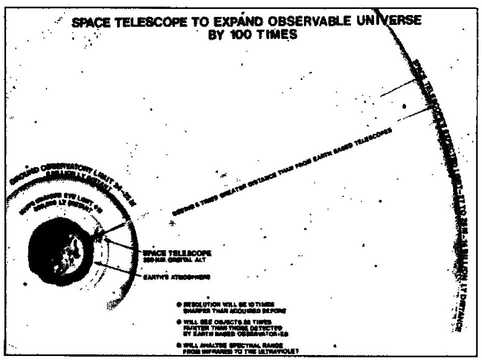

"Hype documented." This "sketch and several variations of it . . . were liberally used in many prelaunch NASA documents, briefings, and other materials meant for the press, educators, and the general public. It claims that our naked eye can see only relatively nearby cosmic objects, which is false since, for example, on most autumn evenings we can readily see . . . the Andromeda Galaxy millions of light-years away. The NASA diagram also claims that ground-based telescopes can study celestial objects only as far away as 2 billion light-years, which is false since long exposures with even moderate-size telescopes can reach . . . more than 10 billion light-years away. In truth, *Hubble* is designed to see cosmic regions more clearly. . ., but it cannot see to appreciably greater distances than can existing ground-based telescopes. . . . Many other publications picked up this misinformation and disseminated it throughout the public and educational domains." [From *The Hubble Wars*; NASA]

the release of "pretty pictures," with the public interest they engendered, that turned the tide of opinion and saved the project.

There are many fascinating astronomical images from Hubble reproduced in the book. Regrettably, some have such small print on and below them that superb visual acuity is required to appreciate them. The fact that coverage of the repair mission is minimal is also regrettable. Chaisson states that, contrary to press reports, not all of the "fixes" worked, and those that did were accomplished only by giving up other capabilities. Is this really a fair assessment of the upgraded telescope, given the discoveries it has made?

The technical descriptions are first-class. Although they are randomly interspersed with anecdotes of personal conflict and hence take time to track down, they provide a reference base that alone is worth the price of the book.

Finally, a word on the spy-satellite cousins of the Hubble telescope. Because of prior experience with military affairs, Chaisson is able to describe developments in that field, which, it seems, far exceeded the effort put into the Hubble telescope. For example, we learn that a decade before Hubble was launched Perkin-Elmer had already built a dozen space telescopes of the Hubble class as spy satellites. Also intriguing is the fact, noted in passing, that the TDRSS satellites used by NASA to communicate with Hubble are a mainstay of military communications, operated by a secretive company whose chief executive officer was killed by a car bomb. At least no one was killed in the Hubble wars.

In short, *The Hubble Wars* is an exciting account of what went wrong—well written, perhaps not completely accurate as a historical record, but definitely very enjoyable for anyone curious about Hubble, astronomy, and big science.

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Ant Invaders

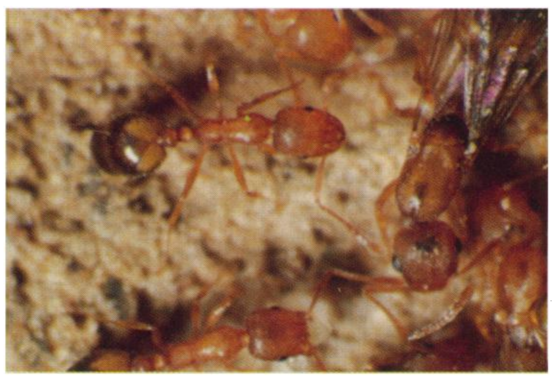
Exotic Ants. Biology, Impact, and Control of Introduced Species. DAVID F. WILLIAMS, Ed. Westview, Boulder, CO, 1994. xviii, 332 pp., illus. $74.85 or £55.50. Westview Studies in Insect Biology. Based on a conference, Galàpagos Islands, Oct. 1991.

When the great voyagers of the 17th and 18th centuries arrived in the New World they likely had among their passengers Pharaoh's ants, natives of the Old World tropics that had already established themselves throughout much of Europe as a result of trade. Although the legacy of these early hexapod colonists is not as widely appreciated as that of their bipedal patrons, it has become increasingly relevant as a symbol of the destructive consequences of biological invasions caused by human activity. Pharaoh's ants (*Monomorium pharaonis*) now occur virtually anywhere humans do, nesting in our buildings and feeding on our food and wastes. Their colonies are transient assemblages of thousands of tiny workers and scores of queens that readily migrate, fragment, or fuse in response to newly discovered food items or disturbance. Their workers rapidly discover food sources (which include all manner of sweets and proteins, including soiled bandages in hospitals) and efficiently exploit them by laying chemical trails to recruit nestmates. Their queens have abandoned the hazardous mating flight of most other ants, preferring instead to mate (incestuously at times) within the safe confines of their nests.

Pharaoh's ant is only one of several species of "tramp" ants that, along with many exotic insects, birds, plants, and fishes, have colonized locations far from their native ranges by means of commerce, travel, or intentional release. The result in many cases is the emergence of new pests that evade the population regulation previously imposed by their natural enemies. Exotics may build up enormous populations that negatively affect native species by means of habitat destruction, disruption of trophic webs, or hybridization, sometimes driving natives to local extinction or permanently altering their unique gene pools. Because ants are dominant components of most terrestrial communities, they can have particularly devastating effects when they come into contact with organisms with which they did not evolve. Thus exotic ants pose a serious threat to biodiversity, simplifying and homogenizing regional biotas that collectively constitute the unique signature of life on Earth.

Biologists study human-mediated biological invasions such as that of Pharaoh's ants for several reasons. One is to develop an ecological theory of invasion that can predict which species will be successful invaders and which communities are favorable to the establishment of invaders. Another is to refine general ecological and population genetic theories that apply to more "natural" situations. For instance, studies of contemporary biological invasions may shed light on the role of competition in structuring communities, the impact of species replacements on ecosystem function, or the effect of loss of genetic variation on adaptation and speciation.

This volume edited by Williams includes 25 mostly brief chapters, many of which discuss a specific exotic ant in a particular setting. Notable gleanings are the apparent consensus that island faunas are especially susceptible to disruption by exotic ants (Reimer; Meier; Fowler *et al.*; Haines *et al.*), the clear documentation in many systems of reductions in native ant species diversity following establishment of exotic ants (Tennant; Zenner-Polania; Fowler *et al.*; Majer; Jusino-Atresino and Phillips), and the demonstration that exotic ants exist within, and



Pharaoh's ants. [Animals Animals]

not necessarily as dominant elements of, diverse ant communities in their native ranges (Tennant; Majer; Patterson). A topic touched on in many chapters is the nature of the ecological mechanisms involved in the displacement or replacement of resident ant species by invading species. Though it is frequently assumed that local reductions in individual abundance or species diversity of natives follow from direct competition or predation by exotics, Majer and Wojcik point out, as have others, that such reductions may be correlated responses to changes in other factors that favor the exotic and disfavor the natives, such as increased habitat disturbance. A high point of the volume is Passera's description of the social and breeding habits of tramp ants that are important for successful invasion. Meier shows that opportunistic feeding habits coupled with efficient, chemically based recruitment systems can be added to Passera's list.

The volume is not without disappointments. There is no explicit conceptual framework that organizes it. The order of the chapters seems largely haphazard and several seem not to belong at all. There is little indication of how studies of exotic ants can help us understand general ecological and evolutionary processes, which is unfortunate because the best studied exotic ant, the fire ant *Solenopsis invicta*, is emerging as a major model system in this regard. Nor does the book contribute significantly toward the development of an ecological theory of invasion. Thus it likely will have little appeal outside a narrow community of researchers who focus on ant introductions and their immediate consequences.

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Vignettes: Eye-Opening

I am convinced that the story of the universe that has come out of three centuries of modern scientific work will be recognized as a supreme human achievement, the scientific enterprise's central gift to humanity, a revelation having a status equal to that of the great religious revelations of the past.

—*Brian Swimme*, as quoted in *Evolution Extended: Biological Debates on the Meaning of Life* (Connie Barlow, Ed.; MIT Press)

It has been said that science demystifies the world. It is closer to the truth to say that science, when it is at its best, opens the world up for us, bringing daily realities under a kind of magic spell and providing the means to see the limits of what we think we know, and the scope of what we do not at all understand.

—*Claus Emmeche*, in *The Garden in the Machine: The Emerging Science of Artificial Life* (Princeton University Press)

Next Values

Time Series Prediction. Forecasting the Future and Understanding the Past. ANDREAS S. WEIGEND and NEIL A. GERSHENFELD, Eds. Addison-Wesley, Reading, MA, 1993. xx, 643 pp., illus. $49.50; paper, $32.25. Santa Fe Institute Studies in the Sciences of Complexity, vol. 15. From a workshop, Santa Fe, NM, May 1992.

The publication in 1970 of *Time Series Analysis: Forecasting and Control* by George Box and Gwilym Jenkins was a landmark in time series analysis. Building on the work of Yule, Bartlett, and others, the authors laid out a methodology for parametric time series analysis. This methodology covers linear time series models. An example of such a model is the first-order autoregressive process, in which the current value is a linear function of the previous value plus a random error. Since 1970, time series modeling has progressed in many directions including extensions to non-Gaussian and multivariate time series, models with non-constant parameters, and models that accommodate measurement error.

Although the family of linear models is quite rich, it is necessary on scientific grounds to consider nonlinear models. An example is the first-order nonlinear autoregressive process, in which the current value is a nonlinear function of the previous value plus a random error. There are two broad approaches to nonlinear time series analysis: parametric and nonparametric. The parametric approach essentially extends the Box-Jenkins approach to parametric families of nonlinear models. This extension involves new methods of data analysis. For example, a nonlinear process cannot be fully characterized by its mean and autocovariance function (or, equivalently, its spectrum) alone. The parametric approach to nonlinear time series analysis is covered in books by M. B. Priestley (1988) and Howell Tong (1990).

There are again two broad approaches to nonparametric modeling: the statistical approach and the dynamical systems approach. In the statistical approach, the relationship between the current value and previous values is estimated by nonparametric regression. In experienced hands, the statistical approach can exploit recent developments in nonparametric modeling outside the area of time series analysis. Some scientific understanding of the underlying processes also does not hurt.

A little background helps to understand the dynamical systems approach. Whitney's theorem in topology says that a smooth, compact manifold of dimension d can be embedded in a Euclidean space of dimension $2d+1$. Takens extended this theory to the embedding of a dynamical system. The practical result is that, if the original system evolves along an attractor, the topology of the attractor can be recovered in the behavior of multidimensional "histories" of an observable time series generated by the system. A history or delay is a finite vector of lagged values of a time series. This result establishes a link between nonlinear autoregressive models and time series generated by dynamical systems, in the sense that the former focuses on multidimensional histories.

Embedding theory has also been used as the basis for a geometric approach to time series prediction. The idea is this. If I knew the attractor of a dynamical system and I knew the trajectory that the system was on, I could predict the future by projecting the trajectory along the attractor. In the case of chaos, trajectories diverge, so this scheme only works in the short term unless the trajectory is known precisely. Embedding theory says that this idea can be applied in the Euclidean space of histories. For example, if I want to predict the next value of a time series, I just find previous values that had similar histories and see where those values ended up one period later. For this approach to succeed, it is necessary that the dimension of the system be small (remember that the dimension of the topologically equivalent Euclidean space is higher) or that the time series be very long: otherwise, the curse of dimensionality ensures that there will be no points in the time series with similar histories.