James Lovelock on **Environmental Ethics**

Lovelock, J., 2016. Gaia: A New Look at Life on Earth. 2nd ed. Oxford: Oxford University Press.

1. Introductory

In the 1960s, personal interest in understanding the nature of life began whilst working in the United States for the National Aeronautics and Space Administration (NASA). Work at NASA involved designing instruments capable of detecting life on Mars, which raised questions about the nature of life (and whether or not the nature of life on Mars might be the same as the nature of life on Earth). An instrument capable of detecting entropy reduction appeared promising conceptually, but highly impractical: entropy (the dissipation and equal distribution of heat) is a complicated and poorly understood process; however, all life forms appear to be entropy reducing.

Research in the United Kingdom revealed little about the nature of life: most biological, chemical, and physical definitions of “life” just documented examples of life forms. Some physicists had produced general definitions, approximately: life is a category of things that consume external substances, use them to reduce internal entropy, and then expel low-grade substances (i.e. waste) back into the external environment. This definition is too broad (for example, it includes fires, hurricanes, and refrigerators); however, it does cover all known life forms. Importantly, it provided the basis for a life-detecting instrument, and a hypothesis for testing planetary atmospheres for life; namely, that the atmospheres of planets with living organisms would be volatile rather than inert (i.e. entropic).

The Gaia hypothesis is that Earth’s atmosphere is an extension of its biosphere (i.e. the sum total of living organisms), and that any atmosphere on a planet with life would also be such an extension. All known atmospheres are inert with the exception of Earth’s, because living organisms are constantly consuming and expelling substances that promote volatility and disequilibrium (e.g. in sunlight, volatile methane and oxygen molecules react to produce inert carbon dioxide and water vapour molecules; however, Earth’s atmosphere has abundant methane and oxygen, suggesting that methane and oxygen are constantly being created). Earth’s atmosphere is a product of living organisms, just like a wasp nest; excessive change could make it uninhabitable unless life is given time to adapt.

2. In the Beginning

Earth was formed approximately four and a half billion years ago, and the earliest traces of life on Earth were left approximately three billion years ago. Life may have been created by radiation from nuclear elements on Earth’s surface (e.g. uranium) and the Sun; however, its continued existence suggests that it began interacting with Earth’s atmosphere from an early stage. If life had not, then it would have consumed the atmosphere’s carbon dioxide, and died as a result of global freezing. Unlike Venus and Mars, Earth’s atmosphere has remained stable in composition and temperature since the creation of life; this suggests a dynamic relationship between atmosphere and biosphere.

For example, life requires an atmosphere that is neither too cold nor too warm; pH that is neither too acidic nor to alkaline (i.e. approximately neutral); and oceans that are neither too salty (e.g. the Dead Sea) nor not salty at all. It is possible that cloud formation or other unknown processes helped to keep the atmosphere stable; however, it is unlikely that they fully account for keeping the temperature, pH and salt content of Earth’s atmosphere and oceans tolerable for life. The apparent replacement of substances like ammonia, carbon dioxide, and methane (all of which are consumed by living organisms) suggests an active global regulation system (i.e. Gaia); otherwise, these substances would have been completely depleted and living organisms would have died.

Moreover, the dynamic relationship between the atmosphere and the biosphere appears capable of responding to significant changes. Approximately two billion years ago, increasing amounts of oxygen began accumulating in the atmosphere (which would have been poisonous to living organisms that were all anaerobic (i.e. not oxygen consuming)); however, the evolutionary process responded, and living organisms capable of consuming oxygen developed. Over the last three billion years, life has avoided burning, freezing, poisoning, and starvation; it is incredibly unlikely that it managed this by blind chance, more likely Earth evolved the capacity for global regulation through the dynamic relationship between atmosphere and biosphere (i.e. Gaia).

3. The Recognition of Gaia

A beach can be imagined in four hypothetical states: (1) smooth and flat (if the tide stopped, then the beach would be left in this state); (2) smooth and flat, but constantly renewed by the tide; (3) smooth and flat, constantly renewed by the tide, but with a sand castle present; and (4) smooth and flat, constantly renewed by the tide, and with both a sand castle and a child present. These hypothetical states are analogous to the hypothetical states of Earth: (1) without life or the changes caused by solar orbit; (2) without life, but with the changes caused by solar orbit; (3) without life, but with the artefacts of life present, and the changes caused by solar orbit; and (4) with life and its artefacts present, and the change caused by solar orbit (i.e. Earth as human beings know it).

Scientific modelling suggests that if Earth's temperature was kept at 15 degrees Celsius, chemical reactions would occur until an equilibrium state (1) was reached: the atmosphere would contain 98 percent carbon dioxide (not 0.03 percent), one percent nitrogen (not 78 percent), and no oxygen (not 21 percent). Likewise, the oceans would contain 85 percent water and 13 percent salt (not 96 percent water and 3.5 percent salt). Whilst solar orbit ensures a perfect equilibrium state (1) can never be reached, a near equilibrium (2) would not be very different: Mars exists in a near equilibrium with trace amounts of oxygen (0.13 percent) and a large amount of carbon dioxide (95 percent) in the atmosphere. There is a small difference between hypothetical states (1) and (2), but a large difference between hypothetical states (2) and (3).

The existence of both a sand castle and a child on the beach, or life and its artefacts (4), allows recognition of Gaia. In the extended analogy, the sand castle (i.e. life's artefacts) is analogous to the atmosphere (and the oceans) with its particular molecular composition. Just as a sand castle would not last a day on the beach in the absence of a child, the atmosphere and oceans (in their present states) would not last a million years in the absence of life (which maintains them). Comparison with Mars and Venus shows that whilst both have different temperatures, they have very similar atmospheres (overwhelming amounts of carbon dioxide, and trace amounts of oxygen). The contrast between Earth and both Mars and Venus reveals that regulation (i.e. maintenance) of Earth's atmosphere occurs on a global scale: this is Gaia's work.

4. Cybernetics

Cybernetics is the study of self-regulating systems, which comes from the Greek kubernḗtēs (meaning steersman, i.e. helmsman or pilot). Cybernetic systems have aims that they are designed to achieve, and constantly adjust to achieve them. For example, human balance is a cybernetic system: its aim is to keep the body upright, and it does this by constantly adjusting muscles based on sensory information. The thermostatic oven is another example: its aim is to maintain a constant temperature. Importantly, cybernetic systems do not rest, because they can never achieve their aim: they must constantly adjust (e.g. to maintain a body's balance if a boat rocks, to maintain an oven's temperature if its door opens) to keep things stable (i.e. as close to their aim as possible).

Human temperature regulation is another cybernetic system: its aim is to keep the body as close as possible to 37 degrees Celsius. Unlike the thermostatic oven, the body has several mechanisms to regulate temperature, including biochemical heat production, blood vessel dilation, core shivering, skin shivering, and sweating. Consequently, scientists took a long time to understand how human temperature regulation operated as a cybernetic system, because so many mechanisms are involved (unlike the thermostatic oven, which uses an electric heater). If Gaia has a temperature regulating cybernetic system, it may be difficult to discover, because it must be a complex and extensive global system; however, Earth's relatively narrow temperature range suggests that it exists (unlike Mars and Venus, Earth's temperature range makes it inhabitable for living organisms).

In complex mechanical cybernetic systems, engineers build in positive and negative feedback loops. For example, a complex thermostatic oven heats quickly during positive feedback (i.e. the hotter it gets, the more heat is supplied); however, as it approaches its pre-set temperature, negative feedback takes over (i.e. the hotter it gets, the less heat is supplied) so the oven heats more slowly. It is possible that positive and negative feedback loops exist in Gaia, just as they exist in the human body. The only difference between living organisms and mechanical objects is the complexity of their cybernetic systems; if they exist, it is likely that the positive and negative feedback loops of Gaia are complex and varied. There is the possibility of significant environmental change if a runaway positive feedback loop initiates a negative feedback loop.

5. The Contemporary Atmosphere

Earth's atmosphere can be divided into four distinct layers: (1) the troposphere, which is closest to Earth's surface, between seven and 10 miles thick, and three-quarters of the mass of the atmosphere; (2) the stratosphere, which is much less dense than the troposphere, contains ozone, and cannot sustain life; (3) the ionosphere, which is where solar radiation breaks down most molecules (except carbon monoxide and nitrogen molecules); and (4) the exosphere, which is farthest from Earth's surface, and where hydrogen atoms escape into space. The disequilibrium of Earth's atmosphere is unique (especially when compared with Mars and Venus), but makes conditions on Earth's surface surprisingly stable: this quality reveals the existence of Gaia.

Earth's atmosphere contains enough oxygen (21 percent) to facilitate the flourishing of aerobic (i.e. oxygen consuming) life; however, if it reached 25 percent, all flammable material on Earth would burn uncontrollably regardless of moisture content (including rainforests and tundra). Consequently, the oxygen content of Earth's atmosphere appears to be maintained at an optimum level. Methane (produced largely by anaerobic bacteria) may be responsible for oxygen reduction, whilst nitrous oxide may be responsible for oxygen production. Likewise, gases appear to have other regulatory functions: nitrous oxide appears to regulate the quantity of ozone in the atmosphere, and ammonia appears to regulate pH (keeping Earth's rainwater neither too acidic nor to alkaline). The combination of molecules in Earth's atmosphere is incredibly unlikely.

Moreover, the atmosphere contains a large amount of nitrogen (79 percent), which increases its density, dilutes its oxygen content, and isolates nitrogen from the oceans. If nitrogen in the atmosphere was reduced to nitrate in the oceans (i.e. its perfect equilibrium state), the oceans would become so salty that almost all living organisms would die. Likewise, carbon dioxide (0.03 percent) and water vapour appear to be regulated, because they exist in the quantities required to keep Earth's temperature stable and allow living organisms to flourish. So many mechanisms appear to be involved that it is difficult to describe exactly how Gaia regulates Earth; however, the composition of the atmosphere is so different from scientific modelling of Earth's perfect equilibrium state that regulation must be occurring.

6. The Sea

The composition of the oceans also suggests that they are maintained at an optimum level for living organisms. Approximately 3.4 percent of the ocean is composed of salt (mostly sodium chloride). Evidence suggests that the salt content of the oceans has remained stable over the last three billion years; however, it should not have done, because every year continental run-off (i.e. rivers draining into the oceans) and tectonic activity (e.g. submarine volcanoes) add hundreds of megatons of salt to the oceans. Only rare halophilic (i.e. salt-loving) living organisms can survive in environments above six percent salt; the oceans should have exceeded this threshold by now (rendering them largely lifeless) but have not, suggesting they must be regulated.

Notwithstanding this, the method of regulation is difficult to identify. Clues may be found in the regulation of silicon in the oceans: silicon enters the oceans via continental run-off, but is quickly transported to the ocean floor by diatoms. Diatoms are microscopic living organisms that use silicon to build their shells, before dying and transporting approximately 300 million tons to the ocean floor every year. It is possible that other microscopic living organisms trap salt and transport it to the ocean floor in a similar way. Alternatively, it is possible that coral reefs are part of a regulatory system for the creation of salt flats; these trap large quantities of salt and may prevent it from building up in the oceans in dangerous concentrations. Likewise, it is possible that shallow bays, landlocked lagoons and isolated arms of the sea serve a similar salt-trapping function.

The oceans also appear to be responsible for regulating global quantities of lesser-known but very important substances. Sulphur, which enters the oceans via continental run-off, appears to be returned to land as dimethyl sulphide gas, which is produced by some algae and seaweeds. Likewise, iodine appears to be returned to land as methyl iodine gas by kelp; this is fortunate, as iodine is essential for the function of the thyroid gland, and without its return to land most animals would sicken and die. The cycles that involve the oceans are poorly understood: fortunately, human beings have interfered more on land (e.g. agriculture) than they have at sea; however, they must be careful to preserve the oceans given their clear importance to regulatory systems. It is likely that continental shelves (i.e. shallow seas) are vital to Gaia's regulatory systems.

7. Gaia and Man: The Problem of Pollution

Pollution is usually viewed from an anthropocentric perspective; in other words, waste products produced by human beings are usually labelled “pollution”, but not waste products produced by other living organisms. For example, Aspergillus funguses produce a substance that causes mutations, cancers, and birth defects in human beings; likewise, many bacteria (e.g. Botulinus), algae (e.g. dinoflagellates), and plants (e.g. Dichapetaluym toxicarium) produce toxic substances. Pollution may be natural, and Gaia may have systems that allow living organisms to adapt and change (e.g. anaerobic organisms, which were driven underground by oxygen, have now adapted to survive in the oxygen free intestinal tracts of aerobic organisms).

Waste products produced by human beings, like waste products produced by other living organisms, are not necessarily problematic. They are only concerning when they cause significant changes in cybernetic systems: for example, human beings have increased the carbon cycle (by 20 percent), the nitrogen cycle (by 50 percent), and the sulphur cycle (by 100 percent). Disruptions in these cybernetic systems may have global consequences, particularly if the habitats where regulatory systems are likely to be located (e.g. continental shelves (i.e. shallow seas), and wetlands) are destroyed or poorly managed by human beings. However, Gaia has proved surprisingly resistant to the production of ozone destroying chemicals and pesticides, which also appear to be regulated, so there may be hope for environmentalists.

More concerning than fossil fuel consumption is the prospect of continental shelf farming. For example, clearing kelp forests may reduce methyl iodine gas production to levels that make Earth uninhabitable for many living organisms (including human beings); or, conversely, over farming kelp may produce methyl iodine gas in toxic quantities. Continental shelves (i.e. shallow seas) appear to be habitats where many of Gaia’s regulatory systems are located. Likewise, rainforests appear to fulfil a similar function; consequently, rainforest fire clearance may have very concerning consequences (including the production of methyl chlorine (an ozone destroying gas)). Certain habitats may have a disproportionate regulatory effect on Earth’s ability to sustain life in its present forms, which has implications for how human being should act.

8. Living within Gaia

Ecologists study living organisms and the relationships between them, but are particularly concerned with the relationships between human beings and other living organisms (a concern shared by environmentalists). Some ecologists perceive human beings as stewards, whilst others perceive them as destroyers (potentially, of all life). The Gaia hypothesis perceives human beings as one part of a complex single entity (i.e. Gaia); however, accepts that they have the ability to modify Gaia in unprecedented ways. Human beings could: (1) impede Gaia’s tendency to maintain tolerable living conditions; (2) destroy Gaia’s vital regulatory organs (e.g. rainforests); or (3) create a feedback loop in a regulatory system that is impossible to control (e.g. carbon dioxide production).

Human beings may be able to anticipate the unprecedented modifications they might otherwise make, and prevent them: (1) human beings have enacted environmental legislation and regulation; (2) human beings have so far managed to avoid destroying or disturbing most continental shelves (i.e. shallow seas) and wetlands (where Gaia's regulatory systems are likely located); and (3) human beings have so far managed to avoid creating a feedback loop that is impossible to control. However, the threat of rainforest destruction and carbon dioxide production indicate that great care is required to prevent disaster. Human beings are part of Gaia, because all living organisms have the ability to modify their environments to some extent; but human beings are different because of both the degree of their modifications and their awareness of them.

Accurately predicting the near future is difficult; accurately predicting the distant future is impossible. In order to make the most accurate predictions, reliable information about Gaia needs to be gathered by scientists and modelled appropriately; however, model-makers are frequently too attached to their models, and skilled data gatherers are rare. Human beings cannot abandon technologies without inflicting harm on themselves; consequently, they should be more discerning in their choices of technologies. There are no laws for living within Gaia, there are only actions and consequences; however, some actions may have very significant consequences, and human beings should take care to prevent disaster. The ways human beings choose to act will affect the environment they end up living in.

9. Epilogue

There is something difficult to describe about the Gaia hypothesis: when Gaia is in harmony, human beings appear to perceive beauty; when Gaia is in discord, human beings appear to perceive ugliness. In childhood, personal experiences of gardening and walking inspired an awareness of symbiosis (i.e. interrelationship) within nature and an appreciation of harmony. It is possible that genetic health is expressed in human beauty, which acts as a proxy for it. Likewise, it is possible that Gaian health is expressed in natural beauty, which acts as a proxy for it. It is difficult to envisage how such a hypothesis could be tested; however, it is possible that human beings are genetically programmed to appreciate natural beauty as a regulatory system for promoting Gaia's health.

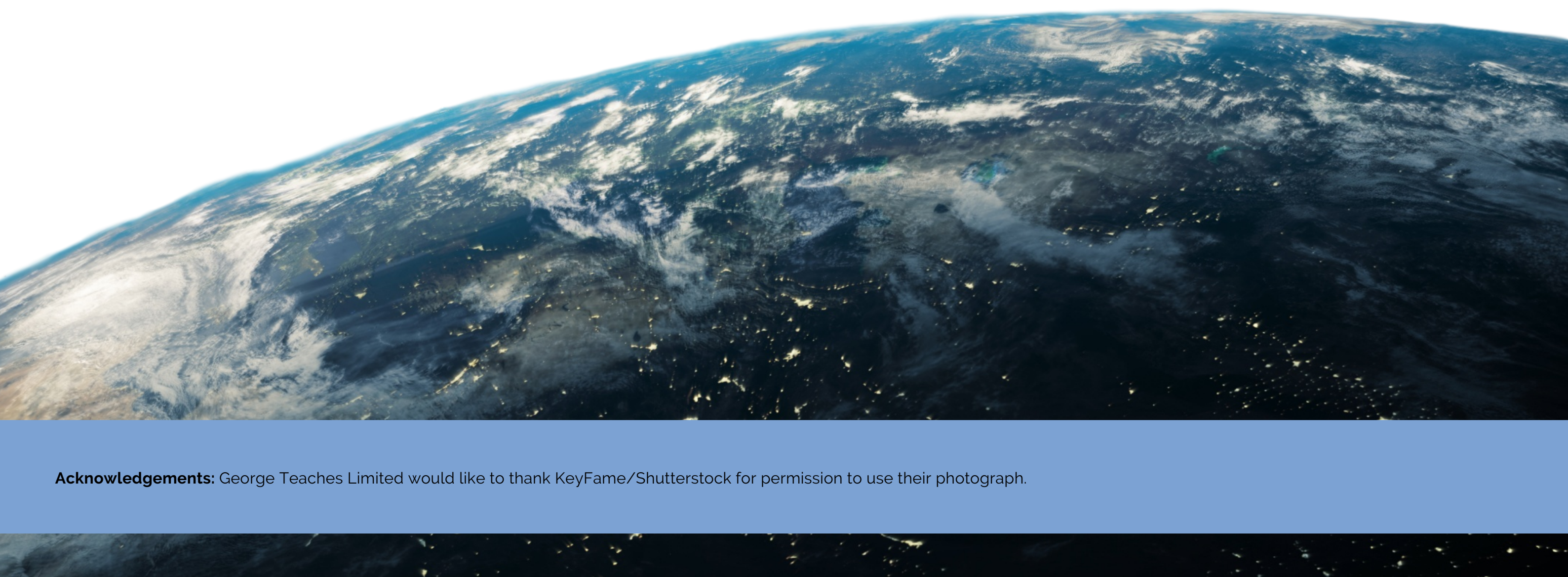
Generally, environmentalists perceive human beings as a threat to living organisms; most religions have also adopted this view, emphasising human responsibility to Earth as stewards (instead of dominators). However, most environmentalists and religious people perceive human beings as in charge or in control of Earth, which is a nonsensical conclusion from a Gaian perspective: human beings are just one part of a single complex entity. Human beings may be best envisaged as Gaia's nervous system, capable of making Gaia conscious. It is possible that human beings could use their technologies to prevent an asteroid strike (e.g. nuclear bombs, spacecraft) or the onset of an ice age (e.g. synthesised gases); in time, human beings may be willing to perceive themselves as part of Gaia.

It is not inevitable that human beings will be the species that continues to manifest Gaia's consciousness or nervous system; other species have large and potentially versatile brains (e.g. sperm whales), which may be capable of achieving this aim. However, human beings and sperm whales are different, because whilst sperm whales have larger brains that may have greater capacity (e.g. for global naviagtion and orienteering), human beings are able to perceive and communicate ideas and thoughts in a much more powerful way. The brain of a sperm whale may be a super computer (compared to the human desktop brain), but it is isolated from any network. Hopefully human beings will stop hunting sperm whales, and learn to use them for the benefit of Gaia, perhaps speeding thought as horses once sped transport.

George Thinks

Read this book! It's not very long, and it's really well written. When James Lovelock wrote Gaia, he wanted it read by a wide audience - he was sounding the alarm. Consequently, his key ideas are clearly communicated and readily understood, even by non-specialists - I'm a theologian, and even I got it! However, Gaia isn't just pop science, it includes some carefully selected technical examples that develop his ideas, and is scattered with personal anecdotes and biographical details. When you finish reading Gaia, you feel like you have both a much better understanding of the way the world works and a new friend.

Of course, there are those who dismiss the Gaia hypothesis and claim it doesn't describe how the world works, which is another reason why Gaia is such an interesting read. As the blurb for the 2016 edition indicates, when it was first published Gaia appeared startlingly original (which is code for "it was ridiculed"); but today it's widely accepted and thoroughly mainstream. In under half a century, the Gaia hypothesis has transformed from an idea derided as hippyish pseudoscience to a central theory underpinning most ecology; it's a remarkable journey, and one that certainly makes for good reading.



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