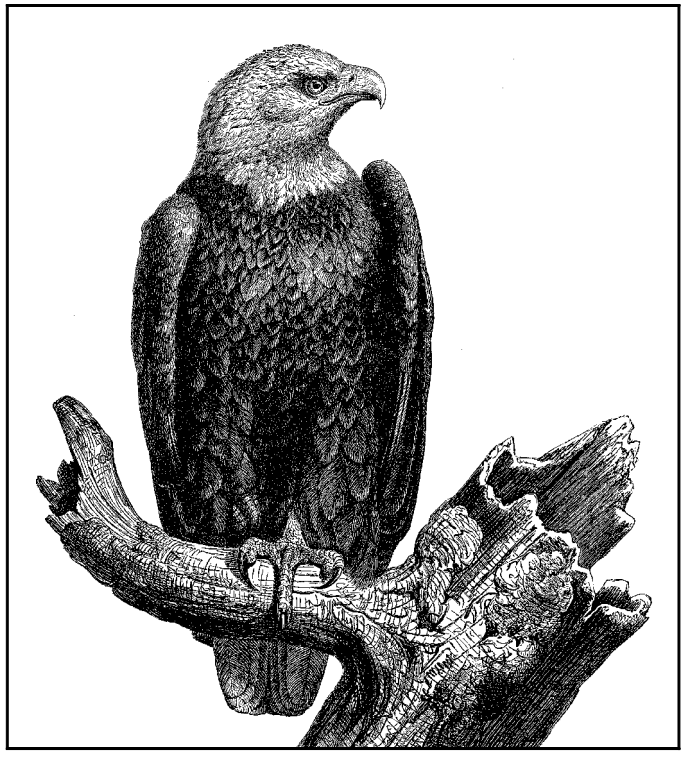
# A tool kit for conservation issues

**Private Property and the Endangered Species Act: Saving Habitats, Protecting Homes.** Jason F. Shogren, ed. University of Texas Press, Austin, TX, 1998. 176 pp. $14.95 (ISBN 0-292-77737-X paper).



To build something as simple as a bird house, one surely needs more tools than just a hammer. To build, then, a successful conservation program for the 90 US species of birds that face the threat of extinction, as well as the nearly 1100 other species of animals and plants in similar peril, a diverse tool kit is essential. That is especially true when most of those nearly 1200 species have a substantial portion of their present and potential future habitat on privately owned land and when conflicts between landowners and environmental regulators have become distressingly commonplace.

On such land, the authors of the various chapters in this slim volume agree, the "hammer" of regulatory prohibitions against harmful private behavior is unlikely to bring about the restoration and active management of habitat needed for real improvement in the status of hard-pressed species. To elicit that beneficial private behavior, a more creative, flexible, and versatile set of tools rewarding such behavior is needed. This is hardly a novel conclusion; Aldo Leopold, one of the more prescient conservationists of the century, observed as long ago as 1934 that "conservation will ultimately boil down to rewarding the private landowner who conserves the public interest" (Leopold 1991). Ironically and unintentionally, the threat of regulatory prohibitions has made at least some landowners wary of undertaking management practices that could benefit rare species on their land.

*Private Property and the Endangered Species Act* is the first book to look broadly at the issue of conserving endangered species on privately owned land. It grew out of a 1996 forum on that topic at the University of Wyoming's Institute for Environment and Natural Resources. Its chapter authors include university scientists, practicing attorneys, an economist, and the former director of the US Fish and Wildlife Service, John F. Turner, who was an effective champion of endangered species conservation during the Bush administration. William D. Ruckleshaus, who was administrator of the US Environmental Protection Agency during the Nixon and Reagan administrations, contributes a thoughtful foreword. At the time of the 1996 forum, the importance of private lands to endangered species conservation efforts was only beginning to be appreciated. In the 3 years since the forum was held, recognition of the need for designing new, more effective approaches to endangered species conservation on the more than two-thirds of the nation that is not in federal ownership has grown steadily.

Although this book takes a broad look at an important topic, it does not delve deeply into any particular aspect of that topic. One can, for example, find much more detailed examinations of the relatively new tool of endangered species "habitat conservation plans" elsewhere (e.g., Noss et al. 1997). Neither does this book include any real case studies that closely examine the actual workings of the policy tools advocated or criticized. A final shortcoming is the book's tendency to accept at face value the characterizations of various conservation efforts by the agencies or interests most closely identified with them. A more critical analysis of the limitations of such efforts is needed.

Despite these flaws, *Private Property and the Endangered Species Act* serves as a useful first effort at cataloging some of the potential solutions to the most challenging, and ultimately some of the most important, wildlife conservation problems of the day. These solutions include tax incentives to reward landowners who go beyond the minimal requirements of the law, cost-sharing assistance to help in the often expensive management practices necessary to improve the status of rare species,

and creative new regulatory approaches, such as endangered species "safe harbor" agreements. Such agreements are designed to make it easier for landowners to carry out habitat enhancement and restoration activities on their own land by removing the potential that the "reward" for such good deeds will be further restrictions on the landowner's use of his or her land. If nothing else, this book serves to remind those who are armed only with a hammer that not every problem is a nail.

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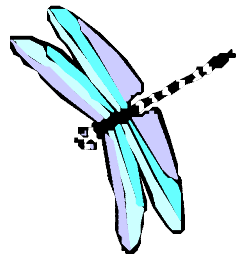
## A CASE FOR INTEGRATED INDEXES

**Restoring Life in Running Waters: Better Biological Monitoring.** James R. Karr and Ellen W. Chu. Island Press, Washington, DC, 1999. 206 pp., illus. $29.95 (ISBN 1-55963-674-2 paper).

Concerned about the continuing decline in the quality of the nation's waters, James R. Karr and Ellen W. Chu have written a book that they hope will encourage effective use of biological data in resource management decision making. They argue that the Clean Water Act has failed to protect the integrity of US aquatic resources because its emphasis on the chemical quality of water fails to address other water quality issues and because some popular engineering practices implemented as a consequence of the act (e.g., chlorination) are ultimately counterproductive. According to Karr and Chu, better resource management will occur when managers have access to tools such as integrated indexes of biological integrity, which allow them to make



decisions based on the biological quality of the system. Their book makes a case for more widespread use of integrated indexes and answers critics' concerns about the use of such indexes.

Scientists involved in biomonitoring projects rarely agree on the best way to reduce, present, and interpret their data. Years ago, Karr developed an integrated multimetric index to diagnose fish community health (Karr 1981). That approach, which quickly became a popular assessment tool, was subsequently adopted for use with benthic invertebrates and is now in widespread use by aquatic scientists. Indexes of biological integrity (IBIs) for fish and benthic invertebrates are easy to understand because disturbance and its impact on complex community structure are reduced to a few responsive variables. The index results are expressed across a gradient of increasing disturbance relative to data from reference sites of lesser disturbance. IBIs have both loyal fans and vocal critics. The fans cite the ability of IBIs to reduce complex biological data to a few easily understood conclusions, and the critics are dismayed by their tendency to oversimplify biological complexity.

This book is addressed to both groups. The organization of *Restoring Life in Running Waters* is unique. Chapters are short, half a page to only a few pages, and organized either by premises that the authors wish to explain or by ideas that they would like to debunk. Each premise or idea is stated and then discussed with examples from the peer-reviewed literature. The authors rely heavily on work done by Karr and his students to substantiate some of the most important premises. Their discussions of the criticisms of multimetric indexes, which they call "myths," are particularly brief but nevertheless convincing. In promoting IBIs and criticizing alternative approaches (such as multivariate statistics, which are harder for general audiences to interpret), the book stresses repeatedly that tools should be used that can most closely describe the biological responses in the ecosystem being studied. Nearly all of the chapters in the book are illustrated with examples from sites across the United States in which Karr and his students have been able to use IBIs to produce what the authors call "visual portraits of biological conditions." There are also well-chosen examples of how multivariate statistics have been used in ways that are biologically irrelevant.

The timing of the book's publication is fortuitous. For several years, the US Environmental Protection Agency has been revising its widely used "rapid bioassessment protocols" (RBPs), which include data reduction and interpretation guidelines (EPA 1997). The protocols that were advocated in the original RBP guidelines (EPA 1989) have been widely used in federal, state, and local biomonitoring programs. They have also been criticized by practitioners who take exception to the shortcuts associated with making the methods "rapid." IBIs are one of the data analysis tools included in both past and present versions of the RBPs. Nevertheless, Karr and Chu criticize key aspects of the data-gathering portions of the benthic invertebrate RBPs and present well-argued alternative approaches. There have been substantial delays in the publication of the revised EPA protocols, which will no doubt be controversial whenever they are finally published. The concepts discussed in this book will give resource managers an organized framework for evaluating whether or not they wish to use revised RBPs as tools in their programs.

*Restoring Life in Running Waters* is likely to expand the popularity of IBIs from core advocates in aquatic ecology to wider fields. It will probably be popular with agency scientists involved in biomonitoring work, and it would be a good text for a graduate seminar in field methods and data interpretation, perhaps resulting in new converts to the use of integrated indexes. Furthermore, it will probably convince some scientists to use these tools in presenting

their data to general audiences. Terrestrial ecologists involved in long-term monitoring projects will find the book interesting because it will encourage them to think about different data interpretation and presentation tools. However, although the authors may win some new followers, they are not likely to change the opinions of hard-core critics of integrated indexes.

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## HUMAN HISTORY AS A NATURAL SCIENCE

**Guns, Germs, and Steel: The Fates of Human Societies.** Jared Diamond. W. W. Norton, New York, 1997. 480 pp., illus. $27.50 (ISBN 0-393-03891-2 cloth).

Evolutionary biologist Jared Diamond's latest book came highly recommended, and with good reason. It is without question one of the most significant books of the decade—indeed, it won the 1998 Pulitzer Prize for general nonfiction. Why? It represents one of the few (along with Flannery 1994), and certainly one of the best, applications of the methods of natural science to the questions of human history. The reframing of the basic historical questions and the discovery of some of their answers, which this approach makes possible, are enormously enlightening, and Diamond's writing style makes the process of discovering them a joy.

Diamond starts with a question he was asked 25 years ago by a New Guinean politician named Yali, who asked, "Why it is that you white people developed so much cargo and brought it to New Guinea, but we black people had little cargo of our own?" Diamond generalizes this question to: "Why did wealth and power become distributed as they now are, rather than in some other way?" He pushes the question sequentially back to the origins of humans on the planet and uses it to motivate an inquiry into the general questions of not only how, but also why human societies developed in the ways, the places, and the times that they did.

To answer these questions, Diamond synthesizes a vast array of data and analytical tools, from paleoecology, to geology, to geography, to linguistics, to the traditional oral and written histories of the world's peoples. He makes several key points that evoke in the reader the kind of feeling of enlightenment that comes when a stunningly obvious but unnoticed aspect of a problem is suddenly revealed. For example, the fact that the Eurasian landmass has a largely east–west orientation, whereas the Americas and Africa are oriented north–south, makes a huge difference in how life on these continents evolved. Eurasia has huge areas of roughly equal latitude (and therefore climate) over which plants, animals, and humans migrated easily. The Americas and Africa, conversely, have many different climate zones of much smaller area at different latitudes, as well as mountains and other barriers to east–west migration. This wide range of climate zones and the presence of physical barriers to intracontinental migration have had a tremendous influence on the evolution, spread, and domestication of plants and animals globally.

Diamond uses this seemingly simple geographic observation as a key "ultimate" factor in developing a theory that explains the broad patterns of human history. In Diamond's theory, the causation runs something like this: The east–west axis determines the ease of species spreading; the more easily that species can spread, the more likely it is to be domesticated[1]; the more plant and animal species that are domesticated, the larger the food surpluses and food storage; the more food that is stored, the easier it is for large, dense, sedentary, stratified societies to develop that then produce the "proximate" factors of the pattern of history, namely, technology (guns, steel), political organization, writing, and epidemic diseases (germs). Diamond fleshes out this broad outline with a host of additional observations and insights to get at a range of interesting questions, including what caused the spread of food production, how ancient crops developed, why most big wild animal species were never domesticated, and why food production spread at different rates on different continents.

This background then allows Diamond to embark on a detailed analysis back through the causation chain of the evolution of germs, of writing, of technology, of government, and of religion. All of the chapters are gems of both scientific logic and writing style. The book then comes full circle to address Yali's question as part of a discussion of the history of Australia and New Guinea, which is followed by the histories of East Asia, Austronesia, Eurasia, the Americas, and Africa, all from the broader perspective and theory developed in the early chapters. Diamond's analysis reveals that the broad patterns of human history and the distribution of wealth and power are a function of the (sometimes subtle and complex) patterns of the environment and the ways in which those patterns have interacted and coevolved with human societies. In response to Yali, Diamond suggests that Europeans and their descendants do not possess more "cargo" today because they are inherently smarter than their New Guinean, African, or

[1]The percentage of potential plant, and especially animal, species that are actually domesticatable is to some degree a matter of luck, and Eurasia was particularly lucky in this regard. For example, fully 18 percent of the species of large mammalian candidates for domestication occurring in Eurasia were eventually domesticated, whereas only 4 percent of the candidates in the Americas and none of those in sub-Saharan Africa and Australia were domesticated. The reasons for these differences make for fascinating reading in Diamond's book.

Australian counterparts. In fact, Diamond makes a convincing argument for just the opposite—that New Guinean and other hunter–gatherer peoples are on average "smarter" than their "civilized" European counterparts, but in ways that are hard to measure on standardized tests. The broad patterns of history are also not explainable from the actions of a few key individuals, as some historians have argued. Rather, according to Diamond, the patterns are ultimately caused by accidents of geography and ecology interacting with human societies over time.

To my mind, Diamond's book is an example of the way that all history should be written. It is comprehensive and explanatory and, therefore, a useful guide to future policy. It allows for the unique contributions of individual humans but puts these actions in the proper context. It helps us to understand our world and our place in it at a level that is essential to have any hope of designing a sustainable human presence on the planet.

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## MANIPULATING NATURE

**Experimental Ecology: Issues and Perspectives.** William J. Resetarits Jr. and Joseph Bernardo, eds. Oxford University Press, New York, 1998. 470 pp., illus. $89.00 (ISBN 0-19-510241-X cloth).

The ghost of Robert H. MacArthur continues to haunt community ecology. In the 1960s, MacArthur and his colleagues revolutionized community ecology by developing simple but effective models of species interactions based on the unifying principles of competitive exclusion and the ecological niche. The equations were often presented with a modest amount of non-experimental field data that nicely matched the qualitative predictions of the models. When MacArthur died at an early age, his colleagues and students gathered for a symposium and produced *Ecology and Evolution of Communities* (Cody and Diamond 1975), which represents the apex of the MacArthurian approach.

But right from the start, trouble was brewing. Dissatisfaction with the MacArthurian paradigm was expressed in three developing research fronts. First, theoreticians quietly extended MacArthur's models and found that the predictions often rested on some delicate mathematical assumptions (e.g., Armstrong and McGhee 1980). Expanding the modeling framework generated complex and exciting dynamics but eroded the simple predictive power of the original models. Second, a heated debate developed over the standards of evidence and the evaluation of non-experimental data (Strong et al. 1984). In particular, proponents of null models asked how community patterns would appear in the ab-

sence of competitive interactions (Gotelli and Graves 1996). In many cases, the answer was, very similar to real communities! Null models generated a lot of unproductive rhetoric, but they also injected new statistical rigor into the analysis of nonexperimental data, which has been sustained by emerging research programs in macroecology (Brown 1995) and the comparative method (Harvey and Pagel 1991).

But the most profound challenge to MacArthur's work came from experimental ecologists. Rather than manipulating equations, these ecologists added and removed species in communities, monitored the result, and evaluated the models in this light. Although experimental manipulations in agriculture and plant ecology have a long history (Fisher 1935), this work did not have a significant impact on the thinking of community ecologists (Jackson 1981). However, influential studies beginning in the early 1960s by animal ecologists (Paine 1966, 1994, Connell 1975) suggested that predation and disturbance might be just as important as competition in structuring communities. It is probably not a coincidence that many of these studies were conducted in the temperate rocky intertidal, where zonation patterns are striking and the sessile adult stages of invertebrates and macroalgae can be readily manipulated.

Experimental ecology has since developed rapidly, and ecologists have carried out sophisticated manipulative experiments in terrestrial, marine, and freshwater habitats. Ironically, much of this experimental work now seems to support the contention that competitive interactions are common in nature (Gurevitch et al. 1992), although the consequences of competition for community structure are rather different from what MacArthur may have envisioned.

*Experimental Ecology: Issues and Perspectives* is an edited volume with 22 contributions from the leaders of experimental ecology. It shows how far the field has come since the early work of Robert T. Paine and Joseph H. Connell and also points out where it may be going next. Just as *Ecology and Evolution of Communities* articulated the MacArthurian approach, this symposium volume gives a state-of-the-art look at experimental ecology.

However, unlike the MacArthurians, these authors are a bit more introspective and cautious about the tools of their trade. A common theme in these essays is the inherent limitations of ecological experiments: they are usually conducted on inadequate temporal and spatial scales, they may be confounded by uncontrolled variables, and they often do not critically address the underlying assumptions of the models they purport to test.

Indeed, a set of hypercritical papers takes experimentalists to task for sins such as carrying out "mechanism-vague" experiments (Arthur E. Dunham and Steven J. Beaupre, chapter 2), improperly inferring the relative importance of different mechanisms from an experiment (Peter S. Petraitis, chapter 10), and generally not being self-critical enough and thereby straying from a strict Popperian framework of hypothesis testing (A. J. Underwood, chapter 17).

But there are balancing viewpoints here as well. Barbara L. Peckarsky (chapter 16) points out that, in contrast to communities in the rocky intertidal zone, communities in streams may not exhibit clear-cut spatial patterns that can motivate experiments. Nevertheless, it is still possible to gain insights by manipulating systems in the absence of a formal hypothesis or mechanism. And John E. Fauth (chapter 20) shows how common garden experiments can be used to make inferences over broader geographic scales.

The most satisfying chapters give the authors' perspectives on long-term field experiments, which often violate most of the rules of good experimental design. James H. Brown, who also contributed to the MacArthur symposium volume, gives an interesting account of the rodent exclusion experiments at Portal, Arizona (chapter 4), and the typical problems encountered along the way: limited replication, droughts, midstream modifications of experimental design, premature generalizations based on early results, and disruptive interruptions in funding.

Although all of the authors stress the importance of testing models with experiments, there are few equations in this book. Elizabeth A. Marschall and Bernadette M. Roche (chapter 14) discuss the way in which information from experiments can be used to evaluate models and make broader generalizations, and Mathew S. Leibold and Alan J. Tessier (chapter 5) emphasize the importance of a mechanistic perspective when designing experiments. Earl E. Werner (chapter 1) makes the important point that the traditional analysis of variance may act as a kind of mental straightjacket that allows for formal hypothesis tests only. To actually estimate model parameters, other designs, including experimental regression models, are more efficient.

Parameter estimation and the comparison of competing models is probably the next step in the evolution of ecological experiments, and two important recent books by Hilborn and Mangel (1997) and Burnham and Anderson (1998) show how this step can be accomplished. In the meantime, *Experimental Ecology: Issues and Perspectives* is an excellent summary of the current state of the art. Although plant ecology is poorly represented, there is a good mix of evolutionary and ecological studies in terrestrial, freshwater, and marine habitats, with experimental units ranging from laboratory microcosms, through ecotrons, to full-scale field manipulations. There is a correspondingly diverse mix of opinions about how experiments should be designed, executed, and interpreted. Now if only funding agencies would add another zero to ecology grant budgets, even problems of inadequate replication could be addressed. I am not a fan of multi-author edited volumes, but this book was thought-provoking and enjoyable. I highly recommend it to all ecologists.

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## MANAGING WATER MORE WISELY

**The World's Water 1998–1999: The Biennial Report on Freshwater Resources.** Peter H. Gleick. Island Press, Washington, DC, 1998. 307 pp., illus. $29.95 (ISBN 1-55963-592-4 paper).

If you weren't already concerned about the world's freshwater situation, you will be by page 2 of Peter H. Gleick's *The World's Water*. More than a billion people on Earth lack safe drinking water, several devastating water-related diseases are increasing in range and occurrence, more than 700 fish species worldwide are formally listed as threatened or endangered, unsustainable groundwater mining continues on every continent except Antarctica, and so on. Gleick, however, is not simply a bearer of bad news. Indeed, he ends his book on a decidedly optimistic note, with a hopeful vision of the world's water situation in the year 2050, provided the many difficult issues regarding water are dealt with intelligently.

Connecting the sobering introduction with the optimistic closing section are six lucid, informative chapters that address some of the most important of these water issues. Gleick describes the changing paradigm at the end of the twentieth century from one focused on ever-increasing water supplies to one stressing careful management of demand. He then examines several themes at the center of humanity's relationship with fresh water: water and human health, the status of large dam projects, climate change and water resources, human conflict and cooperation over water supplies, and the recent laws and institutions meant to manage such conflicts. At the back of the book (along with many other useful resources), Gleick has compiled an extensive data section containing 19 tables on everything from total renewable freshwater supply by country to the numbers of people displaced by over 300 dam projects worldwide. This combination of trend analyses, thematic discussions, extensive references, and voluminous basic data will ensure the book a wide audience. Interested lay readers, students of natural resource management, and water experts will all find abundant use for *The World's Water*.

And this is just the first edition! *The World's Water* is designed to be a series of biennial reports on the state of the world's freshwater resources and the human uses thereof. Each subsequent edition will update and augment the data section, as well as tackle several new themes and issues. Gleick is already promising chapters on water and food security, water and natural ecosystems, and water recycling in the next edition, due in 2000.

In this edition, the very first chapter ("The Changing Water Paradigm") is in many ways my favorite. Gleick surveys the mistakes made, opportunities missed, and sensible institutions never created in our

society's efforts to manage fresh water. Many of these failures point to obvious and simple solutions. For example, Santa Barbara, California, stung by droughts, financed both a seawater desalination plant and a major pipeline to prevent future scarcity. The capital and maintenance costs of the projects increased the cost of water in the city by over 300 percent, providing a powerful incentive to conserve. The result: a 61 percent drop in water use, eliminating the need for the brand new desalination plant, which was promptly removed from regular operation! In this chapter, we also learn that only 40 percent of the water diverted for agriculture worldwide actually produces any food, and we are led to wonder why Americans still use perfect drinking water to flush their toilets. From all of these cases and many more, Gleick's main thesis emerges: as the human population grows and supplies become more and more difficult to augment, enormous opportunities exist to use what we have more wisely.

Throughout the thematic chapters that follow the first, Gleick effectively combines analyses of global and regional trends with specific examples and case studies. In the chapter on water and security, for example, he describes the varied ways in which water plays a role in both inter- and intranational conflict: as a political goal, as a source of tension that may lead to conflict, and as both a weapon and a target of war. Gleick then traces the historical and present conflict over water in South Asia and southern Africa to illustrate these roles, describing some of the attempts at water diplomacy each region has undertaken. Some of the successes in resolving water disputes between Bangladesh and India have even led to an overall spirit of cooperation between the two countries, enabling progress on unrelated issues as well.

The chapter on climate change is somewhat less satisfying than the others because it lacks the specificity and examples found elsewhere in the book. Granted, when climate models can do no better than to predict decreased predictability of water resources under a changing climate, specific policy recommendations are difficult to formulate and examples of any policies enacted must be hard to come by. Still, I couldn't help wishing for elaboration on statements of this type: "such changes will have enormous policy implications." One of Gleick's conclusions is that planners should take steps to prepare dam systems for future water regimes that differ from those in the past. Again, some specifics of what these preparations might involve, even if derived only from his experience and first principles, would have been enlightening and valuable.

If Gleick were accepting requests for future editions, mine would be for a chapter dedicated to interactions among the issues explored individually in this edition of *The World's Water*. For example, Gleick briefly mentions the connection between dam construction and waterborne diseases. He reports that after the Aswan High dam on the Nile began changing a flowing river into a still reservoir, the fraction of the local population infected with schistosomiasis rose from nearly zero to almost 100 percent! There must be many such interactions that can confound (or ease) water-related science and policy.

Overall, this book takes a truly impressive bite out of an enormous topic. And despite the sobering observations at the beginning and sprinkled throughout, it left me distinctly optimistic toward the future. Gleick observes:

> Rather than endlessly trying to find the water to meet some projection of future desires, it is time to plan for meeting present and future human needs with the water that is available, to determine what desires can be satisfied within the limits of our resources, and to ensure that we preserve the natural ecological cycles that are so integral to human well-being. (p. 33)

*The World's Water* contains ample evidence that, although challenges abound, this paradigm shift is afoot. With people like Peter Gleick leading the way with books such as this one, that is doubtless the best news of all.

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## COOPERATION AND CONFLICT AT ALL LEVELS

**Darwinian Dynamics: Evolutionary Transitions in Fitness and Individuality.** Richard E. Michod. Princeton University Press, Princeton, NJ, 1999. 280 pp. $45.00 (ISBN 0-691-02699-8 cloth).

"Life is highly organized into a hierarchy of structural levels, with each level building upon the levels below it." Thus states page 1 of Campbell et al. (1999); indeed, most introductory college and high school biology textbooks emphasize this hierarchy. Although the existence of a hierarchy is easily asserted, questions about the origin, maintenance, and continued development of this hierarchy are not trivial. For example, how did networks of genes evolve from simple replicators? How and why did these networks become encapsulated in cells? What processes allowed cells to come together in aggregates and, later, in true multicellular organisms? How do societies form, and how are they able to persist despite conflict among individuals? During the past 20 years, the evolutionary geneticist Richard E. Michod has addressed these and other questions about evolutionary transitions. His new book, *Darwinian Dynamics*, is an excellent and masterful synthesis of the current understanding about how evolutionary principles work at the various levels of biological organization.

Michod's central thesis is that the emergence of new levels as units of evolution requires cooperation and conflict mediation among the lower-level entities. To Michod, "cooperation (and altruism) and defection are not just special problems in the study of animal behavior, but rather a central issue in transitions to increased complexity" (p. 30). Because of this central similarity, the mathematics used to study evolutionary transitions from one level to the next are remarkably similar across different transitions. This mathematical system, multilevel selection theory, can be powerful because the rules do not change drastically across different levels of the hierarchy: Cooperation and conflict are always present.

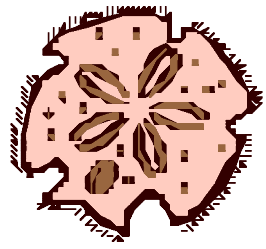
The Price covariance equations are an integral part of multilevel selection theory. Extending the work of Sir Ronald Fisher and other population geneticists, George Price showed that the change in any given quality (including the frequency of an allele) from one generation to the next is equal to the covariance of that trait and fitness. Michod provides a particularly elegant and easy-to-understand proof of this result in chapter 1. Price's equations are easy to use and thus powerful because covariances, like variances, are easy to partition. By partitioning covariances, it is possible to separate the effects of selection into those within an entity and those among entities. The elegance and generality of the Price equations have impressed many theoretical population geneticists, especially those working on kin selection theory (Wade 1980, Frank 1998, Sober and Wilson 1998). Unfortunately, despite their simplicity and utility, these equations are not even mentioned in most evolution and population genetics textbooks. This neglect will most likely be only temporary; in addition to *Darwinian Dynamics*, two recent books on social evolution, by Sober and Wilson (1998) and Frank (1998), provide in-depth coverage of the Price equations.

Michod is one of the few population geneticists who have seriously addressed questions about the origin of life. He makes the case that conflict and cooperation began during the first evolutionary transition as replicators (i.e., genes) became integrated into networks. Building on the work of Manfred Eigen, Michod presents a model of conflict in this process by considering two types of replicators: one type (producer) makes a protein, and the other (defector) can use the protein to replicate itself but does not make the protein. The defector replicator shares in the benefit (B) of using the protein but does not pay the cost (C) entailed in making the protein. All other things being equal, the defector would have an evolutionary advantage. Michod shows how spatial heterogeneity can change this situation. With spatial heterogeneity, each type of replicator experiences a different density of protein. If heterogeneity is sufficiently high, the producer replicator would have an evolutionary advantage. Specifically, the producer should increase in frequency when $F_{ST} > C/BN$, where $F_{ST}$ is Sewall Wright's measure of heterogeneity and N is the size of the local population. Michod notes the analogy between this equation and the famous kin selection equation by William D. Hamilton: $r > C/B$, where r equals relatedness. At the end of chapter 3, Michod discusses the evolution of the cell as an early conflict-mediation device, which reduces conflict by more closely aligning the

interests of the individual genes with those of the group.

Michod returns to spatial heterogeneity in discussing the prisoner's dilemma. In this mainstay of game theory research, individuals can either cooperate with another individual they encounter or they can defect. If one individual cooperates and the other defects, the defector receives a large payoff (whether the currency be fitness, money, or a reduced prison sentence), and the cooperator receives nothing. When both players cooperate, they fare better than if both defect. In situations in which the individuals will not encounter one another again, the best strategy for any individual is to defect. Yet if there are repeated encounters, more benevolent strategies may be favored. One such benevolent strategy is TIT FOR TAT (TFT); an individual employing TFT will always cooperate the first time it encounters another player and, in a repeat encounter, will do exactly what the other player did the last time they met. This strategy is generally successful when it and other benevolent strategies are common, but it has difficulty invading a population when most of the individuals employ the "always defect" (AD) or other non-benevolent strategies. Recent simulation studies have found that TFT can, however, invade a population in which it is rare if the spatial structure of the population increases the chances that TFT individuals will encounter one another. But how could this spatial heterogeneity come about? Michod shows that certain levels of mobility by TFT and AD individuals can result in sufficient spatial heterogeneity for the TFT types to invade when TFT is rare. Thus, the inclusion of spatial heterogeneity in prisoner's dilemma models is not arbitrary; it can arise via a biological property of the individuals.

Later, in chapter 6, Michod presents a series of models explaining how multicellular organisms may evolve from an assemblage of cooperating cells. To Michod, a true multicellular individual organism requires not only the aggregation of cells related by common descent but also the presence of specific adaptations (e.g., a sequestered germ line, modifiers to reduce the mutation rate,



and self-policing systems such as programmed cell death and the immune system) that mediate conflict among the lower-level entities (cells). Michod also discusses the evolution of sex and adult size in relation to the origin of multicellularity.

Philosophers of science, in addition to evolutionary biologists, will find much of interest in *Darwinian Dynamics*. For instance, Michod and Richard Dawkins would agree that organisms cannot be fitness-maximizing agents but would disagree on the implications of this fact. To Dawkins, units of selection must be fitness-maximizing agents; hence, genes and not organisms are units of selection. In contrast, Michod believes that an entity need only possess variation and heritability of fitness to be a unit of selection. There are no maximizing agents in Michod's view of fitness as a "dynamical concept, both as cause and effect of evolutionary change." Classical selection theory, wherein selection maximizes individual fitness, may work well under certain circumstances (e.g., no frequency-dependent selection; only one level in the hierarchy under consideration). During evolutionary transitions and in other situations of frequency-dependent selection, however, classical theory and individual selection are inadequate. Much as Einstein's theories of relativity extended classical mechanics, Michod's multi-selection theory is an extension of classical selection theory.

*Darwinian Dynamics* is well produced and current, with many post-1995 references. However, it does require some familiarity with and patience to go through the math. The struggle is well worth it, however, because Michod has written what should be a classic for decades to come. Darwin (1859) found grandeur in a worldview wherein the immense diversity of life forms arises from a few general principles. Darwin, of course, knew little about cells and still less about genes. It is likely, however, that he would be pleased that his principles apply at all levels of the biological hierarchy.

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## PREDICTING THE GLOBAL FUTURE

**Which World? Scenarios for the 21st Century: Global Destinies, Regional Choices.** Allen Hammond. Island Press, Washington, DC, 1998. 320 pp., illus. $24.95 (ISBN 1-55963-575-4 cloth).

There are problems with forecasting what lies ahead. It is not just, as someone famously said, that most assertions about the future are wrong, including that one. Rather, it is that humans have marked capacity for self-imposed myopia. For example: Thomas Edison on the telephone: "It isn't of any commercial value"; Lord Kelvin, president of the Royal Society of London: "Heavier-than-air flying machines are impossible," "Radio has no future," and "X-rays will prove to be a hoax"; Charles Duell, commissioner for the US Patent and Trademark Office: "Everything that can be invented has been invented"; Field Marshall Foch: "Aeroplanes are interesting toys, but of no military value"; Harry Warner of Warner Brothers: "Who wants to hear film actors talk?"; Thomas Watson, chairman of IBM: "There is a world mar-

ket for maybe five computers at most"; Darryl Zamuck, head of 20th Century Fox: "Television will have no market after the first six months"; Dr. Richard Willis, British Astronomer Royal: "Space travel is utter bilge"; Decca Records: "We don't like their [the Beatles'] sound, guitar groups are on the way out"; and Ken Olsen, president of Digital: "There is no reason for any individuals to have a computer in their home."

More power, then, to Allen Hammond, of the World Resources Institute, for his attempt to prognosticate some political and socioeconomic phenomena of our next half-century. Will, for instance, free markets bring more prosperity to more people? Will poor countries become poorer in the wake of population growth, environmental decline, and incompetent (or effectively no) government? Could conventional economic advance ultimately lead to a reversal in human well-being? Or will governments and societies get their acts together sufficiently "to create a more peaceful, equitable, and environmentally sound world"?

*Which World? Scenarios for the 21st Century* emanates from the 2050 Project on Long-Term Sustainability, a collective endeavor of the Brookings Institution, the Santa Fe Institute, and the World Resources Institute. It presents three principal scenarios, or "World Views," together with their potential repercussions. The first is designated "Market World: A New Golden Age of Prosperity," whereby the engine of global economic integration mobilizes resources, technologies, management skills, and investments that generate prosperity far and wide, followed by political stability and social progress. Particularly prominent, as would be expected in a globalized future, is trade: As early as 2005 it will account, in this scenario, for 40 percent of national output in industrial countries and 50 percent in emergent economies.

But this optimistic outlook could be undermined by a host of problems. The second scenario, labeled "Fortress World: Instability and Violence," postulates that rampant globalization of a narrow economic type could consign "hundreds of millions of humans to lives of rising conflict and violence," destroying the environmental foundations of progress and the social solidarity that progress must reflect.

The third scenario, "Transformed World: Changing the Human Endeavor?" envisages human ingenuity and social inclusiveness working together, also with democracy in both politics and economics, to generate a world in which everyone's lives are enriched, both materially and nonmaterially. The key to this Holy Grail of the future lies with seismic shifts in political and social policies; the drivers comprise empowered citizenry, enlightened institutions, responsible bureaucracies, radical environmental reform, and reconstructed corporations that respect all stakeholders. Panglossian as this scenario may sound, we can take heart from the recent flourishing of nongovernmental organizations. Every twentieth American is a paid-up member of an environmental organization, and in Denmark there are more such members than there are Danes.

Hammond has collated and evaluated his findings through studies of seven major regions of the world, including Latin America, Russia and Eastern Europe, the OECD grouping, and so on. To supply an integrative thread to his book, he analyzes the scenarios and regional surveys through four sets of critical trends: demographic, economic, and technological; environmental; political and social; and a synthesizing factor, security.

Hammond constantly emphasizes the many inter-sectoral linkages that characterize our world. If only he had pursued them in more detail. For instance, the connection between agriculture and water is surely obvious, especially in countries that depend heavily on irrigated crops. In parts of India, over-pumping of groundwater for rice paddies is lowering water tables by as much as 1.5 meters per year. What, then, will happen when the aquifers give out? Much the same applies in the north China plain, which supplies 40 percent of the country's grain. Due to ever-heavier withdrawals of water upstream, the northernmost of China's two big rivers, the Yellow River, now fails to reach the sea for three-fifths of the year. Again, there could be a severe discontinuity ahead. Hammond highlights the prospect that our future could be a "surprise rich" affair with discontinuities aplenty, especially synergized outcomes. If only the book presented more illustrations of this salient phenomenon, one that is sure to become more pervasive.

On the whole, *Which World? Scenarios for the 21st Century* is reasonably well done. The more the pity, then, that Hammond does not try harder to tackle the surprise element in human affairs, especially the self-imposed myopia. Many surprises of the past could have been rendered less surprising. For instance, consider the rise of OPEC: The organization warned for years that once the major oil-consuming nations, especially the United States, imported a certain large amount of oil from cartel nations, a hefty hike in the price of oil could be imposed. Nobody took any notice. Then there were Black Monday on Wall Street and Black Wednesday in the City of London, both being occasions when only a few speculators read the financial tea leaves correctly and went liquid. The most surprising thing about AIDS is that we profess to be surprised: It was surely inevitable that as large human communities pressed ever closer on natural environments, such as tropical forests with their vast reservoirs of unknown pathogens, a new virus would eventually make the crossing to humans—whereupon it would find it was living in a microbe's paradise, with huge numbers of people traveling hither and yon and providing an excellent medium for the disease to spread to communities around the world.

There have been some positive surprises, too. When I bought my first pocket calculator in 1970, I needed a big pocket; I never would have dreamt that today's calculator would be the size of a credit card and powered by the sun. In 1970, demographic experts told the Thai government that it would be absurd to try to reduce the country's average family size from over seven children to two children as soon as the year 2000; Thailand did it in two-thirds of that time. Who would have bet in 1989 that by 2000 we would get rid of the Berlin Wall, the cold war,

Communism, and the Soviet Union—and witness peace in South Africa and Northern Ireland? And who would have expected just a decade ago that a rather obscure computer network would rapidly grow into the huge phenomenon it is today, transforming our world?

The biggest challenges of the future will likely not lie with our lack of technological expertise, investment capital, or burgeoning markets. They will more probably stem from our mental roadblocks, our sclerotic mindsets, and our institutional blinders.

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## DEMOGRAPHIC PATTERNS IN SPACE AND TIME

**The Population Ecology of the Vole *Clethrionomys rufocanus*.** Nils C. Stenseth and Takashi Saitoh, eds. Researches on Population Ecology, Vol. 40, No. 1, 1998. 158 pp., illus. ¥2000, or approximately $17.00 (ISSN 0034-5466; available from The Society of Population Ecology, Shimotachiuri Ogawa-Higashi, Kamikyo-ku, Kyoto 602-8048, Japan; fax: 81-75-415-3662).

Interdisciplinary, international, long-term, and large-scale are buzz words for research in the new millennium, or so they should be. A recent special issue of the Japanese journal *Researches on Population Ecology* illustrates this desired direction. Focusing on the population dynamics of the gray-sided vole (*Clethrionomys rufocanus*) on the island of Hokkaido, this collection of papers serves as an examplar of the kind of leap forward that cooperation across disciplines and nations and the perspective of long-term data sets make possible. The main actor in this story is a rodent that inhabits boreal forests across the entire Palearctic (and has sometimes been viewed as a pest in forestry plantations). The messages from this special issue, however, are much more pervasive than implied by its seemingly narrow focus on a single species at a single location. They contain important implications for ecology in general, for the future character of the research enterprise, and for research funding strategies. Quite incidentally, the project reveals what can be accomplished in a field typically characterized by low-budget ecologists working for a few years on their favorite critters and then publishing results that are often noticed by only a few colleagues.

One message is that this collection of papers is a product of extensive international cooperation. Twelve scientists from two countries (Norway and Japan), both with strong traditions in biological research but geographically distant from each other, have shown what can be achieved collectively. Second, this research is an excellent example of the power of interdisciplinary collaboration, an approach that educators, funding agencies, and even many scientists have inadequately appreciated. In this case, ecologists, modelers, statisticians, ethologists, mammalogists,

## Taking In the Sites

Organisms invisible to the naked eye are revealed in the following Web sites on the microscopic world.

"The Smallest Page on the Web" (**micscape.simplenet.com/mag/wimsmall/smal1.html**) takes a look at the microorganisms commonly found in a freshwater pond. Visitors can click on a picture of a microbe (e.g., a rotifer, ciliate, bacterium, or diatom) for more information, which includes detailed text and color illustrations. Each description includes links to other articles on the topic from *Micscape*, a magazine published by Microscopy-UK.

At **www.microbe.org**, young Web surfers can join microbiologist Sam Sleuth in "Stalking the Mysterious Microbe!" Sam takes his visitors on a fascinating journey through "microbe mysteries" (e.g., are microbes "friends or foes?"), microbes in the news (e.g., the possibility that microbes can provide clues about extraterrestrial life), and a look at careers in microbiology. Young sleuths will also find directions for two experiments—one demonstrating the importance of washing hands and the other developing a "biosphere in a bottle."

The "Microbe Zoo" is always open at **commtechlab.msu.edu/sites/dlc-me/zoo**. The zoo is divided into five thematic areas—Dirtland, Animal Pavilion, Snack Bar, Space Adventure, and Water World—in which visitors can find out, for example, which microbes assist in the preparation of foods or which ones assist in sewage treatment.

The wonderful world of microscopic organisms would be unknown without the assistance of microscopes. The Molecular Expressions Museum of Microscopy (**microscopy.fsu.edu/primer/museum**) provides a comprehensive, illustrated history of the microscope from the sixteenth century to the present, including those developed and used by Antoni van Leeuwenhoek, Robert Hooke, and George Oberhauser, among many other pioneers in microscopy.

Other sites of interest include:

American Society for Microbiology: **www.asmusa.org**

Microscopy Society of America: **www.msa.microscopy.com**

Microscopy-UK: **www.microscopy-uk.org.uk**

foresters, parasitologists, and geneticists have forged the synergism.

Enhancing this synergism, the editors have taken the unusual step of including, in addition to the 10 primary papers, eight short invited commentaries by researchers who work in other parts of the world (two are from North America) and, in some cases, on quite different organisms (e.g., insects, measles virus, Soay sheep). The commentaries provide insights into the relevance of the vole studies in a broader context, and they also build the peer-review process into the original publication. Both are lessons that deserve wider implementation.

Finally, and perhaps of greatest significance, the report is a remarkable tribute to the value of long-term data sets. It is based on 225 long-term data records (spanning 12–31 years) on a single species of vole distributed over the entire island of Hokkaido. The influence of temporal and spatial scale on the understanding of population processes is a "cutting-edge" topic in ecology and conservation biology today (Levin 1992). Within Hokkaido, some populations of the gray-sided vole show multi-annual cycles in numbers (usually 4 years), and some do not. This publication contributes significantly to a resolution of the classically enigmatic problem of microtine rodent multi-annual cycles.

Additional insights emerge on the general subject of population density regulation, on the long-standing controversy about the role of so-called density-dependent and density-independent factors, and on the relative importance of intrinsic and extrinsic influences. The heart of this collection, however, is the analysis, in four papers, of demographic pattern from 1962 to 1992 as it is displayed across the whole of Hokkaido. This analysis, as discussed in the papers by Ottar N. Bjørnstad, Nils C. Stenseth, Takashi Saitoh, and Ole C. Lingjaerde; by Stenseth, Bjørnstad, and Saitoh; and by Nigel G. Yoccuz, Keisuke Nakata, Stenseth, and Saitoh, involves time-series analyses and their coupling across space; the authors employ a number of innovative approaches in these analyses. Strong density-dependent influences were found in all populations, but delayed density-dependent effects were apparent only in those populations showing multi-annual cycles (paper by Stenseth and Saitoh). Populations living in regions with longer winters and more snowfall generally showed density cycles, suggesting possible mechanisms underlying these seemingly implausible density fluctuations. In fact, the length of summer turned out to be a good predictor of cyclicity. Another interesting and unusual finding was that the spatial scale of coordinated population dynamics is approximately 50 kilometers. Ironically, the data for these long-term records were collected by foresters not particularly concerned with these larger ecological questions; rather, they were looking for ways to control rodent damage to tree seedlings.

This collection also includes excellent background papers, among them one on the role of pluralistic approaches in ecological research (by

Stenseth, Saitoh, and Yoccuz) and another on the life history, morphology, and phylogeny of the gray-sided vole, placing it both in the context of its entire Palearctic distribution and within the genus *Clethrionomys* (by Yukibumi Kaneko, Nakata, Saitoh, Stenseth, and Bjørnstad). Two papers follow on the social behavior and organization of *C. rufocanus* (one by Yasuyuki Ishibashi, Saitoh, and Masakado Kawata, and the other by Ishibashi, Saitoh, Syuiti Abe, and Michihiro C. Yoshida). Both papers relate social organization to demographic issues and to microtine ecology in general. Of special note is a paper on interactions among voles, tapeworms (*Echinococcus*), and foxes, by Saitoh and Kenichi Takahashi. The editors provide an informative preface and, following the eight guest commentaries, a final summary paper in which they offer 14 suggestions for future research.

As inspirational and important as this volume is, it also highlights some limitations to the approach that it exemplifies. The results are impressive when it comes to sophisticated descriptions of temporal and spatial variations in populations, but they are weak on mechanism. To be sure, the authors do discuss some mechanistic implications of their data, but persuasive evidence will require detailed, smaller-scale studies on specific populations. Moreover, there is a general tendency in the papers in this volume to ignore the community context of the vole populations and to focus on social behavior and a few climatic factors (see also criticism in the commentary by Richard S. Ostfeld). An important exception is the predator/prey/parasite analysis in the paper by Saitoh and Takahashi.

Future research will benefit from the solid framework generated by the exemplary team effort that this volume represents. I urge the science establishment to heed the lessons proffered in *The Population Ecology of the Vole* Clethrionomys rufocanus and to encourage, both morally and financially, similar efforts. In this era of concern for climate change, loss of biodiversity, and sustainable resource management, support of long-term research and monitoring is critically important. This volume is important for ecologists generally, and it should be seen by all those involved in the administration and financial support of research.

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## DARWIN'S "DEVASTATING PUZZLE"

**Following Form and Function: A Philosophical Archaeology of Life Science.** Stephen T. Asma. Northwestern University Press, Evanston, IL, 1996. 246 pp. $19.95 (ISBN 0-8101-1398-8).

**The Darwinian Shift: Kuhn vs. Laudan.** Caroline Joan "Kay" S. Picart. Copley Custom Publishing Group, Acton, MA, 1997. 191 pp. $17.50 (ISBN 0-87411-909-X paper).

The "Darwin industry" has become so large that it is refreshing to have two treatises arrive that are "intended primarily for undergraduates interested in the principal and recurring questions in contemporary philosophy of science," as stated by Caroline Joan "Kay" S. Picart. Similarly, Stephen T. Asma's study "seeks to uncover some buried strata in the history of knowledge—to disclose an unappreciated and distorted discourse which powerfully shaped and continues to shape the life sciences"(p. 7). Both authors feel that it is not possible to understand evolutionary biology without sorting out a set of philosophical questions. For instance, as Picart discusses, how was natural history reconceptualized from the value-laden perspectives of immutability, permanence, and teleology to variability, dynamism, and chance? How much did Darwin diverge from his predecessors and in what ways? How is evolutionary biology successful as a science?

Transformism is often confused with evolution writ large. Hence, Asma notes, many nineteenth-century scientists could embrace a transformative set of processes as long as these processes were perceived as necessary, constitutive, symmetric, harmonious, designed, pure, elegant, and essential. If change led to perfection and completion, then such a change was allowed under either the tradition "God's law" or "molded by the requirements of physical law," as Asma puts it. These approaches were contrasted with fugitive types, fluctuating forms, and ephemeral flux—which are monstrous, chaotic, and accidental. In contrast, Asma notes, "Darwin's ultimate rejection of the essential/accidental distinction" allowed him to move beyond the dualistic debate. To this day, many students are taught biology dualistically, that is, from either a structural (form) or a functional perspective. Asma attributes this approach to a pre-Darwinian legacy that is often misunderstood—the Cuvier–Geoffroy debate over whether form is functionally determined or historically contingent.

Asma displays remarkable clarity in reformulating our conceptions of which competing philosophies could be consistently held by an individual—a clarity not seen since Hein (1970). Thus, mechanism, vitalism, materialism, reductionism, and holism seem to be a series of oppositional dualities, yet individuals could hold several seemingly incompatible points of view simultaneously that "[do] not depend on scientific evidence for their retention, and will not be shaken by evidence to the contrary" (Hein 1972).

Darwin's "devastating puzzle," as Asma calls it, is the problem of unity in diversity: How can biologists explain the function of a feature if different creatures have the same feature? For example, Asma notes, "it is a great embarrassment to attribute the cause of partitioned skull structure to the peculiar functions of viviparous birthing processes, only to find essentially the same structure in oviparous animals" (pp. 105–106). Darwin's solution is that homology is due to descent (his principle of conservation of ancestral forms). Furthermore, Darwin cites two other cornerstones of his belief, which Asma describes as an "all embracing power of natural selection" and the "complex laws of growth." What is amaz-

## Publishers' Information

Books from the following publishers were reviewed in this issue. To order books, or for more information, contact the publishers at:

**Copernicus**, an imprint of Springer-Verlag New York, Inc., 175 Fifth Avenue, New York, NY 10010; 212/460-1611
**Copley Custom Publishing Group**, 138 Great Road, Acton, MA 01720; 978/263-9090
**Island Press**, P.O. Box 7, Covelo, CA 95428; 800/828-1302
**Northwestern University Press**, 1735 Benson, Evanston, IL 60208; 847/491-5313
**W. W. Norton & Company**, 500 Fifth Ave., New York, NY 10110; 212/354-5500
**Oxford University Press**, 198 Madison Ave., New York, NY 10016; 212/726-6000
**Princeton University Press**, 41 William St., Princeton, NJ 08540-5237; 609/258-4900
**The Society of Population Ecology** and **Springer-Verlag Tokyo**, P. O. Box 2485, Secaucus, NJ 07096-2485; 212/460-1526
**University of Texas Press**, P. O. Box 7819, Austin, TX 78713-7819; 512/471-7233

ing is how contemporary biologists and philosophers are frequently enamored of only one or two of these three principles. Thus, Asma takes on Richard Dawkins, Daniel Dennett, Michael Ruse, Stuart Kauffman, Brian Goodwin, Robert Richards, Toby Appel, Richard Rorty, and other prominent commentators on Darwinism in due course.

Asma would, I think, be very comfortable with Dolph Seilacher's triangular model (Seilacher 1989): form is in the middle of the triangle as the ontological category to be explained, and the three corners of explanation are phylogenetic (i.e., homology, descent, "cladistic" reasoning, archetypes), fabricational (i.e., D'Arcy Thompson–type explanations due to physico–chemical, material, and mechanical constraints; generative laws), and functional (i.e., adaptational reasoning, physiology, behavior, ecological fit). Unfortunately, students are frequently introduced to only one of the three corners of the triangle in most biology classes other than evolution classes per se. Also, some scientists (e.g., Goodwin 1994) seem content to throw away one corner's perspective (i.e., the historical, phylogenetic corner) to privilege the "complex laws of growth."

Thus, Asma moves beyond the Cartesian mind–body dualities of telos–epistemology–function–epigenesis–adaptation with eidos–ontology–form–preformation–homology (archetypes) by reexamining the long-standing dyads of Aristotle versus Plato in Greece, Cuvier versus Geoffroy in France, Paley versus Owen in England, and Kant versus Goethe in Germany—not only in their historical and national contexts, but also in terms of their philosophical importance for biology. Asma transforms our appreciation for Darwin's causal pluralism:

> The original intractable tension between structuralism and functionalism (Cuvier–Geoffroy debate) is overcome by Darwin largely because he understands the causal modalities as co-principles rather than competitors. The original tension between adaptationist and structuralist approach was bound up with a metaphysics that placed all adaptation (design) on the foundation of conscious intentionality (usually the Deity's), and all structuralism on the foundation of mindless materialism. Once Darwin had naturalized teleology (by removing 'conscious design' from natural selection) and naturalized the archetype (by interpreting it as historically real, rather than Ideal [sic]), he could synthesize causal frameworks that had previously opposed each other on metaphysical grounds.
>
> Darwin recognized that the precise place where one causal story breaks down is the exact point of strength for the complementary theoretical strategy.... Yet, with few exceptions, biologists (particularly in the French and Anglo traditions) continue to constrain their science with a rigidly 'dichotomous' interpretation of structure versus function. (p. 127)

Chuck Dyke (1987) integrates Darwin's and Seilacher's three approaches in one simple phrase: "structuring structured structures." Imagine the difficulties students face as they move from professor to professor in biology, each of whom adheres to a side of this classical structure–function dualism or even one corner of the Darwinian–Seilacher triangle. Will the curricular move to "integrative biology" actually achieve integration of these diverse perspectives? Asma's one-liner in response is: "The tree of knowledge, it was claimed, had killed the tree of life" (p. 120).

Picart picks up where Asma leaves off. She considers revisionist versions of Darwin's biographies in light of a contemporary debate in philosophy of science: Does science rely heavily on the personal, social, and historical contingencies of human practice (as Thomas S. Kuhn sees it) or is science (comparatively) rational and progressive (as Larry Laudan contends)? Rather than simply choosing between these views or leaving them as incommensurable, Picart demonstrates the power of both viewpoints:

> The pivot point around which this entire philosophical thesis centers is on the *what-ness* and *how-ness* of science as a human activity. In line with this, inquiries into its historicality, communalism, rationality, and progressiveness have been done. The provocative and problematic linchpin which ties all these themes together is called 'incommensurability.' (p. 130)

Picart employs Laudan's factors of "testability, fruitfulness, simplicity, and consistency" to demonstrate the scientific merit of Darwinian evolutionary paradigms over creationist–fixist paradigms. But she also states: "I affirm Kuhn's position on the nonadjudication of certain features of paradigms. That is, I agree with Kuhn that paradigms do possess a 'hard core'" (p. 130). Her avoidance of fence sitting will help her intended undergraduate audience appreciate that they can make commitments even in the presence of controversy, ambiguity, and ignorance. Whereas others seek differentiation, Picart finds that "for all practical purposes, Kuhn's paradigms or disciplinary matrices are roughly equivalent to Laudan's research traditions" (p. 151).

One of the finest sections of Picart's book—and one that students

should enjoy—is her explication of Darwin's double entendre humor in the phrase "descent of man" versus the great chain of being. In chapter IV she demonstrates seven reasons why historians of science infer that Darwin initially interpreted his Galapagos finch data as a creationist when he collected them. But by the time he reexamined his data in 1837, his explanations could "give coherence to the diverse findings of taxonomy, paleontology, geology, embryology, natural history, comparative anatomy, and physiology" and better withstand anomalies.

Similarly, on the "one crucial question of this book," Picart is able to embrace parts of the Darwinian revolution in science as having both elements of "a sudden, non-cumulative, and unstructured event, analogous to a conversion experience [and] a gradual, cumulative, and structured phenomenon." Thus, she shares with Asma the critique of oversimplification:

> If we were to draw attention to the insights of evolutionary biologists like Buffon, Erasmus Darwin, Lamarck, Etienne Geoffrey St. Hilaire, and Charles Lyell, we would begin to doubt the noncumulative or abrupt character of the Darwinian shift. On the other hand, if we were to study the research tradition held by such thinkers as Linnaeus, Jussieu, Candolle, Cuvier, Owen, and Agassiz, we would see Darwin's presentation as a profound break from the established tradition of creationist–fixism. (Picart 1997, p. 157)

Although Picart's treatment of historical characters depends on dualist simplifications that would bother Asma, she paints a caricature well. Both Picart and Asma conclude their books with pleas that readers understand science more deeply in terms of its history and philosophy. Sadly, their advice is clearly not being heeded by most textbook writers.

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## NATURE FROM A DIFFERENT ANGLE

**Hungry Hollow: The Story of a Natural Place.** A. K. Dewdney. Copernicus, New York, 1998. 233 pp., illus. $26.00 (ISBN 0-387-98415-1 cloth).

Taking a different look at the biological world seems to be A. K. Dewdney's intent in *Hungry Hollow: The Story of a Natural Place*, an episodic tale that combines elements of fiction with nonfictional scientific information. According to the author, Hungry Hollow is a natural place that is representative of any natural area in the deciduous forest zone of eastern North America. Dewdney structures his story around the inhabitants of this area; they include everything from an atom, to a bacterium, to a raccoon, to a human being. In each chapter, the reader not only learns a great deal about the biology of these organisms, but also is brought down to their level via Dewdney's fictionalized account of their existence, for which he employs the techniques of anthropomorphism and fable.

Although the reader experiences a different look at nature through the eyes of several characters, it is the experience of "Dianne sapiens" that is most compelling and that reflects the theme of the book. Having lost her job teaching biology at a university, Dianne returns to her home, which is situated near Hungry Hollow, and begins to look at her world differently: "Although she does not realize it yet, her life has been opening up, and when she walks the Hollow, it is like a new world. She pays attention.... As she disengages her self-image from the world of academe, she reviews the ideas she once accepted without a thought and finds them wanting" (p. 19).

In using the term "wanting," Dianne conveys the inability of biological terminology to capture the aesthetic and almost spiritual side of living things and systems. In fact, Dianne's struggle reflects the age-old conflict between sight and blindness: those with sight are often the most blinded to the truth of what is occurring around them. Dewdney again expresses this theme through Dianne's thoughts as she stares into Hungry Creek: "She wants to see it as clearly as she sees the plants and insects around her. What microscopes have revealed they have also made abstract and unreal" (p. 49).

Dianne is eventually able to "see" other worlds by shrinking in a fashion similar to Alice in Wonderland. In chapter 7, Dewdney sets up the first 5 of his 10 worlds, each of which is one-tenth the size of the previous. World One is measured in decimeters, World Six in micrometers, and World Ten at the level of individual atoms. Dianne herself is able to "experience" five of these worlds, eventually ending up 17 micrometers tall, able to interact with bacteria.

Although this discussion is intriguing, Dewdney could have spent a bit more time in each of the worlds, using Dianne as a medium through which to translate and explore the life forms found there. Instead, he mentions these worlds only a few more times in the text, choosing rather to explore the biology of the organisms in the hollow. Although all of the organisms discussed in the chapters certainly fit into one of Dewdney's worlds, the connection is not explicitly made and expanded on as in chapter 7, which leads to my only complaint with the book—its lack of a central focal point. Certainly, the main characters, Dianne and Lotor the raccoon, provide some focus, but they do not appear in all of the chapters. Each chapter introduces the reader to a new organism and a new mini-plot, which gives the book a disjointed feel. The fact that all of these episodes occur in Hungry Hollow itself does provide some sort of unifying theme, but the detailed explanations and scientific information in each new episode often has the effect of obscuring a continuous narrative.

Despite this slight criticism, it is still fascinating for the reader to share in the experiences and thoughts of the numerous characters, including Rana the frog, Virginia the possum, and an unnamed snapping turtle. The animals, organisms, and plants in the book operate simultaneously at fictional, literal, and symbolic levels. Dewdney's main intent is to discuss the natural history and biology of the organisms that inhabit the fictional Hungry Hollow. However, the hollow and the living things within it also take on symbolic meaning. For instance, the fact that a snapping turtle's back literally supports a variety of organisms is described in great detail, but Dewdney is also interested in the turtle's symbolic role as a supporter of all life, a role also found in Native American creation stories (chapter 10). Similarly, the hackberry tree (chapters 4 and 5) is not just a literal tree, but the figurative "Tree of Life," whose branches "portray the relationships among living things" starting with the trunk, representing life, and extending into the five main branches, representing the five kingdoms.

However, although this symbolic and spiritualized look at living things seems celebratory, there is a sense that all is not well in Hungry Hollow. It seems to be a thriving place, but in fact, as a "microcosm of Earth," the hollow has problems that are typical of all ecosystems. The "Congress of the Birds" (chapter 6) hints at humans' role in environmental degradation. Anthropomorphizing the birds (as he does for several of the animal characters in the book), Dewdney uses them as a mouthpiece for his anger at the destruction of natural things. Humans are on trial at this congress, and the charges are "'genocide and the destruction of natural property,'" as made by the downy woodpecker whose habitat was destroyed by the development encroaching on Hungry Hollow. The red-tailed hawk, stuttering because chemicals have damaged his nervous system, also charges humans with genocide. The birds' caustic discussion of humanity concludes with a disturbing story of two boys killing a turtle out of spite. This congress is a good example of Dewdney's mission to prompt the reader to look at things in a different perspective, through someone or something else's eyes. For instance, one can't help but feel the rebuke in the mourning dove's speech:

> The air [in the city] smells like smoke and oil, there is great noise at all times, and the humans, because they have nothing real to do, are unhappy. They wish to avoid pain at all costs and so do not exert themselves over anything. Their knowledge declines with every generation, and their ignorance is rampant. They think they are free, but they are the greatest slaves that ever were. Pleasure is their master. They imagine that so long as the impulse originates in them, it expresses their freedom. What irony. What supreme irony! (p. 46)

Thinking that they are reading an entertaining story about a different place, how surprised readers will be when forced to examine that inner place of conscience, choice, and culpability! Like other natural areas on Earth, Hungry Hollow faces the threat of bulldozers and new housing developments. Luckily, however, it narrowly escapes this fate when Dianne discovers Native American remains, thus making it a protected natural place—for the time being.

Like the narrative itself, Hungry Hollow the place can be appreciated at multiple levels—literal, symbolic, spiritual, microscopic, and cosmic. Dewdney takes the reader right into the midst of it all, portraying living things and their interactions with numerous details. He urges the reader to cease taking these living things for granted or categorizing them as mere scientific facts—the real challenge is to step back from the microscope and appreciate nature from different, and often surprising, perspectives.

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