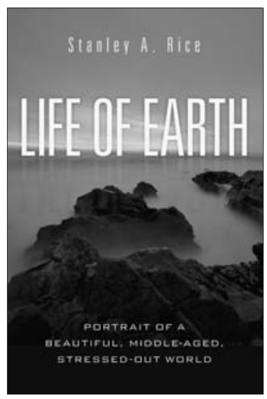
Earth in Perspective

Life of Earth: Portrait of a Beautiful, Middle-aged, Stressed-out World. Stanley A. Rice. Prometheus Books, 2011. 255 pp., illus. $28.00 (ISBN 9781616142254 cloth).

Biologist Stanley A. Rice, author of *The Encyclopedia of Evolution* and *Green Planet: How Plants Keep the Earth Alive*, gives readers a rudimentary sketch of the present state of life on Earth with his latest title, *Life of Earth: Portrait of a Beautiful, Middle-Aged, Stressed-Out World*. In his depictions, Earth appears at turns fascinating, thorny, obstreperous, and sympathetic, but Rice's characterization of the planet as a whole serves an explicit agenda: to present his subject as an environmental victim.

Over the past decade, the most popular overviews of life on Earth have appeared as screen documentaries such as Disney's *Earth* (2007) and the British Broadcasting Company's *Planet Earth* (2006) and *Life* (2009). In contrast, Rice's overview is broader in scope. *Life of Earth* opens immodestly with an account of the origin of the universe, describing the origins of the geological and atmospheric circumstances in which it was possible for both photosynthesis and respiration to emerge. This story leads to a presentation of how evolution produced organisms with adaptations like altruism and religiosity. Rice uses this history to contextualize the current state of life, which he presents as being deeply threatened by human activity and political policy. His portrait of the planet fuels the cause of environmentalism, and what heft his conclusion has depends on reader's opinion of the book's epic, panoramic narrative.

Life of Earth assumes a broad perspective, with particular details of biology presented at a basic level. The science does not become much more complicated than this: "When one DNA molecule becomes two, the new strands are almost identical to the old ones," Rice tells us. "Almost. Occasional mistakes occur during the copying process. These mistakes are called *mutations*" (p. 47). Clearly, the book is pitched to attract readers who have forgotten high school biology. Short segments of text, lasting no more than a few pages, are packed with intriguing facts written in the second person: "When animals began to live on land, they had to bring the ocean with them.



To this day, the balance of salts in your cells is reminiscent of the saltiness of the ocean" (p. 83). Rice's natural-history observations are mixed with anecdotes about pop culture and the author's family. *Life of Earth* is not an academic book and is not particularly aimed at students, but it might be popular with those with no science background who want to be drawn in but not challenged by science. Rice aims to educate that audience with a heavy dose of light entertainment: "Dogs do this also. It's a wild and crazy time when the bitch is in heat" (p. 131), and "Back in the Stone Age, fat women were hot" (p. 123).

But a danger arises from this simple, jocular presentation of science: Ideas are occasionally simplified so much that they become misleading or confusing. For example, Rice defines evolution as natural selection (on p. 48): "The result is that the superior cells or organisms become more common than the inferior ones. This is natural selection: nature selects the superior mutations. That is what evolution is. That is all evolution is." The author should have clarified that superiority of alleles is not absolute, but relative to context, and that processes other than natural selection play a role in evolution. I would not fault a reader for being confused eight pages later when reading that natural selection is a stabilizing force—"the kind of selection that prevents evolution from occurring" (p. 56). I imagine the reader wondering, "How could evolution, being selection, prevent itself?"

Covering a lot of biology quickly, Rice also asserts scientific positions that are not universally agreed on. He embraces the view of human thought popularized by Richard Dawkins, Daniel Dennett, and evolutionary psychology in general. Although that is no fault, the sort of reader first learning how evolution works will not have the perspective to distinguish whether Rice is presenting scientific consensus or merely advancing an angle: "Literature is memes… Science is memes… Everywhere you look there are memes, memes, and more memes, all of them evolving," he writes, as though memes were a universally accepted part of standard biology (p. 70).

A tension between consensus science and individual perspective is most notable with the author's treatment of Gaia—Rice's framing device for the book itself. In his depiction, it is a female being who is stressed out by human beings. Gaia is an idea that "many scientists" share, Rice asserts. Following the approach of Lynn Margulis, to whom the book is dedicated, Rice treats Gaia as analogous to a person, while emphasizing that she is not a person. Like a person, she regulates

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not only herself but also her environment, within limits. She is depicted as having had an infancy and as expecting an old age—one that may not include us. We human beings depend on her; we are Gaia's children and also a part of her.

I suspect that some readers who are encountering the concept of Gaia for the first time will be drawn to how it frames a relationship between humans and a motherly nature. For those who find the Gaia imagery appealing, this book may be persuasive, but it will not suit everyone's taste. The Gaia concept aptly serves Rice's purpose for writing *Life of Earth*, however, by presenting the history of Earth on a human scale. Rice helps us to care for Earth's systems of photosynthesis and respiration and temperature regulation by treating them as analogous to human bodily functions. Yet Gaia's value lies in accomplishing what people cannot seem to do naturally: establishing and maintaining the conditions of life for our species and every other one. This is wondrous and also superhuman. But is it more impressive when anthropomorphized?

Although it is not a book for biologists or for classroom use, *Life of Earth* can be persuasive in its message. In helping readers comprehend the history of life on Earth, it reveals the indispensability of Earth's living systems, and through the central figure of Gaia, encourages us to care about them.

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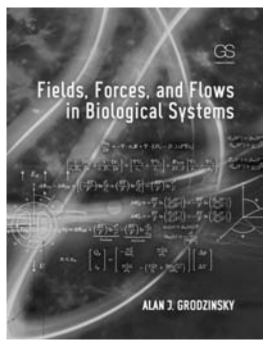
ELECTROMECHANICS FOR THE TWENTY-FIRST CENTURY

Fields, Forces, and Flows in Biological Systems. Alan J. Grodzinsky. Garland Science, 2011. 308 pp., illus. $120.00 (ISBN 9780815342120 cloth).

> "If people do not believe that mathematics is simple, it is only because they do not realize how complicated life is."
>
> John Louis von Neumann

In 1974, Alan Grodzinsky wrote his doctoral thesis at the Massachusetts Institute of Technology (MIT) on membrane electromechanics at a time when computers were scarce and interest in biophysics was just starting to explode. In the following decades, biology saw the invention of fantastic new tools like magnetic resonance imaging, the scanning tunneling microscope, and the atomic force microscope, made possible by



the application of physics to biology. Today, mathematical methods for studying biology are more important than ever. *Fields, Forces, and Flows in Biological Systems*, Grodzinsky's well-illustrated mathematical primer on bioengineering, will stand as a guide for the next generation of electrical engineers interested in biology.

Grodzinsky is well qualified to write a textbook on the principles of bioengineering. He directs the MIT Center for Bioengineering and teaches in the three departments that together span the intended breadth of this book—mechanical, electrical, and biological engineering. Through his research, he has made contributions to cartilage-tissue engineering—particularly its mechanical, chemical, and electrical properties, which have helped researchers to understand and cure bone diseases such as osteoarthritis. Moreover, Grodzinsky is a member of the first generation of scientists and engineers, which includes Leroy Hood and Robert Nerem, to work in the area of bioengineering. His presence during the development of bioengineering into its own discipline gives Grodzinsky a historical perspective, which is evident in the text.

Electromechanics, which is the subject of this book, is composed of the interplay between three subjects—electromagnetism, electrical engineering, and mechanics. The primary contribution of the book is the unified presentation of all the laws of electromechanics within the context of bioengineering systems. Professors and graduate students previously had to gather this material from lecture notes or from articles in *Biophysical Journal* or *Journal of Biophysics*. This book provides all this information in a single place.

In *Fields, Forces, and Flows*, successive chapters present the governing laws of magnetism, electricity, and fluid flow, with numerous examples and a few end-of-chapter problems added to demonstrate their application in biological systems. The author approaches each topic from the perspective of an electrical engineer, starting from first principles, introducing the balance of forces and conservation of energy and momentum, and then proceeding to derive the governing equations. The most important governing equations are derived from scratch, including those of Maxwell and Navier-Stokes, which are presented in the form of vectorial differential equations. Next, he presents the rare analytical solutions to these equations, with initial and boundary conditions given in the context of previously solved bioengineering problems. One oversight is the neglect of computational approaches. However, the most important part of the problem-solving process—a discussion of the physical interpretation of the mathematical solution—is usually given.

Fields, Forces, and Flows is a wonderfully thin stand-alone reference. The author's concise prose allows him to

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fit this body of work into a volume only a half-inch thick—far slimmer than most biology textbooks. Its small size and completeness make it best suited as a desk reference or as a set of lecture notes for highly mathematically trained graduate-level students in a bioengineering class. Its style is a mixture of formal and informal, in the manner of the most-effective engineering teachers. The derivations and proofs are quite formal, as they should be, but in the examples given, the author inserts numerous caveats. At times, one can almost hear Grodzinsky speaking, a seasoned practitioner of biomathematics imparting his years of experience.

It is noteworthy that the author compromises neither on the rigor of the mathematics nor on the biological and chemical aspects of its application. Other interdisciplinary texts in bioengineering usually present simplified equations with the absence of vector notation. Grodzinsky's book, by comparison, is most thorough and complete in its mathematical presentation. Units are given for all variables throughout the text, which aid the reader in understanding the material. Moreover, mathematical tools are taught alongside stunning microscopy images, tables of chemical formulas, and properties of the most important biomolecules and schematic diagrams of the problem at hand. This biological data will save the reader hours of Internet surfing and page turning through other texts.

Exciting examples of electromechanics, such as an analysis of the electric eel or of magnetically driven bone healing, distinguish this book from rigorous mathematics texts. Numerous images also provide a historical tour of recent bioengineering inventions, such as electrophoresis and microelectromechanical systems. The inclusion of photos of certain instruments, however, may date the text as the number and sophistication of bioengineering technologies advances. Similar to many books used at MIT, this one has a strong mathematics prerequisite. To fully appreciate *Fields, Forces, and Flows*, the reader should not only have studied multivariable calculus but he should also be proficient in its application. Such a facility is usually neglected in mathematics courses but is taught well in engineering and physics courses.

The statement on the back cover describes the book as intended "for students in [both] engineering and bioscience." I disagree. The use of vector notation throughout the book precludes the current generation of biology students from incorporating this book into their courses. Biology audiences with a good grasp of single-variable calculus might consider other bioengineering textbooks, such as *Transport Phenomena in Biological Systems* (Truskey, Yuan, and Katz), a text that focuses on biological fluid mechanics rather than on electromagnetism.

This book is clearly written for those with a bent toward and training in electromagnetic issues. In the first five of the book's seven chapters, the author presents applications of electromagnetism, with those of fluid and solid mechanics making up the remaining two chapters. Perhaps this unequal partitioning is justified by the kind of problems important to bioengineers. However, at least half of all bioengineering graduate students have undergraduate degrees in mechanical, rather than electrical, engineering. Therefore, a section highlighting the importance of fluidic and rheological phenomena would have been especially useful to these readers.

Two shortcomings to mention are the lack of color images in the book and the fact that the number of worked examples far exceeds the number of end-of-chapter problems, but both issues can be ameliorated by supplementing this text with MIT's online resource, Open Course Ware, which provides multiple homework problems, as well as exams for all MIT classes. A course with the same title as this book is taught yearly at MIT, and the course's Web site includes color movies and images, as well as references to other textbooks that are less mathematical in nature.

Fields, Forces, and Flows will be most appreciated by those students with electrical engineering backgrounds who will be graduating within the next 10 years. For this audience, the book is an excellent and concise example of an interdisciplinary text on mathematical methods in bioengineering. Not only does the book present all the laws of electromechanics in a single place but it brags justifiably about the numerous applications of these laws in bioengineering technologies. It is historically relevant to note that Grodzinsky's doctoral advisor, James Melcher, was an MIT electrical engineer known for rediscovering and popularizing the entire field of continuum electromechanics and its application. In some ways, Grodzinsky is this century's Melcher, resurrecting electromechanics for the second time and showing clearly and inspiringly its successful application to bioengineering problems.

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WHAT VERY BIG TEETH YOU HAVE

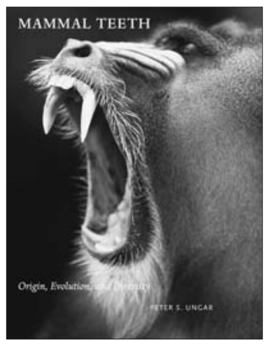
Mammal Teeth: Origin, Evolution, and Diversity. Peter S. Ungar. Johns Hopkins University Press, 2010. 320 pp., illus. $95.00 (ISBN 9870801896682 cloth).

Mammal teeth are a fascinating combination of intricate microstructure and supreme strength. They are at the pointy end of the animal–food relationship in that they are the key tools used in the daily acquisition of energy and nutrients in mammals. As such, teeth are magnificent indicators of ecology (through morphology and chemistry), models of morphogenesis in their development, and indispensible resources for phylogenetics and macroevolution as fossil remains. Teeth are one of the archetypes of morphological study and have been the focus of many significant compendia for the last few hundred years—Owen's (1840) *Odontography*, to name one. Such is their range of variation that they have spawned their own esoteric terminology.

Author Peter S. Ungar, distinguished professor of anthropology at the University of Arkansas, has pioneered a number of important research techniques in teeth through his study of the paleoecology of early hominids, including 3-D microwear and dental topographic analysis. In his new book, *Mammal Teeth: Origin, Evolution, and Diversity*, Ungar sets out to fully explain the biology of teeth and how they are important to the mammals that possess them. As he freely admits, the task is immense in that it covers topics from biochemistry and microstructure to functional morphology and fracture mechanics to nutritional ecology and macroevolution.

Ungar's book is a superb overview of the field of dental morphology, structured in an easily accessible format. The range of information on all aspects of mammal teeth—and on their mammalian families (even the edentulous ones)—results in a one-stop shop for tooth biology. It offers a summary of knowledge, followed by comprehensive references to help the reader delve further. *Mammal Teeth* will be equally valuable to professional biologists, including those who are not well versed in various areas, and to students new to the field, as well as to anyone interested in how and why teeth work.

The book comprises three parts: "Key Terms and Concepts" defines basic dental terminology, "The Evolution of Mammal Teeth" gives full coverage of the history of teeth in all vertebrates, and "The Teeth of Recent Mammals" surveys the dental shape and diversity in extant mammals. The first part, "Key Terms and Concepts," is comprehensive in its range. Besides the basics, this section also covers fracture mechanics (of both tooth and food), dental microstructure and development, and nutritional ecology, as well as the basics of tooth use and the chewing cycle. A brief overview of nongenetic indicators of diet, such as use wear and dental-tissue chemistry, is also included, and a primer on phylogenetic methods, including



the history of mammal classification, is offered to those unfamiliar with them.

The second part, "The Evolution of Mammal Teeth," touches on early experiments in tooth-like structures and surveys the major milestones in the evolution of tooth form and function, including the significant diversity of tooth shape occurring outside the mammalian class. This change in tooth shape is followed by the occurrence of the masticatory apparatus in various groups of synapsids. Ungar then turns to the explosion of mammalian diversity once "the rock has dropped" causing the extinction of the nonavian dinosaurs and the start of the Age of Mammals. Each of the major groups of mammals in the Cenozoic period is briefly covered, as are the general patterns of dental evolution in each epoch.

"The Teeth of Recent Mammals" addresses the dental shape and diversity in extant mammals. This third part represents one of the major achievements of the book—a consistent description of all recent mammal families and their teeth, with corresponding illustrations. Each depiction includes the ecology, body size, and diet of the family, followed by the adult dental formula and a clear description of the adult dentition, with notes concerning the areas of variation within each family. Examples of teeth range in shape and function from flat "washboards" to lethal "spears" to sensory organs (i.e., in the narwhal). This account showcases the massive range of diversity among these groups and demonstrates, in particular, how the diversity of dental form often, but not always, correlates with ecological and body-size disparity. There are illustrations for each family of all higher taxa, but the strict quota of one figure per family means that speciose families are underrepresented in their diversity.

All of *Mammal Teeth* is extremely well organized and flows smoothly, leading the reader through a logical progression of why teeth are integral to the mammalian way of life. Ungar essentially assumes that the reader has no knowledge of biology, and although the book does not generally go into great detail with regard to specialist topics, it does provide a great resource for those wanting to find out more: The citations in the text are comprehensive and include about 2400 key references. Ungar writes in an easy-to-read, engaging style and exudes excitement about the many aspects of the study of teeth and mammals. The book abounds with wonderful turns of phrase that highlight the humor of the author, including the "tooth–food death match" and Dawkins's blind watchmaker "working overtime." In an informal survey, the attendees of the 15th International Symposium on Dental Morphology in Newcastle, United Kingdom, gave a resoundingly positive response to the book, and many of them said they were already using it in teaching and research.

In more controversial subjects, Ungar's viewpoint remains balanced and includes both sides of the issue, such as the causes of high-crowned

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teeth (*hypsodonty*) or the possible multiple origins of vertebrate teeth. He does not evaluate or offer opinion on topics and ideas, although I would have liked to have seen either. In the field of dental morphology, *Mammal Teeth* is a great contrast to a book like *Dental Functional Morphology* (Lucas 2004), which is more of a personal view of the topic. Yet this book offers significant advantages over previous titles—namely, that it includes illustrations of over 140 mammals. Other books are limited to Northern Hemisphere taxa, or they are not comprehensive in all family-level groups.

Another advantage to *Mammal Teeth* is its consistency of style with regard to the figures of skulls and teeth used throughout the book, which greatly aids any comparative study. Skulls are shown as outlines displaying sutures and foramina, and teeth are shaded gray. This design, however, can at times make the positions of skull openings difficult to discern. The drawings of tooth rows follow the common convention for occlusal diagrams of teeth, with cusps indicated as dots, crests as lines, and valleys as dashed lines. This strict scheme can leave some figures tricky to interpret, such as that for *Thylacoleo* (figure 9.3A). I would also favor having tooth positions or series identified on the figure, along with some indication of scale. In general, although the figures are clear, I feel that they often do not convey the beauty and subtlety of the morphology they are representing. A few detailed line drawings are included (such as of marsupial teeth), but additional line drawings or high-quality photographs would have added greatly to the book and possibly increased an appreciation in the reader for the intricacies of dental morphology.

Mammal Teeth is an outstanding and valuable resource for the novice or student starting out in the field, and it can also be used successfully as a reference for professional biologists or odontologists. I will certainly recommend it for my own students working in dental morphology and perhaps for those colleagues who see teeth as just a bunch of old bones.

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