Gaia and creative evolution

René Dubos

Gaia: A New Look at Life on Earth. By J.E. Lovelock. (Oxford University Press: Oxford and New York, 1979.) £4.95.

I HAVE always disliked the expression "Spaceship Earth" to designate our planet and I believe that it has led to faulty thinking about environmental problems. The word spaceship calls to mind a mechanical structure carrying a limited supply of fuel for a defined trip and with no possibility of significant change in design. The Earth, in contrast, has many attributes of a living evolving organism. It constantly converts solar energy into innumerable organic products and increases in biological complexity as it travels through space. I was therefore much interested when Jim Lovelock suggested in *New Scientist* in 1975 that the surface of the Earth behaves as a highly integrated organism capable of controlling its own composition and its environment. He used the name of the Greek Earth goddess Gaia to symbolise this complex biological behaviour of the Earth. Lovelock has now developed the Gaia hypothesis in a book that I have read with immense pleasure. I shall first briefly summarise its factual contents, then formulate a few questions in the hope that they will lead to a further development of the hypothesis.

It is not the first time that the Earth has been regarded as a living organism. In a book entitled *The Land Problem*, Otis T. Mason, one of the early American environmentalists, wrote in 1892, "Whatever our theory of its origin, the earth may be discussed as a living, thinking being . . .". The Gaia hypothesis is more concrete and can best be formulated in Lovelock's own words: "The physical and chemical condition of the surface of the Earth, of the atmosphere and of the oceans has been and is actively made fit and comfortable by the presence of life itself. This is in contrast to the conventional wisdom which held that life adapted to the planetary conditions as it and they evolved their separate ways."

The Gaia concept has its origin in the fact that the chemical composition of our atmosphere is profoundly different from what it would be if it were determined only by lifeless physicochemical forces. In an Earth without life, purely physicochemical phenomena would produce for example an atmosphere containing approximately 98% carbon dioxide with very little if any nitrogen, whereas the corresponding figures for our atmosphere are

approximately 0.03%, 79% and 21%. Lovelock presents numerous other examples of such profound departures from chemical equilibrium and postulates the existence of a global force which is able to bring about and keep fairly constant a highly improbable distribution of molecules. He believes that this hypothetical global force consists of the countless forms of life which create and maintain states of disequilibrium through cybernetic systems. Some of these are described in the book. As I do not have the competence to evaluate the validity of Lovelock's physicochemical arguments, I shall restate the problems he discusses in biological terms with which I am more familiar.

The fitness of an organism to its environment is, of course, an essential condition of its biological success and even survival. All living things seem to be endowed with a multiplicity of mechanisms that enable them to achieve fitness by undergoing adaptive changes in response to those of the environment — genetic changes that occur during the evolution of the species, physiological and anatomical changes that occur during the existence of each particular organism. In higher species and especially in humankind, these biological mechanisms are supplemented by adaptive social forces. Early in the present century, however, the Harvard physiologist L.J. Henderson pointed out that there was more to fitness than the adaptive potentialities of living things. As he claimed in his famous essay "The Fitness of the Environment," the achievement of fitness depends not only on adaptive mechanisms but also on the fortunate fact that the terrestrial environment has certain physicochemical attributes which happen to be just right for life. But this theory now seems essentially meaningless for the following reasons.

Many present forms of life would certainly be annihilated if the surface of the Earth were very different from what it is now. They could not adapt rapidly enough if the salinity, the acidity, the relative proportions of gases, minerals and organic substances — or any of the other physicochemical characteristics of the Earth — were to deviate far from their present values for any length of time. In other words, the present environment does indeed exhibit fitness for the present forms of life but — and this is what Henderson had overlooked — it would have been unsuited to those of the distant past. An atmosphere with 21% oxygen, for example, would have been extremely toxic for the earliest forms of life.

During the past 3.5×10^9 years, the global environment has progressively changed, probably as a consequence of the activities of living things, and living things also have undergone corresponding changes through a feedback process. The Gaia system postulated by Lovelock

therefore seems to be a result of co-evolution. Instead of listing the chemical examples of this creative process discussed by Lovelock, I shall quote a picturesque phrase taken from one of his recent articles: "The air we breathe can be thought of as like the fur of a cat and the shell of a snail, not living but made by living cells so as to protect them against an unfavorable environment."

A few years ago, theoretical discussions were instigated by NASA to consider the possibility of making the planet Mars suitable for human life — which meant providing water, oxygen, moderate temperatures, protection from ultraviolet radiation, and so on. The general conclusion was that Mars could be made habitable only through the progressive introduction of living species capable of creating, over an immense period of time, more and more complex ecosystems similar to the ones which have evolved on Earth during more than 3×10^9 years. This analysis has helped us recognise the profound and innumerable changes that life had to bring about on the surface of primitive Earth to create, for present living things, the fitness of the terrestrial environment that L.J. Henderson had taken as the normal state of affairs.

According to the Gaia hypothesis, the Earth's biosphere, atmosphere, oceans and soil constitute a feedback or cybernetic system which seeks an optimal physical and chemical environment for life on this planet. At any given time, this system results in a relative constancy both in the composition of the environment and in the characteristics of living things. Repeatedly throughout his book, Lovelock refers to this equilibrium as "homeostasis" — a word invented by the Harvard physiologist, Walter B. Cannon, to denote the remarkable state of constancy in which living things can maintain themselves despite changes in their environment.

The word homeostasis, however, does not do full justice to the Gaia concept, which implies in addition that living things have profoundly transformed the surface of the Earth while themselves undergoing continuous changes, in a co-evolutionary process. Practically all the examples that Lovelock discusses refer, in fact, to creative evolution rather than to homeostatic reactions. For example, the accumulation of oxygen in the air which became significant 2×10^9 years ago (as a result of biological photosynthetic activities), probably destroyed many forms of life for which this gas was poisonous. In Lovelock's words, however, "Ingenuity triumphed and the danger was overcome, not in the human way by restoring the old order, but in the flexible Gaian way by adapting to change and converting a murderous intruder into a powerful friend." Cybernetic mechanisms progressively brought about the emergence of biological species capable of living in the presence of oxygen and of using it for the production of energy. In this case, as in

most other environmental changes, the Gaian way was not an automatic homeostatic reaction but a creative co-evolutionary response.

It seems worth considering that the Gaian control results in global homeostasis only over a period of time which is short on the evolutionary scale. One figure will suffice to illustrate the magnitude of the terrestrial changes that are continuously caused by life. In their aggregate, all the green plants now fix approximately 840×10^{12} kilowatt hours of solar energy per year in the form of biomass. This is more than 10 times the amount of energy that all of humankind uses annually, even with its most extravagant technologies. Who can doubt that this continuous process of accumulation of organic matter and energy will eventually affect both the surface of the Earth and various forms of life. Furthermore, Lovelock himself points out that the process of change may pick up speed and complexity as a result of human interventions, and he appropriately quotes me in stating that, on a local level, profound co-evolutionary changes have occurred in certain terrestrial

environments and in their biological systems during historical times.

In the last chapter of his book, Lovelock has the courage to explore the relevance of the Gaian hypothesis to the effects of human interventions into nature. I wish I had space to explain why I agree with him when he states that environmentalists often shoot at wrong targets because the resiliency of the Earth, considered as an organism, probably makes ecosystems more resistant to pollution than commonly believed. As I cannot discuss these problems here, I shall conclude by expressing my wish that in the next edition of his book, Lovelock emphasises not only the homeostatic aspects of the Gaia hypothesis but also its creative aspects. This would be in the spirit of his statement that the Gaia concept is an alternative to the "depressing picture of our planet as a demented spaceship, forever travelling, driverless and purposeless, around an inner circle of the sun". □

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Pollution in perspective

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A Perspective of Environmental Pollution. By M. W. Holdgate. Pp. 278. (Cambridge University Press; London, New York and Melbourne, 1979.) £15.

SOME ten years ago I was invited by a British publisher to write a book with the title *Pollution in Perspective*. This was to have been a 'popular' book in which I would try to distinguish between real, damaging pollution and trivial environmental contamination which, though harmless, nevertheless caused so much public concern. Being an idle fellow I procrastinated, and my text is still mainly in my imagination. Therefore, when I saw Dr Martin Holdgate's new book, with so similar a title, my emotions were mixed. On the one hand I felt guilt for not having completed my own book on such an obviously important subject, and on the other hand I experienced relief that someone else had done the job so competently.

For there can be no doubt that Dr Holdgate has produced an excellent book. Although he modestly denies having given his subject complete coverage, I cannot find any significant gaps. All major topics in the field of pollution are dealt with

clearly, scientifically and with a full understanding of the facts, where these are easily available, and also the lacunae in our knowledge are always mentioned.

The book starts by placing pollution in its ecological context, and then goes on to define pollution and classify pollutants. A very important chapter is "The significance of pathways" which deals with the way substances are dispersed in the air, in fresh water and in the sea. The significance, sometimes overestimated, of the transmission of toxic substances through food chains is assessed. The great value of the book is that it constantly relates the concentrations of specific pollutants in the environment to the real effects on man or other targets. It thus shows how standards for pollution control may be scientifically determined, and how monitoring may be used to determine dangers and enforce controls. The costs of pollution control, and the way these may — or may not — be balanced against benefits are discussed. The international problems caused when pollutants cross frontiers are described.

The general theme is admirably stated in the book's last paragraph:

"Finally, there are grounds for optimism. There appears to be no reason why pollution should be the doom of mankind or the destroyer of the ecological balance of the world. But pollution control is an essential element in sound environmental management. The higher the standards of environmental quality and safety we demand, the more effort we shall have to make, and the more it will cost. It is a matter of wisdom and judgement how much risk is acceptable and how high environmental quality should

stand amid the other goals that compete for the resources of society".

No doubt there are those who will accuse Holdgate of "complacency" for not preaching doom and gloom, but thoughtful readers will welcome his clear assessment of the national and global situation. He shows that if mankind is destroyed by pollution, it will be our own fault.

Within its limits, which I shall discuss later, this book deserves nothing but praise. It is well written, and reasonably free from jargon. It will be a godsend to lecturers in universities, polytechnics and colleges of higher education who have to give courses on pollution or pollution control. Most of them could improve their current lectures simply by reading aloud from Holdgate's text.

My only criticism of the information given is that it is not always up to date. Dr Holdgate is a senior civil servant, with the characteristic respect for his sources, particularly where these are such things as the prestigious reports of the Royal Commission on Environmental Pollution. He reproduces (as others have done) a number of their admirable diagrams. For instance, from their first (1971) report we have graphs showing the amounts of smoke and sulphur dioxide in Britain's air at different dates. These figures show the remarkable improvement in air quality between 1950 and 1968 or 1969. For smoke, we are even given the "projection" for the year 1975, four years before this book appeared. As Dr Holdgate is Director General of Research in the Department of the Environment, where there are many junior scientists who have up-to-date figures for the period since the Royal Commission reported readily available, it is a pity that the diagrams were not redrawn and updated. This is not a trivial point, for the result would have reinforced many of the book's arguments, for the figures would have shown that there has been a further, substantial, improvement in air and water quality right up to the present day.

Notwithstanding this minor fault, this is a book which deserves a wide circulation. However, I fear that its sales will be reduced by the way it has been presented by the publishers, who have not served their author well. The text is set in reasonably clear type, but it is much too small to make reading a pleasure. The sections all bear unnecessary numbers (for example, 2.5.1 Pollution in the air) which may make prospective buyers who run through the pages in a book shop think that they are being offered a government report, and so they will be put off. Finally, the price of £15 for 278 pages (with no expensive plates) will not deter the lecturer who has to deliver a course on the subject, but his students will not be able to afford their own copies. This may, of course, be welcomed by some teachers, who will be able to keep up the pretence