of the Ainu to the prehistoric Jōmon. Despite his use of sophisticated statistics, however, his conclusions savored more of preconceived notions than of anything that derived from the actual metric data. Without actually using odontometric data to test the idea, he debunked the old suggestion that there was a "Caucasoid" element in the Ainu. As with so many Japanese who want to believe that they are descended from the prehistoric inhabitants of the archipelago, he tried to push the idea that the Jōmon played a role in the ancestry of the Japanese which they did to a varying extent. He recognized the fact that most Japanese looked more like mainland East Asians than Jōmon-Ainu people, and he suggested, in the absence of archaeological support, that massive population movements from that mainland had been responsible. His estimate was that more than a million people moved from Northeast Asia to Japan during the time between 300 BCE and 700 CE, a guess that has made more than a few prehistorians uneasy and doubtful.

In 1972 he returned to the University of Tokyo as Professor of Anthropology in the School of Science where he remained until reaching the mandatory retirement age of 60. Starting in 1987, he began what was to be a lifelong affiliation with the International Research Center for Japanese Studies in Kyoto. Actually, he was one of the major figures involved in setting up that Research Center in the first place. In order to make the case to Japanese Prime Minister Nakasone for the establishment of that Center, Hanihara traveled to America in the spring of 1985 and visited a series of Universities to gather expressions of support for the project. His efforts were highly successful, and this points out one of the most prominent aspects of Kazuro Hanihara. He was a marvelous organizer and administrator and was a successful chairman of a Museum and Department as well as a long series of committees. Not only was he admirably well-organized, but he exuded a manifestation of graciousness and charm that clearly nurtured his success.

Hanihara was probably most known for his proposal of a "Dual structure model for the population history of the Japanese" first published in 1991. In this, he proposed that the prehistoric Jōmon of Japan were derived from Southeast Asia which he sometimes referred to as "South Asia" although this did not mean the Indian sub-continent as that designation has usually implied. He suggested that a mixture of Jōmon and Northeast Asians gave rise to the Ainu on the one hand and the modern Japanese on the other. The difference between the two, he proposed, was the result of microevolution in situ. The Jōmon themselves he regarded as qualifying as perfectly good "Mongoloids" although this was not supported by any kind of metric demonstration. The idea that the Ainu represent the continuity of the Jōmon with a bit of input from eastern Asia is indeed supported by an analysis of common variance, and the idea that the Japanese largely represent the morphology of eastern Asia tempered by a trace of Jōmon form in increasing amounts the farther east one goes in the archipelago is also supported by the variance figures. However, the role of microevolution in leading to the Ainu/Japanese differentiation has no basis, and there is no evidence supporting a Southeast Asian locus of origin for the Jōmon themselves.

Last but not least, Kazuro Hanihara was enormously helpful to visiting scholars who knew little or no Japanese. Whether he agreed with the interpretation of the results of their work or not, he was unfailingly gracious and supportive. He figured out bus and train schedules, helped people get to the right stations, he met planes, and made hotel reservations, and many more much appreciated acts of generosity and assistance. For those of us who counted him as a friend, his passing leaves a real sense of loss.

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Book Review

DENTAL FUNCTIONAL MORPHOLOGY: HOW TEETH WORK. By Peter W. Lucas. New York: Cambridge University Press, 2004. 372 pages, 7 chapters, 2 appendices. $130.00 £75.00

Occasionally in science a novel treatment of a familiar subject opens new vistas for exploration and thought. This is the case with *Dental Functional Morphology* by Peter W. Lucas. Part dental anthropology and part physics, this book challenges long held paradigms regarding the morphology of mammalian teeth. Viewed from the perspective that physical characteristics of food drive selection of tooth form, Lucas presents a well thought argument revolving around how dental morphology has evolved in response to the fracture properties of food.

The adage "if you don't eat, you die" can be altered using Lucas' view to "if your teeth don't efficiently fracture foods and reduce particle size to that which is

optimal for energy extraction, you die." As this implies, this volume is really an exploration of the mechanics of eating from the perspective of how biological material is broken down so that as much energy as possible is derived from that which is ingested. Here I will attempt to elucidate the main points that Lucas brings forth and pique the reader's interest enough that you will obtain a copy; although it is not an easy read, it is certainly thought provoking.

The nine sections (seven chapters and two appendices) of *Dental Functional Morphology* can be distilled into two groups, namely the core of chapters 4-6 and the periphery. The periphery sets up understanding of the core. Chapters 1-3 present a good background to the anatomy and functions of mastication, Chapter 7 provides insight into the evolution of mammalian teeth, and the appendices present an introduction to the mechanics of fracture in solids and the mechanical properties of teeth and foods.

Chapter 1, "How To Get Excited About Teeth," briefly outlines what Lucas is up to and begins one thinking of food in terms of how it breaks into smaller particles through the forces of mastication. As stated on page 10 the aim of the book is to consider "the function of teeth in relation to the ingestion, chewing, and swallowing of food. It attempts to elucidate the principles that underlie the evolution of tooth shape and size and those mechanisms by which the dentition can be maintained." The basic point is that teeth need to be viewed as anatomical structures in which selection for shape and size are a result of the physical properties of the material they come in contact with. Ergo, how teeth deal with two aspects of food, the external physical attributes and the internal mechanical properties, influences the evolution of their structure. Lucas puts this in context for the salient aspects of the book in stating, "The chance of hitting a food particle with the teeth is enhanced by making the tooth bigger, *i.e.* by changing tooth size. In contrast, the effects of the force that the tooth exerts on that particle depend on the contours of its working surface–*i.e.* on its tooth shape" (p. 12).

Chapters 2 and 3 offer very good review of the anatomy and function of the mouth, respectively. Included in Chapter 2 is an in depth overview of the micro- and macro-structures of the teeth and masticatory apparatus with excellent lateral head and neck drawings. The last lines of the chapter allow an introduction to Lucas' writing style, which is best described as 'humorously quirky' at times. This last section deals with the muscles of the neck, which he closes thusly, "However, humans have an habitual upright bipedal stance in which the head is balanced only by continuous active contraction of posterior neck muscles such as the longissimi. Without this action, the head falls forward —such as when dozing over a book like this. That is enough about structure" (p. 54). Chapter 3 is a very in depth treatment of the mechanisms of mastication. Jaw movement, food particle breakdown, food movement in the mouth, the mechanics of swallowing, taste, and the role of saliva are all addressed. This chapter begins the process of getting the reader thinking about teeth as processors of organic matter and is a building block for Lucas' argument concerning tooth size and shape developed in the following chapters.

In most books, appendices are sections that supplement the main text and are meant to be perused, or ignored, as the reader sees fit. That is not the case with Appendix A. Before delving into the core of the book, Chapters 4-6, this is necessary reading. As a primer on mechanical properties and their measurement, Appendix A covers material important to understanding the concepts Lucas presents. He suggests the reader at least "skim" this section, I suggest that a careful reading is important particularly if your knowledge of the mechanics of fracture in solids is limited. Pay particular attention to the sections explaining Young's Modulus (E), a measurement of stiffness (elasticity) of materials, and derivations for R (toughness) and K_{IC} (fracture toughness) as a comprehension of these and other formulae is important for following Lucas' logic trail.

Study of tooth shape (Ch. 4), size (Ch. 5), and wear (Ch. 6) is integral to the study of dental anthropology. The importance of shape and size, in particular, transcends the relatively narrow confines of our specialty to encompass the much broader study of the evolution of terrestrial life forms. Since, as we all know, teeth are the most often recovered portions of once living beings, paleospecies rise and fall based on characteristics relating to the size and shape of their teeth. Therefore, a better understanding of possible selective forces impacting dental evolution will lead to a better understanding of evolution in general. These three chapters offer readers the opportunity to reevaluate what they think they know about the evolution of the dentition and gain new insight into the microevolutionary forces at play in the evolutionary give-and-take between the eaters and that which they eat.

It is difficult to explain Lucas' exploration of the properties of food particle fracture and their effect on dental form without detailed description and the repetition of formulae that would expand this review beyond acceptable limits.

The basic premise of Chapter 4, Tooth Shape, is the assumption "that the shape of teeth is an evolved response for overcoming the toughening mechanisms inside foods that frustrate their fracture and that these mechanisms lie at the heart of the diversity of dental form" (p. 96). This focus on the complex structural properties of food is in direct response to the classic, simplistic, view of tooth function that lumps teeth into two broad, ill defined, categories; shearing and grinding. By understanding the true mechanics of fracture in solids, how cracks are initiated and progress, it becomes apparent that "shear" and "grinding" are not what is happening at all during

mastication. Force, applied through the teeth by the muscles of mastication, initiates cracks that lead to fracture and thence, to reduction in size of solid organic matter. The geometry of this fracture (how easily and in what manner it fractures) is controlled by the food particles and not by the teeth since being structurally sound is selectively advantageous. Understanding how foods prevent fracture is important for understanding tooth form. Lucas spends what seems like a great deal of time discussing cusp shape (pointedness) and how this affects fracture propagation, cell toughness, and the fracture characteristics of various foods. However, in the end, one is left with a better understanding of how the structural characteristics of food can influence tooth shape so that structures such as marginal ridges are no longer perceived as accessory features of crown anatomy but as structures that facilitate fracture continuation.

With tooth size, Lucas prods us to view it as something whose variation is tied to the size of the entire orofacial complex, the size of which is, in turn, related to the size of the food that is put into it. Stating that "The overriding philosophy is that physical properties of mammalian diets explain not only tooth size, but also the size of most orofacial structures" (p. 133), he proposes that tooth size should be scaled not to body size as in standard allometric analyses but to the size of the 'food particles' that they encounter. He finds that the size of the anterior teeth and that of the post-canine teeth are affected by different aspects of the diet. On the one hand, jaw and anterior tooth size scale to the size of food as it is put into the mouth while post-canine tooth size is related to external physical properties of the food and how it fractures. Along the way Lucas presents in-depth discussions of the effects of variation in food toughness and tooth size, how food intake speed impacts overall orofacial size, and the differential effects of herbivory and carnivory on structures of the mouth.

Lucas explores tooth wear by examining what actually causes it. From a mechanical standpoint tooth wear is the loss of small fragments from the body of the tooth, therefore, understanding how these fragments are removed is important. Tooth-tooth wear (attrition) and food-tooth wear (abrasion) affect enamel and dentine in different ways resulting in different selective pressures on the structure of teeth. In this view, food-tooth wear impacts tooth size while enamel thickness responds to tooth-tooth wear. The pressures of food-tooth interactions are spread across the whole of the crown and vary from chew to chew. This impacts tooth size because the larger the tooth the more surface comes into contact with food which, in turn, increases the life of the tooth, impacting survival. In contrast, tooth-tooth wear occurs repeatedly, and under high pressure, at very specific points, particularly the cusp tips, resulting in selective response in enamel thickness. While Lucas states that he "did not say much in this chapter" (p. 200), he does present a wide ranging discussion of tooth wear that includes several pages on the response of dentine, an area that is frequently overlooked.

The concluding chapter is self described as "a chapter of ideas, mixing fact with suggestions that, although seemingly logical and based on the previous chapters, might require a lifetime's work to substantiate in any detail" (p. 202). As speculative in nature as it is, this chapter is also a thorough overview at how teeth function and the evolution of the mammalian dentition in light of the emphasis on the fracture properties of food. The last 20, or so, pages deals with diet and human evolution, touching on several areas. An example or two will suffice. On page 238 Lucas anticipates the discovery of *Homo floresiensis* by suggesting that dental reduction, specifically tooth loss, could be tied to dental crowding brought on by dwarfing in small, isolated, mammalian populations. Pages 243-244 cover the molarization of premolars where he ties this trait to the size of the food that is being eaten and postulates that hominids who possess molarized premolars have adapted to eating relatively small objects. In fact it seems that Lucas relates everything in dental evolution to food toughness and particle size. For the most part this appears to work. However, when it comes to applying this theoretical line to dental reduction and the effects of cooking food on tooth size Lucas completely ignores the possible impact agriculture and the resulting foods high in fermentable carbohydrates may have had in the selection for smaller, less complex, molars over the last 10,000 years.

Now for a succinct concluding paragraph. Hopefully this review has given the reader a hint at the complexity and value of *Dental Functional Morphology*. Although "a little thick at times" (reviewer's notes), if taken in the right dosage, with periods of contemplation liberally interspersed, one comes away with a new appreciation for the role food has played in the evolution of teeth. However technical the book may be at times, I think it can also become an important resource for professionals and as a starting point for discussion in graduate seminars. On a theoretical level most of what is proposed within this volume is well supported though it seems that Lucas is, at times, so tied to food particle size and fracture properties that other, simpler, possibilities are overlooked. As in any book of this length there are several nit-picky things that I could address but I'll only attack one. On page 149, line 4, in discussing characteristics of food Lucas says "Fleshy fruits are *designed* for feeding on by vertebrates because these animals can disperse their seeds effectively" (emphasis added). The Darwinian in me recoils at the implications of some unseen hand working its magic in what is otherwise a fine evolutionary synthesis. In the end, whether or not one buys Lucas' premise that the evolution of the mammalian dentition is the result of adaptation to the mechanical properties of food this book is a valuable addition to the dental anthropology literature.

Review by
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