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An analysis of the impact of the Gaia Theory on Ecology and Evolutionary Theory.

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Abstract

This paper investigates the impact of ideas published within the Gaia theory (as set out by James Lovelock in 1979), on the study of Ecology and Evolutionary Theory. Developments within both disciplines have been influenced, and shaped by the Gaia theory and the paper discusses these. The development of the Daisyworld model, which highlighted for ecologists the importance of interactions within an ecosystem between the biota and the abiotic world, contributed to the understanding of biodiversity. The Gaia theory also predicted the causal link between increased biodiversity and increasing stability of populations. The Gaian influence on the development of Evolutionary theory can be found in the idea that life on earth works with the abiotic environment as a self-regulatory system. This idea became the foundation of Earth System Science. These developments have had a wider significance to the study and understanding of science in general. The theory has demonstrated the need for a new way of looking at the development and sustainability of life on earth.

Keywords: Gaia Theory, Ecology, Biodiversity, Evolutionary Theory, Lovelock, Dawkins.

Introduction

When considering how the Gaia Theory has informed and developed ideas within Ecology, it is expedient to consider how these two entities are defined. Firstly, Ecology is the study of the interactions, abundance and distribution of life across different scales, such as the biosphere, the region, the population and the individual (Odum, 1971). Secondly, the Gaia Theory has been defined as a concept which declares that planet earth is a single ecosystem or organism, which regulates itself by feedback mechanisms between the abiotic and biotic components of the system (Lovelock, 1979).

Gaian influence on the development of Ecology

Both Ecology and Lovelock's Hypothesis are concerned with life and its interaction; however, the Gaia theory explicitly links the interaction of biotic and abiotic life together as a system and, furthermore, asserts that this interaction regulates the entire biosphere. Some of the fiercest criticism of the Gaia Hypothesis came from evolutionary biologists, who claimed that there was no place for Gaia, as, for the hypothesis to follow the principle of natural selection, the cosmos would have to be littered with failed planet earths (Dawkins, 1983). In order to counter this criticism Lovelock developed the Daisyworld model. This was a 'mathematical parable' (Wilkinson, 2003, p.266), which described the biological homeostasis of the global environment using a computer generated planet on which black and white daisies grow. In the distant past dark daisies would have grown first because they absorbed more heat. Eventually, they would colonise the planet and their heat absorption would heat the surface of the planet. As the sun's intensity increased, the white daisies would begin to flourish as they had a greater capacity to regulate their temperature by reflecting sunlight. Eventually, as the heat becomes too much for the white daisies to reflect, they eventually die and, consequently, Daisyworld dies (Lovelock, 1991). This model was similar to mathematical models used by ecologists to recreate an ecosystem and influence it in a variety of ways, in order to predict possible outcomes (Allaby, 2005). However, it was different in that it included feedback between the biota and the abiota, which Wilkinson (2003) suggests had been lacking in the reductionist ecological models, which viewed organisms as isolated systems.

The Gaia Theory has greater significance for some aspects within ecology than others. One idea, which has been developed in part through the understanding brought by the Gaia Theory, is the study of biodiversity. Biodiversity is a term used to describe all aspects of biological diversity including species richness, ecosystem complexity and genetic variation (Allaby, 2005). Spicer (2004) states that biodiversity is the variety of life that can be separated into three distinct branches: ecological diversity, such as biomes, ecosystems and habitats; genetic diversity, such as populations, chromosomes and genes; and organismal diversity, such as kingdoms, phyla and species. There is no single measure of biodiversity, but some include number and difference, value and species richness. Biodiversity is one of the 'buzz

words' of the twenty-first century used by scientists, politicians, the media and environmentalists alike (Spicer, 2004). Biodiversity has also been highlighted as a measure of the impact of climate change – where biodiversity changes rapidly, due to changes in environment, such as changes in temperature and precipitation (Henson, 2007). Leakey suggests that there are two main areas within ideas about biodiversity where the Gaia Theory has much to add. Firstly, the Gaia theory develops the idea of interdependence within an ecosystem to a global level with the idea that the biotic and abiotic life interacts via feedback mechanisms, which enable life on earth. Leakey suggests that the extrapolation of this idea to a level of purpose, has caused the rejection of the Theory by some ecologists, but this was not intended by Lovelock, and is perhaps linked to an increasing tendency to be reductionist in the field of evolutionary biology (Leaky, 1996). Secondly, Leaky (1996) states that the Gaia Theory can be shown to have predicted a key development in the debate surrounding the connection between increased biological diversity and increasingly stable populations. Using mathematical modelling, undertaken during studies conducted by Case (1990), the increase in stability of ecosystems was causally linked to the strength of interaction between the species contained within the ecosystem. This is in direct opposition to the traditional explanation that ecosystems, which contained fewer niches, were less likely to have invading species fill them (Leaky, 1996). The development of the ideas surrounding 'niche construction' may also demonstrate the influence of the Gaia Theory on ecological thought. A niche is a term used to describe the place a species has within an ecosystem (Wilson, 2001) and Laland *et al* (1999) suggest that organisms modify their environments, constructing their niche through their choice of habitat, energy and excretion of waste. This modification of the environment (thus benefiting individual species) is taken a step further by Odling-Smee *et al* (2003), as they suggest that models of niche construction can demonstrate environmental feedback overcoming external sources of selection: sometimes environmental modification is favoured above resource consumption. These developments in the understanding of niche construction are due to a better appreciation of the importance of environmental feedback systems and could be attributed to the success of the Gaia Theory in highlighting the interconnected nature of ecosystems, regardless of scale.

Sagan (1990) encapsulates Lovelock's contribution through the Gaia Theory to ecology, and, especially, the debate about biodiversity and stability: he states that the

Daisyworld model (which incorporates realistic environmental variables) demonstrates that variability does increase stability. Sagan also suggests that, through its use, the Daisyworld model has unified the practical ecologists and the mathematical ecologists, as it communicated ideas in a format with which they were both familiar within the discipline of ecology. It is important to remember that not all ecologists are as certain that the diversity-stability issue has been resolved as Sagan suggests, although Leaky says 'resolution may, however, be close' (1996, p139).

Gaian influence on the development of the Theory of Evolution.

Some of the fiercest criticisms of Gaia came from biologists who argued that the Gaia hypothesis was contrary to the rules of Darwinian evolution. This aspect of the criticism levelled at the Gaia hypothesis and the responses made will be examined below, firstly, the key complaint, that of teleology will be explored.

Dawkins argues in his work, '*The Extended Phenotype*' that the Gaia hypothesis is at base teleological, as it sets out with the premise that the biosphere and life contained within it, works collaboratively to maintain optimal conditions for itself (Dawkins, 1999, pg235). Lovelock responds to this accusation made by Dawkins by writing a more scholarly book in language and tone 'The Ages of Gaia' (Lovelock, 1988), in which he sets out a clearer definition of what he means by Gaian science. Here Lovelock changes the substance of his argument as he moves away from suggesting that life alone regulates the planet system for itself, instead he couples together the organismal world and the material environment, which, together, comprise the self-regulatory earth system. This shift in emphasis later developed into 'Earth Systems Science', which joined together the study of the geosphere and the biosphere, and regards the earth as a single dynamic entity. This philosophical approach was formally recognised in the *Amsterdam Declaration*, 2001 (Lovelock, 2006, pg162) which states 'The Earth System behaves as a single, self-regulating system comprised of physical, chemical, biological and human components' (Lovelock, 2006, pg25). Lovelock acknowledges the importance of the criticisms made specifically by Dawkins, he rejects the suggestion that Gaia is teleological, but admits that his first work '*Gaia. A New Look at Life on Earth*' (1979) was 'tightened and improved' by the criticism of Dawkins and others (Lovelock, 2000, pg xii).

Lovelock also admits that there were key problems with the compatibility of the initial Gaia hypothesis and Darwinian principles of evolution (Lovelock, 2006, pg 23). Dawkins highlighted the incompatibility of Darwinian evolution and the initial Gaia hypothesis, in his work 'The Extended Phenotype' (1999). Lovelock's claim that the earth is a single living organism is rejected by Dawkins, as he regards the level of natural selection required by a planet, to enable it to have a homoeostatic apparatus through evolution, impossibly complex. He suggests that not only would the solar system have to be littered with 'failed' planets, it would also have to have some other planets supporting life, and earth is the only planet to do so, of which humans are aware (Dawkins, 1999, pg 236). In particular, Dawkins questions whether Lovelock has created a model to test out his ideas of natural selection on a global scale (1999, pg 236-7.). In answer to this direct question, Lovelock developed the Daisyworld model. Turney (2003) suggests that Daisyworld was created to rebut Schneider's ideas, published in 1984, that living organisms may have an impact on the atmosphere, but they do not regulate it. However, Lovelock states that he developed Daisyworld to answer his critics, namely Dawkins and W Ford Doolittle (Lovelock, 1991). Turney (2003) describes Daisyworld as a good 'rhetorical asset', but it could be argued that Daisyworld is more important than that. As Sagan (1990) recognises, Daisyworld spoke to biologists and ecologists in their own language, moving away from the teleology that sounded implicit in Lovelock's first book. Lovelock argues that the Gaia theory (as presented in the Ages of Gaia, 1988) only adds to Darwin's theory of evolution and does not seek to compete, merely to draw together the evolution of the planet and life that lives on it. (Lovelock, 1991).

Flannery (2005) directly compares the two world views of evolution of Dawkins and Lovelock; he states that the reason biologists in the 1980s found Lovelock's ideas so discomforting was that for them, biology was moving away from global co-operation, towards a globe where individual genes were battling for supremacy (Flannery, 2005). Flannery finds merit in both views and does not suggest that belief and understanding of one theory invalidates the other. Indeed, he cites the paradox, which the Daisyworld model seeks to explain: how has the earth maintained a perfect temperature for abundant life when the intensity of the sun's rays has increased by thirty percent? (Flannery, 2005). Ultimately, Flannery does not fall behind one theory over another in general, but he regards the Gaian world view as more pertinent to investigating the issues in climate change, whilst rejecting any

notion of teleology: 'so let's use the term Gaia as short hand for the complex system that makes life possible, while recognising all the while that it may result from chance' (Flannery, 2005).

The philosopher Mary Midgley also supports the Gaian advancement of the Theory of evolution and suggests a further reason why the reductionist biologists such as Richard Dawkins found the idea of Gaia so improbable. When considering the idea that the 'selfish gene theory' or 'the survival of the fittest' excludes co-operation, love and altruism from evolutionary traits Midgley points to the fact that these traits have still remained among the most dominant species on earth- humans (Midgley, 2002). Darwin himself also rejected a key tenet of what is now included in the Darwinian evolutionary theory, that evolution is a steady rising process of progression and improvement (Midgley, 2002). Midgley states that Darwin never held this to be true saying 'he thought it vacuous, pointed out the obscurity of the metaphor 'higher', and relied on no such paid-up cosmic insurance policy to bail out the human race' (Midgley, 2002). Midgley's discussion of Dawkins' ideas has direct relevance to Gaia's place in the theory of evolution; like Flannery, Sagan and Lovelock himself, she sees Gaia as a complimentary aspect of the development of this theory, not a rejection or denial of it.

It is however, perhaps another philosopher who highlights the fundamental importance of the Gaia theory when discussing the importance of none other than Richard Dawkin's work, 'The Extended Phenotype'. In an Afterword to the second edition of Dawkin's work Daniel C. Dennett says:

'Why is a philosopher writing an Afterword for this book? Is the *Extended Phenotype* science or philosophy? It is both; it is science certainly, but it is also what philosophy should be, and only intermittently is: a scrupulously reasoned argument that opens our eyes to a new perspective, clarifying what had been murky and ill-understood, and *giving us a new way of thinking* about the topics we thought we had already understood' (Dennett, 1999, pg265).

Conclusion

When trying to encapsulate Gaia's contribution to the understanding of aspects of ecology and evolution this idea that scientific thought can provide a 'new way of thinking' is particularly apt. The acceptance of the Gaia hypothesis can be found in the wording of the Amsterdam Declaration, which stated that the earth was 'self-

regulating', this statement is bold, but not because it is stating something new, but because it reiterates something that has been long suspected. Lovelock's contribution through Gaia to Ecology and Evolutionary science is a new way of looking at what is already there, as he himself did when he viewed the images of earth taken from space in the 1960s. An example of this is how Gaia has developed the idea of interdependence within ecosystems to a global level, and has moved against the tide of reductionnist tendencies within evolutionary biological thought of the time. Lovelock's ability to discern interdependent relationships on the micro and global scales has given new understanding to the study of evolutionary science and ecology.

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