tive to behave in the sauna like in a church. As a kid, it made her think of a congregation all naked but for hats, listening to a naked preacher. Now she thought to cover up to go in.

Truly, the main character is the Bee Club, and it has a multiple personality of its own. The theme of cooperation runs through the story despite the club's every effort to not cooperate; each beekeeper has their own ideas about what it even means to be a beekeeper. The other main theme is that of endless struggle. The players struggle to help each other, to keep their bees well and alive, and they struggle to make ends meet. I think many readers will find much familiar as well as amusing.

One thing that made me smile is the scene where "Anjela Novak, Extension Apiarist at the University of California, Davis," gives a presentation to the Bee Club. She begins:

"Our bees are failing, you all know that. For the last six years we've lost around 40% a year nationally." She pointed a clicker and a chart flashed on the screen. "Yeah, and what are you doing about it?" hollered a guy from the back.

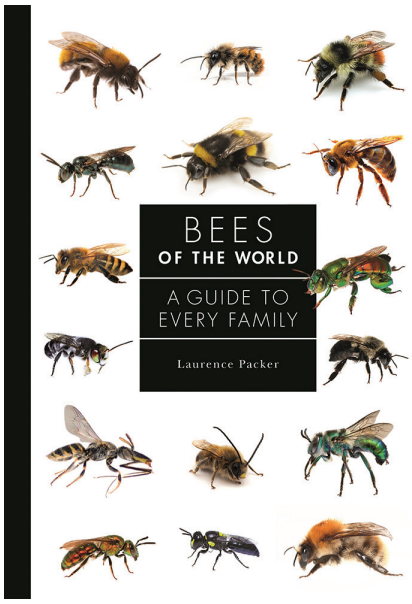
I chuckled and thought "And they call us New Yorkers rude. We would never do that." Anyway, it's touches like that that make the story fun and believable. I am not about to give away any plot twists, but there are plenty, and enough characters that you may see yourself among them. If you like fiction and beekeeping, this is one for you.

BEES OF THE WORLD; A GUIDE TO EVERY FAMILY

by Laurence Packer
Published by Princeton University Press, 2022
ISBN 13: 978 0 691226 62 0
240 pages, $25.99 hardcover (Amazon)

Reviewed by M.E.A. McNeil

This book and the next are extraordinary in their own way, and they merit separate reviews. But both offer a window onto a growing appre-



Jerry Draper

hension over the survival of all bees. And some proponents of native bees are concerned about negative effects from honey bees, a subject to be explored later in this issue. [See "The Alien Honey Bee: What we know about its threat to native pollinators."]

"Bees of the World" is beautiful — a love tome to native bees by Laurence Packer, Professor of Melittology (the study of wild bees) at York University in Toronto. He is founder of the Packer Lab at York, a global center for melittological research, and he is a foremost authority. The pages are illustrated with extraordinary, and often rare, full-page photographs of the bees in their natural habitats, and a world map appears with each entry, highlighting their distribution.

Packer posits that our western honey bee (*Apis mellifera*) is just one among thousands of different species of bees,

The book "Bees of the World" open to the image of a male iridescent cuckoo orchid bee, Exaerete. Males collect fragrances and store them in their hind tibiae. The females lay their eggs in a host brood cell, kill the host egg and reseal the cell. As the small map indicates, the bees are found from Mexico to South America.

and its complex society and longevity are mostly atypical of the rest.

He describes the evolution of bees from tiny thrips-hunting wasps over 100 million years ago. Clearly, he observes, the change to a vegetarian diet, nectar and pollen, was advantageous, since, with the same length of time to diversify, there are fewer than 200 wasp species among the closest relatives but over 20,500 bee species.

Because of their shared evolutionary history, some bees resemble wasps and some wasps look like bees. And so many other insects look like bees, the author remarks, that books on bees have been mistakenly published with mimicking insects on their covers. How does one tell the difference? In short, any insect that is collecting pollen and storing it on their legs or underneath their abdomen is a bee — that is unless it is a male, one of the bees that stores pollen in its digestive system, or a cuckoo bee that leaves its young to be fed by a host species. To have the answer by the short hairs, so to speak, the presence of branched hairs confirms that an insect is a bee. All bees have such hairs, but finding them on some is another mission, since they can be hard to see, even with a microscope.

Then there is the problem of how to tell bee from bee. Packer says, "The answer is not very satisfying." He gets down to taxonomy, but "irritatingly, there are a few exceptions." The book describes and illustrates 104 of the over 500 genera of bees. What is unusual is that he groups them by family, a level of identification that he calls "often the most difficult step," and the reason why typical native bee guides cover limited geographic areas and skip the family level, taking the user straight to the genus.

A sense of humor, familiar to those who know Packer, surfaces occasionally in the narrative: "As usual when experts are involved, bee classification can be a controversial topic." His history of division is interesting in itself. To consider the disputed number of bee families, he follows the American melittologist Charles Michener (1918-2015) who had "in his prodigious memory a larger proportion of humanity's entire knowledge of bees that anyone else will ever possess."

Packer writes, "The most fundamental of these groups are the seven families, and to understand how the experts divide them up we need to pay attention to bee mouthparts and pollen collecting structures." The

reader is offered tutelage through illustrations labeled with terms used frequently in the book to differentiate the biology of bees. By the end of his detailed anatomical explanation, he writes, "By now you may have given up on becoming a bee taxonomist. Please don't; it is a great deal of fun and, in general, is easier to learn the overall appearance of the group of bees than it is to identify them by dissecting their mouthparts. Finding out which family a bee belongs to is often the most difficult step in identification in the earlier stages of someone's bee obsession. Indeed … you will find plenty of examples of completely unrelated bees that look, superficially at least, more similar to one another than to their close relatives."

At this point, the reader may do well enough to turn to the different behaviors, life cycles and habitats of the bees, whatever their doppelgangers. Honey bees have social lives with varying degrees of complexity, communication skills and longevity. The bumble bees are also social, starting in spring with a lone queen emerging from underground hibernation to raise a nest of workers, which in turn nurture more workers. Later in the summer, males and the next year's queens are produced.

Some other bees cohabitate in a common nest with each female laying eggs on the pollen ball in her own brood cell, sharing only the nest entrance. Most other bees live a solitary existence, inhabiting underground tunnels, cavities, plant materials or surfaces — interacting with others of their species only for mating and perhaps fighting over nest ownership. The largest bee makes nests out of resin constructed inside the nests of arboreal termites. And then there are those that have it all done for them; about 15 percent of all bee species lay their eggs in the nests made by other bees, and another over 50 species are parasites living off of social bees.

The book pictures bees that are remarkably diverse in appearance. They come in all colors, some luminescent, as well as black and white. Some appear bald or are striped. The shapes range from long and slender to nearly spherical. The smallest are less than 1/16 inch (2 mm) in length, like the fairy bee, *Perdita minima,* native to North America, and some species of stingless honey bees live inside a nest the size of a walnut with perhaps 600 social individuals. Packer has some fun with a composite photo, placing a fairy bee onto the antenna of a very large bee (*Xylocopa* sp., 1.5 in/38mm long). Surprisingly, some of the heaviest bees are some bumble bee queens.

Packer describes most bees as mass provisioners, meaning that all the food required for the development of the larva is gathered before the egg is laid; it's like "collecting 18 years' worth of groceries, piling them inside the room, giving birth and then leaving your child to develop alone." Nearly all bees use pollen as the major source of protein for their brood, with much of the nutrition coming from microbes growing on the pollen and nectar mixture. But the tropical western-hemisphere stingless bee, *Trigona*, feeds on carrion, and at least three species in tropical Asia obtain the proteins they need from the antibacterial enzymes in the tears of vertebrates. When the Swiss entomologist Hans Bänziger studied the attraction of these bees to his own eyes, he marked them with tiny dots of paint and found that they returned up to 144 times to feed from his eyes in a single day. In addition, 16 species of bees found throughout the northern hemisphere forage on floral oils instead of nectar.

For the multitude of differences among them, bees have much in common with all insects. The egg-laying female lays an unfertilized egg for a male or fertilized egg for a female. The shedding of the larval exoskeleton, Packer writes, is "akin to needing only five sets of clothes from birth to adulthood as bee larvae must change their skins."

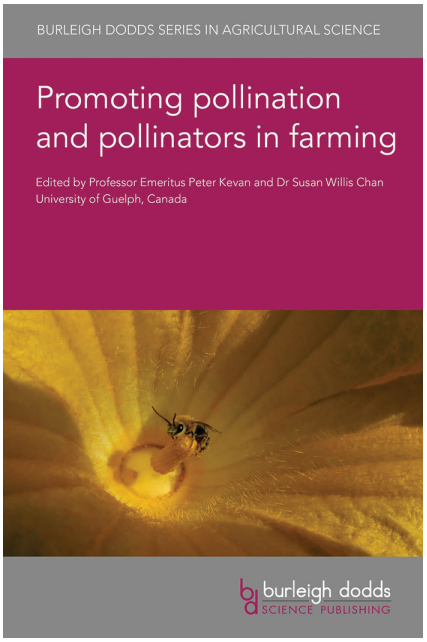
This book is worth adding to a bee library for the wonder of the photos and its depth of information.

PROMOTING POLLINATION AND POLLINATORS IN FARMING

Edited by emeritus Prof. Peter Kevan and Dr. D. Susan Willis Chan
Published by Burleigh Dodds Science Publishing, Cambridge, UK, 2023
ISBN 13: 978 1 801460 98 9
414 pages, $164.91 hardcover (Amazon)

Reviewed by M.E.A. NcNeil

This comprehensive book is a collection of writings by researchers in the area of crop pollination, bee ecology and pathology. They are from seven American universities plus the USDA, from Great Britain including one from Bayer, as well as from Canadian, French, Belgian, Australian and Tanzanian universities. As scientists, they follow each statement in the text with a reference, often on every line. Within the chapters, sections and case studies are numbered and titled. Every page is a dive into a subject, with almost every line a reference to a deeper dive, and the reader is directed at the end of each chapter to even further information, followed by an exhaustive list of references. A review can't as much gloss over the contents as present a quilt of its offerings.



It doesn't matter for the curious that the style is science-write: In this age of alternative facts, the presentation of collected data here is fascinating, informative and doesn't boast of final certainty. The language, depending on the writer (there are 29 of them), is often expanded with vocabulary accessible to the layperson followed by a scientific term — but the styles vary.

The book begins with a history of the ecology and evolution of floral traits. It is likely that insects have been pollinating gymnosperms (seeds dispersed without a protective casing) since before angiosperms (seeds encased in an ovary which forms a fruit) were prevalent. That speculation is bolstered by finds of numerous amber-imbedded insects with specialized pollen-collecting mouthparts, most with gymnosperm pollen on their bodies.

A few hundred million years later,

humans took note. The Romans and Greeks were aware that there were male and female date palms, but it was not until the 18th century that it was accepted that insect vectors transport pollen to effect pollination. Darwin wrote that variety was needed to attract different kinds of pollinating insects, and even predicted the appearance of an unknown orchid pollinator discovered after his death. In the 20th century with the advent of genetics, the study of pollination shifted to molecular mechanisms.

The book reports that up to 95 percent of all flowering plants require the services of other organisms to move pollen from male to female flower parts. A valuable primer on pollination begins with a description of the mechanisms that drive it, covering the floral adaptations of plants, the diversity of animals that pollinate and the evolution of plant-pollinator relationships. Pollen production from meiosis to fertilization is explained and the need for outcrossing is emphasized with an 1877 quote from Darwin, "nature abhors perpetual self-fertilization" — which creates inbreeding depression. It is explained that the anti-selfing mechanisms of separation of pollen and stigma can occur spatially, where the anthers and stigma are separated (herkogamy), or with spatio-temporal separation, where the anthers mature outside the receptive time period of the stigma (dichogamy).

The diversity of pollinators ranges from butterflies, flies, moths, bees, beetles, birds, mammals, reptiles and crustaceans to marine worms. For example, bat pollinators contribute to the pollination of 67 flowering plant families.

Mechanisms that contribute to the interactions of pollination systems are explored, both for the science and for the corresponding crop value. An example is how flowers produce odors primarily to communicate with pollinators for fruit and seed set and how pollinators detect them with their antennae. Floral odor can select for specific pollinators or deter herbivores. A table in the book outlines a dozen floral odor compounds and the crops related to them; for example, geraniol, a terpenoid, is found in blueberries.

A section of the book is dedicated to threats to pollinators — a list familiar to beekeepers. To be fair, the many contributors do not speak with one voice, but all express deep concern when they address the perilousness of the situation. They don't hesitate to call the current epic anthropogenic — human-compelled. Contributor Stephen Buchmann, a native bee expert from the University of Arizona, refers to our present era as in the "sixth mass extinction"— so called because of the rapid loss of biodiversity with an "especially alarming loss of invertebrates."

The differences among writers are of degree, with for some, the most serious threats being habitat loss and disease. For another it is climate change: "Impacts on pollination can be dire," writes an Australian researcher, with mismatches in phenology among the negative effects — "wrong place, wrong time," as temperatures affect forage. Packer writes in "Bees of the World" that "bumble bees are losing their southern ranges but not compensating by expanding northward."

Chemical exposure is also a key problem. For the effect of neonicotinoids on bees, multiple references are cited with negative impacts detected across generations — on gene expression, learning, locomotion, memory, foraging, hygienic behavior, queen viability, reproduction, growth, nest initiating, colony establishment, population stability, crop pollination. A meta-analysis addresses sublethal effects on non-*Apis* bees.

A comparison of safety phrases on product labels from different countries reveals a contrast: One chemical is forbidden from application during bloom in the EU but permitted in Australia, New Zealand and the U.S. if it dries for three hours.

In a chapter on best management practices for pollinator protection, the writers warn that the use of agrochemicals needs to be reduced to keep "the agro-eco system from functioning as a population sink." Integrated pest management (IPM) strategies and holistic approaches are recommended, but there are no more specific mandates: "Altering economic managing practices is challenging and poses more questions than we currently have answers to."

One intriguing answer, for U.S. apple production, comes from a team of researchers from six American universities and the Northwest Horticultural Council. Managed species such as honey bees, bumble bees and mason bees are used, as well as the Japanese orchard bee, *Osima cornifrons*, introduced for apple pollination by the USDA. They report that most bee species visiting orchards in bloom are native, with over 50 recorded in North American apple orchards. In fact, surveys in New York and Pennsylvania in 2017 showed that wild bees could often provide all of the pollination needs for apple orchards when present in the surrounding landscape.

In a side note, beekeepers have welcomed the need for less density of their colonies in self-fertile almonds, because it contributes to their well-being.

An intriguing chapter by researchers from two Belgian universities is dedicated to entomovectoring, the use of pollinators to spread biological control agents (BCAs). The writers propose that the practice fits the ecological goals of the European Green Deal, in which the European Commission aims to reduce net greenhouse gas emissions by at least 55 percent by 2030. The concept is simple: Just as bees can carry small particles of pollen from plant to plant, they can also transport microorganisms. Honey bees, bumble bees and even native bees are now being tested to disseminate various powdery BCA formulations, including viruses, bacteria and fungi. The writers cite an advantage over conventional applications, such as spraying, because the application is applied through the open flower and not to the surrounding plant tissue or soil. Also, each flower receives multiple visits for continuous application.

Honey bees and bumble bees are most often used for entomovectoring. An example cited is the successful application of the biological pest control *Clonostachys rosea* to tomato and pepper plants by the bumble bee *Bombus impatiens*. Failed attempts to create dispensers were made starting in the 1950s, and it was not until 1992 that a device was invented for honey bees to pick up a biocontrol to combat a strawberry plant fungus. Some nests for solitary bees have been developed for the bees to pass through powdery BCA formulations as well.

The price of this book may preclude the casual purchase, but it is carefully edited and would be a valuable addition to a reference library.

One more concern is mentioned in this and the previous book, the interrelationship of managed honey bees with native bees. An article in this issue, "The Alien Honey Bee: What we know about it's threat to native pollinators," addresses what has become, for some, a contentious issue.