New Dancer in the Hive

An insect imposter helps scientists decipher honeybee lingo

By RICK WEISS

A bee or not a bee? That is the question. The answer: It's not a bee at all. But members of the hive can hardly tell the difference. That's why entomologists express such excitement about recent experiments with a European robot honeybee.

Ever since German researcher Karl von Frisch first documented in 1921 that honeybees perform a "waggle dance" to communicate with one another, scientists have dreamed of creating a mechanical bee that could imitate the insects' carefully choreographed behavior. The naturalist J.B.S. Haldane, a contemporary of von Frisch, suggested fruit growers might someday use fleet-footed model bees to tell hivemates the location of trees in need of pollination. And entomologists have long sought a mechanical bug-that-can-boogie to help them decipher the bee's complex dance language, which biologists generally consider one of the more sophisticated systems of symbolic representation in the entire animal kingdom.

But the honeybee six-step is not easily imitated. Previous experiments using mechanical bees only angered hive residents; they would gang up on the intruding model and plaster it with stings.

Now, however, researchers have savored sweet success.

The accomplishment, described this past June in the German journal NATURWISSENSCHAFTEN, has entomologists abuzz. A team led by bioacoustics researcher Axel Michelsen of Denmark's Odense University and entomologist Martin Lindauer of West Germany's Würzberg University has made a computerized bee that performs bee-dance steps properly enough to convince its live sisters it knows what it's talking about. When the researchers program the model to dance a message indicating it has found food 1,000 meters to the southwest, hivemates fly off to that exact location. When they reprogram it to signal a different direction and distance, new recruits go directly to the new destination.

The computer-manipulated brass pellet, coated in beeswax, is "a gold mine," says Gene E. Robinson, a bee specialist at the University of Illinois at Urbana-Champaign. "This is the kind of thing where a technical advance is going to open up a whole lot of biological avenues."

Honeybees use the waggle dance primarily to communicate the direction, distance and quality of food sources. With U.S. farmers paying beekeepers more than $30 million annually for use of their hives to pollinate crops valued at $9 billion, one might suppose the robot bee's developers have a strong interest in using their creation to direct hoards of honeybees to selected locales. Not so, says Michelsen. Robobee's real purpose is far more interesting – and considerably more esoteric – than that of high-tech honey gatherer. The device provides scientists their first opportunity to dissect the honeybee's complex language – a language that researchers now understand just well enough to crudely mimic with their model, but which still holds many mysteries. By programming their model to perform different dances and observing the effects on surrounding bees, researchers hope the robot bee will serve as a sort of Rosetta stone for the honeybee tongue.

"The scientific purpose of all this is to find out what is the language – what's the code," Michelsen says. "There's a long list of possible signals within these dances, so we would like to know which ones are used by the bees."

Scientists have learned a lot by simply observing bees but have had difficulty discerning which aspects of the dance convey real information. The model bee should facilitate that investigation, Michelsen says, by allowing the researchers to mix and match elements of different bee dances. "We just change a few lines of the program and create dances that the bees would never do themselves. Then we see how they respond."

Donald R. Griffin, an entomologist at the Rockefeller University in New York City, puts it in terms almost reminiscent of the movie "Close Encounters of the Third Kind," in which humans use a simple musical progression in their attempt to commune with extraterrestrial beings. "In a general sense," he says, the robot bee "now makes it possible to participate in the communication process."

Might there be more to bee language than the few food-gathering cues scientists now recognize? Do we and bees really have anything to talk about? "One can't tell what will prove possible," says Griffin. "I would hope people will try other kinds of messages . . . and see what happens. Perhaps nothing more will be seen. But nobody will know that until they try, and before this, it hasn't been possible to try."

In fact, nobody expects to engage in scholarly discourse with honeybees. But even if their language is limited, as it appears, to basic information relating to feeding opportunities, their system of communication more than impresses biologists.

"What's remarkable is the ability of these bees to encode information and then decode it through these dances," says Thomas D. Seeley, an expert in bee language at Cornell University in Ithaca, N.Y. "The dances literally encode information about the distance and direction of a target that can be miles away from the nest."

Navigational instructions over a course of miles may not seem like much to us humans, Seeley notes. But that's several hundred thousand times a bee's body length, which for us would be hundreds of miles away. In short, Seeley says, "we've got a creature whose brain has approximately 800,000 neurons – a very small fraction of what we have – and it's doing something that we humans recognize as an extremely complicated and sophisticated behavior."

If the elegance of bee language leaves today's biologists bedazzled, it was downright incredible to naturalists in von Frisch's time. "The initial discovery of dance language was treated with a lot of skepticism," says Robinson of the University of Illinois. "Back then, the idea of a dance language in bees was unbelievable, literally, because it was a bee and not a furry vertebrate that was doing it."

But years of experiments by von Frisch and his students confirmed that honeybees do indeed convey specific information via their dance. Through painstaking observations, which ultimately earned von Frisch a Nobel prize, they documented that the number of waggles, the distance danced, and the direction and intensity of the bee's movements all code for specific details about the site and quality of a discovered food source. Moreover, they found that the smell of a food source lingering on the dancing bee, and the provision of regurgitated food for "begging" bee observers, also help convince bees to investigate the touted find.

Yet over the years, bee models that appeared to imitate all these actions repeatedly failed to elicit appropriate responses from real bees. Unbeknownst to their developers, each was missing the same critical ingredient in bee language: sound.

Everyone knows bees make sounds, and even von Frisch hypothesized that bee language may include an auditory component. But until recently, scientists had not proved that bees respond in specific ways to specific sounds – such as those produced by their rapidly vibrating wings. Without that proof, researchers could only deduce from indirect evidence that sounds might be crucial to bee communication.

"One of the outstanding mysteries of the dance language story is perception by the bees," Robinson says. "We can read the dance by turning a light on and watching the bees, but in their hive, bees are in the dark." Scientists have supposed that observer bees get most of their information by actually touching and tracing the dancing bee's movements. But they've also suspected other cues play a role. "The obvious solution is sound," says Robinson. "But it's been hard to get a handle on it."

It took a remarkable set of experiments by two extremely patient researchers to settle the issue. By training individual honeybees to perform conditioned behaviors in response to sounds that the bees learned to associate with mild electric shocks, William F. Towne of Kutztown (Pa.) University and Wolfgang H. Kirchner of Würzberg University last spring provided the first direct proof that bees can detect airborne sounds (SN: 5/20/89, p.318).

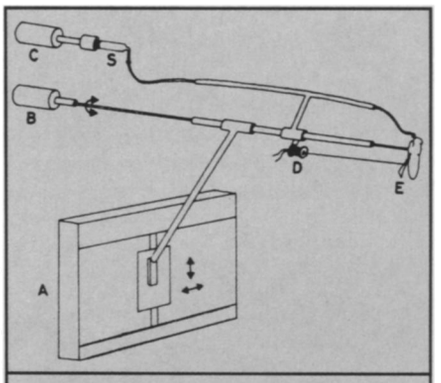

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Diagram (not to scale) depicting a European robot bee (E) and its $125,000 "life support" system. A computer-programmed recorder (A) controls the model bee's figure-eight dance pattern; a step motor (B) makes the model's body waggle; another step motor (C) connected to a syringe (S) pumps scented sugar water through plastic tubing as an offering to nearby begging bees; while an electromagnetic driver (D) vibrates the model's "wing."

Moreover, their work showed that bees detect these sounds not by sensing pressure oscillations as most vertebrates do, but by detecting air particle movements close to the sound's source. (All airborne sounds are composed of both pressure oscillations and air particle movements.) While their research fell short of proving that bees actually use this "hearing" in their dance language, they conclude in the May 12 SCIENCE that "bees' acoustic sense appears to be sensitive enough to allow bees to detect air particle movements that occur within several millimeters of a sound-emitting dancer."

Kirchner and Towne thus provided the missing link in robot bee research. Soon Lindauer, Michelsen and their students had collaborated on a new model bee – one that included a piece of razor blade on its back that vibrated at a frequency of 280 hertz, similar to that of a live dancer's wings.

The robot bee, slightly larger than an average bee, rests affixed to a rod controlled by a computer. The computer directs the classic figure-eight dance pattern described by von Frisch while an electromagnetic driver vibrates the model's stainless steel wing. A step motor connected to a tiny syringe pumps scented sugar water through a soft tube to the front of the model, allowing it to "feed" begging hivemates. And every 10 minutes the computer adjusts the dancer's orientation to accommodate the changing angle of the sun in the sky – the reference by which bees convert dance directions into geographic bearings.

Oscilloscopes and videocameras record the dancer's actions and hivemates' reactions. "It's very impressive to look upon all this equipment and then see only a small dancing bee," says Lindauer.

To date, Michelsen says, the robot bee has successfully convinced hivemates to fly to specified targets almost 1 mile away. "Directional information is a bit more precise with the live dancers," he says, suggesting some elements in the dance have yet to be discovered.

But the robot's lower response rates may simply reflect its inherent mechanical clumsiness. For example, begging bees often appear frustrated when their requests for regurgitated food fail to elicit the sugary offering, while innocent bee bystanders sometimes get a face-full without even asking. Moreover, observer bees trying to get the message from the dancing device sometimes have difficulty getting close to the model, which, lacking sense organs, tends to run roughshod in the hive. "It's just running around without taking any regard for bees that may get in its way," Michelsen says. "And if we are unlucky enough to run over a bee or hit one too wildly, the model is attacked occasionally."

Despite its lack of ballroom grace, the model has already begun providing new information. In August, Michelsen says, "we did create artificial dances to separate individual parameters of the dance, and we could pick up that some parameters are more important than others." But he says it may take years for scientists to decipher all the dance's components, including what differences, if any, body movements and sound encode.

"What the actual role of these two components are escapes us at the moment," Michelsen says. "We had a naive idea that one might code for distance and the other might help to generally motivate the bees. But we now know that this is not the case. It's complicated, and we still don't understand how it all works."

Which means entomologists can look forward to many more summers of Arthur Murray-style honeybee dialogues.

"It's very exciting," says Cornell entomologist Richard Nowogrodzki. All the more so, he adds, because it's "very much in the heritage and the tradition of von Frisch himself, with Lindauer [von Frisch's student] and now Lindauer's students doing much of the work. These experiments have required tremendous care in their design, tremendously precise observations and tremendous patience. It's very elegant and satisfying research." □