

bothersome is the fact that both books contain some errors, so care is needed in using them as secondary sources. For example, Ward and Brownlee give the formation rate of continents as 650–1,300 cubic kilometres per year, a factor of about 1,000 too high. And it seems unlikely that global biomass drops by several thousandfold in an ice age. In the other book, Cockell's Earth has a mainly iron mantle, and his surface of Venus is younger than 250 million years and still active, rather than all about 500 million years old.

Having said that, I recommend both books to the lay reader. They can also be quickly read by a professional astrobiologist and do provide insight. And they would serve as supplemental reading (but not as primary texts) for a non-major class on planetary habitability or astrobiology. ■

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A stratospheric success

Protecting the Ozone Layer: Science and Strategy

by Edward A. Parson

Oxford University Press: 2003. 396 pp. \$65

Protecting the Ozone Layer: The United Nations History

by S. O. Anderson and K. M. Sarma

Earthscan: 2002. 544 pp. \$65, £40

Charles Herrick

When a scientific finding emerges from the field or laboratory, it undergoes a profound transition, changing from a well-formulated, discipline-bound construct into a dynamic and perhaps unruly component of a complex and interactive social system. The societal value of science and technology is created at the interface between laboratory and society, residing in neither alone, to paraphrase my friend Daniel Sarewitz. There is no direct and necessary linkage between the structure of physical reality and the manner in which society applies its scientific understanding of that structure. Rather, the social application of scientific knowledge and technological achievement is mediated through the formation and execution of policies.

Two new books, both entitled *Protecting the Ozone Layer*, chronicle the stratospheric phenomenon of ozone depletion as a window to explore the complex and dynamic relationships between science, technology and public policy. Although no small chore, as they have a combined length of almost 1,000 pages, I encourage readers to tackle both books, as their complementarity is fortuitous and sometimes quite illuminating.

Drawing on such fields as international-

relations theory and political sociology, Edward Parson outlines the formulation and implementation of the Montreal Protocol on ozone-depleting substances and its subsequent annexes, in terms of constructs such as epistemic communities and transnational issue networks. This provides the theoretical basis for his account of how scientific assessments, as distinct from scientific results per se, contribute to the development and maturation of adaptive policy regimes. Anderson and Sarma, on the other hand, offer a historical account based primarily on documentation and the recollections of key players in the ozone-treaty process.

Parson weaves a convincing account of the dynamic conditions that caused the initial slow progression of ozone negotiations between 1978 and 1986, and that then underpinned the swift consolidation of the Montreal Protocol by 1988. Briefly, he argues that scientific findings, considered alone, have little influence on the process of policy formulation. Rather, scientific results acquire credibility, salience and legitimacy only when compiled and interpreted in the context of a formalized, multi-party assessment process. As he writes, assessments "make key scientific statements and their implications common knowledge among policy actors" in the sense "that all parties know them, all know that all know them, and so on". In this way, assessments serve to bound and delimit the domain of reasonable negotiation and, once established, hasten regime formation.

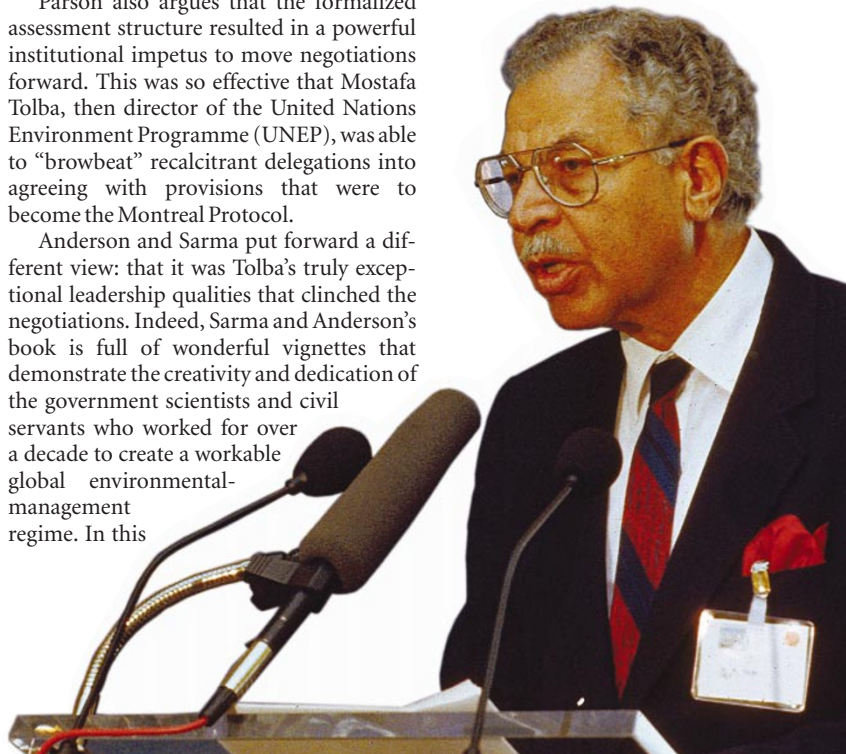
Parson also argues that the formalized assessment structure resulted in a powerful institutional impetus to move negotiations forward. This was so effective that Mostafa Tolba, then director of the United Nations Environment Programme (UNEP), was able to "browbeat" recalcitrant delegations into agreeing with provisions that were to become the Montreal Protocol.

Anderson and Sarma put forward a different view: that it was Tolba's truly exceptional leadership qualities that clinched the negotiations. Indeed, Sarma and Anderson's book is full of wonderful vignettes that demonstrate the creativity and dedication of the government scientists and civil servants who worked for over a decade to create a workable global environmental-management regime. In this

context, many of the individuals quoted or paraphrased cite the importance of informal groups and of a strong and inclusive consensus process that tended to override legalistic hair-splitting. So, did the institutional setting empower the actors, or did an exceptional group of actors combine to stretch the bounds of game-theoretic interpretation?

Both books do a good job of describing the evolution of stratospheric science and its relation to ozone depletion, chronicling the accomplishments of Sidney Chapman, G. M. B. Dobson, Lester Machta, Mario Molina and Sherwood Rowland, along with other pioneers of atmospheric science. They also describe how various stakeholder communities drew from this science base to support their positions and negotiations. I found myself wondering whether history would have been significantly different if industry had chosen an alternative field of battle and engaged the ozone-depletion debate from the perspective of cancer epidemiology, rather than atmospheric chemistry. Epidemiological studies show a rising incidence of melanoma, but evidence linking these skin cancers to increasing ultraviolet radiation, as the ozone layer was depleted, is complex and equivocal, and might have made a far less compelling case.

Neither book focuses heavily on the predicted and/or postulated effects of ozone depletion, merely noting, as Parson put it, that the policy debate was "pervaded by a general sense that effects did not matter".



Tough talking: effective scientific backing helped Mostafa Tolba forge the basis of the Montreal Protocol.

P. DEJONG/AP

How and why were these effects kept off the table? This seems to be a missed opportunity to tell a potentially powerful story about the socio-political construction of scientific assessments.

Like all good writing, these books leave the reader wishing for more: For example, I would have liked the authors to pick apart and compare the story of ozone diplomacy with that of other complex, science-based environmental-management issues, such as the various UNEP regional seas agreements, the Bonn Convention for the protection of the Rhine, or the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Although not global in scope, these and other environmental regimes are also hypercomplex amalgams of scientific information, assessment process and political deliberation. Did ozone diplomacy follow well-established models of behaviour, break completely with past exercises in regime formation, or do a little of both?

Both versions of *Protecting the Ozone Layer* demonstrate that the path between scientific findings and policy formulation is anything but transparent, direct or linear. Instead, the relationship is mediated through a complex web of social, institutional and individual factors, acquiring context and meaning as they are embedded in larger narratives. ■

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Getting up to speed

Principles of Animal Locomotion

by R. McNeill Alexander

Princeton University Press: 2003. 376 pp.

\$49.50, £35

Stephen Gatesy

How did the chicken cross the road? A neurobiologist might answer that commands from the central nervous system, modulated by sensory feedback, generated cyclical walking movements. Alternatively, a physiologist could say that walking came about through myosin's interaction with actin, which created muscular tension to produce the necessary joint torques. On the other hand, a biomechanist might view the whole bird as a point mass rising and falling with each step, transforming gravitational potential energy into forward kinetic energy and back again, like an inverted pendulum. Such disparate responses highlight the wonderfully intricate and dynamic interplay that transpires when animals move through their environment.

In *Principles of Animal Locomotion*, R. McNeill Alexander approaches movement from a physical point of view. He seeks to explore the mechanical principles at work in organisms as different as burrowing earthworms and hovering hummingbirds. More-



How did the chicken cross the road?

over, he tries to account for the metabolic cost, and thus the relative energetic merit, of alternative forms of locomotion. These might seem like lofty goals, but Alexander is up to the task. His publications over the past six decades span such topics as swimming, scaling, gaits, elastic storage, and optimization (to name just a few), giving him the breadth and depth needed to summarize the field.

The book begins with a lucid summary of performance objectives — speed, acceleration, manoeuvrability, endurance, economy and stability — and their potential relationship to fitness. This is followed by a brief discussion of compromises (not all of the objectives are compatible), constraints (not all changes are possible) and optimization (which solution is best?). Alexander then covers muscle mechanics, energetics, scaling and recording techniques, before delving

into specific forms of locomotion. Terrestrial progression is addressed first through simple theoretical models and then by examining walking, running, hopping, climbing, jumping, crawling and burrowing in real animals. Aerial and aquatic locomotion are then tackled, although cilia-driven propulsion is not included. There is also a chapter on the effectiveness of devices for augmenting human locomotion.

Although this book is aimed at an audience ranging from advanced undergraduates to researchers and university teachers, I think that most undergraduates will be overwhelmed and intimidated if it is used as a textbook. Alexander packs in so much information that clarity is often sacrificed for coverage. His curt style is so direct and quantitative (equations are ubiquitous, starting on page 2) that every paragraph is extremely dense. But despite its failings as a textbook, it is an excellent reference tome. Citations (up to 2001) and 33 pages of references (of which 77 are authored by Alexander) will quickly direct readers to the relevant literature. I will use *Principles of Animal Locomotion* and recommend it to my graduate students.

Alexander's facility with simple, quantitative models is both a strength and a weakness. Regrettably, the translation from a living, breathing animal to a mathematical representation of its underlying physics is never explained. In creating such models, which details can be omitted, and which need to be retained? If Alexander wants to appeal to a broad range of scientists, he must take

Standing the test of time

The centenary volume of Munich's Deutsches Museum, *Ingenious Inventions and Masterpieces of Science and Technology*, is a celebration of the long and often troubled history of one of the world's oldest, and largest, technology museums.

The Deutsches Museum was founded in 1903 by Oskar von Miller, a pioneer of electrical engineering. Work on its permanent home — an architectural jewel on an island in the Isar river, which flows through Munich — was begun in 1906, but its completion was delayed first by war and then by hyper-inflation. The building was finally opened in 1925 with great fanfare in a celebration that is sometimes referred to as the Weimar Republic's last party.

A few happy years followed before history struck again. The Nazis didn't like von Miller's cosmopolitan aspirations for the museum, and the Allied forces' bombs had no pity, destroying much of the building as well as around 20,000 display items. But the museum survived and remains one of the world's most significant technology museums.

This coffee-table book, edited by the museum's director, Wolf Peter Fehlhammer, includes illustrations of treasures from the past along with current exhibitions. These range from



Otto von Guericke's first vacuum pump and hemispheres, forged in 1663, to the 1962 recreation of the Altamira cave with its Stone Age paintings, to the Helios space probes, solar observatories constructed in Munich and launched in the 1970s. The illustration shows a timepiece dating from 1630 from southern Germany, one of the earliest instruments for measuring time.