But the controversy that dominates *Homage* is between Lovelock and the group to which he turns to refute again and again: reductionist biologists. Lovelock's rejoinder to his Darwinist critics was the "Daisyworld" model he and his former student Andrew Watson constructed. His claims for this model, even within *Homage*, vary considerably. The caveat that it was "never intended ...to be more than a caricature" clashes with far-reaching assertions:

> Daisyworld is a synopsis of Gaia Theory. It shows how organisms evolving under the rules of natural selection are part of a system that is self-regulating....
>
> ...There is much at stake, for if Daisyworld is valid, then seventy-five years of neo-Darwinist science will need to be rewritten.

Daisyworld is a model planet having black and white daisies with separate fitness curves such that the black ones like it cooler and the white ones like it warmer. As the sun heats up over hundreds of millions of years, black daisies approach their optimum temperatures, become more fit, and thereby increase their numbers, causing the albedo (reflectivity) of the planet's surface to drop. This is a positive feedback, because while more sunlight is absorbed by the dark flowers the planet further warms. Black daisies increase until the temperature passes their fitness peak and moves into the fitness range for the white daisies. These then begin to multiply and replace the black daisies; this shift increases the planet's albedo, which serves as a negative feedback on further warming. The planet's overall temperature is stabilized for eons even though the sun inexorably increases its luminosity. But eventually, the white daisies are heated past their fitness range and can't resist further warming. The biota then collapses and temperatures rise rapidly to the level an inorganic rock would experience.

As a climate modeler, I am fully sympathetic with attempts to use simplified approaches to demonstrate basic principles. But relevance to Earth's history of principles suggested by virtual worlds requires empirical demonstrations that processes and parameters in the models have close parallels in the real world. Overall model behavior must be able to be matched against actual Earth behavior at comparable scales.

Lovelock and his supporters do not need Daisyworld and its nonempirical baggage to argue for emergent properties of complex biological-physical systems. Modern complexity theory is full of relevant examples, and the Gaians can proudly note their early recognition of emergence in Earth systems. But, as I argued at both Chapman Conferences, selection of surface albedo via daisies would, on the actual Earth, have little climatic influence because most of the surface is obscured by clouds and hazes. If we tweak a few parameters in Daisyworld to make it more like Earth, how much of the Gaian emergence would be suppressed? This criticism doesn't mean that some processes on Earth, once modeled credibly, won't have precisely the homeostatic characteristics Lovelock and Margulis predict. But the uncertainty is why we do the science; most answers are still out there, waiting for the next generation of Earth-as-a-system scientists to uncover.

In the meantime, we should credit Lovelock for such contributions as his early insight about Gaian emergence, the possibility of stabilizing feedbacks, and the stimulation of scientific debates that led to the uncovering of fascinating processes like algal emissions of dimethyl sulfide (which affect cloud albedo and may be a biotic feedback mechanism). These are accomplishments enough for any team, let alone an independent scientist.

Today, very few Earth scientists seriously doubt that there is emergence, as Lovelock and Margulis anticipated three decades ago. Moreover, the pair's persistent calls for serious scientific inquiry into bio-physical interactions at all scales in the environment, Lovelock's "geophysiology" (*6*), is a major spur to progress in understanding Earth as a system. It seems clear that the war to view Earth as a system is over. Now let's get on with the jobs of improving descriptions of natural systems and looking for emergent properties at all scales (being open to the likelihood that some will seem "Gaian" and some not). In the end, we will all know more about this fascinating life support system we have inherited. I warmly thank Jim Lovelock, Lynn Margulis, and the Gaia disciples for an important impetus in pushing us to look across all scales and processes for answers—even if, as is so often true in science, not all their original ideas will survive intact after a fair and dispassionate analysis.

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BOOKS: HISTORY OF SCIENCE

Culturing American Life

Audra J. Wolfe

In 1910, Charles Marlatt, acting chief of the United States Department of Agriculture's Bureau of Entomology, ordered the burning of two thousand cherry trees sent by the Japanese government as a gift to the city of Washington. Marlatt feared that the trees hosted a variety of parasitic organisms, which posed an immediate threat to American vegetation. The Imperial government had offered the trees in an act of cultural diplomacy—the Japanese would accept the so-called Gentlemen's Agreement to end Japanese immigration and the Americans would replace the elms in their nation's capital with oriental cherry trees. In authorizing the trees' destruction, Marlatt flexed newly acquired bureaucratic muscle and simultaneously expressed his philosophy of biological nativism. Two years later, when the Japanese government offered another shipment of trees duly inspected by the Imperial Quarantine Service, the Imperial Horticultural Station, and the Imperial University, the USDA accepted every one.

Biologists and the Promise of American Life From Meriwether Lewis to Alfred Kinsey
by Philip J. Pauly
Princeton University Press, Princeton, NJ, 2000. 329 pp. $29.95, £18.95. ISBN 0-691-04977-7.

Throughout *Biologists and the Promise of American Life*, historian Philip Pauly skillfully uses examples such as this one to recast the story of biology in the United States as cultural history. Authors of such histories of American biology usually turn to one of two familiar examples: eugenics or the teaching of evolution in schools. Although Pauly addresses these incidents as well, he expands the boundaries of the genre by examining a wide array of topics from national exploration and the culture of collection to sex education and scientific information syndicates. To do so, he confidently marshals lessons from international relations, environmental history, history of education, and even leisure studies. The result is a

The author is in the Department of History and Sociology of Science, University of Pennsylvania, Logan Hall, 249 South 36th Street, Philadelphia, PA 19104, USA. E-mail: awolfe@sas.upenn.edu

Unwelcome gift. Japanese cherry trees being burned on the grounds of the Washington Monument, January 1910.

tantalizing and ambitious study that places American biologists squarely in the middle of national social, political, and economic development.

Except for a group of turn-of-the-20th-century academic biologists who focused on research and institution building, American biologists consistently applied their skills to national problems. Asa Gray's 1840s description of a uniquely American biogeography, for example, provided scientific justification for the doctrine of Manifest Destiny. Later, in the Progressive Era, leading biological educators hoped that teaching the children of the striving urban middle class about natural life would help them to develop into forward-thinking, cooperative adults dedicated to the improvement of their cities and their nation. Because their notion of "evolution" focused on the future rather than the past, biological educators remained unmoved by the Scopes trial; so long as they could continue to provide an evolutionary perspective to the next generation, they cared little about theories that merely explained the past.

Pauly's concept of "culture" owes more to 19th-century agriculturists than to anthropologists or literary critics. When Pauly refers to biologists' attempts to "culture American life," he means their efforts to improve the reproduction, growth, and distribution of plants, animals, and humans. From this perspective, current practices in biotechnology research that seek to "improve nature" are not very much at odds with historical practice. This is, in some ways, a further exploration of an argument Pauly made in *Controlling Life* (Oxford University Press, 1987), his biography of Jacques Loeb (experimental biology's most iconic figure). By prodding Americans to farm carp, harvest durum wheat, and breed hybrid apples, 19th-century federal naturalists encouraged an approach to American ecological independence based on manipulation and intervention. Although Pauly does not explore the issue, this last point offers interesting comparative evidence for a thesis advanced by revisionist historians of the scientific revolution—namely that much of the progress in science has been intimately connected to the processes of economic and political nation building.

Pauly has an elegant writing style that makes this book a pleasure to read, and he is willing to take narrative risks not typically seen in works of history. One chapter, for example, takes the reader on a cross-country tour of U.S. biological institutions in 1887; the virtual trip comes complete with arrangements for lodging and transportation. Pauly also has an uncanny ability to point out the crucial effects of seemingly mundane events on the history of the life sciences. The establishment of a national mail service, for instance, vastly accelerated natural history collecting by ensuring that specimens would reach their destinations. In addition, the author displays a sensitivity to issues of class and gender too rarely seen in histories of science. As might be expected in a work of such broad scope, Pauly needs to deploy all of these gifts to hold his narrative together. Even when he doesn't quite succeed, *The Promise of American Life* offers a remarkable vision of the place of science in American life that will be enjoyed by historians and scientists alike.

BROWSINGS

The Swamp: On the Edge of Eden. ***Kerry Oliver-Smith et al.*** **Harn Museum of Art, University of Florida, Gainsville, FL, 2000. 64 pp. $10. ISBN 0-9629384-8-3.**

Human responses to swamps have ranged from celebration of primordial beauty to fear of malevolent darkness. The paintings, photographs, and sculptures selected by curator Oliver-Smith sample artists' reactions to the swamplands of the southeast United States at scales from panoramic landscapes to microscopic details. The works include both realistic portraits (such as Ana Barrado's silver print "Wild Palms, Islamorada, Florida Keys") and fantastic impressions. This catalog also presents quotations from literary and scientific sources, as well as essays by art and cultural historians and a wetland ecologist. The exhibit continues at the Cummer Museum of Art & Gardens in Jacksonville, Florida, through 15 April.

Computers Ltd. What They ***Really*** Can't Do. ***David Harel.*** Oxford University Press, Oxford. 239 pp. $25, £14.99. ISBN 0-19-850555-8.

Although we have all grown accustomed to nearly continuous improvements in the performance of hardware and software (and reductions in their costs), computers are subject to fundamental constraints that will limit what they can do. In this overview written for a broad audience, Harel focuses on proven limits. Some problems cannot be transformed into algorithms, others are logically undecidable, and still others are physically intractable. The author aims to discourage futile efforts and encourage new approaches such as parallelism, randomization, and quantum and molecular computing. He also discusses how his bad news is actually good news for fields like cryptography.

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