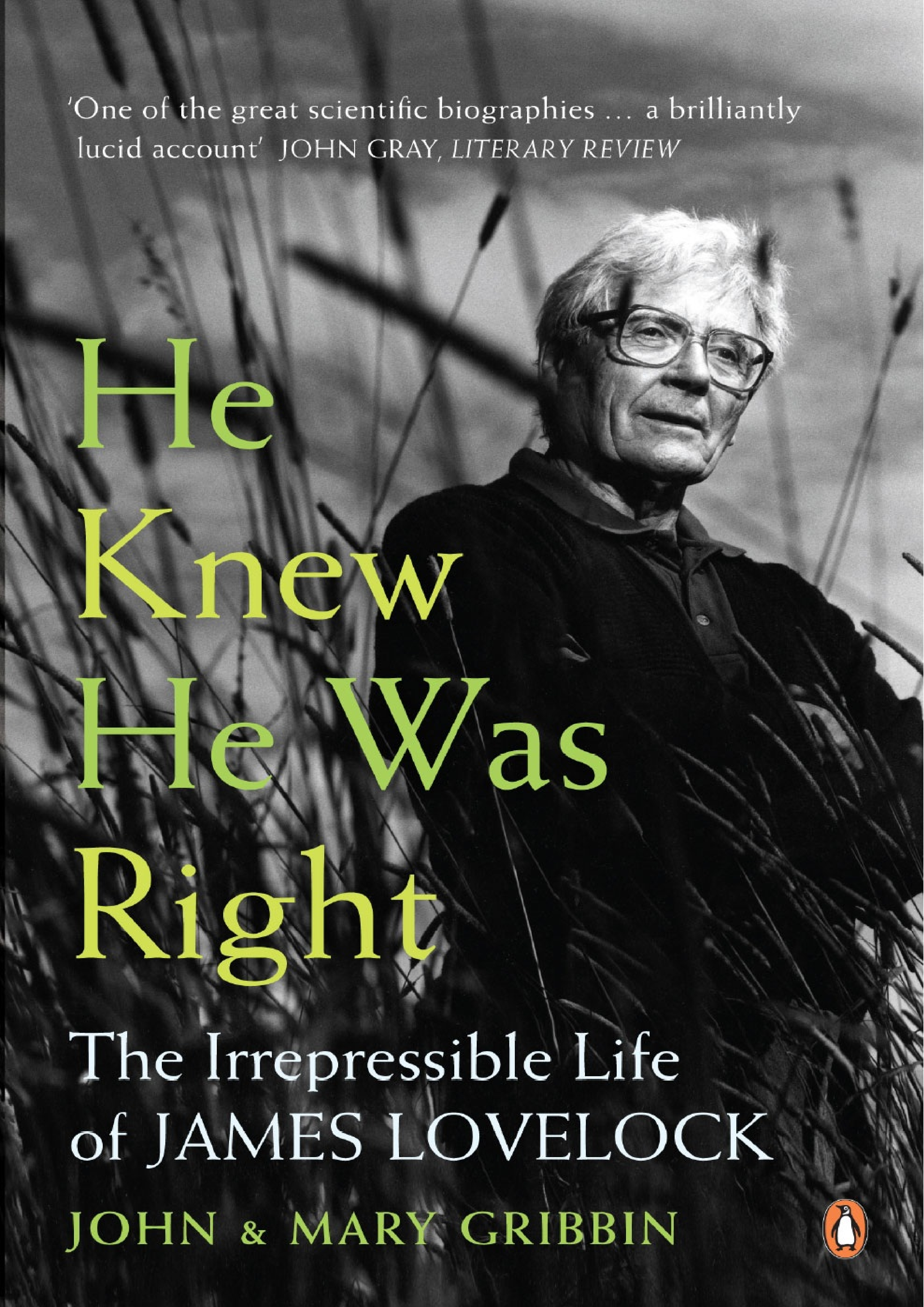

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He Knew He Was Right

The Irrepressible Life of JAMES LOVELOCK

JOHN & MARY GRIBBIN

PENGUIN BOOKS

HE KNEW HE WAS RIGHT

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ABOUT THE AUTHORS

John and Mary Gribbin are two of today's greatest writers of popular science. Together they have collaborated on many books, including *Ice Age, Richard Feynman: A Life in Science* and *Stardust*. John is also the author of bestselling titles including *In Search of Schrödinger's Cat, Science: A History* and *Deep Simplicity*.

JOHN GRIBBIN AND MARY GRIBBIN

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Citation for the Wollaston Medal, awarded to James Lovelock by the Geological Society in 2006

Even in the illustrious history of the Society's senior medal, first awarded to William Smith in 1831, it is rare to be able to say that the recipient has opened up a whole new field of Earth science study. But that is the case with this year's winner, James Lovelock.

Lovelock does not lack for honours after his long and distinguished career in science. As well as more lately being created Companion of Honour and Commander of the Order of the British Empire, he became a Fellow of the Royal Society in 1974, and garnered many awards for his pioneering work in chromatography. Lovelock invented the electron capture detector for gas chromatography – an instrument whose exquisite sensitivity has subsequently been central to several important environmental breakthroughs. For example, during the 1960s it enabled the documentation of widespread dissemination of harmful and persistent pesticides like DDT, and later on the technique was extended to the polychlorinated biphenyls (PCBs). Lovelock himself famously used the technique to chart the ubiquitous presence of chlorofluorocarbons – CFCs – in the atmosphere, triggering the discoveries (by Rowland and Molina) of the harmful influence of CFCs on atmospheric ozone – work for which they received the Nobel Prize for Chemistry in 1997. He has also developed instruments for exploring other planets than our own, including those aboard the two Viking craft that went to Mars in 1975, about which I know he will tell us in a moment.

But Lovelock really came to high public prominence for the scientific concept that has captured the imaginations of Earth scientists, biologists and public alike – the concept for which we as geologists chiefly honour him today – the Gaia Hypothesis and Theory. This view of the planet and the life that lives on it as a single complex system, in some ways analogous to a homeostatically self-regulating organism, is what has given rise to the field we now know as 'Earth System Science', also the most recently formed of this Society's Specialist Groups.

It is hard to overemphasize the unifying nature of this holistic worldview, which has broken down artificial disciplinary barriers that have existed since the late eighteenth and early nineteenth century when Societies such as this were first formed, and the wonderful richness of insight that has flowed from the multidisciplinarity that has followed. This is especially so in the understanding of feedback loops between life and the environment, especially the dimethyl sulphide – cloud albedo – surface temperature (CLAW) hypothesis, and the whole idea that life coupled with its material environment regulates planetary temperature and chemical composition over long timescales by influencing rates of silicate weathering.

James Lovelock, it gives me enormous pleasure to reward this towering career with the highest honour the Society can bestow.

Preface
The Edge of Chaos

In Greek mythology, Chaos was the first thing to appear, a formless void out of which Gaia, the Mother of the Earth, emerges. In modern science, chaos theory describes the behaviour of systems which are so sensitive to conditions that a very small change in one property can lead to a large and unpredictable change in the whole system. As we described in our book *Deep Simplicity*, stable systems which are insensitive to their conditions are dull and uninteresting places where nothing changes. At the other extreme, completely chaotic systems are so wild and unpredictable that nothing interesting can happen there, either. But right on the edge of chaos, where stability begins to break down, interesting things happen and complex structures emerge.

To highlight how this happens, we can imagine a smoothly flowing river in which there is one large rock sticking out above the surface. The flowing water of the river divides around the rock, and joins up again seamlessly on the other side, so that small chips of wood floating on the water follow these ‘streamlines’. If there is rain upstream, the flow of the river will increase, and as it does so it goes through at least three distinct changes.

First, as the flow builds up, little whirlpools appear behind the rock. These vortices stay in the same place, and a chip of wood floating downstream may get trapped in one of them and go round and round for a long time.

At the next stage, as the speed of the water flowing downstream increases, vortices form behind the rock, but don’t stay there. They detach themselves, and move away downstream, retaining their separate existence for a while before dissolving into the flow. As they do so, new vortices form behind the rock and detach in their turn. Now, a chip of wood might get caught in one of these eddies and be carried downstream still circling around in the vortex as long as the vortex lasts.

As the flow of water increases still further, the region behind the rock where the vortices survive gets smaller and smaller, with vortices forming and breaking up almost immediately to produce a choppy surface in which there are seemingly only irregular fluctuations – turbulence. Eventually, when the flow is fast enough all trace of order in the region behind the rock disappears. No vortices form and the entire surface of the water breaks up behind the rock into unpredictable chaotic motion.

Interesting things happen on the edge of chaos, and one of those interesting things is life – in particular, life on Earth. But the edge of chaos is a dangerous place to live, because small changes in the environment can, in certain circumstances, lead to large and not always predictable consequences. Humankind is now making just such a change to the environment of the Earth, causing a rapid (by geological standards) rise in temperature which, it is claimed, may flip the climate system into a new state, like a vortex breaking off and floating away downstream. This emergence of chaos in the scientific sense could produce chaos in the everyday sense of the word, as society collapses under the pressure.

Gaia is also the name given to a theory which describes how the different components of the Earth System, living and non-living, have worked together for eons to maintain conditions suitable for life. In a reversal of the story of the Greek myth, could chaos be about to bring about the death of Gaia? Are we also living on the edge of chaos in the everyday sense of the term? To answer that question we will need to investigate the relationship between global warming and Gaia, encapsulated in the work over the past forty years of James Lovelock, the father of Gaia theory.

Introduction

'I don't understand what's going on. I'm delighted, but I'm baffled. Absolutely baffled. It's not the sort of thing you expect at the age of 87.' Jim Lovelock had just returned from a lecture tour of the United States, where he had been promoting his book *Revenge of Gaia*. For half his life he had been promoting the idea that the living and non-living components of Planet Earth act as components of a single system, dubbed 'Gaia' by the novelist William Golding, in which biological processes play a major part in controlling the physical environment. For almost all that time, the idea – which crucially sees the Earth System involving both living and non-living components in feedbacks which have, until now, maintained conditions suitable for life – had been ridiculed by the scientific establishment. Even when some of Lovelock's ideas began to become part of the mainstream, most scientists couldn't bring themselves to use the term 'Gaia', preferring to refer to Earth System Science. But in 2006, everything changed.

On his tour, Lovelock spoke at universities across the USA. 'Everywhere I went,' he told us in amazement, 'I was introduced as "the originator of Gaia theory", which they described as "the basis of Earth System Science".' Still slightly jet-lagged from the trip, he shook his head in wonder. 'They didn't even call it a hypothesis. They called it "Gaia", and "theory". Something's happened this year to cause a sudden swing from "this is dubious, we're not sure about it," to "this is solid science." ' His American wife, Sandy, proudly took up the tale: 'And what Jim is too modest to tell you is that everywhere we went he received standing ovations. Sometimes, even before he spoke.'

We were visiting Jim and Sandy at their remote home on the Devon/Cornwall borders, to lay the groundwork for this book; not just a biography of Lovelock himself, but also an account of the intertwined stories of Gaia theory and global warming – for, of course, it was the sudden appreciation that the world really is warming at an unprecedented rate, and that this is due to the activities of humankind, that had equally suddenly made Gaia theory respectable. It is now widely recognized that the most critical global problem facing us today is environmental. Whether or not climate change itself has reached a 'tipping point', after which drastic change is inevitable, the middle of the first decade of the twenty-first century seems to have marked a tipping point in the public perception of climate change, which is now seen as a real and dramatic threat. Lovelock has been warning about the danger of global warming for decades, but had generally been regarded as a somewhat hysterical prophet of doom. In 2006, it became clear that he had been right all along.

After coffee, we all went for a walk around the thirty-five acres of land that the Lovelocks are 'giving back to Gaia'. Although it was already the last week in September, the temperature was in the low twenties; we came to a wide river bed, where a trickle of water flowed across the stones. 'That's the lowest I've seen it since I moved here thirty years ago,' said Jim. 'Hard to believe there used to be salmon in the river here.' But on a brighter note, he told us that in the unmanaged woodlands wild orchids have returned, their seeds carried on the wind; and we saw for ourselves several badger setts. In the meadows, wild flowers proliferate in spring.

After our walk, we got down to work, pulling out the material we needed from the Lovelocks' archive, pausing now and again to linger a little over some key document, and to note how attitudes had changed. Where a generation ago Gaia was regarded as at best cranky and at worst alarmist, it is now more and more accepted as a warning truth, an idea whose time has come and an idea we must embrace to save the world.

Even a quick glance at the material confirmed our view that the time is therefore ripe for a book which sets Lovelock's life and work in the context of what is happening to our planet now, and which spells out for those who still think of Gaia as some kind of crazy left-field idea that the oneness and mutual interdependence of both life and non-life is the key to understanding both the past and the future of the Earth. We have known Lovelock for more than thirty years, but the specific trigger for this book, and the reason for our visit to him in September 2006, came at an event earlier that year in Brighton, where we were struck by the response of young people to him and his ideas. Few of those people who now see Lovelock as an iconic figure know about his life and his earlier work as a chemist and inventor – work which included twenty years of medical research (among other things, discovering just how the common cold is spread by coughs and sneezes), inventing the detectors used to search for life on Mars, providing scientific backup for the emotional message of Rachel Carson's book *Silent Spring*, and the observations which led to the discovery of the depletion of ozone in the now-notorious 'hole' over Antarctica.

In his personal life, he was a Quaker and conscientious objector in the Second World War (later changing his mind in view of the evils of Nazism, but continuing to see the policy of mass bombing of civilian targets as a crime), supported his family for a time on a visit to the United States by selling his blood, and gave up a salary of $40,000 a year (a small fortune in 1963) to become an independent scientist based in an English village – a base from which all his best-known work emerged.

After such a long and exciting life, as he entered his ninth decade at the beginning of the twenty-first century, Lovelock was contemplating a quiet retirement and wondering what the next decade would hold – he did not anticipate that just over halfway through that decade his profile would be higher than ever, he would be a bestselling author, and he would be embroiled more deeply than ever in the fight to get politicians to see sense about global warming. But Lovelock is no ordinary octogenarian. Two days earlier, he had heard that his contract as a consultant to the Ministry of Defence had just been renewed, giving him, as he gleefully pointed out, the prospect of maintaining the relationship up to the age of 90. Shortly after our meeting that September day in 2006 he was off again, this time to Japan (via Cardiff) to spread the word about Gaia. We returned to Sussex with a car full of Lovelock's papers and several hours of recorded reminiscences, to begin to try to do justice to one of the most important scientists of the past hundred years.

This book is written not in the expectation of making any converts to the acceptance of the reality of global warming and Gaia theory, both of which are now well established and need no proselytizing; we do hope to set in its historical context the development of one of the crucial ideas of the twentieth century, and the way it was developed by a most unusual scientist, one whose entire life can be seen, with hindsight, as a unique preparation for his revolutionary insight. But the story begins more than a hundred years before he was born.

John Gribbin
Mary Gribbin
March 2008

Prologue
A Beginner's Guide to Gaia

The Gaia concept was first formulated as a scientific hypothesis by James Lovelock, in the 1960s. It grew out of his work for NASA on experiments designed to detect life on Mars. The idea was presented in scientific papers in the 1970s and in a book, *Gaia: A New Look at Life on Earth,* in 1979. The essence of Lovelock's argument is that the Earth can be regarded as a single living system, in which components traditionally regarded as 'non-living' (such as the cycle of weathering of rocks) are important to components traditionally regarded as alive, while components traditionally regarded as alive are important to 'non-living' systems. Feedbacks involving both kinds of process have, according to the Gaia hypothesis, maintained conditions suitable for life on our planet over billions of years, in spite of external threats such as the steady warming of the Sun which would otherwise have made the Earth uninhabitable. A good analogy, made by the American Lewis Thomas, is that the Earth is like a single living cell; or, as a student of the biologist Lynn Margulis put it, 'symbiosis seen from space'.

A *hypothesis* is a scientific idea put forward to explain known facts but as yet untested by experiment. A *theory* is a scientific idea that has made successful predictions about the outcome of experiments, and is therefore much stronger than a hypothesis. The Gaia concept is now widely regarded as a fully fledged theory, because Lovelock and others have used it to make predictions which have been borne out by experiment and observation – in particular, the idea of Daisyworld, which we discuss in Chapter 8. The original hypothesis was proposed to explain why active chemical substances such as oxygen and methane persist in stable concentrations in the Earth's atmosphere, making Earth the Goldilocks Planet – 'just right' for life. Lovelock suggested that the long-lasting presence of these gases is a signature of life, and that detecting such substances in the atmospheres of other planets would be a reliable way to detect life. The corollary was that since the atmospheres of Mars and Venus contain scarcely anything except the stable, un-reactive gas carbon dioxide, there can be no life on either of them. This prediction has (so far) been borne out by observations made by spaceprobes, and is another successful prediction of Gaia theory.

Lovelock's idea received little attention from the scientific community until he wrote an article about it in the magazine *New Scientist* in 1975. This led in 1979 to his first book on the subject; it provoked a hostile response from many evolutionary biologists at the same time that it was taken up and championed with almost religious fervour by some environmentalists and members of the Green movement. In both cases, the choice of the name Gaia (suggested to Lovelock by his friend and neighbour the novelist William Golding from that of the Greek goddess of the Earth) played a big part in determining the strength of the reaction.

The chief criticism of Lovelock's idea was that as the Earth is a single system, there is no way for competition between different planets to produce the kind of world we live in by natural selection. How could different individuals in living populations, let alone the non-living components of the system, work together for the good of all when each individual has evolved through selection and 'survival of the fittest'? Richard Dawkins, best known as the proponent of the idea of the selfish gene, argued in his book *The Extended Phenotype* (1982) that this would require foresight and planning. He dismissed the idea that feedback could stabilize the Earth System, and said 'there is no way for evolution by natural selection to lead to altruism on a global scale'. Lovelock addressed these criticisms in his later work, in particular his book *The Ages of Gaia* (1988). Apart from specific rebuttal of some of the criticism, he argues that critics such as Dawkins take too narrow a view, while he sees things from the perspective of a general practioner rather than a specialist – the medical analogy is apt, because Lovelock cut his scientific teeth in medical research.

A related criticism is that the planet as a whole cannot be alive, because it cannot reproduce. But Lovelock points out that this rests upon a very limited definition of life centred on the ability to replicate and pass on genetic information to succeeding generations. It would exclude as 'non-living' such obviously living things as a mule, or a post-menopausal woman. A better definition of life involves self-sustaining systems occurring in feedback loops, feeding off an external flow of energy, as we discuss in Chapter 3.

Lynn Margulis sees things slightly differently from Lovelock, although she is an enthusiastic supporter of the idea of Gaia. She says that Gaia is 'not an organism', but 'an emergent property of interaction among organisms'. Gaia is 'the series of interacting ecosystems that compose a single huge ecosystem at the Earth's surface.' But she agrees with Lovelock that, 'the surface of the planet behaves as a physiological system in certain limited ways.'

The debate about Gaia has intensified in the twenty-first century because of its relevance to the problem of global warming caused by a buildup of greenhouse gases in the atmosphere as a result of human activities. Lovelock believes that unless drastic action is taken to alleviate the situation, the increase in temperatures will soon reach a tipping point that takes the Earth System beyond the limits where the present set of natural feedbacks can operate, and that before the end of the present century the planet will 'flip' into a much hotter state maintained by a different set of feedbacks. This conflicts with the conventional wisdom, which assumes that, although the consequences of the warming may be unpleasant, it will proceed in a more or less steady fashion for decades, with no sudden jumps.

The increasing pace of the observed climate change has stimulated research in all areas of Earth System Science, and the shift of opinion in favour of Gaia theory is highlighted by the 'Amsterdam Declaration' made jointly in 2001 by four international global change research programmes – the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change (IHDP), the World Climate Research Programme (WCRP) and the international biodiversity programme DIVERSITAS. They 'recognize that, in addition to the threat of significant climate change, there is growing concern over the ever-increasing human modification of other aspects of the global environment and the consequent implications for human well-being', and go on to say:

Research carried out over the past decade under the auspices of the four programmes to address these concerns has shown that:

• The Earth System behaves as a single, self-regulating system comprised of physical, chemical, biological and human components. The interactions and feedbacks between the component parts are complex and exhibit multi-scale temporal and spatial variability. The understanding of the natural dynamics of the Earth System has advanced greatly in recent years and provides a sound basis for evaluating the effects and consequences of human-driven change.

• Human activities are significantly influencing Earth's environment in many ways in addition to greenhouse gas emissions and climate change. Anthropogenic changes to Earth's land surface, oceans, coasts and atmosphere and to biological diversity, the water cycle and biogeochemical cycles are clearly identifiable beyond natural variability. They are equal to some of the great forces of nature in their extent and impact. Many are accelerating. Global change is real and is happening now.

• Global change cannot be understood in terms of a simple cause–effect paradigm. Human-driven changes cause multiple effects that cascade through the Earth System in complex ways. These effects interact with each other and with local- and regional-scale changes in multidimensional patterns that are difficult to understand and even more difficult to predict. Surprises abound.

• Earth System dynamics are characterised by critical thresholds and abrupt changes. Human activities could inadvertently trigger such changes with severe consequences for Earth's environment and inhabitants. The Earth System has operated in different states over the last half million years, with abrupt transitions (a decade or less) sometimes occurring between them. Human activities have the potential to switch the Earth System to alternative modes of operation that may prove irreversible and less hospitable to humans and other life. The probability of a human-driven abrupt change in Earth's environment has yet to be quantified but is not negligible.

• In terms of some key environmental parameters, the Earth System has moved well outside the range of the natural variability exhibited over the last half million years at least. The nature of changes now occurring simultaneously in the Earth System, their magnitudes and rates of change are unprecedented. The Earth is currently operating in a no-analogue state.

This is as good a summary as any of why Gaia theory is so important today.

1

The Greenhouse before Gaia

Scientific understanding of human-induced global warming is older than you might think. The idea that carbon dioxide released into the atmosphere by burning fossil fuel would warm the planet was clear to at least a few scientists more than a hundred years ago; and that was barely two hundred years after the scientific revolution which, among other things, led to an understanding of atmospheric chemistry. The importance of what is now called the anthropogenic greenhouse effect began to emerge not in the late twentieth century through the work of people like James Lovelock, but in the early nineteenth century through the work of people like Jean-Baptiste Joseph Fourier (usually known as Joseph Fourier).

Of course, nobody could begin to understand the role of carbon dioxide in keeping our planet warm until it was known what carbon dioxide was, and that it was present in the atmosphere. In the seventeenth century, Robert Boyle had begun to appreciate the nature of the atmosphere when he described it as the product of the 'exhalations of the terraqueous globe', a rather Gaian description by which he meant the products of volcanic activity, decaying vegetation and animal life. Although this seems obvious today, it was a profound step forward from the old idea that the atmosphere was made up of some mystical substance known as the ether. It was only in the 1750s that Joseph Black showed that air is a mixture of gases, not a single substance, and isolated one of those gases, then known as 'fixed air' but now called carbon dioxide – the first component of the atmosphere to be identified. Two decades later, Daniel Rutherford isolated nitrogen from air, and oxygen was identified by Joseph Priestley and independently by Carl Scheele. In the early 1780s, Henry Cavendish determined the composition of air to be almost exactly 79 per cent nitrogen and 21 per cent oxygen, with just traces of other gases, including carbon dioxide; the scene was set for nineteenth-century scientists to begin to understand how this blanket of air keeps the Earth warm.

Although nobody at the time had any inkling of the role that his discovery would play in the story of global warming, with hindsight that story can be seen to begin in 1800, when the astronomer William Herschel was studying the warming effect of light from the Sun passing through different prisms and coloured filters. To his surprise, he found that when light from the Sun was split up into a rainbow pattern by a prism, a thermometer placed beyond the red end of the spectrum warmed up, even though it was receiving no visible light from the Sun. He had discovered what later became known as 'infrared' radiation – radiation like light but with wavelengths longer than red light, invisible to our eyes. But it was a quarter of a century before this invisible radiation was first linked with global warming.

Fourier, who was born in 1768 and died in 1830, came to the study of global warming late in his life, but he is the first person known to have appreciated that the atmosphere keeps the Earth warmer than it would be if it were a bare ball of rock orbiting at the same distance from the Sun. Fourier was very interested in the way heat is transmitted, and among other things he calculated an estimate for the age of the Earth based on how long it would have taken for a ball of molten rock to cool to the Earth's present state. His estimate was a hundred million years, a number so staggeringly large that he didn't dare publish it – many people in his day still believed in the age of the Earth based on a literal interpretation of the chronology in the Bible, which comes out at about six thousand years. But Fourier's estimate is only 2 per cent of the best modern estimates for the age of the Earth.

The calculation of how hot (or rather, how cold) a bare ball of rock orbiting the Sun at the same distance as the Earth would be is relatively straightforward, and Fourier and his contemporaries got it more or less right. But we don't have to worry too much about the calculation because there is indeed a bare ball of rock orbiting the Sun at the same distance as the Earth – our Moon – and scientists have measured its average temperature. Like the Earth, the surface of the Moon gets colder at night and warmer by day, but averaging over the whole ball of rock it is a chilly –18°C. Averaging over the entire Earth in the same way, the surface temperature is 15°C. Something keeps the surface of the Earth about 33°C warmer than it would otherwise be – and that something, as Fourier realized, is the atmosphere. He carried out his studies of global warming in the 1820s, and in 1824, summarizing work that he had previously reported in various places, he wrote that 'the temperature [of the Earth] can be augmented by the interposition of the atmosphere, because heat in the state of light finds less resistance in penetrating the air, than in repassing into the air when converted into non-luminous heat'.[1] In other papers published in that decade he made the analogy that heat is trapped near the surface of the Earth by the atmosphere in the way that heat is trapped inside a hothouse. Specifically, he referred to the warming inside a box with a glass cover, exposed to the Sun, and suggested that the glass lid retained the 'obscure radiation' (now known as infrared) inside the box. His analogy was wrong, but much later the term 'greenhouse effect' came to be almost inextricably associated with global warming – so much so that we shall use it in this way ourselves.

Why was Fourier wrong? The air in a greenhouse gets hot because the rays from the Sun passing through the panes of glass in the greenhouse heat the ground inside the greenhouse, which gives up warmth to the air above it. Hot air rises, and outside a greenhouse air warmed in this way rises and carries