plants. They thus demonstrate that eco-systems are to be viewed as capital assets, supplying both services and savings.

There are a host of similar initiatives around the world. The authors describe in detail how Australia is tackling its farmland salinity crisis through its Murray–Darling Basin Initiative, which, with an investment of US\$1.4 billion over the first three years, plus a major tree-planting effort, covers 360,000 square miles and accounts for 40% of the country's agricultural production. The United States offers cash payments for a range of environmentally supportive farming practices. Similarly, Costa Rica supplies payments to farmers who protect ecosystem assets on their land, with compensation based on the ecosystem services provided. The book presents additional breakthroughs in Vancouver, Adelaide and Rio de Janeiro, as well as broad-scope efforts such as tradeable pollution permits for sulphur and carbon dioxide, and safeguard measures for wild pollinators that support one-third of our food crop harvests. The authors emphasize that there are now hundreds of such enterprises, all showing that conservation need not always cost money, rather, it can save it in huge amounts.

In essence, the strategy counters a basic environmental problem: that goods and services without price are usually viewed as without value. As a result, to cite Richard Sandor, a financial innovator in Chicago who has been devising ways to mass market a number of environmental commodities: "Nature [without prices] becomes like an all-you-can-eat buffet" — and few people don't overeat at a buffet. A further result, as the authors document with illuminating detail, is that the "importance of ecosystem services is often widely appreciated only upon their loss". Fortunately, the green gold entrepreneurs are "establishing a truly new economy of Nature, with focus on the self interest factor that makes the strategy self sustaining". The challenge is to change the rules of the game so as to produce new incentives for environmental protection, readily available through the profit motive.

The two books are exemplary expositions of the environment's role in fostering socio-economic advance as part of human well-being. Each in its way is enlightening from start to finish. ■

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More on the environment

Cradle to Cradle: Remaking the Way We Make Things

by William McDonough & Michael Braungart
North Point Press, \$25

Eco-economy: Building an Economy for the Earth

by Lester R. Brown
Earthscan, £17.99

State of the World 2002

by The Worldwatch Institute
Earthscan, £12.95 (UK); W. W. Norton \$29.95 (hbk), \$15.95 (pbk) (US)

Guide to Sustainable Development and Environmental Policy

edited by Natalia Mirovitskaya & William Ascher
Duke University Press, \$89.95 (hbk), \$34.95 (pbk)

Building machines more like humans

Flesh and Machines: How Robots Will Change Us

by Rodney A. Brooks
Pantheon: 2002. 288 pp. \$26

The Body Electric: An Anatomy of the New Bionic Senses

by James Geary
Weidenfeld & Nicolson: 2002. 256 pp. £20
Igor Aleksander

As robots are made to be more like humans, and human organs are replaced by mechanical artefacts, will humans cease to be more 'special' than machines? A hurried reading of the dust jackets of these two books may give the false impression that they are ill-informed texts written to create fears about advancing bionic aliens mischievously created in frankensteinian laboratories. Actually, nothing could be further from the minds of

the authors. Both books cover serious scientific and philosophical issues in the design of humanoid robots and the replacement or supplementation of organs.

Rodney Brooks, an influential roboticist from the Massachusetts Institute of Technology, has been building what he calls 'artificial creatures' for some years. In *Flesh and Machines* he writes autobiographically of his flight from 'representational' artificial intelligence, in which the programmer endows the robot with a full description of its environment so that it might act intelligently. Brooks now takes an alternative 'situated' approach in which the robot is equipped with ways of reacting appropriately to its environment without the burden of referring all its actions to pre-digested models supplied by the programmer. Indeed, one of his early models was an insect-like hexapod called Genghis that reacted to the heat emitted by mammals in its vicinity. Later systems include the celebrated Cog, a waist-up robot that moves its limbs and eyes appropriately in the presence of a human. Another machine, Kismet, responds to humans with appealing facial gestures.

An evident weakness in this approach is that Brooks may need to return to some inner representation to introduce the contemplation that humans use a lot of the time, before reacting to their environments. This does not need to be done through pre-programming but in a brain-like fashion through a rapid evolution of, and learning in, an artificial nervous system. Brooks argues that this is just an elaboration of what he has achieved already, but this remains to be seen.

The book moves from an autobiographical to a predictive style in which visions of

robots range widely from helpful house servants to agents on planetary missions. But my greatest enjoyment came from the end of the book, which is more philosophical. Brooks' philosophy is blunt: abilities that some hold dear as being specially human (for example, emotions and consciousness) are available to machines simply because humans are machines, albeit immensely complex ones.

He prepares a robust response to potential attacks by detractors who believe that the 'specialness' of human consciousness either lies in an as yet uncomprehended presence of quantum physical action in the brain, or is not available to physics at all. He accuses some philosophers of simply being afraid to contemplate the possibility of a conscious machine. According to Brooks, the adversaries will have to prove their points or admit that humans can be understood from physical control principles. Despite this, Brooks has his own little *je ne sais quoi* which separates the biological from the artefactual. The 'juice', as he calls it, that is missing is a proper mathematical understanding of complex biological mechanisms. He does not see this as an insurmountable difficulty, but rather as an achievable and exciting target for science.

The second book, *The Body Electric*, is a clear and readable report of the way that human sensory systems are being replaced or supplemented by technological artefacts studied in a variety of research laboratories across the world. Journalist James Geary tells an exciting story not only by reporting his in-depth interviews with key researchers, but also by asking the beneficiaries of some prostheses what this has done for them. People who have seen, heard and learned to speak for the first time are the best ambassadors for this science — their accounts detract from any false impression that humanity is being insidiously invaded by the silicon chip.

Inevitably, reportage can fall prey to some odd views held by those who are being interviewed. A British engineer, for example, insists that a radio chip he had implanted under the skin of his forearm to open doors and cause his computer to greet him is a major step towards the automatic transmission of emotions and, eventually, thoughts, between humans. Here the scientific challenges of encoding thought and emotion distributed over billions of brain cells are suspended, and would a chip in the pocket not have opened the door just as well?

By contrast, the rest of the book presents real scientific work on vision, hearing, touch and even taste. The question is always the same: how can a sensory faculty be restored to an individual who may have lost it? Often this needs an enormous amount of ingenuity, mainly because the human brain is adept at integrating the input from many sensory

modalities. For example, in order to 'see', the brain integrates signals from the retina with signals from the oculomotor system that moves the eyes. The key question is whether what's left of the brain's apparatus when parts go missing will be able to accept and adapt to the retinal implant in order to bring to the perceptual mind some sense of seeing. Geary answers this by sharing the delight of a 63-year-old Belgian woman who, after having been blind for over 20 years, began to see dots of colours when her optic nerve was stimulated by the output of a small video camera.

Having dealt with the senses, Geary approaches the problem of artificial minds. He talks to some who insist that they can create a mind just by throwing neural networks together and letting the mind emerge, as well as to others who have more principled approaches along the lines of the work reviewed by Brooks. Geary, rightly, just reports, and leaves it to the reader to spot the outliers.

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theory of evolution may be understood (could, even, have been created) in isolation from its social milieu. Wallace allows no such facile judgements. How should we appreciate the remarkable practical and theoretical achievements of this man, knowing that he promoted table-tapping and utopian community with equal seriousness and fervour?

Stephen Jay Gould, in his preface to Andrew Berry's *Infinite Tropics*, appears somewhat unnerved by this paradox, referring uncomfortably to Wallace's "promiscuous... outpourings" of non-scientific writing. Berry responds to the challenge by grouping Wallace's writings thematically, while recognizing that this artificially categorizes his interdisciplinary thought.

Jane Camerini's solution for her slimmer collection is to gather Wallace's writings chronologically. Each section is introduced by a succinct and historically sensitive essay, locating Wallace in his social and political context. She is at pains to show that his spiritualism and socialism were not intellectually anomalous, but were interwoven with his motives and methods for natural history. Where Berry leads the reader from extract to extract, patiently glossing each development in Wallace's thought, Camerini is more inclined to let Wallace's writing speak for itself, allowing the variety of material to suggest its own connections.

One interesting thread thus highlighted is the significance of land in Wallace's life and thought. Time and again it recurs in his writings: his youthful land surveys in Wales; his records of the relationship between the Welsh farming community and the land; the sense of injustice with which he describes the effects of the General Enclosure Act of 1845. In the same period, Wallace records his frustration that a botany book contained no information about plant distribution. Soon after, we see his punctilious mapping of the Amazon; his vital evolutionary connection drawn between phylogeny and distribution; and his socialist writing for the Land Nationalisation Society. Towards the end of his life he was critical of US land use. We also read his children's recollections of their mutual chagrin over

Putting evolution in context

The Alfred Russel Wallace Reader: A Selection of Writings from the Field

edited by Jane Camerini

Johns Hopkins University Press: 2002. 248 pp. \$42.50, £29.50 (hbk); \$18.95, £13 (pbk)

Infinite Tropics: An Alfred Russel Wallace Anthology

edited by Andrew Berry

Verso: 2002. 320 pp. £19, \$27

Charlotte Sleight

Charles Darwin kept many of his opinions, especially on politics and religion, under his hat. As a result, biologists, historians, marxists, keynesians, atheists and fundamentalists have all enjoyed debating ever since what Darwin 'really' meant. This kind of parlour game is no fun with Alfred Russel Wallace. A far more colourful and opinionated Victorian, he promulgated his beliefs to anyone who would listen. Ranging through socialism, geography, exobiology, phylogeny, female suffrage, natural selection, land reform and spiritualism, his sheer breadth of interests creates a challenge for the anthologist: how to group his writings to give the truest impression of his life and work.

This is a healthy challenge. Darwin's silence on contentious issues has obstructed a truly historicized understanding of his natural history, suggesting to some that the