

micrographs of minute external structures coupled with CT scans of insect tracheal systems offer glimpses into the complexity of these amazing animals. Philatelists will recognize Igor Siwanowicz's stellar image of a male diving beetle's front foot recently issued as a postage stamp. Usually wedged into this section, the topic of Wings and Flight stands alone as its own chapter. Unlike those of vertebrates that evolved from forelimbs, insect wings likely evolved from tissues atop and along the sides of the thorax. Wing modifications, the power of flight and the opportunities it provides, plus the nonflying roles that wings play in insect courtship and defense are reviewed.

Sumptuously illustrated, *Development, Metamorphosis and Growth* includes essays on insect life cycles, chromosome structure and sex determination, modes of sexual and asexual reproduction, courtship and mating, egg structure and development, egg laying, metamorphosis and its regulation via hormones, and growth. The chapter *Natural History* is a colorful exploration of the dominance of insects in terrestrial ecosystems, although several pages are dedicated to aquatic species and their adaptations. Predators, parasitoids, and parasites are given their due. Sociality among insects is traced from basic parental care bestowed by lone females to the complex caste systems of truly social termites, ants, bees, and wasps. Insect-plant interactions are examined, a relationship between two supergroups of organisms that extends back more than 400 million years. Impacts on Humans and the Environment considers insects as crop pollinators and pests, vectors of disease-causing agents, and our efforts to control them. Attention is paid to those species that serve as model organisms in biomedical and evolutionary research. The last pages offer sobering assessments of insect population declines worldwide due to habitat loss, biocides, climate change, and invasive species.

As an entomologist and author, I have a deep appreciation for the challenges faced by those who tackle a broad and complex subject such as insects and distill it to a popular audience. The authors have done a superb job in striking just the right balance of natural history and science with prose infused with their passion for all things insect. *The Complete Insect* will appeal to entomologists keen to share insects with family and friends, as well as anyone interested in learning more about the world's largest and most diverse group of animals.

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WHAT A BEE KNOWS: EXPLORING THE THOUGHTS, MEMORIES, AND PERSONALITIES OF BEES.

By Stephen Buchmann. Washington (DC): Island Press. \$30.00. xviii + 278 p.; ill.; index. ISBN: 9781642831245. 2023.

As the title says, this volume is about bees. But unlike most bee books, this one was written by a pollination ecologist who knows bees as much as plants, and this makes a difference. Stephen Buchmann takes us on a fascinating journey into the recent discoveries in bee behavior and cognition, and explains how the surprisingly sophisticated inner life of bees help them better interact with their environment. Although many authors (including myself) would probably have focused their volume on the well-studied honey bees and bumblebees, Buchmann treats rightly bees as a large and diverse group of insects. He reminds us that many of them are single moms. Some, like the cactus bees, have weird sexual habits. Not to mention the vulture bees that unusually prefer meat over pollen.

This is an entertaining book written by a trained storyteller. The author regularly takes us into his favorite work place, the Sonoran Desert of southern Arizona, where he observes and studies various kinds of bees. I was delighted, for instance, to hear about his early experiments on bee vision and UV perception. Lots of glue gun, cardboard sheets, plastic bits, and duct tape.

But this is also the work of a trained professor. University students will learn about many key concepts in ecology and evolution, such as sexual selection and the arms race that shape plant-pollinator interactions. In the first chapters, Buchmann describes "what we know a bee knows," with textbook knowledge about their everyday lives, social activities, perception of the world, how they choose plants, and how they mate. But as the book progresses, he discusses "what we are not completely sure a bee knows." He describes recent studies suggesting more sophisticated cognitive abilities, emotions, pain, and the possibility of consciousness. All of these discoveries are changing our perception of insects, as more complex creatures than previously thought and that we probably need to treat differently. Buchmann himself explains how he very much prefers observing live bees in the field rather than dead pinned specimens.

The volume ends with some considerations about bee declines that the author started to document in the mid-1990s. Sadly, since then things have only gotten worse. We can all individually take actions to support and protect pollinators. But perhaps the most powerful thing we can do is to encourage this book be read by the broadest possible audience, so that people, just like Buchmann, realize how

human bees are and how much we need to care about them.

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THE FORAGING BEHAVIOR OF THE HONEY BEE (*APIS MELLIFERA*, L.).

Edited by John Purdy. Academic Press. Amsterdam (The Netherlands) and New York: Elsevier. \$127.50 (paper). ix + 222 p.; ill.; index. ISBN: 978-0-323-91793-3. 2024.

This is an edited volume of nine chapters written by 13 academic, government, and independent contributors from four countries (United States, Canada, France, and Israel). The chapters are of somewhat uneven quality and coverage. The book is meant to be an introduction to the foraging ecology of the world's dominant pollinating insect, the western honey bee at the level of university students and faculty.

Foraging ecology is the behavior of individuals and bee colonies flying out several kilometers from the nest, as recruited worker bees return with pollen, nectar, water, and plant resins. The introductory chapter is especially good, covering topics of bee evolutionary origins, the 11 *Apis* species, along with the regulation of foraging activity, division of labor, nutrition, cognition, motivation, memory, and other topics. That chapter includes an especially complete illustration and table detailing important clades from the ancestral Hymenoptera, through the origin of true bees from ammoplanine (thrips hunting) wasps, and up to the groups within the family Apidae, tribe Apini, and species of the largely paleotropical honey bee genus *Apis*. Geological time estimates, and supporting references, are given for these evolutionary changes that are rarely presented in other volumes on honey bees and their biology. Interestingly, there was no mention of the extinct fossil honey bee *A. nearctica* (described in 2009) from the middle Miocene of Nevada, an exception to often touted generality that honey bees only evolved in the Old World.

The following chapters cover topics that include adaptations for foraging, social foraging, navigation (including cognition, learning, and memory), foraging energetics, pollination ecology, simulation modeling, managing honey bees for commercial pollination, and a final chapter on knowledge gaps and future directions for honey bee research. Chapter 7 (by Purdy and Drummond) on heuristic and metaheuristic simulation models (especially blueberry crops) for studying honey bee foraging is especially good. Another excellent discussion is Chapter 6 on pollination ecology by Brunet and Minahan. I was, however, disappointed to find a very short

summary chapter almost completely lacking in looking ahead to new technologies for monitoring bee foraging in nature. Even old but innovative technology, such as ferrous thoracic labels and hive recovery magnets (N. E. Gary) was not mentioned. Further, there was nothing about some very exciting newer bee tracking devices or methods, including X-band harmonic radar units, RFID tags, quantum dots, or the use of drones (unmanned aerial vehicles; UAVs) to track flying bees in real time, just to mention a few. Perhaps there should have been an additional chapter devoted solely to the methodology of studying foraging bees. Regrettably, and in typical fashion for this publisher, we find a high price for a paperback book of only 200 pages. This simple fact will keep the volume out of the hands of its main intended audience, including university students and hobbyist beekeepers.

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COMMON BEES OF WESTERN NORTH AMERICA. *Princeton Field Guides.*

By Olivia Messinger Carril and Joseph S. Wilson. Princeton (New Jersey): Princeton University Press. \$35.00 (paper). 415 p.; ill.; index. ISBN: 9780691175508 (pb); 9780691249438 (eb). 2023.

THE JEWEL BOX: HOW MOTHS ILLUMINATE NATURE'S HIDDEN RULES.

By Tim Blackburn. Washington (DC): Island Press. \$30.00. ix + 277 p.; ill.; index. ISBN: 9781642832730. 2023.

A few decades ago we used to have outbreaks of miller moths at the Rocky Mountain Biological Laboratory, and biologists would wield their butterfly nets indoors instead of outdoors to capture the multitude of moths in the old cabins. But such outbreaks no longer occur and, anecdotally, the moths on windows at night have declined. Despite the multitude of ecological studies of butterflies at that field station, moths have been unstudied, so we do not know the reasons for the decline. So, I was intrigued by the title of this book, hoping to learn more about moths.

The author (a professor of invasion biology) describes how he received a moth trap for his birthday in 2018, which he used on his London roof terrace, and subsequently in more rural areas. The diversity and abundance of moths he trapped and identified provide the basis for this wide-ranging book. "My questions about moths need answers that reach from a morning on my roof terrace to embrace the complete geography and history of life as we know it" (p. 230). He uses the biology of the many moths