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Evolution for the Community Ecologist

The Geographic Mosaic of Coevolution. John N. Thompson. University of Chicago Press, Chicago, 2005. 400 pp. $28.00 (ISBN 0226797627 paper).

With the exception of consumer–prey interactions, the study of ecological communities has resisted efforts to integrate evolution into its theoretical foundations. John Thompson's *The Geographic Mosaic of Coevolution* takes a leap toward solving this problem and dramatically expands the evolutionary framework for other ecological subdisciplines. Thompson's latest contribution joins forces with rapidly expanding research (e.g., Stinchcombe and Rausher 2001, 2002) demonstrating that the magnitude or direction of natural selection on traits that mediate interactions between species is strongly affected by the presence of other community members.

Ecologists, and in particular community ecologists, should read this book. I make this recommendation from the perspective of an evolutionarily challenged community ecologist, one who found in Thompson's book exceptionally thought-provoking arguments and evidence for biotically driven evolutionary relationships among species, and for the importance of spatial and temporal conditionality of these relationships. Conditional interactions among species are a focal point in community ecology, and Thompson's articulate integration of ecological conditionality into community evolution made me rethink and reorganize my own perspectives on the natural world. Perhaps evolutionary sophisticates will be much more familiar with the arguments in *The Geographic Mosaic of Coevolution,* but for ecologists focused on the importance of species interactions to the conceptual issues of community theory, the book is a wealth of new ideas. Not only will pondering the geographic mosaic affect the way we think about evolution, it will affect the way we think about the processes that determine the distribution and abundance of species.

Exceptionally clear and well written, the arguments for the geographic mosaic of coevolution struck me as a babushka doll, the outer shell composed of repeated, relentless emphasis on the primary message: "Natural selection on interspecific interactions varies among populations partly because there are geographic differences in how fitness in one species depends on the distribution of genotypes in another species." (The repetition is effective: I got the message.)

The second layer is a well-organized outline of the basic conceptual components of the geographic mosaic theory, presented in two parts. In part 1, "The Framework of Coevolutionary Biology," chapter topics include raw materials for coevolution, local adaptation, and coevolutionary diversification. In part 2, "Specific Hypotheses on the Classes of Coevolutionary Dynamics," the main topics are antagonistic and mutualistic interactions and coevolutionary displacement.

The innermost layer is a comprehensive presentation of an amazing number of empirical examples for the framework and hypotheses. Thompson shows both breadth and depth in his choice of those examples, and his simple style of explanation makes the important concepts that they illustrate accessible to the nonspecialist.

Die-hard anticoevolutionists may be disappointed that Thompson mostly ignores old arguments about undeniable proof for coevolution and bases his epistemology on relationships among species that are difficult to explain in any way *but* coevolution. However, those who get past their disappointment will have the opportunity to contemplate novel ideas about evolution and ecology.

While the coevolutionary process Thompson details is fascinating and wonderful, the explicit theory for a geographical nature of any biotically driven evolution brings new excitement to community ecology. Conditionality in community interactions may actually mean something. Spatial conditionality in species interactions appears to almost always drive divergence in evolutionary trajectories, which may feed back to community organization in ways that this book makes clear. Moreover, evidence showing that evolutionary relationships among pairs of species can be altered by the presence of other species brings new light to the contentious subject of community evolution. Thompson implicitly recognizes that the value of the geographic mosaic goes beyond strict coevolution ("not all interactions are tightly coevolved"), and that greater knowledge of past, present, and future interdependence among species contributes to a better understanding of the processes that form communities.

As someone who is particularly interested in plants, I was curious about the paucity of examples involving interactions among plants. Thompson missed some important studies of plant interactions that vary in a geographically explicit manner (for example, the work of Roy Turkington and Lonnie Aarssen), others that have strong implications for evolved variation in plant interactions, and at least one theoretically relevant paper, but it is the dearth of extant relevant literature on the evolutionary nature of plant interactions that is especially intriguing. Even the simplest comparisons of competitive intensity among plant populations from different locations within their distributions would have been a major step toward understanding how plant interactions fit into the geographic mosaic concept. Integrating geographical mosaics into processes such as indirect competitive networks—see the discussion on page 329—would be profound. Clearly, exploring Thompson's

ideas within plant communities is a major opportunity for future research.

Although my particular interest in the geographic mosaic theory is in its relevance and importance to community ecology, Thompson's fundamental goal is to squarely identify the process of coevolution as a foundational biological principle. I think he succeeds. Old arguments against coevolution, based on the lack of irrefutable experimental proof of reciprocal evolutionary relationships—as if anything big in ecology or evolution were based on irrefutable proof—seem hollow in the light of carefully described evolutionary mosaics of crossbills and pine trees, parsnips and webworms, yucca moths and yuccas, toxic newts and resistant garter snakes, and hummingbirds and heliconias. New arguments for the importance of interspecific interactions, variation in their outcomes in different communities, and local adaptation of populations to each other are robust and compelling. Thompson's empirical examples and cogent arguments provide a new way to look at community ecology's past, but evidence that "reciprocal evolutionary change shapes interspecific interactions across continents and oceans and over time" points to its future.

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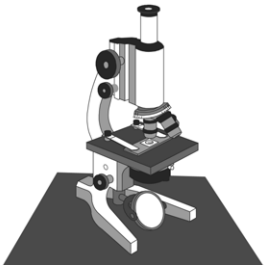

RETHINKING THE GENE

The Epistemology of Development, Evolution, and Genetics: Selected Essays. Richard M. Burian. Cambridge University Press, Cambridge, United Kingdom, 2005. 288 pp. $32.99 (ISBN 0521545285 paper).

Richard Burian, although not as well known as some more prolific philosophers (e.g., Elliott Sober, Phillip Kitcher, Michael Ruse), has been an important figure within the philosophy of biology for 25 years. Burian was awarded a doctorate in philosophy from the University of Pittsburgh in 1971 and currently teaches at Virginia Tech, with joint appointments in philosophy and in science and technology studies. After a transformative year at Harvard studying with Richard Lewontin and Stephen J. Gould, Burian began working in the philosophy of biology. *The Epistemology of Development, Evolution, and Genetics* will finally make his ideas available to a wider audience. This book is not light reading, but historians and philosophers of biology, as well as practicing biologists with interests in the history or philosophy of their discipline, will benefit from the breadth and depth of Burian's historical, philosophical, and biological insights.

The Epistemology of Development, Evolution, and Genetics contains an introduction and 11 other chapters (9 of which were previously published). Part 1, "Methodological Issues," consists of two chapters. The first addresses epistemological questions about the use of model organisms (e.g., What makes an organism a good model? What epistemic problems might arise from focusing on model species?), while the second argues that unification is an important methodological ideal guiding biological research. Part 2 has three essays on evolution, one of which suggests that a tightly integrated evolutionary biology is neither desirable nor possible, while another defends Dobzhansky's claim that "nothing in biology makes sense except in the light of evolution." Part 3, entitled "Genetics and Molecular Biology," contains three chapters about gene concepts, focusing particularly on philosophical questions about conceptual change. The third essay examines different ways of conceptualizing adaptation. Part 4 includes three chapters on development.

The concepts in part 3 merit elaboration. Burian outlines a distinctive realist explanation of how scientists maintain continuity of reference in the face of sometimes dramatic changes in the meaning of terms. According to Burian, historians and philosophers should distinguish two kinds of gene concepts. Research often begins with an imprecisely defined ("schematic") gene concept. In time, geneticists also develop "substantive" concepts that specify more fully what genes are. This framework allows us to understand the continuity of genetic research (via the schematic concepts) while recognizing the important discontinuities in the substantive concepts. In this way, Burian tries to defend a form of realism about genes and to answer Kuhn's worry that our successive theories about genes are incommensurable.

Although only a small sample of Burian's oeuvre, the essays in this volume provide a wonderful introduction to his work, revealing both the tremendous range and the philosophical, biological, and historical depth of his scholarship. Burian turns with ease from the history of genetics to thorny philosophical problems about conceptual change in genetics, to the subtle ways in which recent work in "evo–devo" may force a reexamination of the homology concept. Furthermore, although the essays were written over a span of 22 years (1983–2005), the collection is surprisingly well integrated. Indeed, one might view the essays as extended meditations on the two counterpoised themes of part 1, the role of model organisms and the goal of integration (unification). Thus, two main themes of the book are contextualism and the struggle to develop a unified understanding of biology in the face of the hierarchical complexity of the biological world.

Burian presupposes that the biological world is hierarchically structured. Important biological processes occur on different temporal, geographic, and tax-

onomic scales, which range from biochemical analysis of metabolic processes that occur in seconds within a single species to rebounds from mass extinctions that involve hundreds of species living on different continents over millions of years. Building from this assumption, Burian develops his two main themes.

The first, contextualism, is a consequence of contingency and historicity. Because biological systems are the products of complex and contingent histories, the results obtained by working with one model system may not be generalizable to other biological systems. This perspective leads Burian to defend the contextualist claim that reliable inferences in biology generally—always?—require understanding of the details of biological systems, details that typically have been constructed through contingent historical processes. Contextualism, as a principle of the epistemology of biology, has encouraged disciplinary pluralism. Because biological systems are so complex and multifaceted—and exist at so many distinct temporal and geographic scales—biologists have had to develop a variety of concepts, theories, and methods to study them.

This pluralism then raises questions about the need for unification, the second main theme of the book. Burian's general methodological ethos is to allow pluralism and healthy disagreement, concede the real difficulty of achieving synthesis, and yet acknowledge that (in the long run) it is epistemically important to ensure that our various theories are at least compatible, if not tightly integrated. Let's see how these themes weave throughout the book.

Burian's contextualism holds that biological systems must be understood in detail and in context. For example, he claims that "the contingency of evolutionary processes must be considered.... Proper evaluation of the knowledge gained by working with a given organism or group of organisms requires that knowledge to be set into a comparative and evolutionary framework" (p. 24). Given the contingency of biological systems, we can generalize from a model organism to other systems only with great care. Biological contextualism also shapes his vision of the relationships among the fields of biology. In Burian's view, the "so-called synthetic theory is better viewed as a treaty than as a theory" (p. 89). Rather than providing a fully worked-out paradigm (in Kuhn's sense of a disciplinary matrix), the synthesis is a loose structure that houses many competing theories—theories that have been developed to solve problems that arise when studying particular model organisms or specific levels in the biological hierarchy.

The second main theme of the book concerns the persistent tensions between the various subdisciplines of biology—particularly the vexed relations among evolutionary biology, developmental biology, and genetics during the 20th century. Burian focuses on a number of specific "hotspots": (1) the tension between Mendelian genetics and evolutionary biology that was ultimately resolved by the "modern synthesis"; (2) the tension between embryology and genetics during the first half of the 20th century; and (3) current attempts to develop a more integrated account of evolutionary developmental genetics. The tension between embryology and genetics centered on a familiar critique of Mendelian genetics (what Burian calls "Lillie's paradox"): Genetics, viewed as the study of chromosomal inheritance, cannot explain the differentiation of cells in development. Because all cells have exactly the same set of chromosomes, it

must be the cytoplasm that controls differentiation and development. In the last three chapters, Burian traces these tensions from their early-20th-century formulations up to recent developmental genetics.

According to Burian, interfield conflicts often lead to important theoretical insights. For example, he suggests that the ongoing attempt to develop an "evolutionary developmental genetics" that integrates (or provides a treaty among?) evolutionary biology, developmental biology, and genetics will require rethinking the homology concept. Drawing on recent findings on homeobox genes, Burian argues that the concept of homology is more complex than previously thought. Developmental genetics has revealed that many regulatory genes are strongly conserved, so that disparate organisms have similar genetic resources. Burian describes evolution as a process of tinkering with these genetic and developmental resources: Often, the regulatory genes are duplicated and subsequently co-opted to control a new function. As a result, homologous gene sequences can be used to build nonhomologous phenotypic structures.

Burian takes this idea a step further to make the more controversial claim that homologous segments in insects can be formed by nonhomologous developmental processes. If this is correct, it further complicates the problem of identifying homologous characters for phylogenetic analysis.

One important aspect of the book that doesn't fall neatly into either theme concerns the idea of a "genetic program." Some researchers (e.g., Gehring) have suggested that homeobox genes are "master control genes." On the basis of a beautiful summary of posttranscriptional processing and alternative splicing, Burian argues against the idea of a genetic program: "Genes alone do not provide a blueprint for the organism" (p. 243). Although he clearly values the insights of molecular biology (and, therefore, a broadly reductionistic style of research), Burian is critical of some forms of reductionism. He does not believe that the disciplines that study smaller parts can, or should, displace fields that study wholes. Indeed, Burian thinks that findings from molecular biology are pushing biology toward a form of holism

The account of biology that Burian develops in this volume is subtle rather than flashy. The extensive footnotes in some chapters make it clear that this book is not popular history or philosophy. But for those who are willing to invest some time, the rewards of this volume are considerable: Burian presents a nuanced account of a number of important developments in 20th-century biology. Although his contextualism leads him to focus on particular moments in the history of biology rather than present a sweeping narrative, these local stories do point toward a cohesive account of the nature of biological knowledge.

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HOW ECOLOGY CAME TO BE

The Evolution of American Ecology, 1890–2000. Sharon E. Kingsland. Johns Hopkins University Press, Baltimore, 2005. 328 pp., illus. $50.00 (ISBN 0081881714 cloth).

Sharon Kingsland, a professor of the history of science at Johns Hopkins, traces the development of North American ecology from its roots in natural history and systematics to its new focus on the role of humans on our crowded planet. She shows how the opportunity to watch the opening of a new continent influenced American ecologists, who focused their attention in the early 1900s on concepts like succession and disturbance, while their European counterparts, who never had the opportunity to see their continent in pristine condition, preferred to explore far-off lands.

Plant biology dominates Kingsland's treatment of the history of ecology. She begins the tale at the New York Botanical Garden, where the politics of priority in naming new plants energized early field systematists, who were keen to compete against the old schools in Europe and Asa Gray's dominance at Harvard. She dedicates nearly an entire chapter to Nathaniel Lord Britton, director of the Botanical Garden from 1896 to 1929 and long-time competitor of Asa Gray.

Of course, ecology has had a long association with systematics, and it depends upon good taxonomy to tell us what things are. Despite Britton's urge to collect more specimens and name more species than his contemporaries, his most important role may have been in helping to establish the Desert Laboratory on Tumamoc Hill in Tucson, where Daniel MacDougal, Forest Shreve, Frederic Clements, and others were so effective in honing their thoughts on ecology in the early 1900s. They established long-term research plots, which are still monitored today, against the background noise of Tucson's suburban sprawl.

Kingsland devotes much attention to the changing views of the role of humans in nature. Throughout the book, she establishes *Man and Nature,* written by George Perkins Marsh and published in 1864, as a benchmark against which to measure the views of all who have followed. For instance, she argues that Frederic Clements sought an understanding of nature so as to empower humans to control it. The early systems ecologists, working with brothers Gene and Tom Odum, built the concept of the ecosystem, focusing on energy flow and nutrient cycling so as to include humans and human-dominated systems, complete with their flows of money and information. Ecosystem science now permeates much of how we view ecology and how we study it. Unlike Marsh and Clements, most ecologists are now certain that *Homo sapiens* is not above and apart from nature. We must devise new ways for a sustainable existence with a functional biosphere if we are to survive happily on Earth.

Clements also struggled to find an organizing principle for ecology, so that it could progress by experimental approaches and avoid sinking into a set of disconnected studies of natural history. In short, ecology had to outgrow its de-

scriptive phase and embrace experiments with strong inference, which allowed rapid progress in physics and biochemistry at the end of World War II. Beginning in the 1950s, experimental field studies proliferated, among them seminal work by Katherine Keever to elucidate plant succession in North Carolina, and by Robert Paine to do the same in the intertidal zone along the coast of Washington.

By beginning her coverage in 1890, Kingsland misses the influence of early explorers and naturalists—Lewis and Clark, Thoreau, and Audubon—on the development of ecological thought in the United States. Indeed, I was struck by the absence of much discussion of animal ecology and animal systematics throughout the book. Surely the influence of ornithologists such as Joseph Grinnell (1877–1939) and S. Charles Kendeigh (1904–1986) rivaled that of their botanical counterparts in the early 1900s. The Princeton School, led by Robert MacArthur, gets only a half page of coverage, despite its overwhelming influence on population and community ecology during the 1960s and 1970s. How many pages of our journals have been devoted to explanations of the patterns of species diversity and what controls it, by first- and second-generation students of MacArthur? Similarly, there is no reference to Aldo Leopold, whose early book *Game Management* (1933) and later writings in *The Sand County Almanac* (1949) have influenced so many ecologists now seeking to find a proper role for humans in nature.

I would also be curious to read what Kingsland thought of why ecologists abandoned worries about human population growth. Early population ecologists Edward Deevey (1914–1988) and Lamont Cole (1916–1978) clearly outlined the consequences of exponential population growth in a closed environment. Paul Ehrlich popularized this thinking in his seminal book *The Population Bomb* (Ballantine, 1968), only to see the problems of human population growth disenfranchised as part of the environmental movement during the 1980s.

Despite these omissions, Kingsland does a masterful job weaving together the history of ecology in the United States, providing a detailed look at how ecologists have grappled with the basic question of the role of humans in nature. Kingsland, who lives within the urban LTER (Long Term Ecological Research) site in Baltimore, ends her book with the hope that studies of urban ecosystems will give us a new and better view of human ecology. Kingsland believes we can find the proper role of humans in the biosphere by understanding the connection between the products of ecosystems that are delivered to our door each day and the proper preservation and management of nature beyond the city boundary.

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THE GREENING OF ACCOUNTING

National Environmental Accounting: Bridging the Gap between Ecology and Economy. Joy E. Hecht. RFF Press, Washington, DC, 2005. 240 pp., illus. $60.00 (ISBN 1891853937 cloth).

Academics and the general public have long recognized the shortcomings of the gross domestic product (GDP) as a measure of a country's well-being. GDP's exclusive focus on goods and services bought and sold through market transactions has resulted in an aggregate measure of economic activity that can be faulted on several levels (Revkin 2005), with many critics noting its failure to account for natural resource depletion, nonmarket amenity values, and the social costs of pollution. These critics have also questioned the treatment of defensive expenditures designed to offset environmental degradation as increments to GDP. Such limitations have resulted in an unusual coalition of environmentalists, ecologists, economists, and accountants who advocate "green" accounts, or modifications to traditional national income accounting procedures that address the aforementioned shortcomings. Although these diverse groups agree that current procedures are deeply flawed, they disagree—sometimes stridently—on how to reform them. The result is a vibrant, but often confusing, literature on green accounts that is limited to a small community of academics and government accountants.

Joy Hecht's *National Environmental Accounting* attempts to ameliorate this confusion and bring a much larger audience into the discussion. On the basis of her extensive field experience working on the environmental dimensions of national income accounting throughout the world, she assembles an integrated assessment of how government statistical agencies can incorporate different aspects of the environment into national accounts. Her focus is almost exclusively on national environmental accounting procedures that either have been previously adopted or are proposed in the UN Statistical Commission's 2003 revised system of economic and environmental accounts. Relative to other reform proposals, these approaches are best described as incremental, in that they preserve the traditional national income accounting structure and incorporate the environment largely through separate satellite accounts that measure natural resource depletion and pollution-induced environmental degradation in either physical or monetary units.

National Environmental Accounting has two major strengths. First, Hecht focuses on what has been done—and on what can be done, short of a radical reorientation—within the existing national income accounting framework to incorporate the environment. Although her opening and final chapters describe the plethora of proposed alternative ecological and economic approaches to integrating the environment into national income accounts, she does not digress into a lengthy description and comparative study. Instead she focuses on the incremental changes that are being

adopted by national income accountants and on their relative strengths and weaknesses. The choice here of depth over breadth is shrewd—it allows her to meticulously explain current approaches to amending the existing national income accounting framework to better incorporate the environment and use specific country case studies as illustrations.

The book's other major strength is the breadth of the audience for which it is written. By no means is this book intended for only academics and government accountants with extensive experience in the area. On the contrary, a careful study of Hecht's book will give readers with just a rudimentary understanding of accounting, economics, and ecology a sense of existing practice and the major issues in national environmental accounting. Indeed, the book reads like an introductory textbook on the topic, minus the end-of-chapter review questions and problem sets.

My sense is that some readers will take away from *National Environmental Accounting* a general dissatisfaction with the incremental approaches to creating green accounts that Hecht seems to at least implicitly favor. Environmentalists and ecologists, for example, might find it disconcerting that the lion's share of the adjustments involve natural resource depletion and not ecological services. Economists, by contrast, might be disappointed by the absence of a unifying framework that distills the accounts down to a single monetary measure. Underlying both of these critiques is the belief that national accounts should measure human welfare, not income or production. But to professional accountants who dominate the government statistical agencies that construct these aggregate measures, a summary statistic of human welfare is too vague and subjective to be a meaningful objective for an index published by the government.

I generally concur with this assessment out of a belief that politicians will manipulate subjectivity in government statistics for their personal gain or for that of their party. However, I am by no means suggesting that experimental human welfare indices such as genuine savings, and the genuine progress indicators that several academics and policy analysts have proposed (Harris and Fraser 2002), are not valuable complements to government statistics employing the national environmental accounting procedures that Hecht describes. Such academic research is absolutely essential for green accounts to mature. Rather, there should be a clear delineation of responsibilities, with government statistical agencies publishing the more incremental statistics that build on existing accounting procedures, and academics and policy analysts publishing the more subjective (and politically controversial) statistics that aim to measure human welfare.

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BRED IN THE BONE: BONE MICROSTRUCTURE BRINGS DINOSAURS TO LIFE

The Microstructure of Dinosaur Bone: Deciphering Biology with Fine-scale Techniques. Anusuya Chinsamy-Turan. Johns Hopkins University Press, Baltimore, 2005. 195 pp., illus. $85.00 (ISBN 080188120X cloth).

One hundred years ago, Adolf Seitz began the microscopic study of dinosaur bone. Thirty years ago, Armand de Ricqlès posited that bone microstructure was a clear indicator of the thermal biology and physiology of dinosaurs. He added fuel to the fire of the debate over hot-blooded versus cold-blooded dinosaurs by concluding that the histological characteristics of dinosaur bone indicated high rates of metabolism, high rates of sustained growth, intensive bone–body fluid exchange, and endothermy.

Data available now, however, indicate that this is an overly simplistic view. Anusuya Chinsamy-Turan, a professor of zoology and a fellow of the University of Cape Town, South Africa, presents recent findings on the histology of dinosaur bone, and assesses what bone microstructure can and cannot explain about the biology of dinosaurs and Mesozoic birds. In this well-written, well-edited volume, she concludes that bone microstructure does indicate how bone formed during growth, and it does provide information on how factors such as seasonality, ontogenetic age, and lifestyle adaptations affected its growth, but she also finds that speculations about physiology based on bone histology are just that: speculations.

Chinsamy-Turan's analysis of the relationship between fibrolamellar bone and high vascularity brings together a vast array of data from many reptilian taxa, both extant and extinct. The author shows that fibrolamellar bone is not restricted to nonavian dinosaurs, mammals, and birds, but is widespread among the Reptilia and among animals that have long been considered ectotherms, such as Permian dicynodonts and gorgonopsians (nonmammalian synapsids). The correlation between fibrolamellar bone and high metabolism is not supported by the data. She does the same careful review of the data on Haversian bone, zonal bone, growth rings in basal birds, growth plates of dinosaurs, dinosaur lungs and ventilation, nasal turbinates, and oxygen isotopes, and concludes that although the data do not support proposals that dinosaurs were endothermic, they do indicate that dinosaurs were active and dynamic animals in the Mesozoic world.

Chinsamy-Turan has done the scientific community a great service by pulling together the wealth of information about dinosaur bone microstructure, and interpreting that information clearly and logically. Starting with a clear explanation of the organization of bone tissue on a

microstructural level and the changes in bone composition during fossilization, she moves on to a helpful overview of dinosaur phylogeny and an insightful explanation of modern approaches to the study of dinosaur bones. Detailed descriptions of bone biology and beautiful color plates of dinosaur bone histology make dinosaur osteology accessible to any biologist who is fascinated with the biology of dinosaurs, as well as to both professors and graduate students working in this field. This portion of the book will be especially useful to anyone preparing a lecture on dinosaur biology for a class in general biology, vertebrate zoology, or herpetology. The book does contain a few errors in biochemistry, such as the confusion of DNA and proteins (p. 18) and uncertainty about the use of polymerase chain reaction (p. 39), but these do not detract from the overall excellence of the book.

There is a wealth of information about the biology of all vertebrates hidden in the bones of living and extinct animals. The classical approach of histology is often overlooked in today's modern molecular biology laboratories, but *The Microstructure of Dinosaur Bone* makes clear that this approach is a vibrant and essential tool in developing a good understanding of the evolution of animals with backbones. What is needed now are more studies of extant animals so that researchers can better understand how the relationships between the ecology, physical environment, and physiology of vertebrates such as reptiles are reflected in the histology of their bones. There may be much more variation in bone physiological processes—the remodeling of bone structure and the formation of growth rings, fibrolamellar bone, and Haversian bone, among others—than researchers have discovered to date. Detailed studies of the bones of reptiles across their ranges could provide fascinating insights into how this tissue grows in response to differences in the physical and biotic environments.

Following her detailed treatment of dinosaur bone biology, Chinsamy-Turan delights the reader with a treatise on how dinosaurs grew and the biology of early birds. The final chapter on dinosaur physiology evidences an enthusiasm for the subject that is contagious. This chapter, like many other parts of the book, can be readily understood by that high school student whose excitement over dinosaurs takes her to the museum to look at skeletons. *The Microstructure of Dinosaur Bone* will help make the rest of high school life bearable while this future paleontologist looks forward to unearthing her own fossils.

Chinsamy-Turan's accessible, engaging book contains enough personal reflections and professional opinions to keep readers enthralled. It brings dinosaur biology to life and puts a face on the normally mundane world of bone histology. The clarity of *The Microstructure of Dinosaur Bone,* and the obvious enthusiasm with which it was written, ensure that it will widely read by those interested in paleontology, whatever their level of learning.

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MEANINGS OF LANGUAGE

The Language of Life: How Cells Communicate in Health and Disease. Debra Niehoff. Joseph Henry Press, Washington, DC, 2005. 309 pp., illus. $27.95 (ISBN 0309089891 cloth).

The purpose of *The Language of Life* is to summarize knowledge and present the most recent findings on cellular signaling mechanisms at the cellular and organ levels. Clearly, Debra Niehoff has read a great deal and talked to scientists who work on the subjects she covers, and her qualifications for writing about cellular communication would seem impressive: She trained as a neurobiologist at the Johns Hopkins University School of Medicine, and worked as a research scientist in both academic and industrial settings. Niehoff has also written several publications about the life sciences. However, she didn't perform any of the research she describes.

The Language of Life covers a vast amount of material. A brief description of the chapter topics alone conveys the book's wide scope.

The first chapter, about chemotaxis, starts with an account of the reactions involved in the movement of the *E. coli* flagellum, and details how it changes direction in the presence of a toxic stimulus or, alternatively, goes straight ahead toward a source of food. Three-dimensional drawings, here and throughout the book, nicely complement the text. (Also helpful throughout the book is the thorough index, which includes textbooks and other research literature on the topics Neihoff describes, up to 2002.)

Chapter 2 gives an account of the discovery of hormones. Niehoff explains how a signal such as adrenaline becomes bound to its receptor, ß-adrenergic receptor, which is a most complicated process that was unraveled by a number of scientists who were eventually able to combine their different findings to make a coherent story.

Chapter 3 moves to embryology, where the reader is introduced to the three requirements of a developing embryo: (1) a sense of direction, or polarity, illustrated by the fruit fly embryo; (2) the separation of inside from outside, with the hydra embryo and the frog egg as an example of a metazoan; and (3) compartmentalization, wherein compartments subdivide again and again in processes controlled by "hedgehog," a signaling protein, and other complementary signalers. Readers also learn about gene expression in different locations—how genes controlling eye formation, for example, are switched on in the right place and at the right time—and about the development of the nervous system and how a cell may, or may not, develop into a neuron.

Chapter 4 covers homeostasis in health and in disease. Again readers encounter the hedgehog signaling protein: Lambs feeding on the corn lily are born with a single monstrous eye because a toxin in the plant interferes with the cells' ability to respond to hedgehog, which is suppressed. The same chapter includes a description of the genetic basis of cancer, diabetes, and obesity, all examples of diseases in which the body's homeostatic mechanisms have gone wrong.

Chapter 5 tackles the nervous system, beginning with Ramón y Cajal and his histological studies of the brain and moving on to the transmission of messages across synapses and an explanation of how a growing axon meets its target sense organ. This chapter contains a fascinating account of the neurobiology of learning and memory both in *Aplysia* and in the mammalian brain. Even in the former there is short-term and long-term memory; in mammals, the major memory organ appears to be the hippocampus, with another body, the amygdala, situated on top and acting to associate emotions with the memory tracks from the hippocampus.

Also of note in this chapter is an account of the immune system, which turns out to comprise three systems: One is innate, one adaptive, and the third dependent on dendrites (cells with a number of outgrowths). Adaptive immunity is dependent on lymphocytes covered with antigen receptors possessing the ability to distinguish between millions of bacterial and viral features. Dendrites and T-lymphocytes communicate through an "immunological synapse" comparable in important ways with the neural synapse, which may be the rationale for including the nervous and immunological systems in the same chapter.

The concluding chapter is an account of an annual meeting of the Alliance for Cellular Signaling, "a consortium of investigators with a common interest in the language of life."

Interwoven with this copious material are anecdotes from Niehoff's family life. Jenny and Haley, her teenage daughters, are apparently quite a handful to manage. I was trying to learn about cell signaling, however, and I found the family lore distracting. Eventually, when her daughters' witticisms or comments on their appetite for Pop-Tarts interrupted rather dense scientific arguments, well loaded with acronyms, I became fully exasperated. Nonetheless, Niehoff uses two examples from her life to good effect. In the first, she describes the physiological results of a near car crash she suffered, which is entirely relevant to an explanation of the homeostatic mechanisms the body uses to overcome shock. The second useful example deals with the terrifying experience of riding a runaway horse, and explains why she was unable to overcome her fear: Unpleasant memories are hard to eliminate. On the whole, though, the personal anecdote as literary device fails to captivate.

Unfortunately, Niehoff does not appear to understand the properties of metaphors, the other device she employs throughout the book. She equates cell signaling with a language, and in the widest sense, perhaps it is. But it is not a language in the sense that English and French are languages. Language is simply a metaphor in this case, one that she stretches too far, claiming to find equivalents for words and sentences among the chains of chemical reactions. The two major features of human language are its syntax, and the fact that young children can use the rules of syntax to create new sentences, without having been specifically taught those rules. Woe to the biologist who uses the rules of biology to create new facts!

According to Niehoff, cells inform, wheedle, exhort, reassure, nurture, criticize, and instruct. Elsewhere, platelets shout "You there!" at fibroblasts (p. 144); cells "coo" and "bellow." I find such expressions merely distracting, not elucidative. What am I to infer from them?

Architecture is the other metaphor Niehoff uses for cell design and structure, with more success. This analogy works better than the one with language because both cells and buildings have to deal with the effects of mass and force.

Students preparing for their doctoral exams will find the book useful for its breadth of coverage. The layman interested in cell signaling is advised to persevere. Harassed women scientists with unruly teenage daughters may well sympathize with the author, who, I think, should decide whether she intends to write novels or write about science and medicine.

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SOILS CONSIDERED HOLISTICALLY

Fundamentals of Soil Ecology. 2nd ed. David C. Coleman, D. A. Crossley Jr., and Paul F. Hendrix. Elsevier, London, 2004. 408 pp. $49.95 (ISBN 9264105549 paper).

Throughout history, little has mattered more to humans than their relations with soil. Indeed, the fertility of soil has provided the basis for many ancient civilizations, whereas its abuse through inappropriate farming methods has led to the decline of others. Given the importance of soil to humans, it is surprising that so little is known about its ecology, relative to what is known about aboveground communities. This, however, is changing. The last decade has seen an explosion of interest in soils and their ecology, driven largely by curiosity about the vast diversity of organisms that live in soil and by a growing recognition among terrestrial ecologists of the importance of soil and its inhabitants to ecosystem structure and function. The authors of this book have, for many years, been at the forefront of the discipline of soil ecology. Indeed, their collective work has

contributed significantly to the understanding of the underground world and has helped fuel the growing interest in this field of exploration.

Against this background comes the second edition of *Fundamentals of Soil Ecology,* a revised version of the already successful first edition, which has been widely adopted as the basic textbook in this area. The new book, however, reflects the rapid development of the subject over the intervening eight years, especially in relation to a growing understanding of the biological function of microbes and the importance of food web interactions and species diversity in soil. The new edition also reflects recent technological developments in soil ecology that have revealed new reservoirs of diversity and helped deepen our understanding of soil.

The book has nine chapters. Chapter 1 provides a brief historical perspective of soil ecology and describes the physical nature of the soil habitat. This chapter is important because understanding the community structure and activity of soil biota first requires an appreciation of the nature of the soil matrix in which they live. The three chapters that follow introduce the main players in the soil food web. These chapters take the reader on a journey from the primary producers, which fuel the soil food web, to the microbes and fauna that depend on them. The text is richly illustrated and effectively blends information on the biology of individual groups of organisms with an understanding of the factors that control their distribution. Methods for studying primary producers and components of the soil biota are discussed as well.

Chapters 5 and 6 examine soil food web interactions and their significance for the generalized ecosystem processes of decomposition and nutrient cycling. Within these two chapters is one of the more important messages of the book: Researchers need to take a holistic perspective to understand the roles of soil biota in driving ecosystem processes because, as the authors emphasize, decomposition and nutrient cycling are expressions of the activities of the entire soil fauna and its interactions with microbes. The importance of this point cannot be stressed enough.

New to the second edition is chapter 7, "Soil Biodiversity and Linkages to Soil Processes," which reflects the rapid development of this area of investigation in recent years. In this chapter the authors not only provide new insights into the diversity of soil communities but also critically review recent studies that have explored links between soil biological diversity and ecosystem properties. The authors also explore the problems ecologists face when trying to interpret data from these difficult studies. Chapter 8 considers future developments in soil ecology, focusing mainly on soil carbon dynamics and global change, and the final chapter provides guidelines for those interested in pursuing practical, hands-on studies in soil ecology.

This book provides an excellent introduction to the field of soil ecology and is essential reading for any student or researcher with interest in the belowground world and the functioning of terrestrial ecosystems. Indeed, it has all the traits of an excellent textbook: It is well written, richly illustrated, informative, thought provoking, and well supported by a comprehensive and up-to-date literature base. What is unique about the book, in my view, is that it takes a truly holistic perspective to the study of soil ecology, highlighting the importance of the food web approach—emphasizing the central role of trophic interactions—and the role of soil as the organizing center for terrestrial ecosystems. The lead author and his coworkers are pioneers of this approach to soil ecology, and this book exemplifies their contribution to this field. I recommend this book strongly.

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NEW TITLES

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