Box 2.7. Anti-Gaia

Paul Crutzen

A recent review of the Gaia theory (Crutzen 2002), largely building on arguments presented before by others, summarises the case against the radical versions of Gaia: *Optimising Gaia* which states in James Lovelock's own words that "climate and chemical composition of the Earth are kept in homeostasis at an optimum by and for the biosphere", and its somewhat weaker form *Homeostatic Gaia*: "The notion of the biosphere as an active and adaptive control system, able to maintain the Earth in homeostasis we are calling the Gaia hypothesis". The problem with these *healing Gaia* versions is that they rest on the false assumption that the influence of the biosphere in the Earth System is dominated by negative (healing) feedbacks, counteracting cosmic disturbances and those imposed by the non-living physical parts of the Earth System. Major examples to the contrary can be given, such as the *Snowball Earth* episodes some 2 200 and again 600–750 million years ago when on several occasions most or all of the Earth was covered by glaciers (Hoffmann and Schrag 1999), thereby wiping out much of the then existing life forms. Another example of anti-Gaian behaviour is that of the atmospheric concentrations of the greenhouse gases CO_2 and CH_4 during the glacial and inter-glacial periods of the quarternary.

A further interesting example goes squarely against one which is often presented by the Gaia proponents (Box 2.6) in support of healing Gaia, stating that the constancy of the atmospheric oxygen content at about 21% over the past 350 million years is regulated by the frequency of forest fires: if the atmospheric oxygen level gets too high, more frequent forest fires will re-establish equilibrium. However, integrated over geological timescales actually the contrary is the case: while between fires the forests re-grow, recurrent fires will produce and accumulate increasing amounts of long-lived elemental carbon (charcoal), thereby actually increasing the oxygen and lowering the atmospheric CO_2 content. This positive feedback on the atmospheric oxygen content should be further explored (Kuhlbusch and Crutzen 1995). (It is interesting to note that the impact of the huge meteoritic collision at the K-T boundary some 65 million years ago may have been particularly severe because for the first time large amounts of sunlight absorbing black carbon particles were produced by the extensive forest fires, causing global darkness and subfreezing surface temperatures.)

With many arguments against it, it is good that the healing Gaia concept is now abandoned as a general principle about the role of the biosphere in Earth System, being replaced by versions such as *habitable Gaia*, building on "shared habitability bounds for all known life" (quotes from Box 2.6), a notion which can be further condensed into the questions of why there is this great variety of life on Earth, how it could have co-emerged under such diverse and variable environmental and climatic conditions, and how stable it is. In the new Gaia version, "the effects of life within the system continued to be emphasised, but the focus shifted to understanding emergent properties of the whole system, including self-regulation in the meaning that the whole system of life and its material environment at the Earth surface self regulates". Throughout Earth's history, it appears that this has indeed been the case in stepwise fashion, interrupted by disastrous breakdowns of the existing *equilibria* and adapted biospheres resulting from extraterrestrial causes and internal destabilising forces in the highly chaotic Earth System. If this is the new Gaia, it is closer to what is known now about the Earth System, except maybe for the notion of self-regulation, but it is difficult to see what is actually new.

Self-regulation is a term which is now used instead of *homeostasis* (Box 2.6) and which is also often used in the IGBP community, as in this book and in the Amsterdam Declaration (Box 6.11), whose first sentence is grossly misleading when it is taken out of the context of the rest of the declaration. Those who misinterpret this statement could incorrectly assume that the Earth System as a whole, including the human component, will self-regulate, whatever this vague term means. Such a misinterpretation on self-regulation trivialises the already severe, and strongly growing, impacts by humans on the environment on all scales.

To address the goals of the IGBP to understand, detect and predict major disturbances and instability regimes in the Earth System on timescales of centuries up to millennia, there is little that the new Gaia has to offer as a guiding principle. Also, regarding the creation of new science, the contribution of old Gaia has been modest, contrary to what is often claimed by its supporters. The important role of dimethylsulphide (DMS) in producing cloud condensation nuclei over the oceans (Charlson et al. 1987) can qualify as a Gaia discovery, but whether DMS acts in a *hurting or healing Gaia* fashion is an open question. Measurements are too few to yield a definitive answer. For many researchers in the field of atmospheric chemistry and climate, the greatest stimulus for improved understanding of the processes which determine (note, not regulate) the Earth System has come from the need to understand, predict, and help to avert the ever growing influence of human activities in the *Anthropocene*, the main objective of the IGBP and the other global change programmes.

There is no doubt about the great importance of biological and life processes within the Earth System on all scales and going back far in the past to the miraculous emergence of life from non-living matter. Whether there will ever be something like a unified theory on the evolving role of the biosphere in the Earth System, however, is difficult to say and may well not be possible. Lovelock bravely attempted this but did not succeed. Reaching this goal will be much more difficult than arriving at the unified field theory in the physical world, which, even after its discovery, will be understood by only very few.

About 70 years ago, the Russian geologist Vernadsky (1930) made some prophetic statements which relate closely to the goals of the IGBP and global change research. He stated "Thus the ubiquity and pressure of life can be considered as the expression of the natural principle governing the biogenic migration of elements in the biosphere" and "In an insignificant time the biogenic migration has been increased by the use of man's skill to a degree far greater than to be expected from the whole mass of living matter". Further, "The surface of the Earth has been transformed unrecognizably, and no doubt far greater changes will come", and finally, "We are confronted with a new form of biogenic migration resulting from the activity of the human reason".

Understanding the natural rhythms and patterns of Earth System functioning is an essential prerequisite to understanding the impacts and consequences of global change. Such understanding lays out the field on which the recent changes to the global environment are being played out. The next chapter of this book focuses on the source of these changes to the Earth System – human beings and their societies – and examines in detail how this one species has become a force of global significance over the last few hundred years. Chapters 4 and 5 then place this new force back into the Earth System itself, drawing on the background understanding of Earth System functioning described in this chapter, and ask two fundamental questions: How much are human activities changing the functioning of the Earth System and what are the consequences?

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