surprised me most about this book is that so little is said about the confrontation of the scenario with the data. I suppose the authors were worried that any detailed discussion would rapidly become obsolete.

The proposal that cosmic strings guided the formation of the large-scale structure of the universe is boldly speculative, and, like most speculative ideas, it is likely to be wrong. But there are several potential observations that could provide persuasive evidence in support of the scenario within the next decade—strings could be detected either through their influence on the microwave background anisotropy or as a result of their gravitational lensing properties. Such a discovery would be extraordinarily exciting for both particle physicists and cosmologists: for the particle physicist, the universe would provide us with a glimpse of short-distance physics well beyond the standard model; for the cosmologist, the structure of matter at $10^{-30}$ cm would explain the structure of the cosmos.

***John Preskill***
*Department of Physics,*
*California Institute of Technology,*
*Pasadena, CA 91125, USA*

■

## Bee Work

**The Wisdom of the Hive.** The Social Physiology of Honey Bee Colonies. THOMAS D. SEELEY. Harvard University Press, Cambridge, MA, 1996. xiv, 295 pp., illus., + plates. $49.95 or £31.50.

This book addresses the deceptively simple question of how worker honey bees acquire information and organize their work. It records its author's 15-year research odyssey to determine how honey bees use the dance language, interactions between workers, and information about colony conditions to meet immediate and long-term colony needs. This work begins where the pioneering dance language and communication research of Karl von Frisch, Martin Lindauer, and their students left off. Seeley goes well beyond the dance language to explore how bees acquire and integrate information about conditions inside the colony and the location and quality of resources in the field. He discusses how worker bees make decisions about foraging and food storage tasks, as well as how comb construction is regulated. These are marvelous stories of adaptation, made vibrant by comparisons with other levels of biological organization such as individual cells, multicellular organisms, and other animal societies, with reference also made to economic theory and ergonomics.

Observation hive in portable hut. Bees enter the hive, which is suspended from a metal bar, through a tunnel leading from the window in the far wall of the hut. The hut's roof is constructed of translucent fiber glass, and shuttered windows can provide additional light. Fresh air enters through louvers at the base of the hut, and the hut's roof can be tilted open to provide further ventilation. The hut is bolted together and hence can easily be dismantled for transport. [From *The Wisdom of the Hive*]

"A worker honey bee foraging on buckwheat flowers. Note the proboscis, which is unfolded to probe for nectar, and the load of pollen packed on the outer surface of the hind leg." [From *The Wisdom of the Hive*]

Members of a colony of bees that have been individually labeled for identification. The labeling system used "makes possible the discrimination of 4000 individuals, which is a convenient population size for colonies used in experimental studies." [From the dust jacket of *The Wisdom of the Hive*]

Seeley's main point is that individual bees can perceive only a small amount of the total information available in a colony, yet the hive's "wisdom" lies in worker bees following simple rules to determine and accomplish work priorities. For example, a colony can increase its nectar-collecting rate when returning foragers perform waggle dances to recruit nonforagers to begin foraging. When the nectar supply in the field diminishes, decreased dancing shuts off the system. Similarly, more bees are recruited to receive and store nectar when returning foragers perform a different dance, the tremble dance. This dance occurs when the returning foragers have to conduct overly long searches before encountering nectar-receiving bees in the hive. As Seeley puts it, "Waggle dances and tremble dances play complementary roles in keeping a colony's rates of nectar collecting and processing well matched, for the former enables a colony to boost its collecting rate while the latter enables it to boost its processing rate."

In physical design and chapter organization *The Wisdom of the Hive* is structured to recall von Frisch's *The Dance Language and Orientation of Bees*, also published, in its first English edition (1967), by Harvard University Press. This approach was risky, since it invites comparison with the earlier book, but the quality of Seeley's writing and the significance of his findings justify the analogy. His book is a worthy successor to von Frisch's classic and a landmark synopsis of how social insect colonies integrate complex information.

Seeley's writing is clear and eloquent, but this is not a light, coffee-table book, and concentration is required to follow the experimental detail he presents. Nevertheless, the dedicated reader will be rewarded with a rich and flowing portrait of a scientist at work as well as with a remarkable account of what a worker bee does and how she knows when, where, and how often to do it.

Another pleasing aspect of the book is that it shows that good science does not require expensive, high-technology equipment: a simple sugar-water feeder, a glass-walled bee hive in a hut, a set of artist's paints, and a camel's hair brush can still tease out wonders of nature. Seeley's book reminds us that probing questions, rigorous experimental design, careful observations, long hours of data collection, and keen intuitive insights still have a place in today's fast-paced, tool-driven scientific world. It is especially fitting that he has used the honey bee, a paradigm of hard work and cooperation, to remind us of how rewarding scientific endeavor can be.

***Mark L. Winston***
*Department of Biological Sciences,*
*Simon Fraser University,*
*Burnaby, BC V5A 1S6, Canada*