we should require an insight into the plan of nature, into the import of life that I believe is denied us. There may even be some who will, despite the great achievements of the natural sciences, feel that it is best if there remain closed doors for which no key will ever be found.

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