Two New Bee Books
Reviewed by M.E.A. McNeil

The bees are in their winter cluster, leaving the beekeeper to settle down with some good reading. A review of two new bee books finds that they each enhance the other.

Bees, Biology and Management, Peter G. Kevan, Enviroquest Ltd, Canada, 2007.

This book brings to mind the old Willie Dixon tune "You Can't Tell a Book by its Cover": "I look like a farmer, but I'm a lover." Well, this looks like a text book -- with black and white charts, drawings and diagrams. (Right off, on the title page the reader is left to puzzle out what an Anthecology Department does.) But plain and academic as it looks, the book reads like the work of a bee lover. No one not enamored could write such caring biologic descriptions of twelve different kinds of sensory hairs on the bee or the tongue lengths among the eight races of *Apis mellifera*.

Developed from a course taught since 1893 at Guelph University, Ontario, Canada, the book clearly describes bee anatomy, physiology, and behavior in relation to anthecology – the study of pollination. There is a sub-text of wonder throughout the biology section, which encompasses most of the book. Occasional exclamation points dot the text, with the writer's astonishment poking through – such as the observation that the wings are outgrowths of the body wall (!). You can hear him saying, "Amazing, eh?" Even so, his superlatives are spare, making "most" or "best" herald a solid scientific fact, and he is not shy of labeling conjecture. Even so, his superlatives are spare, making "most" or "best" herald a solid scientific fact, and he is not shy of labeling conjecture.

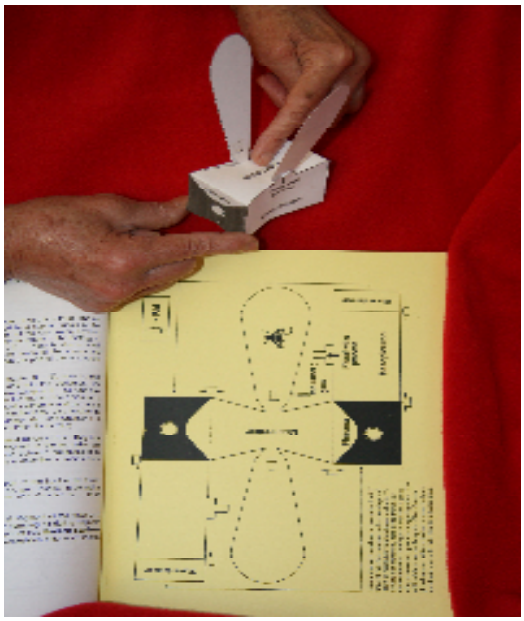

Photo: Jerry Draper

A constructed cutout pattern in the Kevan book illustrates the way wing muscles interact.

As to the twelve types of sensory apparatus, Kevan describes mechanoreceptive and chemoreceptive sensilla all over the bee exoskeleton, with about 40,000 on each antenna. These specialized microscopic structures, made of thin cuticle, interact on a molecular level with the environment in a kind of key and lock relationship that produces a nervous impulse. Responding neurons are variously sensitive to touch, strain, gravity, movement, flight speed, energy expenditure, or temperature. Some specifically sense humidity and carbon dioxide.

The chemical signals go both ways, and Kevan counts at least 36 pheromones produced by bees – infochemicals that convey information among bees in their chemosocial life style. He charts the producing glands and their functions: for example, the Nasinov gland excretes seven pheromones, recognized as particular to a colony, that promote nest and nest-mate recognition as well as orientation during swarming. The queen produces a multi-glandular pheromone blend of at least nine compounds, the most complex pheromone blend known in any organism for inducing a single behavior -- retinue attraction. Drones secrete a drone attracting pheromone.

Electrochemical signals travel along the nerve cells as they "fire" and transmit impulses, which jump from nerve cell to nerve cell via synapses. They are controlled by enzymes, and, bringing the description up short, we learn that most pesticides destroy these enzymes. Without the regulation of this enzymatic activity, the membrane is overly stimulated, causing death by nervous exhaustion.

To the now familiar list of problems for bees, Kevan adds the possibility of toxicity of almond pollen. Although he does not elaborate in the book, his lab work suggests that prolonged exposure to amygdalin, a toxic cyanoglycoside in almond nectar and pollen, could possibly be detrimental to honey bees' health.[1]

Kevan moves his text on by saying "the guts beckon". Indeed guts beckon only for those in rapt fascination with this anatomical tour, and by now, the reader is. The honey crop, we learn, folds when empty, but it can hold an additional 85% or so of the weight of the individual worker bee. A short, muscular organ, the proventriculus, acts as a valve into the main digestive organ, the ventriculus. "The proventriculus moves about in the honey stomach, somewhat like a stubby tentacle with an X-shaped opening between its thick, bristly and muscular lips. The special hairs on the ends of each of the four lips gather pollen and other particulates from the stored nectar and allow that to be passed back through this 'mouth' into the ventriculus." Science fiction does not get better.

Simple sugars can be transported across the wall of the ventriculus into the hemolymph (a clear liquid without red blood cells that carry oxygen in humans; it carries CO2 waste). The haemolymph bathes the organs in the head first, then flows back to the abdomen where it picks up nutrients. It is cleansed by the Malpighian tubules, functioning like floating kidneys in the haemolymph, cleaning up waste. The bee's rectum can expand to store an entire winter's waste.

His systematic description of this "natural structural engineering" brings Kevan to flight: "The machinery that the muscular engine operates is an amazing system of mechanical joints, springs, and boxes." His analogy for the coordinated muscular contractions that produce the up and down motion of the wings is a metal party clicker – stable when depressed and released. The mechanism is well illustrated with a cut-out model reproduced in the book, designed by the Smithsonian, which shows how the muscles work to raise and lower the wings. The actual motion of the wing is more like a figure 8, he adds. (The Tautz book expands on the use of these flight muscles for heating.)

The sound of the exploding endophallus of the drone when he mates with a queen prompts a brief departure from scientific description: "When he is to become a Pop, he pops." He then flips backward, is dragged through the air upside down by the flying queen and eventually falls to the ground leaving part of his genitalia behind.

Wonder after wonder of bioengineering is described: The stinger is a complex machinery of plates, hinges, springs and needles; 12 fanning bees can move about one liter of air through a hive in a second (60 l/ minute). Amazing, eh?

About twenty pages of the book are dedicated to a summary of bee management, and a similarly short section discusses wax, pollen, and honey. Why do bees store honey above the brood nest? The brood is warmed and the heat rises, keeping the honey from crystallizing. A section on products of the hive includes a curious addition: In some parts of the world, bee larvae are sold as a commodity to be eaten as a protein source. Brood ready to pupate is knocked out of the frames onto a tray to be eaten raw, fried or boiled -- providing nutrients similar to those in beef and soybeans. An acquired taste. The book concludes with a useful short section on native pollinators.

Brood picking brings to mind nit-picking, which is the purview of the reviewer. This book would benefit from careful editing; not all the cross references are accurate, but the bit of hunting required is not onerous. Some terms are not defined, and there is no glossary. In a photo showing the grafting of queens, the egg appears to have turned to larvae, which would make it too old (the voice of failure speaking here). A map showing "suggested" waves of bee migration out of Asia, long believed, is outdated by the data from the bee genome project tracing the origin of the honey bee to Africa.[2]

On the other hand, the book is ahead of the curve in warning of the ectoparasitic mite *Troilaelaps clarae*, a dangerous mite now on *Apis dorsata* in Asia. It jumps to *A. mellifera* with devastating effect where the two co-exist.

Read this book with this caveat: If you are not already a bee geek when you start, you will be one when you finish. Don't say you weren't warned. It is a treasure of a work.

The Buzz about Bees, Jürgen Tautz, photographs by Helen R. Heilman, translated by David. C. Sandeman, Springer, Berlin, 284 pages, $39.95.

This showy book might look like a slick city cousin next to the plain but substantive Kevan book, but the two are complementary – each filling out and extending the other.

And what a show the Tautz book is. The 200 color photos by Helen Heilman are superb in composition, clarity, and printing. That they don't merely decorate but illustrate the narrative puts them in a class by themselves.

Jürgen Tautz is a behavioral biologist at Germany's University of Würzburg in northern Bavaria. He heads the BEEgroup, a research team using high-tech tools -- from heat-sensitive cameras to tiny tracking devices -- to study honeybee biology.[3]

Photo: Helga Heilmann

A worker removes the mating sign from a newly mated queen, returned to the hive.

Tautz makes a convincing case that the honey bee colony is a superorganism with its own "almost eerie emergent group intelligence" -- functioning like a single creature. He takes an evolutionary point of view, going back to the primordial cell with its genome (hereditary material) in its nucleus. The cell self-replicates, perpetuating its genome immortally. It joins with supportive but non-replicating cells to form multicellular organisms that are the vehicle for the genome. The bee colony can be seen as evolving in the same way – with the queen and drones passing down the genes and the workers as the support organs providing nourishment and maintenance.

This idea of the superorganism is not new, as the author points out. Apiarist Johannes Mehring (1815-1878) made the comparison of the bee colony to a vertebrate animal. That the colony as a whole is more than the sum of its parts was known by Aristotle. The way Tautz puts it is that properties emerge at a colony level that are not present at the level of the individual; in turn, the whole determines the behavior of the component parts. His book explores this interplay.

Mutations in self-replicating organisms occur randomly. Sexual replication, in contrast, results in genetic variants with every generation, since germ cells from two different individuals are combined. There is risk involved with mating, but "Nature did not avoid complicated sex by producing and dividing immortal cats, because this is technically far too difficult." Honey bees reproduce by achieving the advantage of self-replication without losing the genetic diversity of sexual reproduction: They divide the colony by swarming and, at the same time, synchronize the gestation of sexually reproductive individuals with the cycle of division.

The interplay of adaptations for both plants and animals is examined by Tautz, and he sometimes simplifies by using anthropomorphic terms; he is careful to put such language in quotes (the molecules "strive"), so as not to assign motivation to an evolutionary process. Wind alone was the first pollinator, but it inefficiently required huge amounts of pollen. When insects discovered pollen as a source of nourishment, they first simply ate the flower anthers. The transport of pollen between blossoms co-evolved with bees, and resulted in the relocation of flowers' germ-cell bearing parts to a wide variety of shielded interiors. This in turn influenced flower constancy (the propensity of bees to forage on one kind of flower at a time) since it eliminates the repeated trial and error required for finding the nectar gland in different flowers. For the flower, as a result, pollen is not wasted on the stigmata of a different species.

Photo: Helga Heilmann

Mutual grooming among worker bees is one of many group behaviors to prevent the spread of pathogens.

Nectar evolved from a by-product of photosynthesis in ferns, which predate flowering plants. This sweet waste product was adapted by flowers to attract pollinators, and bees developed both mouthparts specific to gathering nectar and a crop to carry, in volume, nearly half the body weight of the bee. Flowers produce only a small amount of nectar, which is replenished. This strategy attracts repeated bee visits for adequate pollination with the least cost in nectar. Foragers taking the last drop of nectar mark the flower with a chemical "empty" sign which fades about as quickly as it takes the flower to replenish the store.

Petals of many flowers have nectar guiding patterns that reflect ultraviolet light. Also the mating sign (detached drone genitalia) hanging from a mated queen is UV reflecting – to which the eyes of drones are especially sensitive.

Tautz points out that color does not objectively exist outside the perception of living organisms. The sensor cells of an animal determine what part of the spectrum of electromagnetic waves will be perceived as light. For example, humans can see a range between longer (red), and shorter wavelengths (violet). Bees don't see the same long wavelengths but can see comparatively shorter wavelengths than humans can -- ultraviolet light, which they use to navigate when the sun is obscured. The sky pattern of polarization for shorter wavelengths is more stable, therefore it is a better orientation cue. The human eye can see this polarization through a lens, but the polarizing lens is built into the bees' eyes. (Kevan illustrates the bands of vision for bees and humans at about the same length, with the bee band moved down the spectrum toward the UV end.)

In general, bees have poor optical acuity and need to be as close as a few centimeters to see detail. They switch off their color vision when they are en route to a destination, making them color blind until they begin slowing to circling blooms, when the colors appear. Although they have no problem discerning color at the feeding site (naïve bees choose blue and yellow), they perform poorly in discerning colors upon returning to colorful hives. Yet hive markings in the form of patterns can be recognized – like the traditional painted hive entrances. (Kevan illustrates these markers, including those from a 1914 experiment by von Frisch.)

Bees can see in slow motion, with rapid movement that appears blurred to us perceived clearly by bees. (Kevan further describes this as flicker fusion, the lapse that makes a film viewed by humans as continuous action.) Small flowers, without the advantage of large color splashes, are often found on thin, flexible stalks that move with a breeze.

Tautz's own work makes additions to the familiar list of bee roles: heater bees and filling station bees who feed them. These he describes as the bees that control the crucial temperature of he brood nest with precision, particularly the capped pupa cells. The heater bees warm their bodies with a technique originally used to warm up flight muscles, contracting them without out moving the wings (for the anatomy of this trick, see Kevan). They then either press down on the brood cell cap or enter adjacent empty cells for half an hour or so, until they cool off. During that time they are fed honey by the filling station bees. The "perfect" brood nest with no empty cells is one where heater bees can't do this job.

It is worth noting that genetic variation among the half sisters creates bees with varying sensitivity to temperature, with the most sensitive activating to either heat or cool; if the optimum temperature is not reached, the next most sensitive join in, and so on, using the fewest resources to get the job done. Tautz adds that bees raised at higher temperatures possess better learning ability and better memories, although winter (longer lived) bees are more likely to have been raised at lower temperatures. Intriguing photos in the book show these heater bees as glowing spots on the comb.

The comb itself is described by Tautz as part of the superorganism. Unlike most nests, made of found materials, it is extruded by the bees. It functions as living space, pantry, and nursery but also as skeleton, memory store for chemical signals, immune system and transmitter of vibratory signals.

The key to the precision of the hexagonal cells lies not with the bees, but in the properties of the wax, as Tautz's BEEgroup observed. It is chemically complex, with more than 300 components that are transformed by temperature – not continuously but in stages that the bees exploit. They build cylindrical tubes and then raise the temperature of the wax with body heat, at which point, like soap bubbles, the round shapes naturally expand into hexagons.

An area of comb near the hive entrance appears to be chemically marked as a "dance floor" where returning foragers go to recruit. According to Tautz, what has been called the "waggle run" part of the bee dance is really more of a standing vibratory motion, with the physics of the comb sending waves through it to attract bees to make direct contact with the forager.

Photo: Helga Heilmann

Communication is the basis of behavioral coordination, according to Tautz.

This book is so beautiful and informative that it is forgiven the clichéd and ubiquitous "Buzz" in the title. The translation by David Sandeman is so seamless that it takes an analogy to "former times of socialism" to remind the reader that the book was written in German. The translation of royal jelly as "sister milk" is both charming and more descriptive. Not often are books on bees translated to English, and we are the richer for this one.

The associated Website, http://www.beegroup.de does not yet have the promised background material for each chapter, references to the literature, internet links, photos, videos, and sound files. One hopes that Sandeman signs on for the English version as it currently goes through translation by the aptly named Yahoo: "If you liked to experience more over the life of the honey bees, throw nevertheless times a view of our current works."

One gaffe that needs to be corrected is the quote attributed to Einstein ("When bees vanish from the earth, mankind will have just four more years to live….") that has been discredited as postdating him by many years.[4]

There appears to be a lack of research support for the book's contention that "…honeybees are so successful … as to leave little room for the coexistence of similarly occupied competitors." Norman Carreck, editor of The Journal of Apicultural Research finds "there have been many studies, but evidence for direct competition is very inconclusive." He cites Robin Moritz (from Germany), "Even in the most dramatic experiment: the invasion of the African honey bee in the Americas, which has been scrutinized for many decades, there are no reports of extinctions of pollinators". Carreck has traced the possible origin of this questionable assumption to an unsubstantiated statement in Darwin.[5]

This book maintains, as is often written, that New World African bee is a hybrid. It may be time to reexamine a supposition that was made before it was possible to determine the genetics, which show that the mitochondrial DNA of African bees is unaltered from those brought to Brazil half a century ago. Although the European and African bees can mate, the F2 and F3 generations do not survive, according to the work of Chip Taylor at Ohio State University. Also, rather than "this hybridization manifests itself as a lack of fine control of the colony's response to an alarm" the aggressive response of the African bee is an adaptive characteristic suiting it to several conditions in its original habitat. Also, the "'derailed' alarm communication…acts in an all or nothing way" is disputed by many reports of wide variations in the aggressive behavior of individual African colonies in the Americas.[6]

Tautz and Kevan do have a substantive disagreement. Tautz writes that "bees have no true sense of hearing." Kevan says that "for many years it was thought that honey bees were deaf," however they can "hear airborne vibrations at low frequencies" through the auditory sense organs on the antennae, the Johnston's organ. The science appears to give the nod to Kevan.[7]

Both of these books are valuable and deserve many future editions, which will no doubt be continually reedited and updated. The Tautz book is being translated into twelve languages and has been listed by Popular Science as one of the best science books of the last decade. The Kevan book is in the lineage of a University of Guelph course that has been taught for 115 years.

Rating for both books: six legs, two wings, two antennae and no stinger – tens. Kudos to Kevan and Tautz. These books are valuable additions to a bee library.

M.E.A. McNeil, a writer-illustrator, is an alumna of Marion Ellis' Master Beekeeping Course at The University of Nebraska. She keeps bees in Northern California with her husband, Jerry Draper.

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[1] *American Bee Journal, 2005,* Vol. 145, No. 6, 507-509; in addition see I. London-Shafir, et al, Amygdalin in almonds and pollen—facts and possible roles. *Plant Systematics and Evolution,* Vol. 238, 2003, 87-95.

[2] Thrice Out of Africa: Ancient and Recent Expansions of the Honey Bee, *Apis mellifera,* Charles W. Whitfield, Susanta K. Behura, Stewart H. Berlocher, Andrew G. Clark, J. Spencer Johnston, Walter S. Sheppard, Deborah R. Smith, Andrew V. Suarez, Daniel Weaver, and Neil D. Tsutsui (27 October 2006)
Science **314** (5799), 642. [DOI: 10.1126/science.1132772]

[3] Details about the current research of BEEgroup can be found in English at:
http://www.bienenforschung.biozentrum.uni-wuerzburg.de/wir_ueber_uns/research_projects/sociophysiology/
and
http://www.bienenforschung.biozentrum.uni-wuerzburg.de/wir_ueber_uns/research_projects/molecular_biology/

[4] See: http://www.snopes.com/quotes/einstein/bees.asp.

[5] See: Moritz, R.F.A. (2005) Beekeeping for maintaining biodiversity. In *Beekeeping and conserving biodiversity of honey bees*. M. Lodesani and C. Costa (Eds). Northern Bee Books; UK.1-14.
Also: See Butz Huryn, V.M. (1997) *Quarterly Review of Biology*, 72, 275-297 as well as Goulson, D. (2003) *Annual Review of Ecology, Evolution and Systematics*, 34, 1-26.
Carreck finds the Darwin reference is in the fourth edition of The Origin of Species (1866) in which he says: "In Australia the imported hive bee is rapidly exterminating the small stingless native bee". Carreck worked with Randall Keynes, who is a great great great grandson of Darwin and part of the team working on the complete publication of all of Darwin's notebooks. There is no supporting evidence in the writings, and no source reference, leading Carrack to conclude that Darwin had picked up the information either in Australia or from a correspondent and had no opportunity to do field studies.

[6] McNeil, M.E.A. "Waiting for Scutellata", *The American Bee Journal,* August. 2006, Part 1 of 5, 663.

[7] Dynamic Range Compression in the Honey Bee Auditory System toward Waggle Dance Sounds, S. Tsujiuchi, E. Sivan-Loukianova, D. Eberl, Y. Kitagawa, T Kadowaki. See: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1794319