Is the Earth
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. **BY OLIVER MORTON**

The small crowd milling about an Oxford University courtyard on a sunny Easter afternoon is an unusual mix—part academic, part acolyte. Ron Williams, 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, thick-sweatered, 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 *Gāia* (pronounced GUY-yah), after the ancient Greek earth goddess. And so Lovelock did.
IS THE EARTH ALIVE?

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 grimacing, 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 quasi-religious 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 that 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 Daisystem. 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, Daisystem'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 even 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 Daisystem 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 Darwinian 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
IS THE EARTH ALIVE?

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 envi-
enronment that he and his colleagues may have under-
played. This intrigues him deeply—and that may
help bring Gaia a new respectability.

Hamilton first began investigating Gaia ideas while working with a young pro-
tégé of Lovelock’s, Tim Lenton, now at Edinburgh’s Institute of Terrestrial Ecol-
y. 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 a
cooler climate. When Bob Charlson, a pro-

fessor of atmospheric sciences
and chemistry at the University of Washington who
worked 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.

Gaia, fascinated by these plankton, now starts to look at the
plankton itself. 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 terri-
tory. Producing dimethyl sulfide, in short, could help cre-
ate 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 thou-
sands 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 brown 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 pos-
sibility that these clouds are significantly cooling the
planet is important. But these insights don’t prove the
Gaia 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 envi-
enronment in ways that depend on
the parameters the model starts
with. Their first stab at an
answer, presented at the Oxford con-
ference, 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 sedi-
ments and tend to build up a dam, like coral
colons. 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 Hen-
derson 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 originalsg, 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.
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.

Danworld 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 Danworld 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 co-author on the original Daisystem 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 pur-