

Harper; p. 219). However, we must remain vigilant and not *prima facie* accept our models and theories as fact. As Popper and now Penny remind us, good scientific thinking is defined by its inherent falsifiability, and it is up to us to subject our ideas and models to the scrutiny of the Popperian lens. Good science will stand, bad science will fall, but there is considerable promise that lies ahead both for the scientific endeavor, and for evolutionary thinking.

CHARLES J. ALT, *Science, Princeton Day School, Princeton, New Jersey*



### TAXONOMY, SYSTEMATICS, AND PHYLOGENETICS

SPECIES CONCEPTS IN BIOLOGY: HISTORICAL DEVELOPMENT, THEORETICAL FOUNDATIONS AND PRACTICAL RELEVANCE.

By Frank E. Zachos. *Cham (Switzerland): Springer*. \$159.00. xii + 220 p.; ill.; index. ISBN: 978-3-319-44964-7 (hc); 978-3-319-44966-1 (eb). 2016.

This is a book that I did not think I needed and assumed that I would not like. Like many systematic biologists, I did a deep read into the literature on species concepts in the months leading up to my qualifying examination because I knew that I needed to have something coherent to say about species concepts during my oral examination. To this day, I am not sure that I succeeded. In subsequent years I made peace with the species problem—ably described by Zachos as the incongruence caused by the continuous nature of the evolutionary process and the requisite hierarchy of taxonomic practice—and resolved not to lose any sleep over it. So it was with a sense of professional obligation rather than a sense of excitement that I sat down to read this volume. I could not have been more wrong.

*Species Concepts in Biology* is an efficient and effective book that neatly summarizes several centuries of progress on the species problem. Impressively, it is also a good read. It begins with an epigraph from Einstein—a scientist whose professional interests concerned matters somewhat less complicated than the species problem—and then largely accomplishes the directive offered by the cosmologist: “Everything should be made as simple as possible, but not simpler” (p. 1). Its stated goal is to “provide biologists with a distillation . . . of the species debate” (p. 96) and Zachos’ volume largely achieves this. Even as it necessarily concerns complex topics that lack a clear resolution, it manages to be cogent and direct.

The author begins with a survey detailing the development of ideas about species, including chapters largely concerned with history and ontology. Readers who are tempted to skim through the center of his book—which contains an annotated list of some 30 species concepts—should not do so, as it is here that the ramifications of the philosophical argument about the nature of species come to the forefront. Zachos makes an admirable attempt to relate these concepts to one another, and illustrates clearly the point that it is the diversity in natural systems and evolutionary processes that makes it necessary to have such a plurality of species concepts in the first place. Perhaps the highlight of the volume is the penultimate chapter that explores the practical relevance of species concepts while reminding readers that species names matter to conservation, biodiversity research, and the biological sciences as a whole.

Zachos wrote this book for biologists. To those of a certain age (myself included), his volume synthesizes papers that were written over decades, likely read in no particular order, and brings out the connections and contradictions in this literature. The author finds common themes and puts ideas into their proper historical context. I particularly benefited from the third chapter, which discusses philosophical issues relevant to the species problem in an accessible manner. However, the readers who will most appreciate this book are those who are entering the field of systematic biology, particularly students who know that they need to understand the species problem in order to conduct the work that they plan to do. For these readers, *Species Concepts in Biology* offers a readable synthesis of the biological thought on what species represent, and a summary of how researchers have tried to delimit them. It will not be the last word on this subject, but it represents by far the best starting point.

BRYAN C. CARSTENS, *Evolution, Ecology & Organismal Biology, Ohio State University, Columbus, Ohio*



### BEHAVIOR

MIXED-SPECIES GROUPS IN ANIMALS: BEHAVIOR, COMMUNITY STRUCTURE, AND CONSERVATION.

By Eben Goodale, Guy Beauchamp, and Graeme Ruxton. *Cambridge (Massachusetts): Elsevier (Academic Press)*. \$50.96 (paper). xi + 203 p.; ill.; index. ISBN: 978-0-12-805355-3. 2017.

As the authors comprehensively document, mixed-species aggregations and groups surround us. They define groups as being characterized by spatial prox-

imity and interactions, but do not assert that the interactions must be symmetrical or beneficial for all involved (consider the aggressive mimicry found in some coral reef fishes). Broadly, interactions may be mutualistic, commensal, or parasitic. They prime readers to consider the community consequences of both aggregations and groups.

With this broad definition, Goodale et al. first describe the situations under which such groups may form (Chapter 2), and then survey taxa (Chapter 3) where they note, among other things, that mixed-species aggregations and groups in insects and microorganisms are woefully understudied and that mixed-species groups can be found in plants and later provide more detailed examples. Two chapters are specifically focused on adaptive hypotheses that they separate into foraging, physical, and reproductive factors (Chapter 4) and predators and other antagonists (Chapter 5). The next chapter reviews communication, much of which is likely to be eavesdropping, but some that has clearly evolved as communication. Leadership and sentinel behavior are presented in Chapter 7, while Chapter 8 discusses conservation. The final chapter summarizes findings and identifies knowledge gaps.

I found the book fascinating in its breadth and now have a much broader and deeper appreciation of mixed-species groups. The authors present frameworks that can be used to guide future research, highlight future research questions, and point out how new methods may enhance our knowledge of both mechanism and function. They highlight the benefits that will come from more experimental studies.

I have a few quibbles. First, and as they note, mixed-species groups are often reported in birds. The authors suggest that this reflects the fact that many birds are relatively social and mobile, and this is a preexisting bias for the formation of mixed-species groups. Yet, as they also note, there is a lot more going on in aquatic animals that we struggle to study. And, as Goodale et al. describe, eavesdropping is common and may involve nonsocial species. Second, it took until page 136 to introduce social network analysis and the discussion was brief. Admittedly, they point out that future advances will come from these tools, but I believe a deeper discussion could have helped guide future studies for these tools provide concrete ways to quantify roles of different species (a topic they discuss more broadly). Third, I am absolutely convinced that the ubiquity of mixed-species groups means that these interactions are something worth conserving, but I felt that the discussion of conservation relevance lost an opportunity to guide future work. Highlighting the role of social network statistics would have been valuable and providing more examples or possible applications would

have been warranted. These are minor concerns for this well-written book that is required reading for anyone interested in interspecific interactions.

DANIEL T. BLUMSTEIN, *Ecology & Evolutionary Biology, University of California, Los Angeles, California*

BEHAVE: THE BIOLOGY OF HUMANS AT OUR BEST AND WORST.

By Robert M. Sapolsky. New York: Penguin Press. \$35.00. x + 790 p.; ill.; index. ISBN: 9781594205071 (hc); 9780735222786 (eb). 2017.

If at the end of reading Sapolsky's latest book you come away believing that "when you explain a behavior with one of these disciplines [endocrinology, epigenetics, genetics], you are implicitly invoking all the disciplines—any given type of explanation is the end product of the influences that preceded it" (p. 7), he will have achieved his objective. Through the reading of this volume and arriving at this perspective, you will have saved yourself the reading of: a basic neuroscience textbook; an introductory endocrinology textbook; a beginning psychology textbook; a number of important individual volumes by prominent behavioral scientists (e.g., John Bowlby, Antonio Demasio, Joshua Greene, Joseph LeDoux, Konrad Lorenz, Richard Nisbett, Steven Pinker, John B. Watson, David Sloan Wilson, and Edward O. Wilson); and classic studies by Lawrence Kohlberg, Paul MacLean, Walter Mischel, Richard Nisbett, and Jean Piaget. This volume is the distillate of fields as varied as evolutionary biology, neuroanatomy, and social cognition, and what a vital essence it really is.

A careful passage through the 675 pages of text will provide readers with an invaluable and highly accessible corpus of information relevant to the evolutionary and behavioral sciences. Sapolsky, who variously describes himself as an ethologist (p. 83), neurobiologist, and primatologist (p. 4), is in a position to marshal immense amounts of information, including the latest scientific discoveries, in a fashion that few of us can rival. Drawing upon his experience as a pedagogue, included within are three appendixes that act as primers in neuroscience, endocrinology, and molecular biology. The value of this approach for the neophyte in these areas is immeasurable.

The creative and integrative layout of the book is a success. It begins with a chronological and developmental framework to the biological basis of our behavior, which is equally engaging as it is comprehensive. Considerations of historical and social-cultural nature then take focus. Sapolsky is aware of the ways in which culture becomes an important determiner of human behavior, and the volume benefits greatly from not sticking to studies carried out