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Mammal Teeth: Origin, Evolution, and Diversity

Author: Alistair Evans

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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.

DAVID L. HU

David L. Hu (hu@me.gatech.edu) is an assistant professor of mechanical engineering and biology and directs the Biolocomotion Laboratory at the Georgia Institute of Technology, in Atlanta.

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

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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 is followed by the change in tooth shape and masticatory apparatus in the 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.

ALISTAIR EVANS
Alistair Evans (alistair.evans@monash.edu) is a dental functional morphologist and an Australian Research Fellow in the School of Biological Sciences at Monash University in Melbourne, Australia.

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