

## LETTER TO THE EDITORS

### GAIA AS SEEN THROUGH THE ATMOSPHERE

THE CLIMATE and the chemical composition of the Earth is usually said to be uniquely favourable for life; indeed, it is not commonly known how small are the changes which might render the planet unsuited for the contemporary biota. An increase in oxygen concentration to 25 per cent would so increase the probability of fires that even tropical rain forests might be in hazard. A change in atmospheric pressure of 10 per cent, assuming that the composition remained unchanged, would cause a change of 4°C in the mean surface temperature; enough to set the world on an unfavourable climatic course. These are but two examples chosen from many which might show just how well suited is the environment of Earth for life. Or, is it more probable that the biosphere interacts actively with the environment so as to hold it at an optimum of its choosing?

The purpose of this letter is to suggest that life at an early stage of its evolution acquired the capacity to control the global environment to suit its needs and that this capacity has persisted and is still in active use. In this view the sum total of species is more than just a catalogue, "The Biosphere", and like other associations in biology is an entity with properties greater than the simple sum of its parts. Such a large creature, even if only hypothetical, with the powerful capacity to homeostat the planetary environment needs a name; I am indebted to Mr. William Golding for suggesting the use of the Greek personification of mother Earth, "Gaia".

As yet there exists no formal physical statement of life from which an exclusive test could be designed to prove the presence of "Gaia" as a living entity. Fortunately such rigour is not usually expected in biology and it may be that the statistical nature of life processes would render such an approach a sterile one. At present most biologists can be convinced that a creature is alive by arguments drawn from phenomenological evidence. The persistent ability to maintain a constant temperature and a compatible chemical composition in an environment which is changing or is perturbed if shown by a biological system would usually be accepted as evidence that it was alive. Let us consider the evidence of this nature which would point to the existence of Gaia.

During the period that life has existed on Earth, at least 3 giga-years, there have been profound changes in the chemical and physical environment. RUBEY (1951), CLOUD (1968), HOLLAND (1964). The pE has gone from less than  $-5$  to  $+13$  and the output of radiant energy from the sun will have increased by approximately one astronomical order, if it is a typical star moving along the main sequence. The change from reducing to oxidizing conditions carried the atmosphere through a sequence of quite different chemical compositions and at the same time the solar output was steadily increasing; yet the geological record and the fact of the persistence of life shows that the surface temperature did not vary by more than a few degrees from its current levels. These changes in the Earth's environment probably, although not certainly, occurred slowly enough for life to adapt. Even so, it would have been a remarkable coincidence for these environmental changes always to have followed that narrow path whose bounds are the conditions permitting the continued existence of life. It is even more improbable that this could have happened in a system where the energy received from the sun was also changing by a substantial amount. In the face of these improbabilities the presence of a biological cybernetic system able to homeostat the planet for an optimum physical and chemical state appropriate to its current biosphere becomes a possibility.

Another body of evidence which favours the existence of Gaia comes from a consideration of the contemporary atmospheres of the Earth and of Mars. It has frequently been stated, LEWIS and RANDALL (1923), HUTCHINSON (1954), SILLEN (1966) that the presence of nitrogen in the present atmosphere is a chemical anomaly, for the stable form of the element nitrogen at the present state of oxidation of the Earth is the nitrate ion in solution in the oceans. An even greater chemical disparity is the simultaneous presence of oxygen and of methane in the air. In fact a close examination of the composition of the atmosphere reveals that it has departed so far from any conceivable abiological steady state equilibrium that it is more consistent in composition with a mixture of gases contrived for some specific purpose. Such an examination was used to prove that the presence of life on Earth could be inferred simply from a knowledge of the chemical composition of the atmosphere (HITCHCOCK and LOVELOCK, 1967). The cratered moonlike appearance of Mars revealed by the television experiment aboard the 1965 Mariner space craft (LEIGHTON *et al.*, 1965) suggested that Mars was unlikely to bear life. This evidence together with the arguments above were used (LOVELOCK and GIFFEN, 1969) to predict that Mars would have little or no nitrogen in its atmosphere.

Finally it can be shown that if life on Earth were to cease, the oxygen and the nitrogen would decline in concentration until they were both trace components in an atmosphere of water vapour,

carbon dioxide and noble gases. Earth without life would have an atmosphere whose chemical composition was a reasonable interpolation between those of Mars and Venus and appropriate to its station in the solar system. Life is abundant on Earth and the chemically reactive gases almost all have their principal sources and sinks in the biosphere. This taken with the evidence above is sufficient to justify the probability that the atmosphere is a biological contrivance, a part and a property of Gaia. If this is assumed to be true then it follows that she who controls the atmospheric composition must also be able to control the climate. In this hypothesis the air is not to be thought of as a living part of Gaia but rather as an essential but non-living component which can be changed or adapted as the needs require. Like the fur of a mink or the shell of a snail.

The concept of Gaia has been intuitively familiar throughout history and perhaps only recently has it been distorted by anthropocentric rationalizations. One of these, fashionable in discourse upon the "Environment" is that we are travellers within the "Space Ship Earth" and that the biosphere is there as a "Life Support System", presumably for our special benefit. Analogies of this form; are used in considerations of the possible consequences of; species deletions, destructive changes of the land surfaces by farming and pollution. They are both misleading and unnecessary as a replacement for the older concept of the Earth as a very large living creature, Gaia, several giga-years old who has moulded the surface, the oceans, and the air to suit her and for the very brief time we have been part of her, our needs.

*Department of Applied Physical Sciences  
University of Reading*

J. E. LOVELOCK

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