# Dance of the Electronic Bee

Article and photographs by MARK W. MOFFETT

*In breakthrough experiments the world's first successful robot honeybee "talks" to live bees in their own language—the dance. With this ungainly but effective mimic, scientists are unlocking secrets of animal communication.*

WITHOUT FUSS or fanfare historic discoveries are being made in a shed near Würzburg, West Germany. There a team of scientists has tested a tiny mechanical honeybee that, communicating like a food-finding scout bee, directs followers to distant locations.

Among all the means by which animals communicate—from the infrasound of elephants to the visual displays of great apes—it is the dance of the "lowly" honeybee that most scientists view as genuinely unique. Honeybees, like people, can exchange information about things remote in space and time. A bee, by dancing, informs her nestmates of the location, type, and quality of food she has found. She comes intriguingly close to using true language.

This fact has been known for years. As a student I recall watching honeybees dance in an observation hive at the Milwaukee County Zoo. Armed with a book by Nobel Prize winner Karl von Frisch, who discovered that bees use dance to communicate, I deduced that my bees were telling nestmates about a spot 300 meters to the southeast. Then I surprised myself by finding an isolated bed of flowers humming with bees at that exact location.

I was thrilled by my correct reading of the dance, yet my feelings could hardly compare to those of Danish and West German scientists when, in August 1988, they first put an imitation bee on a comb in a darkened hive, directed it by computer, and realized they were "talking" to real bees.

Knowing that the bees would beg for a sample of nectar, the scientists were able to deliver. They released a drop of peppermint-scented sugar water

through a tube above the brass robot's head (left), simulating regurgitation by a real bee.

Although the robot is anatomically incorrect and rigged with rod, nectar tube, and an electromagnet covered with colored tape (above), bees don't see these in the dark. The robot had been smeared with wax and placed in the colony overnight to absorb local odor because resident bees are known to attack intruders from foreign hives.

WINGS vibrating, hindquarters waggling, a bee dancing on the side of the honeycomb (above right, marked with red paint) directs followers to nectar or pollen found on a recent journey. She dances a figure 8 that details distance and direction. A few bees stay with her for several dance circuits. As they get the message and fly out to duplicate her journey, their places are quickly taken by others.

The angle between the dance direction and the vertical is known to signal the direction from the hive to food in relation to the sun (diagram, page 139). At the center of the figure 8 the bee waggles her abdomen and quivers her wings, indicating the distance. The intensity of the dance plus the samples offered and the lingering odors on the bee's body suggest the type of food and its quality. But many details are still unclear.

I was observing the honeycomb in the darkened research shed under red light that was invisible to the bees. Though they are of the same species *(Apis mellifera)* as the North American honeybees I'm accustomed to, they are differently colored.

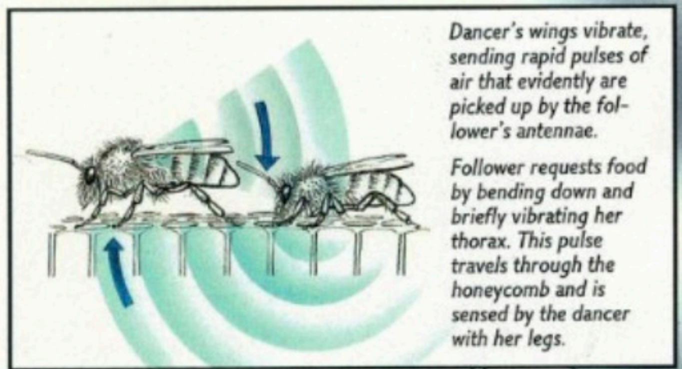
In the dark the follower bees apparently "hear" the message of the dancer. Her whirring wings produce strong currents of air, according to experiments conducted by Axel Michelsen, an expert on animal hearing at Odense University in Denmark. With student Per Kryger, he used tiny microphone probes with tips a few millimeters apart to record and measure these minute air-particle oscillations. When amplified, the sound reminded me of the flutter of a dove on takeoff. The air waves fade so fast that follower bees must be close to the quivering wings to sense them. The rapidly dissipating sound does not seem to disturb nearby hive inhabitants that may be following other dancers.

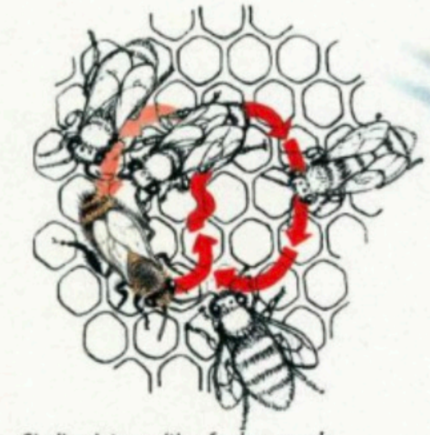
The bees seem to perceive the sound with their antennae. Experiments by Wolfgang Kirchner of Würzburg University and William Towne of Kutztown University of Pennsylvania overturned previous opinion that bees are deaf. In addition Michelsen and Kirchner, using a laser beam to measure vibrations, showed that followers beg for samples by pressing their bodies down and transmitting a burst of vibration through the honeycomb.

Despite such scientific advances, many uncertainties remained about the significance of certain aspects of the dance as communication. The ideal solution was to build a robot that conformed with a real dancer in as many ways as possible. The robot had to dance a figure 8, give out samples, and broadcast sound in the proper way. Previous bee models duplicated other parts of the dance, but not the correct sound.

The key was the single wing, made from part of a razor blade. Inscribed with an "S" and lying across the robot's back (lower left), it reminded the team of Superman's cape. The front edge of the wing was glued to an axle rotating on two bearings that resemble beady eyes. A wire attached to the razor wing reaches an electromagnet that vibrates it to mimic the sound patterns produced by real dancers. The main rod connects to motors, all shielded by the black curtain behind computer operator Axel Michelsen (upper left).

Michelsen programs the computer to describe a location to which the robot will direct its followers; the motors are then set in motion. The computer automatically adjusts the angle of the dance every ten minutes as the sun moves across the sky. Occasionally Michelsen puts a tiny microphone close to the buzzing model. A glance at an oscilloscope assures him that the robot continues to produce the correct sound. Although it cannot perceive vibration messages from followers that are seeking a food sample, the operator periodically grants a sugar-water sample.

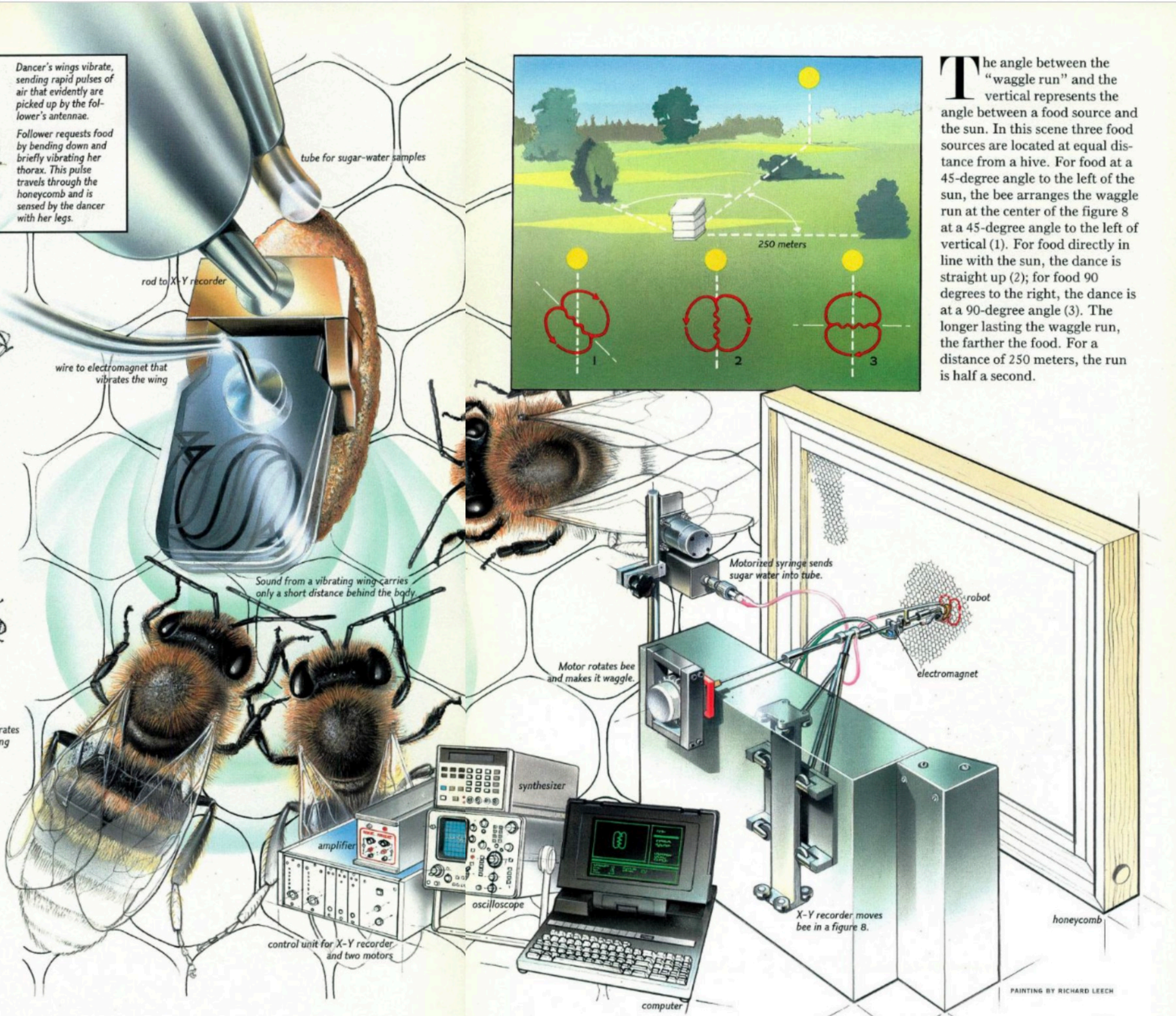


*Circling into position for her waggle run, a dancing bee is surrounded by followers.*

*At the center of the figure 8 the dancer vibrates her wings and waggles her body while moving forward. Followers "listen" intently.*

*Now the dancer circles to the opposite side of the figure 8 to position herself for a repeat of her waggle run.*




The angle between the "waggle run" and the vertical represents the angle between a food source and the sun. In this scene three food sources are located at equal distance from a hive. For food at a 45-degree angle to the left of the sun, the bee arranges the waggle run at the center of the figure 8 at a 45-degree angle to the left of vertical (1). For food directly in line with the sun, the dance is straight up (2); for food 90 degrees to the right, the dance is at a 90-degree angle (3). The longer lasting the waggle run, the farther the food. For a distance of 250 meters, the run is half a second.

PAINTING BY RICHARD LEECH

LIVE BEES were paying close attention to the little robot. But were they following its directions with accuracy? To find out, observers had to track food gatherers after they left the hive.

Departing bees were provided with a tiny exit hole below their comb, but some single-minded novices headed for the open shed door, here being closed by Wolfgang Kirchner.

To learn the destination of the bees, Bent Bach Andersen (above), an electronics engineer from Odense who constructed the robot bee, and other volunteers—including preeminent bee authority Martin Lindauer of Würzburg, a principal investigator—sat beside peppermint-scented bait to count arrivals during a three- to six-hour period while the robot danced. Experiments were scheduled for August, when harvested grainfields around the shed offered few natural sources of food to distract their subjects.

Bait was placed at regular intervals in a straight line as far away as 1,500 meters to test the bees' reckoning of distance or at a set distance but in various directions from the hive to test direction-finding skills.

During the experiments 200 to 300 bees arrived at a site when instructed by a live bee. The dancing robot sent from 20 to 100 bees to their goal, yet fewer than 10 bees located the site when the robot offered samples but did not dance.

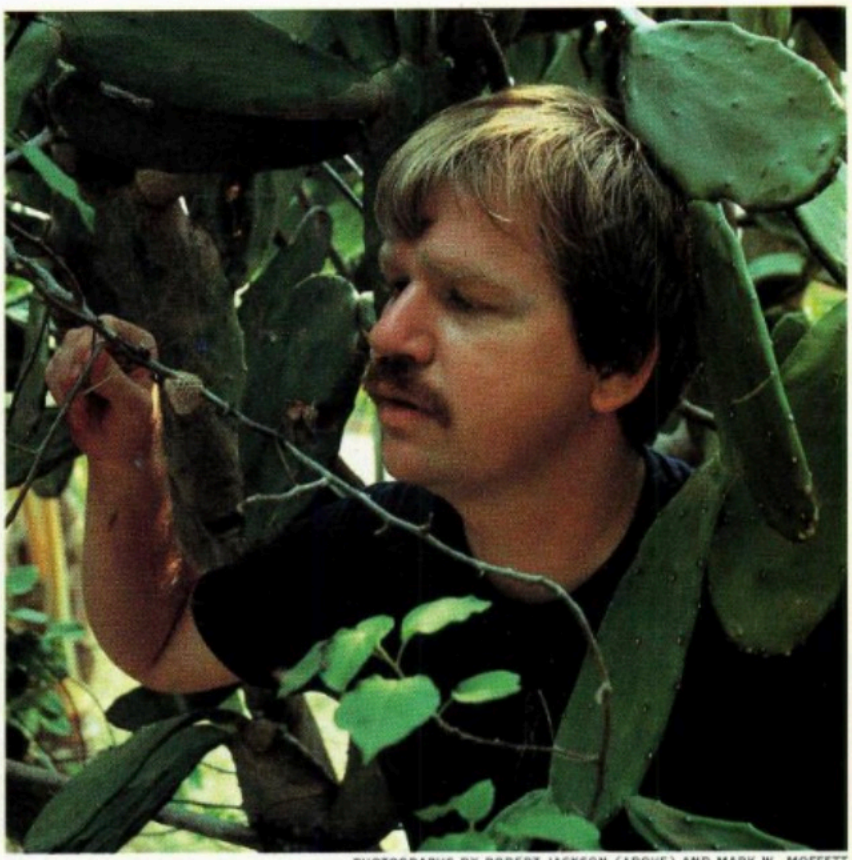
We now know that both the waggle and the correct sound pattern are necessary for communication: When either is omitted, recruitment to observer stations doesn't occur.

There is certainly much more the robot can teach us. Eager to find out exactly how bees communicate, the team dreams up strange dances. What happens if the waggle run takes place on the outside of the figure 8? Or if a bee waggles at one place in the dance and buzzes in another? Or if the waggle is set for 1,500 meters and the sound for 250?

Since subtle distinctions in the dance can be programmed into the robot, bee researchers for the first time are able to do tightly controlled communications experiments. At last we have a powerful tool with which to tease apart the details of an elegant insect language. □

# On Assignment

IT CAME NATURALLY to world-roving zoologist MARK W. MOFFETT, given his longtime interest in how animal societies are organized. When he was studying jumping spiders in Sri Lanka, Mark sought out the dwarf honeybee, *Apis florea,* smallest of the honeybee species. He knew it



PHOTOGRAPHS BY ROBERT JACKSON (ABOVE) AND MARK W. MOFFETT

behaved quite differently from the more familiar species, *Apis mellifera,* he had been observing for the robot bee article in this issue.

Unlike those bees, which nest in cavities, dwarf bees of Asia construct nests on branches amid dense foliage to avoid detection. To guard the nest—full of inviting honey that draws ants and other predators—hundreds of bees blanket their home with their bodies, up to several layers thick (above). The living curtain also helps control the temperature of the nest. This unusually small colony hovers nearby as Mark inspects their nest (top right).

While all honeybees dance to communicate the location of food, dwarf bees perform in the open atop their nests (right)—a view never before published in such detail. The dancer orients straight at the flower target, lifting her abdomen like a flag so followers can see it. Her dance is silent, and followers apparently get the message just by watching. For species that dance in dark cavities, some experts believe wing sounds evolved to provide a "voice."

Curiosity has always characterized Mark, who recalls, "I was a permanent problem to my parents. From about age three I just wanted to sit in the backyard and watch ants." At 17 he began traveling in Central and South America with expeditions to investigate lizards, snakes, beetles, and butterflies. After graduating from Beloit College in Wisconsin, Mark earned his Ph.D. in biology at Harvard, based on 28 months of travel in Asia—studying ants.

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