rewards for high-prestige science after the Second World War which led to a research style, particularly in the United States, very different from that of pre-war Europe. She contrasts the self-consciously philosophical style of the Germans with the peer-review-panel-conscious, grant-dependent Americans Robert Briggs and Tom King, who in 1951 managed to clone frogs' eggs from embryos.

Kolata provides a nice account of the specialization that led to a distinctive bioethics movement in the United States with its roots in concerns about the rationing of health care (kidney dialysis in particular), medical experiments (the Tuskegee syphilis experiment and hepatitis B) and the new genetic medicine. She shows how, in the deeply distrustful environment of the United States in the late 1960s, these diverse issues were brought together, and provides a valuable stimulus to further thought about the period.

To many at the time it seemed that science would go on remorselessly, despite the fledgling concern for bioethics. In 1978 the science writer David Rorvik claimed a scoop: the report of the first cloning of a human being. Coming shortly after reports of recombinant-DNA technology, it seemed to the public all too likely. Films such as Ira Levin's *The Boys from Brazil* explored the implications of cloning. The discussion of what ultimately proved a fantasy crystallized the opinion that this was a premature panic.

Yet around the same time the distinguished embryologist Karl Illmensee was becoming an academic celebrity for apparently succeeding in transferring the nucleus of one mouse into the embryo of another. He then became the centre of controversy when it was claimed that he had misrepresented his experiments. Kolata has clearly spoken to many of the participants in the Illmensee affair. Was Illmensee's work genuine? She explores its history in great detail, not resolving the question but pointing out the way it came to raise ethical issues in the context of cloning.

Kolata then considers the case of Steen Willadsen, who worked with farm animals in the Agricultural Research Council's Unit on Reproductive Physiology and Biochemistry at Cambridge. He managed to create chimaeras by successfully transferring nuclei not just between animals but also between species. Unlike his US counterparts, he was not under pressure to publish. When he did, he chose *Veterinary Record* as well as *Nature*. He wanted to engage in "great absorbing endeavours".

Kolata was so involved personally in the third part of her account that it seems almost autobiographical at times. It describes how the technologically inclined Keith Campbell, working with Ian Wilmut, who had preceded Willadsen at Cambridge, produced Dolly and then marketed her. The science, which is clearly described, is a matter of record, so the distinctive aspect of the book is perhaps the story of the interaction between the pragmatic Scottish context and the US bioethics community.

Kolata describes the media blitz that hit the Roslin Institute. The institute had been preparing for three months to cope with considerable public response and, on the Sunday when the British newspaper the *Observer* broke the story, six people were in place to handle enquiries. But the scale of interest was far greater than anything anticipated. The ethicist Ronald Munson is quoted as exclaiming: "Here we have this incredible technical accomplishment and what motivated it? The desire for more sheep milk of a certain type."

Kolata addresses the implications for philosophy and medicine and cites both enthusiasts and sceptics. But potential practical uses of the technique are not her concern; rather, her focus, like that of many critics, is the possibility of human clones. Here I think she is less successful at grappling with the issues, which are admittedly still ill-formed.

Is *Clone* a magisterial reflection on how Dolly has brought to fruition the century-old dream of embryology? Clearly not: Gunther Stent's name acquires a 'd', Driesch has become Dreisch, characters have been omitted, and so on. Yet the extraordinary worldwide interest in cloning has stimulated a reflective and timely essay. In the heat of the moment, Kolata has given us a mature reflection on the shifting borders between technology, philosophy, public concern and science; and she has managed to tell some good stories, too. □

Robert Bud is at the Science Museum, Exhibition Road, London SW7 2DD, UK.

Homage to Earth

Gaia's Body: Toward a Physiology of Earth
by Tyler Volk
Copernicus: 1998. Pp. 269. $27, £19

Peter Westbroek

It is almost two decades since the inventor James Lovelock brought an ancient goddess back to life. She was Gaia, mother Earth, who, in Lovelock's view, had made our planet a comfortable home for life for the past four billion years.

The 'Gaia hypothesis' has always aroused controversy among the scientific community. The idea of a 'homeostatic superorganism' was accused of being poorly defined and

The shell of Aphrodite

Since antiquity, molluscs — in particular the nautilus — have been associated with Aphrodite, the goddess of love, as a symbol of the female pudenda, sexual desire and aphrodisiacs. Although the female paper nautilus forms a shell, the male, as shown in this nineteenth-century lithograph, does not; to fertilize the female, one of the tentacles of the male separates from its body and swims towards her as a giant penis. The mollusc is one of several animals that have sneaked into Christian Ratsch's *Plants of Love* (Ten Speed Press, $19.95, pbk), a leisurely, visually enticing romp through the history, botany, chemistry, pharmacology and identification of various aphrodisiac plants. User instructions are also included. *Caveat emptor*!

impossible to falsify. Furthermore, because Gaia is unique and hence not subject to natural selection, some evolutionary biologists could not perceive an organizing principle or mechanism by which global homeostasis could be explained. And worst of all, Gaia received an extra mystical flavour as it was adopted by the New Age movement.

Over the years, Lovelock and his collaborators have done their utmost to clarify the concept and make it suitable for scientific research. Despite its flowery title, *Gaia's Body* is a further attempt at demystification, and, I dare say, is a major step forward.

For years Tyler Volk has been studying the carbon cycle, crop growth for the US space agency NASA's closed systems, and the climatic effects of evolutionary change. It is this personal mix of system dynamics and Earth and life science that makes him talk about 'Gaia' rather than 'biosphere'.

This book has convinced me that Volk is right: it is not Gaia but biosphere that is the woolly concept. Biosphere conveys little more than a vague notion of where life can be found. Gaia, as described by Volk, relates to a dynamical system with a particular behaviour and clearly defined boundaries. It comprises not only life itself, but also the atmosphere, soils and ocean with which it interacts. This definition identifies the system well, as material is circulating far more rapidly within it than is exchanged with its environment, the deeper Earth and outer space. These exterior domains set the boundary conditions for Gaia: they provide energy and topographical relief, supply basic nutrients, and act as the ultimate recipient for refuse.

Volk argues convincingly that Gaia may be compared to a physiological system, even if it does not evolve in the strict Darwinian sense. Atmospheric and ocean circulation and the continent-draining water cycle intimately connect all its parts. For example, Keeling's annually oscillating curve of atmospheric carbon dioxide in Hawaii reflects the alternating photosynthetic and respiratory cycles of continental vegetation in the Northern Hemisphere. In addition, the finer details of this curve record the multiple interactions of all the additional components of the carbon cycle.

Another case in point is the recycling of essential nutrients, which is high for oceanic phosphate. This property of Gaia sets the stage for a huge amplification of biological activity on Earth. Also fascinating is Volk's account of how the cycles of nitrogen and phosphate are coupled in the ocean, in both sea water and organisms.

These examples, and many others discussed by Volk, indicate that Gaia is organized, at least to some degree, despite the evolutionary biologists' theoretical reservations. Volk argues that, instead of natural selection among other planetary systems, it is the proliferation of life within the constraints of the Gaia system that automatically brings about the organization.

What are the functional parts of Gaia? Are they the ecosystems, the hierarchy of systematic taxa, or the cycles of elements? Volk emphasizes a subdivision in what he calls biochemical guilds: groupings of organisms that perform similar functions, such as photosynthesis, respiration, sulphate reduction or nitrogen fixation. He then describes some important species-transcending "molecules that run the world", such as chlorophyll, Rubisco and glutamine synthethase, and explains how they combine to form both the cellular and the Gaian metabolic web.

This leads him to the idea, developed by G. J. Williams in his book *The Molecular Biology of Gaia* (Columbia University Press, 1996), that the molecular controls on the activities of these universal enzymes are also responsible for fine-tuning the global biogeochemical cycles.

The attraction of Williams's hypothesis is obvious. It allows us to study Gaian metabolism directly from its molecular biological underpinnings and to ignore the ecological level of biological organization. It may even work for the cycling of some critical nutrients, such as phosphate and nitrogen.

But what about the production of the most important carbon sink on Earth, calcium carbonate, virtually all of which is made by organisms. In the open ocean more than 200 species of coccolithophore algae and foraminifera make calcium carbonate, and the amount produced depends on their success in proliferating. They compete with thousands of other organisms, are subject to intensive grazing as well as bacterial and viral infections, and have to cope with the vagaries of ocean circulation. However fuzzy and complex the ecosystem concept may be, it cannot be ignored.

Despite this and other minor shortcomings, *Gaia's Body* is an outstanding contribution to global ecology. Its main virtue is that it brings the Gaia concept to the heart of science. By defining clearly the boundaries of the Gaian system and placing biogeochemistry in that context, the concept loses much of the the fuzziness it may have had for some scientists.

The book is very well written and easy for a broadly educated audience to follow. Although I am familiar with much of the content, the details are knitted together so well that I read it as an exciting novel. I am pleased to see that Lovelock's invention is getting such an excellent follow-up. It is to be hoped that *Gaia's Body* will further the acceptance of Gaia by the scientific community. □

Peter Westbroek is at the Leiden Institute of Chemistry, Gorlaeus Laboratories, University of Leiden, PO Box 9502, 2300 RA, Leiden, the Netherlands.

New in paperback

Scientific and Ordinary Action: Ethnomethodology and Social Studies of Science
by Michael Lynch
Cambridge University Press, £14.95, $21.95
An empirical approach to the sociology of scientific knowledge that attempts to avoid the pitfalls of 'scientism' and 'foundationalism'.

Science, Nonscience, and Nonsense: Approaching Environmental Literacy
by Michael Zimmerman
Johns Hopkins University Press, $14.95, £12.50
"Zimmerman's account of [the battle between creationists and Darwinian evolutionists] is fascinating and at times frightening", John Adams, *Nature* **381,** 125 (1996).

Krakatau: The Destruction and Reassembly of an Island Ecosystem
by Ian Thornton
Harvard University Press, $18.95, £12.50
"Exciting, information-rich... will provide hours of truly pleasurable reading and also clear and deep insights into the fascinating biology of islands, the struggle to construct comprehensive theories for difficult processes and the techniques for preserving species diversity", Lawrence B. Slobodkin, *Nature* **381,** 205 (1996).

The Snow Leopard
by Peter Matthiessen
Vintage, £5.99
Matthiessen recounts his 1973 trip with the field biologist George Schaller to the Himalayas in search of the rare snow leopard, and tells of the inner spiritual journey that it engendered.

Higher Superstition: The Academic Left and Its Quarrels with Science
by Paul R. Gross and Norman Levitt
Johns Hopkins University Press, $16.95, £14
Since its publication in 1994, this book has been at the centre of the 'science wars'. "Convincing, and therefore frightening.... This is a conversation that needs many participants — including, most especially, those who have chosen to ignore or shrug off what has become an embarrassment to serious scholarship", Donald Kennedy, *Nature* **368,** 409 (1994).

Hunting Down the Universe: The Missing Mass, Primordial Black Holes and Other Dark Matters
by Michael Hawkins
Abacus, £7.99
"A good yarn. But I think the actual situation is more prosaic and less polarized.... In due course, as more data on quasar fluctuations accumulate, [the author's] hypothesis is very likely to be disproved to the satisfaction of any sapient individual", William H. Press, *Nature* **388,** 138 (1997).