**Discover**



Oct99
Discover

*By Morton, Oliver*

Magazine: DISCOVER THE WORLD OF SCIENCE; OCTOBER 1999

IS THE EARTH ALIVE?

-------------------

The idea that organisms collaborate to keep the planet habitable was once dismissed as New Age earth science. Now even skeptics are taking a second look.

The small crowd milling about an Oxford University courtyard on a sunny Easter afternoon is an unusual mix--part academic, part acolyte.

RonWilliams, for example, a professor of biochemistry at the University of Toronto, is retired but still active, sharp of mind, neat in appearance, the sort of person you'd expect to find enjoying academic discussions at Oxford. Peter Horton, a few decades younger and trying his hand at living off the land in the south of France, is bearded, thicksweatered, and direct. He has not been in formal education since he was a teenager. Still, he has come to Oxford for the same reason Williams has. And it's not a religious one, although it can seem that way.

Williams and Horton are here because of James Lovelock. Eighty years old but quick and amiable as ever, Lovelock has for 30 years promoted the idea that Earth regulates itself as if it were one huge organism, not just a collection of millions of relatively independent life forms. Among Lovelock's earliest audiences for this idea was the Nobel Prize-winning novelist William Golding. During walks through the Wiltshire countryside, Lovelock would tell Golding about how plankton control the greenhouse effect and about how forest fires regulate oxygen levels. Golding, intrigued, suggested he call this system Gaia (pronounced GUY-ya), after the ancient Greek earth goddess. And so Lovelock did.

When the public first heard about Gaia in the 1970s, it liked the message. At a time when people could talk about the Age of Aquarius without grinning, the notion of Earth as a single living being, not quite what Lovelock proposed, but not inaccurate either, seemed to fit. Academic scientists, on the other hand, were not impressed. And the quasireligious name didn't help. But worst of all was the concept itself-- the Earth in some way alive?

Today, 30 years after Lovelock gave his first seminar on the idea to a nonplussed audience in Princeton, New Jersey, Gaia has made some progress. While to many mainstream researchers Gaia remains out-of-bounds, some ideas that flowed out of Lovelock's Gaian thinking have been proven correct, even if their provenance is forgotten or hushed up. And a growing number of scientists have decided to center their work on the Gaian concepts. Some are gathered here at Oxford for the third meeting of the Gaia Society, which sponsors this sort of research. But there's still a problem. Even among believers, there's no real consensus as to what Gaia is or how it really works.

Oxford zoologist William Hamilton, perhaps the world's most eminent evolutionary biologist and a man no one would have expected to take an interest in Gaia a few years ago, puts it this way: "Lovelock is a figure like Copernicus." Copernicus came to believe in a strange phenomenon that his contemporaries rejected: The Earth moves around the sun. But he never came up with a proper explanation for it; that was left to Newton. As far as Hamilton is concerned, "Jim's still waiting for his Newton."

Lovelock, like Copernicus, started off by looking at the planets. Because he had invented some of the most sensitive chemical measuring devices ever, Lovelock was asked by NASA in the 1960s to help design life-detecting instruments for Mars missions. After thinking the problem through, Lovelock decided that the best way to detect life on another planet was to look at the atmosphere. If a planet had life like Earth's, its atmospheric composition would reflect it.

The proof, he argued, is in every breath you take. Earth, abundant with life, has an atmosphere composed of an unstable mixture of gases. If you bottled a sample of Earth's atmosphere for a million years, the mingled gases would react with one another. But strangely, if the mixture is left outside the bottle, it stays reasonably stable because life forms absorb some of the gases and replenish others.

Lovelock surmised that if Mars had life, its atmosphere would show similar characteristics. The fact that it didn't, he concluded, meant that Mars was dead--and therefore not worth the cost of sending spacecraft to look for life. This was not the answer NASA wanted, although all subsequent studies have tended to support it.

Lovelock went on to look at other ways in which life might shape the development of Earth. For example, we know that when the solar system was formed the sun was dim and that it has heated up ever since. Yet Earth wasn't too cold for life in the beginning, and it isn't too hot for life now. That's because the composition of the atmosphere has changed. Huge amounts of warming carbon dioxide have conveniently been absorbed by little planktonic shellfish and used to make shells. When the animals die, the carbon dioxide is locked up as their remains turn into chalk or limestone.

Then there is sulfur, which has to be recycled from the sea to the land for life to go on. Lovelock suggested that this recycling was done by living creatures rather than by inorganic processes. He was proven right. Plankton pump more sulfur into the atmosphere than all the world's volcanoes. Lovelock started to think that Earth was in some sense alive, its various cycles part of a great physiology

Of all those who objected to the idea, no group was more vehement than evolutionary biologists. They don't believe in free lunches. They believe creatures are out to help themselves and their relatives survive, not to help strangers. The idea that some creatures waste effort making the world a better place for others didn't make sense to them. As for global self-regulation, the complex physiological systems of living beings do not come about by chance. They evolve. Many different versions are tried out; only the best leave descendants. That's natural selection. And natural selection cannot apply to a whole planet, which has no competitors or ancestors.

To convince the evolutionary biologists, Lovelock needed a way of demonstrating how organisms could act selfishly yet still interact to control the planet. His solution was to invent a computer model called Daisyworld. Imagine, he said, a cold planet with a dim young sun. On this planet are two kinds of daisies, black and white. The black daisies begin to spread across the face of the world, soaking up sunlight and warming themselves. In doing so, they take the chill from the ground and warm the air. But as the sun slowly grows warmer, Daisyworld's temperature remains stable because the white daisies begin spreading around the world, reflecting the sun's rays back into space. They cool themselves, the ground beneath them, and the air above. The black daisies, on the other hand, bake to a crisp and die out. So the planet's surface grows ever whiter, and its overall temperature stays the same.

The charm of this parable is that the daisies didn't set out to keep the planet's temperature stable, but still they did so. The rigors of the environment controlled the daisies' fate, and the temperature regulation came free. Evolutionary biologists still didn't buy it. William Hamilton, who has done more than anyone else to understand how genes can, in some circumstances, make the creatures that bear them nice to one another, saw Daisyworld as rigged. He pointed out that if the daisies had been allowed to evolve, rather than forced to sit with the same temperature preferences they started out with, they would adapt themselves to the sun's ever-increasing heat and allow the environment to go to hell. "It doesn't account for how the phenomenon [large- scale stabilities in the environment] appears," says Hamilton. "That's what we're still waiting for."

Which brings us back to what Gaia is supposed to be. Is it a system, a property of a system, a process, a thing? All those views could have found support at the Oxford meeting. New York University biology professor Tyler Volk, for example, calls Gaia a thing: a system comprising Earth's soils, oceans, atmosphere, and biomass. For Volk, Gaian studies show how things circulate through this system. No need for Daisyworlds, no need for anything but natural selection. On the other hand, Lee Klinger, a researcher at the National Center for Atmospheric Research in Boulder, thinks there's more to Gaia. To him, it's basically similar to all sorts of other complex phenomena, from atoms in magnetic fields to gamblers playing the stock market.

For the hard core, Gaia is about biology, not earth science or complex systems. Their battle cry is symbiosis, the many varied ways that creatures have of coming to depend on one another. That's something Gaians think traditional evolutionary biologists don't know how to deal with. Hamilton disagrees with that. But he agrees that there seem to be long-term stabilities in the environment that he and his colleagues may have underplayed. This intrigues him deeply-- and that may help bring Gaia a new respectability.

Hamilton first began investigating Gaian ideas while working with a young protege of Lovelock's, Tim Lenton, now at Edinburgh's Institute of Terrestrial Ecology They were thinking about the plankton that release a kind of sulfur into the ocean, where it reacts and forms dimethyl sulfide. Some of this gas escapes into the atmosphere, interacts with oxygen, and forms little acidic particles. The particles help form cloud droplets, and more droplets mean thicker, whiter clouds. Bob Charlson, a professor of atmospheric sciences and chemistry at the University of Washington who collaborated with Lovelock, reckons that if the ocean did not release dimethyl sulfide, the number of droplets in the most common marine clouds would be less than half of what it is today So if it weren't for sulfur-producing plankton, the planet might be much hotter. The plankton's product could conceivably be changing the nature of the clouds enough to cool the planet by as much as 10 degrees Celsius.

Gaians take this as evidence that these plankton are part of Earth's way of staying cool. But why should the plankton bother? That was the question that struck Hamilton. As an evolutionary biologist, he tended to think organisms are mostly interested in improving their odds of reproduction. He couldn't accept that plankton cooled the world with no benefit for themselves. So he enlisted Lenton's help in looking for a payoff.

Their answer was strange but appealing: Plankton encourage clouds because clouds help plankton spread their genes around. Hamilton and his colleagues showed that dispersing some of your seeds always makes sense, even if their chance of thriving wherever they end up is tiny If this is true, then contributing to the release of dimethyl sulfide may be one way plankton can move to new territory Producing dimethyl sulfide, in short, could help create winds that whip up whitecaps and loft plankton into the air. If plankton somehow get into the clouds, they could travel significant distances-hundreds or even thousands of miles --before coming down.

It's a nice idea, one you could expect natural selection to favor. It may even be true, though no one has yet caught the astronaut algae on their way to the clouds. But does it support Lovelock's theory? The fact that the clouds are being made by the plankton is interesting. The possibility that these clouds are significantly cooling the planet is important. But these insights don't prove the Gaian theory that life and the environment come together to form a self-regulating whole.

To try and get a better take on Gaia at that most basic level, Hamilton and ecologist Peter Henderson are trying to build a more realistic model to replace Daisyworld. They want a model that shows a suite of organisms whose interactions stabilize the environment in ways that don't depend on the parameters the model starts with. Their first stab at an answer, presented at the Oxford conference, could be called Damworld.

Imagine Damworld as a basin ringed by mountains, in which a single species of algae lives. The rain that falls into Damworld can leave only through one narrow outlet. Living in the outlet are creatures that feed on the algae. These creatures anchor themselves to the sediments and tend to build up a dam, like coral polyps build up a reef. The third species is one that breaks down dams for food. If the dam rises, the lake behind it swells, creating a larger supply of sunlight-warmed, nutrient-rich water in which various organisms thrive.

If you have just those three species, then the dam's height oscillates fairly regularly When it gets big, there's more for the dam-busters to work on and the dam starts to crumble. When it crumbles, the dam-busters starve and the builders make the dam bigger again. But Henderson and Hamilton aren't content with just three species. Each time the model runs, they add new species to the original three. These species are similar to the originals, but with randomly assigned food and habitat preferences that are just different enough to make things interesting. Sometimes the newcomers cooperate with the established species; sometimes they compete.

Each time the model runs, the result is different. But over many runs, some statistical trends emerged. Worlds with tall dams, on average, accumulate more species and richer ecosystems than those with shorter dams. What's more, they also resist shocks better. They're not without problems, but they are robust. In damless worlds, the model often ends with everything going extinct after the introduction of some vicious new species. While total extinction can happen in worlds with big dams, it is much rarer.

What seems to matter most in the model is how much control the various species gain over the physical aspects of their world. The more profound the links between what's alive and what isn't, the more stable things seem to get. Big changes can still occur in such systems, but they are not necessarily irreversible.

Damworld seems to suggest that the more intimately life intermingles with its physical environment, the more the two may together move toward stability But it offers no certainty: Sometimes dammed ecosystems are unstable. That Gaia-like properties develop in the Damworld model only sometimes, not always, could point toward another concept of Gaia. This concept was voiced at the Oxford conference by Andrew Watson, a professor of environmental science at the University of East Anglia. Maybe, he said, Gaia is an accident.

Watson, one of Lovelock's first disciples and his coauthor on the original Daisyworld paper, argues that with just one Earth to study, you simply can't say much about Gaia. Just because life persists on this planet despite all sorts of change doesn't mean that it had to. Yes, some nice, big, simple feedback loops involving atmosphere and organisms may have done a lot to make the planet livable, but that doesn't mean these interactions were a necessary outcome of life being there in the first place. Maybe we just got lucky

And that brings us back to where Lovelock began: looking at the atmospheres of other planets. Although NASA didn't much like Lovelock's theory that the Martian atmosphere proved the planet lifeless, it has adopted his theory for finding life outside the solar system. When planets the size of Earth are found, the next order of business will be studying their atmospheres through spectroscopy to see whether they are deathly stable, like those of Mars and Venus, or alive and kicking like Earth's.

The extraordinary space telescopes needed to make such measurements are in the works. If the search turns up living planets, Watson's accident theory, and the general credibility of Gaia, could be tested. If the sustainability of life on planets is a matter of luck, life will be most common around young stars, where its luck hasn't yet been tested. But if life makes its own luck, as Gaia would have us believe, then there will be life on planets around stars of all ages. We could know within a few decades.

And what does Lovelock make of this? He's happy that Gaia is still alive, still attracting interesting people, still provoking new lines of thought. If not all of it accords with his own ideas, well, fine.

Lovelock didn't present any new hypotheses or results at the Oxford conference. But he did kick off the proceedings with what he styles as a sermon, and that was where he made his contribution to the debate: "Gaia is a theory of science and is therefore always provisional and evolving. It is never dogmatic or certain and could even be wrong. Provisional it may be but, being of the palpable Earth, it is something tangible to love and fear and think we understand. We can put our trust, even faith, in Gaia, and this is different from the cold certainty of purposeless atheism or an unwavering belief in God's purpose.... I have put before you the proposition that Gaia, in addition to being a theory in science, offers a worldview for agnostics. This would require an interactive trust in Gaia, not blind faith. A trust that accepts that, like us, Gaia has a finite life span and is provisional."

That may sound like a best-of-both-worlds cop-out. But you could also read it as the words of a wise old man who knows that a powerful metaphor never relies on only one meaning, who wants broad-minded scientists in a broadminded world to keep asking the questions he has asked, and not to be put off by criticism or seduced by dogma. These could be the words of a man who knows that science never exists in a moral vacuum, but rather in a preexisting atmosphere, and who wants that atmosphere to be off balance and alive, not stuck in a dead equilibrium.

PHOTO (COLOR): Atmospheric scientist James Lovelock uses payments from his inventions to support his research into Gaia: the idea that the Earth regulates itself like a living being.

PHOTO (COLOR): Like Copernicus (top) and Darwin (bottom), James Lovelock has drawn attention to unexplained phenomena. He named his theory after the ancient Greek earth goddess, Gaia (middle).

PHOTO (COLOR): Lovelock has written: "Gaia forces a planetary perspective. It is the health of the planet that matters, not that of some individual species of organisms."

~~~~~~~~~

By Oliver Morton
~~~~~~~~~