also be gleaned in these pages concerning the development of the research institutions that supported science around 1900. Valuable aspects of the book include its discussion of Mt. Wilson Observatory (chapters 4 through 6), insights into behind-the-scenes events at the Carnegie Institution of Washington, and a long bibliography of works by Ritchey. The citations of primary literature would be much more useful, however, if article titles were not omitted.

Another problem is that sometimes the detail takes over, to the detriment of the story. For example, much of the genealogical discussion in chapter 1 seems inadequately connected to our understanding of Willis Ritchey. Likewise, knowing what now stands on the spot where Hale first lived does not contribute to our understanding of historical events. This book is primarily a story about Ritchey, Hale, and the advent of big telescopes. These side stories are simply distracting. I am disappointed with the book on one other point. With all his familiarity with these events, Osterbrock could have drawn more general conclusions. Biographies often display this limitation.

Nevertheless, the reader can draw his or her own conclusions, from an important story. *Pauper and Prince* provides a detailed look at how an accomplished maker of instruments fit into the scientific community in early-20th-century America. More such studies are needed—perhaps studies about makers of less dazzling instruments such as geophysical prospecting equipment—alongside more interpretative works.

Gregory A. Good
Department of History,
West Virginia University,
Morgantown, WV 26506–6303

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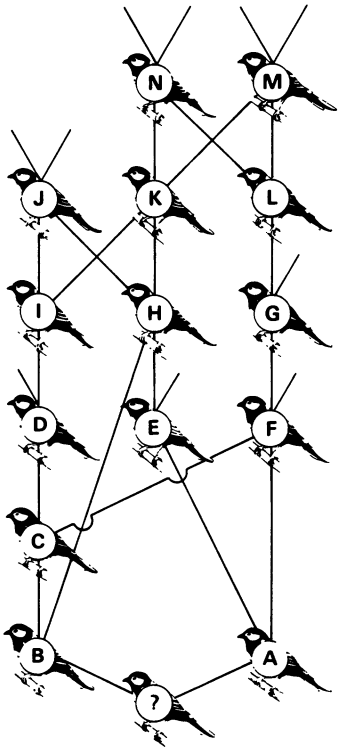
Inbreeding and Evolution

The Natural History of Inbreeding and Outbreeding. Theoretical and Empirical Perspectives. NANCY WILMSEN THORNHILL, Ed. University of Chicago Press, Chicago, 1993. viii, 575 pp., illus. $80 or £63.95; paper, $32.50 or £29.95. Based on a symposium, 1989.

As William Hamilton recalls in the epilogue of this volume, "My mother says that shortly after I was born, ants attacked me in my cradle. The place was Cairo, so I like to guess the ant was 'Pharaoh's,' *Monomorium pharaonis*. . . . I like the idea because, besides being a notorious lover of sweet things, this tiny yellow ant is noted for indiscriminate inbreeding within the nest, including brother with sister." Because of this general fascination that inbreeding, both in our own species and other organisms, holds for humans, the title of this volume will attract attention. However, readers must be forewarned of the need to pick and choose among the contributions, which are highly variable in level of rigor and authors' agendas.

The impact of inbreeding on evolutionary processes, plant and animal breeding, and, recently, conservation biology is a topic of detailed research. To understand its long-term impact in terms of evolutionary genetics, we need to know the level and pattern of inbreeding and the type and extent of its effect on fitness (these issues are the primary focus of this volume). In addition, the magnitude of genetic drift, the importance of mutation in restoring variation or reducing fitness, and the relevance of gene flow in introducing genetic variation may play critical roles. All of these are complex topics by themselves, and their integration into a coherent framework is a truly difficult task.



A pedigree of great tits as compiled by A. J. van Noordwijk and W. Scharloo. There are at least ten relations between A and B, yielding an inbreeding coefficient of 0.145. [Reprinted from *Evolution* **35** (4), 678 (1981)]

Given the obvious difficulty of obtaining information on inbreeding and outbreeding from natural populations, it is surprising that there is little effort in this volume to utilize the information gained from examining cultivated plants and domesticated animals or from forestry genetics, laboratory experiments on *Drosophila*, or studies of human populations, either by anthropologists or by population geneticists. Part of this lack may be deliberate, given Shields's comment that "we must stop interpolating from theory and artificial systems (domestic stock, laboratory populations, or zoos) and gather the critical data in nature. Only then can we be reasonably certain whether inbreeding or outbreeding are good, bad, or indifferent in particular circumstances." Many scientists, including evolutionary biologists, use model organisms and controlled environments to understand complicated phenomena, hoping to establish some general principles. I think that the understanding of inbreeding and outbreeding has greatly benefited from such research in the past and could benefit from additional critical studies of this nature.

This volume is a group of 18 papers stemming from a symposium. Perhaps the best that can be hoped for from such a volume is a summary of the state of a research area or of individual authors' research that provides an entrance into the original literature (there are 105 pages of references in this volume for this purpose). Three of the reviews I found particularly useful as summaries of research areas. Waller provides a reasonable overall examination of the parameters important in mating systems of plants; Waldman and McKinnon give a thorough summary of inbreeding and outbreeding studies in fishes, amphibians, and reptiles; and Lacy examines some of the extensive data accumulated in recent years from mammal populations in zoos. Also quite worthwhile is the original contribution by Werren, which presents new results on the theory of inbreeding depression in haplodiploids, a group of animals that may have high levels of inbreeding.

On the other hand, several papers are devoted to advocating particular viewpoints while ignoring contrary scientific evidence. For example, in his contribution Mitton dismisses the majority viewpoint that recessive detrimental alleles are primarily responsible for inbreeding depression and related phenomena. Instead he takes the position of what may be the last panselectionist and attributes the phenomena to widespread single-locus overdominance. The chapter by Shields seems to have as its main objective to rebut the 1986 review on inbreeding in birds and mammals by Ralls, Harvey, and Lyles, an article that I view as a landmark contribution to the literature. To be more successful, the volume needed critical contributions from such authors as Brown, Deborah and Brian Charlesworth, Lande, Lynch, Ritland, Templeton, or van Noordwijk.

I applaud the attempt to bring together research on inbreeding in plants and animals; often there is a split by kingdom. The extent of inbreeding in general is, of course, very different in the two kingdoms, making its effects on fitness also quite different. A

significant proportion of plants have some form of inbreeding, usually self-fertilization, and expected inbreeding coefficients above 0.9 are not unusual. By contrast, the extensive surveys compiled here report only two vertebrate populations, of splendid fairy-wrens and great tits, that have matings suggesting inbreeding coefficients above 0.05. (For comparison, 25% full-sib mating and 75% random mating every generation result in an inbreeding coefficient of only 0.077 at equilibrium.) Further, a follow-up study of the wren nestlings showed, according to Rowley, Russell, and Brooker, that "more than 60% of the nestlings examined could not have been sired by any male in the social group that raised them." In other words, inbreeding rates based on observed pairings may be grossly inaccurate because of extrapair copulation or other phenomena. In invertebrates, particularly arachnids, there may be species that have higher inbreeding levels, but the documentation is relatively poor (surprisingly, there are no references in the book to the elegant work on selfing in slugs and snails by Selander).

I think one of the most important implications of the low level of inbreeding found in most vertebrate populations is that it might very well result in a high genetic load. If populations of such species radically decline in numbers or are brought into a captive situation where there is inbreeding, the expectation is that inbreeding depression would be a severe problem. Although not all captive endangered animals show inbreeding depression for juvenile survival, the component of fitness easiest to document, it is generally recognized as a severe problem in maintaining many endangered species.

One of the major topics of discussion in the book is the theory that there is an optimal level of inbreeding, two of whose chief proponents, Shields and Waser, played a central role in the original symposium. Most people, though I have found not all, will agree that the offspring of closely related individuals generally have lower fitness than those resulting from random matings. Further, it generally appears that crosses between distantly related individuals (from different species?) also generally have lower fitness. There may thus be an optimum level of inbreeding between these two extremes at which fitness is higher, but that it is on the same spatial scale as dispersal in most species seems unlikely. The middle ground may be very wide, with little fitness differential and therefore insignificant potential for selective change. Overall, there is virtually no evidence given here for outbreeding depression in animals that favors its existence on the scale at which even maximum dispersal might occur. For plants, Waser provides a table of examples divided into sections based on whether the best performance is from the longest-distance outcross, the shortest-distance outcross, or an intermediate outcross. As he states in summarizing this survey, "Empirical evidence is mixed at best. . . . Even those studies listed in the table as demonstrating isolation by distance usually show patterns in poor quantitative agreement with theoretical predictions."

As we broaden our knowledge of inbreeding and outbreeding in various species, it seems the subject becomes more complicated and fewer generalities are possible. Or, as Hamilton puts it in conclusion, "It seems that notwithstanding all the facts and theories in this book (including mine), we hardly begin to know answers to any of these questions."

Phil Hedrick
Department of Zoology,
Arizona State University,
Tempe, AZ 85287

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Auditory Cognition

Thinking in Sound. The Cognitive Psychology of Human Audition. STEPHEN McADAMS and EMMANUEL BIGAND, Eds. Oxford University Press, New York, 1993. xiv, 354 pp., illus. $67.50 or £45; paper, $26.95 or £17.50.

The definition of cognition adopted by the editors of this book is one that would be familiar to most cognitive psychologists: " 'Cognition' refers to the notion of knowledge. It has been used in a more specific sense to designate the conditions that allow humans to develop knowledge of the world." Clearly, sound is one pathway to knowledge of our environment. Yet cognitive science has long been dominated by studies focusing on visual input. When sound has been studied in the context of cognition, it has generally been limited to speech. With *Thinking in Sound: The Cognitive Psychology of Human Audition* McAdams and Bigand suggest that the time has come to formulate an auditory view of cognition that is general enough to encompass any auditory signal.

Overall there is not much that is new in this book, with one important exception—the material on sound source determination, or auditory scene analysis. The auditory system does not directly transduce the source of sound. (In this way it differs from other sensory systems, such as the visual system or the skin.) Rather, the auditory periphery provides a time-frequency code of the acoustic sound field that arrives at the two ears from all of the sound sources that surround us. It is through higher-order mechanisms that process the time-frequency code that the auditory system segregates the sensory information into units that allow for the determination of the original sound sources, which is a fundamental perceptual ability. It seems clear that the ability to make use of the information gained about the auditory scene demands attentional, memorial, and informational processing. That is, cognition plays a major role in auditory scene analysis in any realistic acoustic environment. Many theorists also argue that cognitive processes play a role in forming or modulating the perceptual ability to determine the sources of sound. Sound source determination has only recently been recognized as an important element of auditory cognition in all acoustic settings. *Thinking in Sound* combines work on sound source determination and knowledge in the more traditional areas of auditory processing to form the beginnings of a unified view of auditory cognition.

Most of the book follows a traditional "bottom-up" path to cognitive processing, starting with perception and ending with recognition. Bregman describes his view of auditory perception in a synopsis of his recent book *Auditory Scene Analysis* (MIT Press, 1990), outlining some postulates of perceptual regularities that govern the temporal (sequential) and spectral (simultaneous) organization of sensory information required for auditory perception. Warren continues the discussion of auditory perception, concentrating on temporal organization. Jones and Yee address theories of selective and divided attention to scenes of auditory events. Auditory memory is discussed by Crowder, and theoretical and empirical work on sound source recognition is described by McAdams. The remaining three chapters deal with auditory cognition in three special situations. Peretz describes many clinical cases of auditory agnosia—the inability to comprehend auditory input—and the insights into cognition that they have provided. The study of music has spawned many theories of auditory perception, and much of this work is reviewed by Bigand. In the final chapter, Trehub and Trainor describe the development of auditory processing of complex (especially nonspeech) sounds in infants and children.

Almost every contributor to this book wrestles with basic terminology, revealing that the field of auditory cognition is still in its infancy. The glossary at the end of the book is helpful in this regard, but it does not contain terms such as "object," "event," "entity," or "image," all of which are used (by different authors) to refer to the perceptual units on the basis of which the sources of sound are determined. Uni-