and approaches developed for ARTs might well prove to be useful in a far wider field of inquiry.

The book is organized into four main parts. Part I summarizes the study of ultimate causes and origins of ARTs, and ranges from the application of phylogenetic methods through to game-theory modeling. Clearly, there is something about the persistence of multiple alternative tactics within a single population that arouses the modeler within, and even 'empirical' chapters later in the book often reveal a deep interest in concordance of patterns with model-derived predictions. That strong link between theory and data is a substantial strength of the field, and of the book.

Part II explores proximate mechanisms that generate ARTs, and not only reviews the broad interplay between genetic and environmental factors but also delves into ontogeny of ARTs and the kinds of neural and endocrine mechanisms that modify developmental trajectories to generate discrete ARTs. Much has been learned, but the immense diversity of ARTs, and their broad phylogenetic distribution and lability, suggest that generalities about proximate mechanisms might lie well in the future.

Part III of the book, by far the largest, comprises taxonomic reviews of ARTs. Many of the chapters provide extensive tables of case histories, facilitating comparison and the search for general patterns. The level of detail varies considerably, with fish receiving 50 pages whereas reptiles and birds barely rate more than 10 pages apiece. That diversity partly reflects biology – fish clearly are the paragons of ARTs – but also individual approaches by the authors. For example, the chapter on reptiles focuses primarily on the authors' own work on a single lizard species, and makes relatively little attempt to review the broader literature on other reptile taxa (on a personal note, it would have been nice to see more material on snakes). Nonetheless, these chapters provide enormous detail on a dazzling array of examples. It is hard to know whether to be more impressed by the extraordinary convergences in tactics between organisms from dissimilar lineages (such as 'satellite males' in everything from horseshoe crabs through to waterbuck) or by the cases of strong phylogenetic conservatism (such as the deep disparities between urodele and anuran amphibians in reproductive modes, and thus in the kinds of ARTs available to males).

Part IV brings together 'emerging perspectives' – a grab bag of new directions and approaches ranging from communication systems through to sexual conflict and cooperative breeding systems. This section reinforces the usefulness of ARTs as systems to investigate some of the hot new topics in evolutionary ecology. ARTs give us the opportunity to quantify mechanisms and fitness consequences of alternative phenotypes manifested by individuals that are genetically similar to each other, living in the same place at the same time. The reduction of confounding factors provides a more robust opportunity for comparisons and, hence, for testing hypotheses, than is usually afforded by interspecific comparisons.

In total, the book succeeds admirably in its aim of reviewing current ideas and information on this most entertaining of phenomena. The field is thriving, and is facilitating clear exchanges and collaborations between theoreticians and empiricists. And even for those of us for whom ARTs are only a side issue in our research, the book contains so many examples of bizarre sexual proclivities that it will provide endless amusement for dinner table conversations with our nonscientific peers. I enjoyed this book for its documentation of fascinating sexual strategies as much as for the ways that science has managed to use that diversity to pose and answer interesting questions. I suspect that Charles Darwin, the avid naturalist-observer, would have enjoyed both facets of this volume as well.

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Book Review

Weighing the evidence in evolutionary biology

Evidence and Evolution: The Logic behind the Science by Elliott Sober, Cambridge University Press, 2008. US $90 (392 pages) ISBN 978-0-521-69274-8

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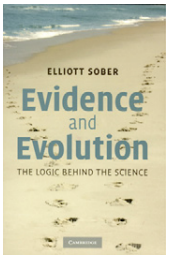

The joke among scientists is that 'philosopher' is the last stage of one's scientific career, to be arrived at when one can no longer get grants funded or graduate students to advise. Despite the fact that some of the greatest minds in evolutionary biology (from Darwin to Ernst Mayr) were very much interested in the philosophical aspects of what they were doing, the bad joke persists in the halls of academia.

A possible cure to the malady might be offered by the reading of the new book by philosopher Elliott Sober, who has written plenty of smart and provocative stuff before [1] about natural selection, phylogenetics, genetic drifts and other recurrent topics in evolutionary biology. The basic idea of *Evidence and Evolution* is, as the subtitle says, to examine the logic underlying the practice of evolutionary biology, something that ought to be of more than passing interest to the scientists in the field (and no, one cannot simply assume that working in an area of research means being aware of the often complex assumptions that make conceptual and empirical work in that area possible).

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Despite the author's efforts and declared intention, this is no easy reading for either a biologist or a philosopher, but it is stimulating material for a graduate seminar, especially if aimed at an interdisciplinary group of students and faculty. Sober's basic idea is to lay the groundwork by examining the major contenders for methods of inferential reasoning in quantitative biology and then to deploy those methods in three generally important cases: the debate over so-called intelligent design, the study of natural selection and research on common ancestry.

This plan makes for intense reading, considering that there are only four chapters in the book (one about methods, three for applications), with 80–100 pages per chapter. The methods Sober considers include Bayesianism, 'likelihoodism' and three versions of frequentism, what he calls 'probabilistic modus tollens,' Neyman-Pearson testing and model-selection theory. In a very pragmatic fashion for a philosopher, Sober does not feel compelled to choose among methods of evaluating evidence, and simply points out the strengths and weaknesses of each approach.

There is one test, however, of which Sober is severely critical (and he is the latest in a long list [2]). Ironically, this is by far the most common approach to statistical hypothesis testing, Fisher's test of significance. Fisher's test is an example of probabilistic modus tollens, which is an invalid form of reasoning. To see what the problem is, let us briefly look at deductive (standard) modus tollens, which is a common and valid form of reasoning. Deductive modus tollens works like this: (premise 1) if H, then O; (premise 2) not O; (conclusion) therefore not H. For instance: (premise 1) if DNA is a double helix, then we should observe certain diffraction patterns when carrying out X-ray crystallography of the molecule; (premise 2) we do not observe the predicted diffraction patterns; (conclusion) DNA is not a double helix. This deduction is valid, meaning that the conclusion necessarily follows from the premises, if the premises are true. As it turns out, of course, my second premise is false, so my conclusion does not hold, DNA really is a double helix.

You might have noticed a similarity between modus tollens and Popper's idea of falsificationism [3], and you would be right on the mark, because Popper built his theory of scientific method precisely on the use of modus tollens. What is the problem, then? The issue Sober raises is that when we go from deductive to probabilistic (i.e. statistical) modus tollens we lose validity, meaning that the conclusion does not necessarily follow even if the premises are true. Probabilistic modus tollens works like this: (premise 1) the probability of O|H is very high; (premise 2) not O; (conclusion) therefore not H. This does not follow, because many very reasonable hypotheses make the prediction that certain observations are very improbable, so not observing a particular fact about the world does not in itself falsify the hypothesis.

Sober goes on to apply this and other insights into how evidence is evaluated to show precisely why proponents of intelligent design are dead wrong (it is not, surprisingly, for the usual reasons trotted out by some evolutionary biologists), to understand the best ways to contrast the alternative hypotheses of drift and selection and to discuss tests of natural selection versus common ancestry in the case of comparative phylogenetic studies. There is much good food for thought here, and the book is well worth the investment of time and neural firings that it requires to get to the end of it.

References

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