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BOOK REVIEW Open Access

Endless bones most beautiful: Book review of Vivian de Buffrénil, Armand J. de Ricqlès, Louise Zylberberg, Kevin Padian (eds) 2021 Vertebrate Skeletal Histology and Paleohistology

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Paleohistology has brought to vertebrate paleontology a major leap of knowledge, similar to non-invasive imaging. It has enhanced the possibility of addressing questions of physiology and life history based on the study of fossils. Its progress is tied to the understanding of bone microstructure and ontogenetic change in extant species for which direct observation is possible and there is an obvious connection to biomedical research—and potentially to bionics. Some extinct species are better known in their bone microstructure than living ones, and curiously, some non-mammalian clades have been more intensively studied than mammals. It has been long reported that in mammals the life record in ontogeny that is preserved in the bone microstructure of other vertebrates is erased, an assumption that has been productively challenged for some time, as several chapters in this book show (e.g., de Buffrénil et al., 2021).

The book edited by Vivian de Buffrénil, Armand J. de Ricqlès, Louise Zylberberg, and Kevin Padian is the most ambitious and comprehensive survey of bone paleohistology, designed to be relevant to those working on extant species too. There is no other book on the subject anywhere close to it in its broad scope, notwithstanding major treatments of this century such as Chinsamy-Turan (2005) on dinosaurs or Padian and Lamm (2013) largely on methods. Earlier treatments are discussed in a history of the field by A. de Ricqlès in a rich introductory chapter. In breadth, de Buffrénil et al. (eds) is several books in one, the general areas covered in 40 chapters (!) are basic biology of bone, cartilage and teeth, mechanistic aspects of bone growth and remodeling, and surveys across phylogeny of many major clades, as well as several chapters dealing with broad questions on patterns and mechanisms.

Several chapters provide much of the background needed to understand paleohistology—there are introductory chapters on the vertebrate skeleton, of microanatomical features, cartilage, type 1 collagen, and bone tissue types, among others. I still prefer the encyclopaedic and single-authored book by Hall (2015) for this subject, but the collection of papers is an excellent and broad introduction, easily completed by other overviews on fundamental subjects (e.g., Schneider, 2018 on the neural crest; Wagner, 2014 on homology). There are several vignettes on special technical applications by experts in them, for example on CT-Scan Imaging, synchrotron use, on 3D Histomorphometry, and on FIB–SEM Dual-Beam Microscopy. These sections are likely to age given constant new developments (e.g. Bailleul et al., 2021 on DiceCT applied to fossils), but they sure provide useful reminders and introductions to the power of such approaches.

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The volume is a combination of current, topical content with a rather classical thematic coverage and documentation of primary data. It is wonderful to see a field that flourishes based on new information and careful consideration of the biology and taphonomy of the evidence (Montoya-Sanhueza et al. 2021). Much of such new evidence is presented while discussing major patterns and questions in chapters treating many different major clades. There are abundant pictures of fossils and of histological sections of great quality, in colour. My background bias made me notice especially the data on the Paleocene metatherian *Pucadelphys*. For a volume of such a comprehensive scope, missing a chapter on teleosts is noticed. Examples of the latter can be found in Witten et al. (2021), and the conferences "Interdisciplinary Approaches in Fish Skeletal Biology" offer a survey of the subject.

A great virtue in many chapters is to identify open questions and issues, treated in individual chapters and more globally in a summary essay by Houssaye et al. (2021). The thorny subject of bone types is surely one of them. The chapter with the survey of mammals concludes with the open questions on the morphogenesis of the compacted coarse cancellous bone, formed in the metaphyses through the compaction of bony trabeculae.

This field owes much in the last decades to scientists based in France (Francillon-Vieillot et al., 1990), and many of the editors and contributors are from there, but there are contributors from other countries, including several from the global south. The potential of paleohistology can be fulfilled if practitioners are geographically expanded. In paleohistology as in any other discipline, a major challenge will be to develop a research field that is truly inclusive geographically given the great inequalities in access to training and to resources.

The study bone histology could benefit from using domestic forms as subjects, given their ubiquity (Firth, 2006) and the intraspecific variation expressed in different breeds in their diverse function and life history traits (Sánchez-Villagra, 2022). The presence of chondroid bone (a skeletal tissue sort of intermediate between bone and cartilage) in ducks, a recent discovery (Prondvai et al., 2020), may be more widespread feature and its relation to growth rates in their limbs a matter of research interest.

Large data approaches could contribute to making palohistology more prominent, by discovering phylogenetic and functional patterns (e.g., Hayashi et al., 2020; Rössner et al., 2021; Amson et al. 2022). This will require collaborative efforts and coordinating. For this field to prosper, there needs to be a concerted aim to have better comparative sampling and thus produce stronger inference and more significant phylogenetic results. This book hopefully stimulates by its sheer size and scope that kind of ambition. A great subject could be island mammals (van der Geer et al., 2021). A model is the genomic studies of domestication—in the case of works on dogs, these have brought together people with diverging opinions on core issues of the subject—and yet they joined forces to collate data that only together could serve to produce great results (Bergström et al., 2020). In my somewhat limited experience as a member (no longer) of this community, I have the impression that there are as many only right ways to do paleohistology as there are palaeohistologists—very much like morphometrics. The most peculiar and destructive reviews I have obtained have been on palaeohistological papers. Hopefully, the field will not advance 'one funeral at a time' (Azoulay et al., 2019), but instead broad collaborations of research teams with diverse views, backgrounds and even contradictory opinions will be practiced and editors will advance the field supporting a plurality of views and tests of hypotheses.

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