

Gaia: Goddess and Idea

Laurence Levine

Gaia is the one who gives us birth
She's the air, she's the sea, she's Mother Earth
She's the creatures that crawl and swim and fly.
She's the growing grass, she's you and I.
From "Gaia Song"

THE CHORUS OF CHILDREN'S voices sends these lyrics rising to fill the hall with their sweet innocent tones. They have just finished their responsive readings and soon the dancers will come and cast long writhing shadows before the fires. It is around Christmas time, the dark terrors of winter are still with them, and every person must help to make it through to Spring. What better way is there than to buoy their Goddess Gaia with song and dance and a rousing session on theory.

Theory? No, this is not a Druid rite, but the annual festival, "Gaia Song," given by the Commonwealth Institute of London under the partial sponsorship of IBM. And the theory the children will learn has to do with ecology, not mythology, even though it bears the name of the ancient Greek goddess for earth.

The theory states that earth acts as a living thing, a super-organism served by its constituents -- living and nonliving -- in the same way that the organs of the body serve the person. The rocks, oceans and atmosphere, the microbes, people and

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plants, participate together in tightly integrated systems to regulate oxygen, carbon dioxide, and temperature at levels fit for life. So we are here thanks to Gaia and shall stay because she can also/heal herself.

Gaia has a natural constituency with broad appeal especially for those interested in ecological and holistic thinking. Many spiritually minded persons find her irresistible. She shines, too, for the feminist extremists, the throngs of whole-grain enthusiasts, and most of the other types often assembled under the "New Age" umbrella.

A publishing industry has sprung up to supply disciples with Gaian books, musings on massage, messages about endangered species, and instructions on lifestyles. Gaian organizations provide platforms for their adherents. The Liechtenstein-based Foundation for Gaia, the Gaia Institute of the Cathedral of St. John the Divine in New York City, founded by Lindisfarne members, offer seminars, lectures, and entertainment programs.

James Morton, the Dean of that institution, has found the Gaia principle useful in bringing strays back into the fold. In his hands, Gaia becomes a tool to counter the apathy, alienation and secular pursuits that compete with religion. As he explains, Gaia points to the greater whole in a religious way since Gaia does what religion means to do - to knit together. He has commissioned Paul Winter's help in the knitting process. This composer, noted for the incorporation of nature sounds into his music, has created a *Missa Gaia*. Now wolf calls, whale sounds, and the voice of the loon rise with the Kyrie and resonate with the Sanctus and the Benediction among the high Episcopalian arches.

James Lovelock did not have anything like this in mind when he first formulated the Gaia theory. The idea came to him in the early 1960s when he went to work for NASA on the Viking mission to Mars. The space agency hired Lovelock in their world-wide efforts to find creative scientists to pioneer the new field of space exploration. NASA administrators probably heard of him through his work as an atmospheric scientist at the National Institute for Medical Research in London where he invented the Electron Capture Detector (ECD). This device was the most sensitive instrument available for the time and quickly proved its value in the discovery of widespread contamination of DDT. This insecticide turned up

in such diverse places as human breast milk, Antarctic penguins to the California Condors.

These data quickened the conscience of the nation when they appeared in Rachael Carson's *Silent Spring*. Her landmark book spurred an era of environmental activism that led to the global banishment of the insecticide. Years later, the ECDs stirred the pot again when they detected chloroflourocarbons (CFCs) in the upper atmosphere. A new wave of environmental activism was set in motion as the world community realized that these pollutants threaten the ozone layer and now the use of CFCs as spray propellants and refrigerants has been banned through international agreement. Interestingly enough, Lovelock's invention still looks for trouble. ECDs are used in airports to sniff out explosives in the baggage.

Few would have predicted all this environmental action would occur when NASA first invited Lovelock to come and work in the USA. It was still the early sixties, Rachael Carson had just published her book and Jim Lovelock seemed comfortably established in his niche in London. Why should he accept an invitation to uproot his family and go to work in a foreign country? Life was secure where he was. He had already put in sixteen years at the National Institute for Medical Research. He was ripening towards tenure and if he stayed put he was all but assured of a cozy retirement. Well, that was the problem. Lovelock felt too secure, too packaged, for his personal tastes. He felt that his creative juices would dry to a sterile crust if he continued under the thumb of the bureaucracy.

Lovelock was ready to begin to live a different kind of life. He wished to model his future after novelists who work in solitude without bosses or customers and without having to answer to anyone. He cherished their independence. Lovelock wanted to become a free-lance scientist with a cottage lab in the English countryside far from the pressures of the tenure mills and the demands of administrators. A lucrative appointment in the states, the chance to network with other scientists, and the possibility of consultantships would help set him on his way. Thus, he could not resist the official invitation from the director of NASA. As he himself describes it:

It all started one morning in the spring of 1961 when the postman brought a letter that was for me almost as full of promise and excitement as a first love

letter To receive an official invitation to join in the first exploration of the moon was a legitimization and recognition of my private world of fantasy. My childhood reading had moved on that well-known path from Grimm's Fairy Tales through *Alice's Adventures in Wonderland* to Jules Verne and H.G. Wells. I had often said in jest that it was the task of scientists to reduce science fiction to practise. Someone had listened and called my bluff.²

Despite all this early promise he had an early falling out with NASA over the Viking's strategy for life detection on Mars. He could not see how mucking around on the surface of the planet could yield any hard evidence either for or against the existence of life. After all, a similar mission to earth would yield no evidence of life if the lander happened to put down in the Sahara desert. Besides, he thought it was a waste of money to go there in the first place. Lovelock believed that the key to the life puzzle was visible from Earth. It lay in the Martian atmosphere.

This was tough talk. The big-name scientists who lent their reputations and talents to the project were disturbed; congress would not be too happy either. Apparently, Lovelock was not out to win a popularity contest, but, forever the maverick, he simply did not see things the same way as most other scientists. So he invented a strategy more consistent with his unique perspective.

If life existed, Lovelock argued, it would use the gases of the atmosphere and change its composition. Plants hold down carbon dioxide because they use it in photosynthesis to make carbohydrates. They also produce oxygen as a byproduct. Accordingly, if life existed, carbon dioxide should be a minor constituent and oxygen a more conspicuous component of the atmosphere. Just the opposite is true for Mars. No appreciable oxygen exists there, but carbon dioxide is very prominent because there is not much on the planet to pull it down. It simply remains where it was after Mars cooled.

On earth, again according to Lovelock, chemical effects keep carbon dioxide low, but photosynthesis really does the lion's share, as explained above. In addition, aquatic creatures use the carbon dioxide to make their shells. These accumulate

² James Lovelock, *The Ages of Gaia A Biography of Our Living Earth*, First ed. (New York: W. W. Norton, 1988) 4

on the sea bottom and eventually form the chalky limestones from which the gas may be released in a variety of ways. Acids free carbon dioxide from limestone in a process akin to the action of sour milk on sodium bicarbonate. The gas also finds its way out after tectonic processes carry spent shells, along with the sea floor, deep into the mantle layer. Here the heat transforms the carbonates and releases the carbon dioxide through volcanos. Perhaps the fastest turnaround occurs when we bring vegetables from the garden to the table, and burn them in our own bodies.

Whatever remnants of oxygen that may have existed on Mars became locked up in the "rusting" of materials. The same thing has happened on earth. But once photosynthesis evolved, oxygen production managed to saturate all the "rusting tendencies," balance them off, so to speak, and fill the atmosphere to its present level.

Methane is another atmospheric component that signals the presence of life. According to Lovelock's analysis, this gas should never coexist with oxygen. As coal miners and especially their widows know, methane and oxygen gases make an explosive mixture responsible for most major mine disasters. Methane and oxygen simply annihilate each other. That they can be found together on Earth means that the methane must be replaced as it is destroyed. Myriads of methane producing microbes see to that. They live in the soil, in our own large intestine, in the stomachs of cows, and the guts of ants. We owe the modest amounts of methane in the atmosphere to their combined activities.

Intuitively, we know that Lovelock must have been correct in his estimate of the effects of life on the atmosphere. We use oxygen to oxidize materials in our energy yielding chemistry and blow off carbon dioxide as a byproduct. Microorganisms produce methane as they lust for fiber in their metabolism.

We are on just as intimate terms with nitrogen, the most abundant of the gases. This gas is an essential component of our essential molecular marrow - it is in the core structures, the proteins, DNA and the like. We obtain this gas from the action of microbes that live in the soil and repackage it from the atmosphere in a sort of give and take with plants.

Both carbon dioxide and oxygen move in and out of circulation, yet they have held in just the right amounts for life to continue. Temperature also stayed the same so that water has

never entirely frozen or boiled away during the long history of the planet. If it did life would have surely ended.

Earth could easily have plummeted into an abysmal freeze for the sun burned about thirty per cent dimmer during the early history of the planet. But the temperature did not fall. Nor did it rise when the sun reached its present state of brightness. What warmed the planet when the "furnace" damped, and what cooled us when its output increased? Most scientists agree that carbon dioxide, methane and water vapor saved us. These are the greenhouse gases. They enable the earth to control the amount of solar radiation retained at its surface: the more gas, the more heat. As temperatures fell, more of these gasses filled the atmosphere. When temperatures increased, more of the gasses left. Temperature and gas form a feedback system, and work together like a thermostat and a furnace.

According to Lovelock, living things act as the thermostat. They respond to temperature changes and kick in or pull out the greenhouse gases. Thus life and nonlife interact in seamless cooperation to regulate the intensity of the greenhouse effect and maintain the world in a "seemly" condition for life. The basic pillars for the house of Gaia rest on such foundations. But the final piece of the edifice, the keystone of the Gaia hypothesis, Lovelock's idea that the entire thing lives, requires a conceptual leap that still stymies many scientists.

Experts find it enormously difficult to reach a consensus over a definition for life. This is a thorny problem, enormously complicated to begin with, and confounded by all the exceptions.³ Lovelock attempted to cut through the complications with an extremely reductive definition based on some elementary properties. All systems eventually run down; they always tend to reach an equilibrium. Hot food, for example, cools down to the temperature of the environment. But anything alive does not behave this way. It staves off equilibrium by the constant expenditure of energy. Life means spending energy. It is an uphill climb with heat given off at every step. Once death occurs the lifeless body cools, and in this state it is analogous to the ball fallen to the bottom of the stairs, motionless, at equilibrium with the forces acting upon it.

A planet without life would have an atmosphere entirely at equilibrium with the rocks. Lovelock calculated what the

³ Aydin Orstan, "How to Define Life: A Hierarchical Approach," *Perspectives In Biology and Medicine* 33.Spring (1990): 391-401.

earth's atmosphere would be like if life should fail, and found that it matched that on Mars, gas for gas. He concluded, therefore, that Mars was a barren cinder -- without blasting off in that direction. All the data were gathered from the home planet.

The living and the nonliving parts of the earth collaborate to hold temperature, and the other conditions, at constant levels, just as the organs in our own bodies maintain blood sugar levels. In effect, the whole earth follows Canon's central principle, that the living body strives to maintain the constancy of its internal environment at levels beyond their equilibrium values. Lovelock's conceptual leap was to apply Canon's principle to the earth and call it alive. Having gone that far he needed a name for this superorganism. William Golding, the British novelist, Nobelist, his good friend and neighbor, suggested that he call it, "Gaia."

Lovelock's acceptance of Golding's suggestion tells us something about his personal nature. Though an admitted agnostic, he also must be spiritually inclined. And this, coupled to his global view, his leaning toward Gaia as metaphor and as imagery, reveal his essential poetic nature - but more, he has taken the license of the ultimate free-lancer. Beholden to no one except himself, he made the enormously risky conclusion that the earth lives.

Lovelock's first public announcement of the Gaia hypothesis came out in the Proceedings volume of the *American Astronautical Society* in 1968. He published a more structured letter to *Atmospheric Environment* in 1971. But it was not until two years later, following his intense collaboration with Lynn Margulis, that the skeleton of the Gaia hypothesis became fleshed out in the first formally detailed papers. Her name has been linked with Gaia's ever since.⁴

The collaboration seemed extremely unlikely. Margulis epitomized much of the trappings of the traditional science that Lovelock eschewed (for example, the peer review system). In addition, Margulis staunchly rejects his most seductive explanations. She restricts her vision of Gaia to the harder data, to the surface and its atmosphere, where Lovelock extrapolates clear down to the center of the earth. Besides all this, Lovelock is a loner who appears to be comfortable in his blue

⁴ James Lovelock, and Lynn Margulis, "Atmospheric Homeostasis: The Gaia Hypothesis," *Tellus* 26 (1974): 1-10; Lynn Margulis, and James Lovelock, "The Atmosphere as Circulatory System of the Biosphere - The Gaia Hypothesis," *CoEvolution Quarterly* Summer (1975): 31-41

cardigan while throwing the switches in the solitude of his cozy cottage lab. The opposite seems to appeal to his collaborator. Lynn Margulis seems to be most comfortable out in the open, chatting with her students at the University of Massachusetts at Amhurst where she is Professor of Biology. However, the differences between them pale into insignificance before their common grain.

Both Margulis and Lovelock get on as innovators who do not allow the traditional molds to restrict their thinking. Most people could never conceive, as Lovelock did, of the entire world as a living thing. Few could not make the long leap of the imagination to proceed from questions of atmospheric chemistry and the geology of ancient sediments to get to that coherent whole. Lynn Margulis is no stranger to that scene.

She was an early proponent of an untraditional view about the origin of the specific cells that gave rise to multicellular life. Called eukaryotes, these cells bear their DNA in a sac called the nucleus. They also have structures called chloroplasts and mitochondria. The chloroplasts green the landscape with their contained chlorophyll and function in the photosynthesis of plants. Mitochondria perform the crucial energy conversions that involve oxygen gas. We can not live without them.

Margulis championed the hypothesis that the mitochondria and chloroplasts were once free living bacteria that entered cells a long time ago and remained ever after. They managed to stay together and evolve with their hosts because their relationship bestowed mutual benefits. Biologists call such trysts "symbiosis."

Margulis' views were at first regarded as being "off the wall." But convinced of the soundness of her vision, she persisted to marshal evidence using examples of extant symbioses supported by evidence from diverse disciplines. Her views have now gained wide acceptance. The quantitative molecular data have convinced most biologists that cells obtained their mitochondria and chloroplasts through an ancient symbiosis. In 1982, her achievements won the highest level of recognition that this country can offer any scientist. She was elected to the National Academy of Sciences.

In a sense, Margulis shares with Lovelock that intuitive poetic vision that brings disparate parts together in a cooperative global synthesis - for Lovelock, life, Earth and atmo-

sphere; for Margulis, the different cells in a dynamite combination that vastly accelerated the engine of evolution.

Margulis is also a long time champion for microbes. She has worked hard to remind the scientific establishment of their importance and their contribution to ecology - how much of our lives we share with them, and not just because of their capacity to cause disease, but also:

Every spoonful of garden soil contains some 10¹⁰ bacteria;⁵ a small scraping of film from your gums might reveal about 10⁹ bacteria⁶ per square centimeter of film - the total number in your mouth is greater than the number of people who have ever lived. Bacteria make up a significant percentage of the dry weight of all animals. They cover the skin; they line nasal and mouth passages, and live in the gums and between the teeth; they pack the digestive tract, especially the colon.⁷

Lovelock's and Margulis' publications met with considerable controversy, especially because they said that Gaia sought to create an *optimal* physical and chemical environment for life. The statement implies purposeful action, that a thinking entity made a conscious attempt to do something good for all life on earth. Mainstream biologists, for example Richard Dawkins⁸ and W. Ford Doolittle,⁹ objected to this line of reasoning. They argued that nature does not think ahead or behave in any kind of purposeful manner. It just behaves. Furthermore, they could not accept Earth as a living entity because it neither reproduces nor evolves in the traditional Darwinian sense. What would earth compete with for natural selection to operate - Mars and Venus?

Conditions have not always been optimal or even beneficial as Lovelock and Margulis have suggested. The first oxygen to appear soon after photosynthesis evolved killed off many species, and the entire history of life is littered with more extinctions than survivals. Besides all this, geologists believe

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⁷ Lynn Margulis, and Karlene Schwartz V., *Five Kingdoms*, 2nd ed. (New York: W. H. Freeman, 1988) 25

⁸ Richard Dawkins, *The Blind Watchmaker*, (New York: W. W. Norton & Company, 1986) 9.

⁹ W. Ford Doolittle, "Is Nature Really Motherly," *The CoEvolution Quarterly* Spring (1981): 58.

that Lovelock and Margulis overstated the case for life's regulation of carbon dioxide. They believe that life's contribution fades to insignificance besides the rocks and other nonliving components.

In response, Gaians argue that a seventy year old person lives without reproducing as an organism. Yet reproduction may proceed beneath the surface regardless of the advanced age. Gaians then compare this person with the earth and point out that plenty goes on among its various constituents. For example, Gaia's "tissues," the burgeoning mats of microbes, for example, heal themselves all the time. The question of reproduction does not trouble Gaians.¹⁰

The Gaia hypothesis can also accommodate extinctions. Though somewhat battered by the frequency and the extent of the decimations, the Goddess survives. Catastrophes occur. Though they upset the balance, they have not yet wiped out all species. Of course, some do become extinct, but new ones arise after a period of evolutionary adjustment. It is as if Gaia regulates herself and life returns.

Margulis provides further fuel for the controversy. She disagrees with the traditional Darwinist's emphasis on the role of competition in evolution and gives cooperation and co-evolution of both species and environment a more prominent role.

Nevertheless, the debate has persuaded both Lovelock and Margulis to shift emphasis. Much to their credit, Gaia now reigns in a "soft" version. She regulates within limits narrow enough for life to continue, rather than at the optimum as in the original "hard" version.

Lovelock has also responded to aspects of the debate with experiment. He devised a computer model to counter the criticisms that Gaia acts purposefully. Called Daisyworld, the model shows how natural selection acts on "daisies" of different colors to regulate the temperature of an imaginary planet when the sun changes in brightness. When the sun cools, for example, dark daisies multiply and warm Daisyworld by the absorption of solar radiation. The reverse would apply for light ones. These daisies would tend to bring down tempera-

¹⁰ Robert A. Berner, and Antonio C. Lasaga, "Modeling the Geochemical Carbon Cycle," *Scientific American*, 260, March (1989): 74; James F. Kasting, Owen B. Toon, and James B. Pollack, "How Climate Evolved on the Terrestrial Planets," *Scientific American* 258, February (1988): 90-97.

¹¹ For an interesting Gaian perspective on the "reproduction question" see: Dorlan Sagan, and Lynn Margulis, "Gaia and the Evolution of Machines," *Whole Earth Review* Summer (1987): 15-21.

ture when the earth heats up because they reflect solar radiation much as a parasol reflects sunshine. But Lovelock also endowed the daisies with different temperature preferences for optimal growth - darks prefer cooler temperatures, lights the warmer. So as temperatures rise beyond the tolerance of the dark daisies, they decline in numbers, Daisyworld cools, and the lighter "flowers" increase until they pass their optimum and make room for their darker cohabitants. Thus daisyworld may regulate the environment and hold the "seemly" conditions for life through endowed properties rather than bestowed purpose.

James W. Kirschner agrees, but only because Lovelock contrived them to behave that way. He merely transfers purposeful behavior from the daisies to the mind of the investigator. Well, the model is yet to be completely tested out in the real world, and some scientists, somewhere, probably will find a way to get at it. That is really what matters most for Lovelock and Margulis.

Indeed, Gaia has stimulated scientists of diverse disciplines to have a new galvanizing and organizing principle to focus their work. For example, a most important and promising result of the Gaian approach involves a recent spate of papers about a certain exudation from ocean-going photosynthetic plankton¹² which reached into the atmosphere where it may affect climate.

Almost thirty years after Gaia first stirred for Lovelock, the American Geophysical Union has given Gaia the respectability of an international congress at its Chapman Conference of 1988. Top scientists gathered with the purpose of hammering out experiments to test the Gaia hypothesis. Not much seemed resolved though the debates continued for a solid week. The sparks flew, but we probably will not know what they ignited in the minds of the participants for a long time.

Lovelock's latest book contained a codification of his defence against the challenges made by several scientists. It is also his account of Gaia's emergence during the history of life on earth. As Lewis Thomas explains in the forward:

This book by James Lovelock describes a set of observations about the life of our planet which may, one day, be recognized as one of the major discontinuities

¹² Richard Kerr A., "No Longer Willful, Gaia Becomes Respectable," *Science* 240.April (1988): 393-395.

in human thought. If Lovelock turns out to be right in his view of things, as I believe he is, we will be viewing the earth as a coherent system of life, self-regulating and self-changing, a sort of immense living organism.
from *Ages of Gaia*

Perhaps this will be Gaia's most important contribution. It is an idea with broad powerful appeal. For scientists, Gaia is a launching platform into discovery and cross-disciplinary thinking. For the disenchanted it is a perch, and for those who have strayed from the fold, a source of renewed spiritual energy. Even secular humanists may feel her draw as a metaphor for transcendence without God. Few of us who have seriously dealt with the Gaia hypothesis will ever see Earth and life in the same way again.

Acknowledgement

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