long-range predictions of rival hypotheses. For specialists and those developing a research interest in cooperative breeding it is indispensable. While there is much of interest to general ornithologists, sociobiologists, behavioral ecologists, and evolutionary biologists, not all of these may wish to read each data-rich chapter. It is thus unfortunate that there are no summaries for individual chapters. However, each chapter is subsectioned in detail, and the overall introduction by Stacey and Koenig and the summary by Smith point the way to studies that may be of particular interest to non-specialists.

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Caste Systems

Social Insects. An Evolutionary Approach to Castes and Reproduction. WOLF ENGELS, Ed. Springer-Verlag, New York, 1990. vi, 265 pp., illus. $52.40.

The castes of social insects provide a challenge to biologists at two levels of analysis: Why did they evolve, and how is a developing insect channeled into becoming a sterile worker or a reproductive queen? This volume describes advances in our knowledge of caste formation that have occurred in the 19 years since the publication of E. O. Wilson's classic *The Insect Societies*. The 13 authors, only one of whom is a North American, bring a decidedly European view. All groups of social insects are represented in the volume, and the literature reviewed is both extensive and up to date.

The emphasis is functional. The interplay of nutrition, hormones (especially juvenile hormone), and behavioral dominance in determining the fate of a developing social insect is presented in detail. Considerable information is also presented on the diversity of caste systems occurring in termites, ants, wasps, and bees. The resulting picture is more complex and interesting than the rather simple paradigm that has been adopted by most modelers of social evolution.

Especially noteworthy are the chapters by Michener on halictine (sweat) bees and xylocopine (carpenter) bees. Michener presents a new caste terminology for sweat bees, summarizes recent findings in reproduction and caste determination, and convincingly argues for multiple origins of true sociality within the Halictinae and the need to study variation among and within populations. He characterizes carpenter bees by their long adult life and their tendencies for extended parental care, mutual tolerance, and partial reproductive division of labor. This has led to the frequent evolution of facultative castes rather than true sociality in the Xylocopinae.

Engels and Imperatriz-Fonseca present a stimulating contrast between the reproductive strategies of meliponine (stingless) bees and honey bees, both based on advanced social colonies founded by swarms. Stingless bee workers are unmated but fertile, and they are responsible for a large proportion of the male offspring in a colony. Moreover, stingless bees are rarely completely monogynous, in contrast to honey bees.

The book does have its drawbacks. Bees are heavily emphasized (six of nine chapters), and termites and ants with their diverse caste systems are allocated only one short chapter each. Despite the book's subtitle, an evolutionary approach is nearly lacking in most chapters. Hypotheses concerning the evolution of castes from the viewpoints of inclusive fitness and the ecological costs and benefits of reproductive altruism are given brief mention at best. The authors generally do not recognize that patterns of evolution of social behavior can be best hypothesized by phylogenetic analysis of non-behavioral characters. The book is poorly edited for grammar, especially the contributions from authors whose native language is not English. A summary chapter should have been included to synthesize the diverse caste systems of the different taxonomic groups.

Nevertheless, this book presents a wealth of information on caste formation and reproduction in social insects that would otherwise be overlooked. It is a valuable building block for future research from a more evolutionary viewpoint.

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Physiological Darwinism

Nature as the Laboratory. Darwinian Plant Ecology in the German Empire, 1880–1900. EUGENE CITTADINO. Cambridge University Press, New York, 1990. xii, 199 pp., illus. $44.50.

In 20th-century America, we do not usually think of physiology as a field with much potential for Darwinian theorizing. Darwinism belongs to systematics, population genetics, ethology, and other related branches of outdoor biology, not to the laboratory-bound study of organic functioning; and it is hard to imagine that anyone might have ever thought otherwise. However, as Eugene Cittadino reveals in *Nature as the Laboratory*, some people have indeed thought otherwise: in the late 19th century, a whole school of German botanists once set out to interpret plant structures as physiological adaptations to the external environment, established and maintained through the action of natural selection.

Simon Schwendener, who initiated this movement with his book *Das mechanische Princip im anatomischen Bau der Monocotylen* (1874) and who trained or supervised many of its practitioners, was not himself a Darwinist. He was simply interested in applying mechanical principles to anatomical structures. However, his more radical follower, Gottlieb Haberlandt, who had a special interest in tissues engaged in photosynthesis, argued that the forms he studied were adaptations to the external environment. Haberlandt initially encountered strong criticism from scientists steeped in the morphological traditions of German botany, who considered structure and function as essentially unrelated phenomena and who insisted that trying to *explain* morphological forms was to speculate beyond the bounds of empirical science. Haberlandt countered that Darwinian theory justified his seemingly teleological assertions: natural selection had divised increasingly complex mechanisms for effecting photosynthesis and other processes as evolution proceeded.

Despite the criticism, Haberlandt soon convinced other botanists to investigate the adaptive significance of anatomical features, and many of them set out to test their assumptions in a variety of environmental settings. Georg Volkens studied transpiration in the deserts of Egypt and Arabia. An enthusiastic imperialist, he later conducted botanical expeditions to the new German colonies of East Africa, the Caroline, Mariana, and Marshall islands of the Pacific, and North East New Guinea. Haberlandt and Ernst Stahl separately worked at the Dutch experimental station established by Melchior Treub in Java. Heinrich Schenck and A. F. W. Schimper spent time working with the Darwinian naturalist Fritz Müller at his home in southern Brazil. The tropics held a special interest for all these investigators, since they assumed that most plants had originally evolved there. Temperate and arctic forms were simply specialized survivors that managed to adapt to the less favorable conditions further north.

According to Cittadino, these late-19th-century Darwinists had their greatest influence on the nascent science of ecology. He acknowledges that 20th-century ecology has been primarily concerned with the study of plant associations, not individual adaptation

to the environment. However, he points to a continuing tradition of interest in physiological ecology, especially on the part of Germans like Hans Fitting and Heinrich Walter.

From a historical perspective, I think the early German ecologists were important quite apart from their modest subsequent influence. Looking back to the past, we find it very easy to assume that the appropriate linkages among ideas have always been the ones we share today, but Cittadino's book warns us that the Darwinism we know is not necessarily the one people have always known. Some historians have recently argued that real Darwinism hardly existed in late-19th-century Germany. In all likelihood, they were simply looking for the wrong kind of Darwinist. As Cittadino so ably shows, the physiological ecologists developed their own brand of Darwinism—as authentic and distinctive as any other.

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Waging Geology

The Highlands Controversy. Constructing Geological Knowledge Through Fieldwork in Nineteenth-Century Britain. DAVID R. OLDROYD. University of Chicago Press, Chicago, 1990. x, 438 pp., illus., + plates. $65; paper, $29.95. Science and Its Conceptual Foundations.

The Highlands controversy was one of a series of 19th-century debates about how the stratigraphic succession of the British Isles should be unraveled. Because British geologists were pioneers in the study of stratigraphy, the debates involved questions about stratigraphic methodology as well as about the nature of the succession, and, moreover, the divisions of the stratigraphic column that resulted had a significance that extended well beyond the boundaries of Britain. Roderick Murchison, intensely ambitious and always ready to extend his own stratigraphic empire, was at the center of three of the most prolonged struggles. The first was over the interpretation of certain rocks in Devon in southwest England: Murchison, arguing for a "Devonian system" with characteristic fossils, prevailed over the first director of the Geological Survey, Henry de la Beche, albeit having had to modify his initial stand in significant ways. The second was about whether certain Welsh strata should be included in the Silurian system, as Murchison insisted, or in the Cambrian system, as Adam Sedgwick contended. This was eventually resolved by the acceptance of Charles Lapworth's proposed new intermediate system, the Ordovician, but not before the two erstwhile friends had turned into bitter enemies. We have excellent treatments of these two controversies by Martin Rudwick, *The Great Devonian Controversy* (University of Chicago Press, 1985), and James Secord, *Controversy in Victorian Geology* (Princeton University Press, 1986).

Now in a third book, beautifully produced by the University of Chicago Press, David Oldroyd gives a lucid and scholarly account of the third controversy. Murchison postulated that the strata of Scotland ascended in a regular sequence from the Fundamental Gneiss of the Hebrides and the northwest coast toward the east. James Nicol protested that this was not the case; instead, he argued, there was a huge fault running from the north coast through Skye. Archibald Geikie, the rising star of the Geological Survey, entered the fray on Murchison's side but was gradually forced to change his mind as a third alternative was developed by amateurs such as Charles Callaway and Charles Lapworth. Eventually consensus was reached that the complex geology of the Highlands was the result of low-angle thrusting and related metamorphism caused by forces acting from the southeast. Oldroyd's recounting of the story is charmingly enlivened by his obvious love of the countryside over which he tramped in the footsteps of Geikie and Lapworth and Callaway.

But the authors of these three volumes see them as more than simply contributions to the history of geology; they also see them as contributions to the study of science more broadly conceived. Indeed, a colleague once remarked to me that he hoped that studies of 19th-century stratigraphic controversies might serve as a base for working out some of the basic conceptual frameworks of science studies in this decade just as studies of puritanism and science had done in the 1960s. In particular, these three authors see their work as contributions to the study of scientific controversy, a topic that has been at the center of recent research in the history, philosophy, and sociology of science. To the dismay of their non-relativist colleagues, relativists have argued that the resolution of controversy depends on social, not cognitive, factors. These three studies present a remarkable and relevant data base for adjudicating the issue. Like Rudwick and Secord, Oldroyd is meticulous in his use of sources and admirably clear in his final analytic chapter. Like them, he concludes that geological knowledge was socially constructed. But again like them, he draws back from the extreme claims of some sociologists of knowledge and maintains that although evidence did not perhaps fully determine the outcome of the controversy, evidence *did* constrain the knowledge that was produced. Hence these three historians have reached consensus that both social and cognitive factors contributed to the closure of controversies. Whether this mediating consensus, based on one subdiscipline in one country in one century, will bring to closure the controversy about controversy in history, philosophy, and sociology of science only time will tell.

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Some Other Books of Interest

Trends in Theoretical Physics. Vol. 1. P. J. ELLIS and Y. C. TANG, Eds. Addison-Wesley, Redwood City, CA, 1990. xvi, 412 pp., illus. $49.50.

Upon its establishment in 1987 the Theoretical Physics Institute at the University of Minnesota developed as part of its program a colloquium series in which distinguished speakers would present overviews of a wide range of topics in the field. Prompted in part by the consideration that "there seems to be no journal which deals with the whole field of theoretical physics at a level accessible to the non-specialist," the organizers have in this volume brought together the results of the first (1988–89) series of lectures. Two of the lectures deal with subjects in astronomy—G. E. Brown on information provided by Supernova 1987A (Shelton) about the equation of state of nuclear matter at high densities and M. Ruderman on the search for gamma rays from stars. Representing plasma and condensed matter physics are lectures by D. Montgomery on relaxed states in driven, dissipative magnetohydrodynamics and C. M. Varma on the heavy fermion problem. Quantum gravity and string theory are assessed by S. Deser and D. J. Gross respectively. Other lectures deal with the non-relativistic description of the three-nucleon system (F. S. Levin), detection of the quark-gluon plasma (G. Bertsch), the standard model in elementary particle physics (M. K. Gaillard), tunneling in many-fermion systems (J. W. Negele), quantum mechanics and macroscopic realism (A. J. Leggett), quantum chromodynamics (S. J. Brodsky), and electroweak interactions with nuclei (J. Walecka). The lectures vary in degree of technicality, but the "non-specialists" to whom they are addressed are clearly physicists rather than lay persons. A second volume in the series is planned.—**K.L.**