Aristotle observed it, and Karl von Frisch was awarded the Nobel Prize for explaining it: the waggle dance – a dance used by honeybees to communicate the location of food sources.

Dancing **with Bees**

With his lederhosen and white hair, the elderly man looked well groomed. Countless generations of pupils were shown the educational films in which zoologist Karl von Frisch explained the dances of honeybees. His research on these insects and their behaviors earned him fame and renown throughout the world. **Tania Munz** from the **Max Planck Institute for the History of Science** in Berlin is researching von Frisch's life as part of a project on scientific observation.

TEXT **TINA HEIDBORN**

The man whistled and the fish swam over to him: fish were among Karl von Frisch's favorite experimental animals – particularly a blind bullhead catfish called Xaverl. Von Frisch had Xaverl so well trained that he swam over to the scientist when he whistled softly, proving that fish can hear. But even more than fish, von Frisch liked bees. "The waggle dance looks comical. But it is not really comical, it is incredibly interesting. It is one of the most amazing occurrences in the insect world. And that's saying a lot," he once commented, looking back on his work.

The decoding of the waggle dance of the honeybee earned the behavioral biologist the Nobel Prize in 1973, along with a huge amount of general interest. "The hype was enormous," says historian of science Tania Munz, who is currently working on a book about Karl von Frisch.

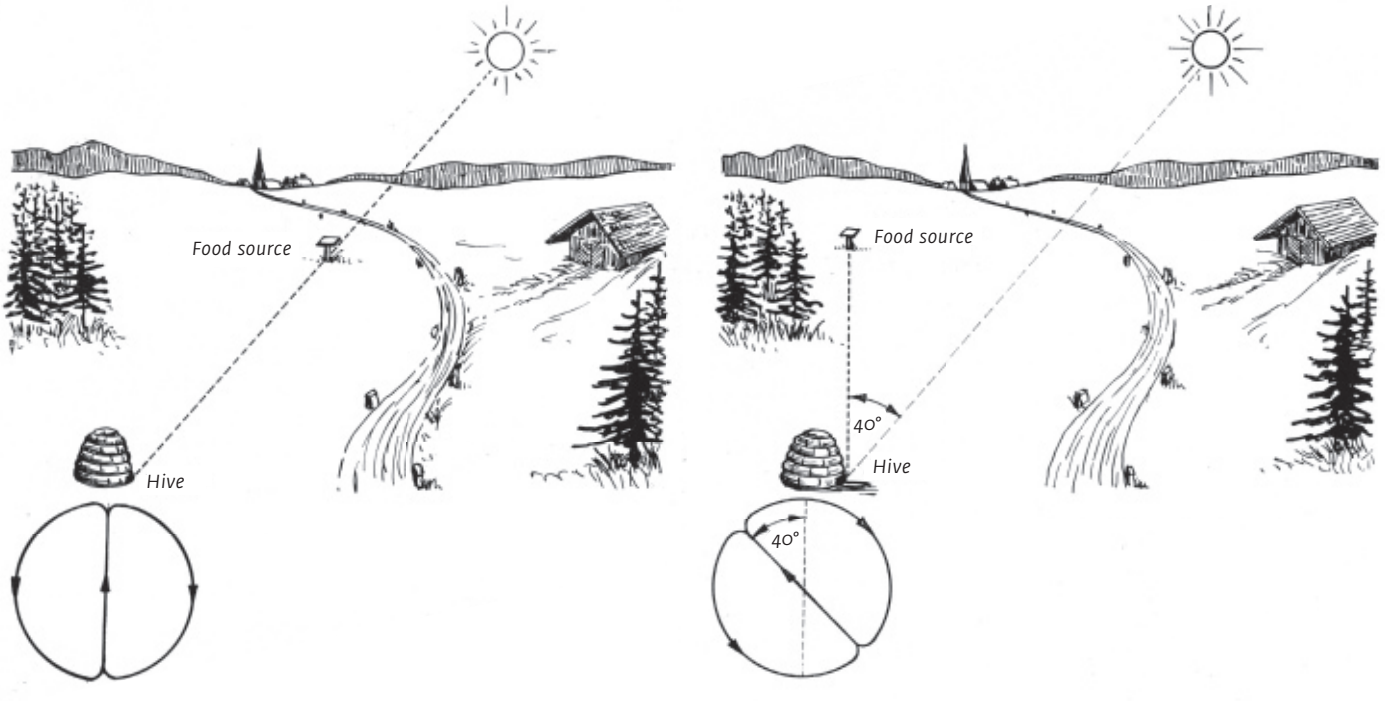
What von Frisch discovered in the mid-1940s was a source of fascination, and not only to his fellow researchers. "Von Frisch gave many public lectures in schools and other educational institutions. For example, I found a letter in the archive from a school asking the scientist to come and give a lecture. He had already visited the school the previous year. Von Frisch wrote in response to the renewed invitation that he'd already presented on the bees and now could give a lecture on fish – also a fascinating topic. The school replied that that would, no doubt, be very interesting, but could he please speak about the bees," reports Tania Munz.

The American researcher, who also holds Swiss citizenship, arrived at the topic of her book through von Frisch's Nobel Prize acceptance speech. "I found the experiments fascinating. Von Frisch worked with great care, precision and creativity. He simply conducted good research – and this is demonstrated by the fact that his studies are still cited today," she says. As a sensory physiologist, von Frisch had been focusing since the 1920s on questions concerning sensory perception in animals, such as: Can fish or bees hear sounds? Can bees distinguish between colors, smells, and tastes?

TAIL WAGGLING AS A DISTANCE INDICATOR

For his experiments, Karl von Frisch developed an ingenious marking system with which he was able to track individual bees within a swarm. This enabled him to explore the meaning and purpose of the so-called bee dances that had already been noted by Aristotle. Von Frisch postulated that honeybees convey information about food sources to their fellow bees with the help of certain round and waggle dances. >

Illustration: SPL-Agentur Focus



Animal polar coordinates: The angle to the beehive and the waggle movement indicate the direction and distance of the food source.

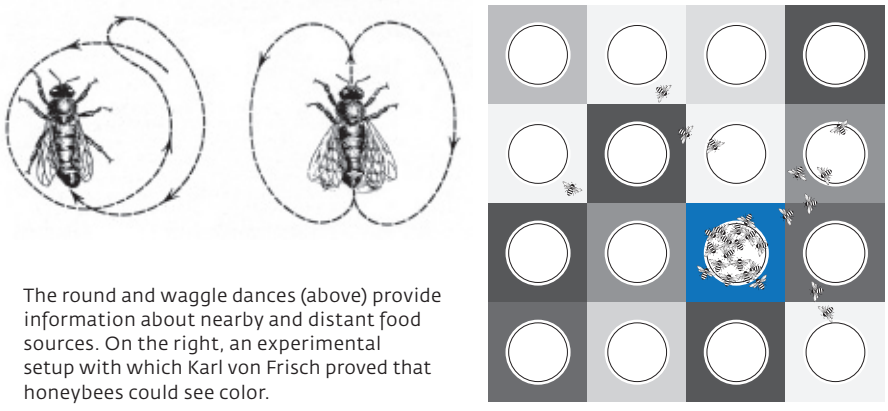
When they return from an abundant food source that is no more than 100 meters away, they inform the other bees with a round dance. If the food is further away, the successful bee waggle dances for hive mates in the shape of a figure of eight: starting with a straight line, followed by a semicircle, another straight line and a semicircle in the opposite direction. The angle the bee assumes in the hive in relation to gravity corresponds to the angle to the sun that the bee flew on its path to the feeding place. The speed at which the bee shakes its hindquarters back and forth ("waggles") indicates the distance to the food source.

THE FOURTH INSULT TO HUMANITY?

"The discovery that animals could communicate in such detail and, moreover, symbolically caused a sensation," says Munz. "However, von Frisch's discovery also brought up some serious questions about the self-image of humans. If even such lowly animals as insects can communicate so brilliantly, what were the implications for the perceived difference between animals and humans? For centuries, language had been the sole preserve of humans (at least as far as humans were concerned). It was seen as the boundary that divided *homo sapiens* from the other living organisms on earth. Von Frisch's findings eroded this self-image.

But Karl von Frisch's research did not meet with universal acceptance. Criticism was expressed even before he was awarded the Nobel Prize, in particular by American biologist Adrian Wenner. Wenner firmly believed that the bees conveyed information in their dances, but he questioned the significance of this information. According to Wenner, the smell of a food source was the sole factor in determining whether a bee would find it or not. The information conveyed by the dances was not used, and even ignored.

"Karl von Frisch was over 80 when this debate began," says Tania Munz. "He had produced enormous volumes of data and studies, he had a lot of students, and was no longer actively involved in empirical research at the time." But thanks to his extensive and



The round and waggle dances (above) provide information about nearby and distant food sources. On the right, an experimental setup with which Karl von Frisch proved that honeybees could see color.

Image from: Karl von Frisch, Erinnerungen eines Biologen, Springer, 1957 (top and bottom left); image from: Karl von Frisch, Der Farbensinn und Formensinn der Bienen, Zoologische Jahrbücher, Abteilung für Allgemeine Zoologie und Physiologie, 1915 (bottom right)

rigorous studies and the support of numerous international colleagues, he was able to hold his own in the dispute. And of course the awarding of the Nobel Prize also gave von Frisch's cause a huge boost.

The debate concerning the information content of the honeybee dances is still ongoing today. A perennial source of controversy among the bee research fraternity, it has remained a focus of debate for decades. Just late last year, a scientist revisited the topic in an article in the German newspaper Süddeutsche Zeitung: Jürgen Tautz, a biologist from Würzburg, explained that bees cannot locate a non-smelling food source with the help of the waggle dance alone, and that Karl von Frisch overestimated the significance of location information in the waggle dances.

AN EXCHANGE OF SCIENTIFIC BLOWS

With this article, Tautz joined the endless ranks of von Frisch critics – and promptly garnered strong disagreement from his own sphere. For example, Randolf Menzel, a colleague from Berlin, immediately insisted that the bee dances contain an abundance of important information and fulfill a significant motivational and instructive function. In this recently kindled exchange of blows, the focus of the debate involves the human interpretation of the animal dance.

Historian Tania Munz observes the dispute with scholarly interest, but without taking sides. "I am not a bee researcher and I cannot settle the argument," she stresses. What is certain is that bee communication is extremely complex and the last word in this debate has not yet been heard. Munz can, however, appreciate the dispute in the context of the developments that have taken place in recent decades. As a historian of science, she sees the current debate as an interesting replay of the dispute between Wenner and von Frisch in the 1960s and 1970s.

Nevertheless, Munz vehemently defends von Frisch on one point of criticism originally raised by Adrian Wenner and currently being brought into play: she deems the claim made by Wenner and his successors to the effect that von Frisch himself was clearly more cautious in the statements he made in the 1920s and 1930s to be unfair. Karl von Frisch did not assemble his final theory until the mid-1940s. At that time, he recanted his earlier findings and developed what would become his final version of the meaning of the bee dances.

The Max Planck researcher is also able to position von Frisch's interest in bees in a broader historical context. "During the National Socialist era, it was discovered that von Frisch had a Jewish grandmother. As a result, the Nazis wanted to force him out of the university system. However, many people expressed their support for him. And von Frisch himself argued that his research could help in fighting the Nosema infestation that posed a threat to the bee populations in the early 1940s," says Munz. As the bees were the most important crop pollinators, the Nazis viewed von Frisch's work as making an important contribution to maintaining the German population's food supply.

Karl von Frisch at the microscope in 1942. Frisch, who had a Jewish grandmother, was able to continue working during the National Socialist era in Germany because his research played a role in the fight against the Nosema infestation of bees. Above all, von Frisch's work generated important impetus for research in communication.

Photo: Ullstein bild

» The examination of the core questions underlying serious research intensified as a result of von Frisch's work: How does one carry out research without becoming personally involved? How can animals be observed with maximum objectivity? And is this even possible or, indeed, desirable? How can scientists avoid the traps of anthropocentrism and anthropomorphism? These questions, too, must be understood in their specific historical contexts.

Consequently, he was allowed to continue researching and even received official state funding for his work.

Von Frisch's work in a different field, that of communication science, would take on a significance that outweighed that of the German Reich's honey production. His insights and experiments inspired other scientists to engage with questions concerning animal communication. By way of background information, Tania Munz mentions that, from the perspective of the history of science, research on communication became a prominent global trend after the Second World War. Computer scientists and cyberneticists studied it in the context of artificial intelligence, and a short time later, Noam Chomsky's deep grammar theories revolutionized the world of linguistics.

In laboratories all over the world, scientists started to hang on the lips and mandibles of bees, monkeys, birds, whales and dolphins in an attempt to study their languages. The chimpanzee Washoe, who learned over 30 symbols from a sign language, emerged as the star of this research circus.

However, it was not exclusively the fascination with Karl von Frisch's work that inspired emulation. Tania Munz sees in the enormous interest shown in this field a countermovement to the dominance of behaviorism. "People had had enough of behaviorism. It had forbidden them from commenting on anything that went beyond what was strictly observable behavior," she says. At the same time, the examination of the core questions underlying serious research intensified as a result of von Frisch's work: How does one carry out research without becoming personally involved? How can animals be observed with maximum objectivity? And is this even possible or, indeed, desirable? How can scientists avoid the traps of anthropocentrism and anthropomorphism?

FOCUS ON THE HISTORY OF OBSERVATION

The fact that research is also subject to trends and occasionally undergoes changes in direction is one of the phenomena historians of science study. Tania Munz's work on Karl von Frisch is part of a larger project entitled "The History of Scientific Observation" that Munz and her colleagues at the Max Planck Institute for the History of Science are currently working on.

Doctoral student Nils Güttler, for example, is working on the development of plant geography starting in the 18th century. "The main question the project addresses concerns how scientists identify and stabilize an object of investigation," he explains. The question as to how plants are distributed across the earth encompasses a vast, almost impenetrable study area: the entire globe. The question came into focus with explorers and their explorations during the 19th century, in particular with Alexander von Humboldt. A form of representation that would influence the discipline thereafter, the geographical map, developed as a result.

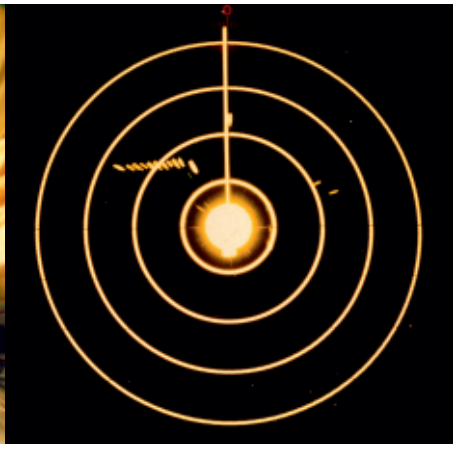
"The field of observation could now be organized with the help of maps," explains Güttler. As a result, reports the scientist, the object of scientific observation was molded into a particular form – a form that was not freely invented, but that emerged from the observations and became increasingly established as a kind of yardstick.

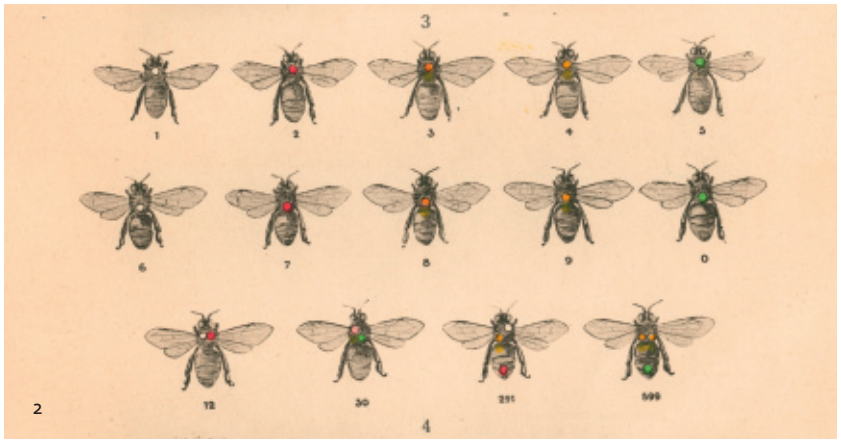
However, the maps that Alexander von Humboldt developed are now obsolete: they are too abstract and extensive. Today we know that the distribution of plants is influenced by more factors than those that von Humboldt identified: temperature and soil conditions are not the only factors that play a role here, as he claimed. After von Humboldt's death, the theories of evolution altered the view of the maps. The occurrence of plants and plant communities observed at the time was increasingly viewed as a result of historical processes, such as migration.

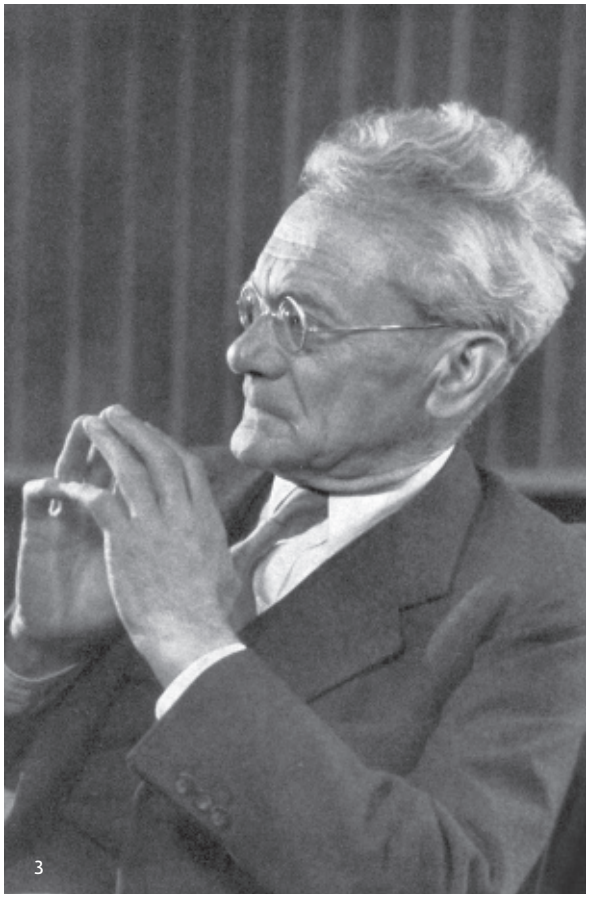
"The perspective from which I consider an object is crucial," says Güttler. And this changes frequently during the course of the history of science. Science historians refer to the "period eye," the particular perspective of a certain historical research generation or epoch. Accordingly, Alexander von Humboldt had a different perspective on plant geography than that of today's scientists.

Tania Munz has been aware of this historicist dimension of scientific research since her work on Charles Darwin, the subject of her master's thesis. Today's scientists would no longer work

Photos: SPL-Agentur Focus (top right, 2), MPI for the History of Science (right)







1 | Researchers can track the flight of insects today with the help of a tiny radio transmitter (top left). The marked insect's track appears on the screen as a line of short dashes (top right).

2 | The historical model on which the modern technology is based: Karl von Frisch marked hundreds of bees with tiny dabs of paint and was able to identify each individual with this low-tech process.

3 | Achieving groundbreaking new insights without the help of sophisticated technology: Bee researcher Karl von Frisch (1886 to 1982).

Image from: Karl von Frisch, Über die 'Sprache der Bienen': Eine tierpsychologische Untersuchung, Zoologische Jahrbücher, Abteilung für Allgemeine Zoologie und Physiologie, Vol. 40, 1923, Table 1 (bottom)

the way Darwin did, she says. "Darwin not only used different methods, he also amassed information from widely differing sources. For example, he used information he obtained from colleagues who he viewed as reliable. These would probably be described as anecdotes today and could not be presented as scientific sources. That standard did not exist at the time."

The importance of changing and often evolving possibilities for observation can also be demonstrated on the basis of Karl von Frisch's work. The marking system he devised for bees created completely new possibilities for observation: it made it possible for the first time to identify individual bees in the hive and at the different food sources. However, thanks to the development of new technologies, today's bee researchers are far more advanced in their methods. They can also track bees in flight, for example with the help of radio transmitters.

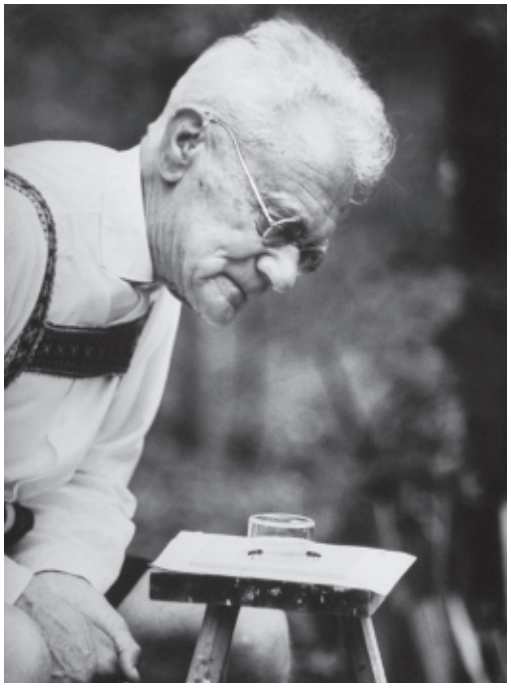
SUCCESS BASED ON A SIMPLE PROCESS

Technology now also enables the use of programmable robot bees – a step forward compared with the artificial wooden bees developed by one of Frisch's colleagues. "However, Karl von Frisch's bee research also shows that innovation and new ways of thinking and looking at things do not depend on advanced technology," says Munz. The marking of the bees by hand would have to be classified as a low-tech procedure, and yet it yielded an immense gain in knowledge.

Von Frisch, who was born in Vienna in 1886, was completely open to new technologies and processes. For example, he made use of film recordings, particularly in the presentation of his research. "Von Frisch was the first scientist to show a film at the 1924 meeting of the German Society of Naturalists and Physicians. This meant that he could present the bees in the conference hall, even in winter when the ground outside was covered in snow

» By a happy stroke of fate, I was born with a love of the animal world. This was a source of some discomfit to my parents.«

Karl von Frisch felt at home with animals, even as a child. Even at a ripe old age, the zoologist, behavioral scientist and sensory physiologist inspected the bee hive constructed specially for his research.



and the bees were dozing in the hive. Needless to say, that made quite an impression," reports Tania Munz.

For Karl von Frisch, the observation of bee dances and other animal phenomena was a lifelong preoccupation. The love of different animal species was something he acquired in his childhood home. As a child, he kept an entire zoo, reportedly consisting of 170 wide-ranging animal species that he observed with passion. His father, a renowned surgeon, would have preferred his son to have followed in his professional footsteps. Frisch thus first studied medicine before switching to zoology.

As the scientist himself put it, observing animals was something he simply could not resist. "Every frog interested me more than my school work," he once reminisced. "By a happy stroke of fate, I was born with a love of the animal world and a delight in the observation of their living impulses. This was a source of some discomfit to my parents. The fact that, despite this, they fostered my inclination in every way was decisive in terms of my future profession."

He continued: "Animals of all kinds – bought, as gifts, caught by me – were permanent guests in my nursery. My mother also liked to have a cheerful bird, usually a blue tit, around during the bleak winter months. It was allowed to fly around the room, giving it its freedom in the spring. I quickly learned from my mother to see animals as sentient beings." ◂

GLOSSARY

Anthropocentrism
The view whereby humans see themselves as the focus of worldly reality.

Anthropomorphism
The assignment of human characteristics to animals, gods or natural elements.

Behaviorism
A theoretical position that assumes that the behavior of humans and animals can be studied using a scientific method that focuses only on external manifestations and behaviors. Behaviorism was established in the early 20th century and became popular in the 1950s, in particular through the work of Burrhus Frederic Skinner.

Nosema
Nosema disease (also known as nosemosis) is a disease of the honeybee caused by the zygomycete species *Nosema apis* and *Nosema ceranae*. Nosema is the most common disease of mature bees and is highly contagious.

Mandibles
The typical mouthparts of the arthropods belonging to the Mandibulata clade. They consist mainly of a strong lower jaw and are suited to the biting and chewing of plant and animal foods or as a gripping device for the transport or manipulation of objects.

Sensory physiology
The study of seeing, hearing, feeling, smelling, tasting, and the sense of balance. The main focus of the science is on the different mechanisms that convert physical stimuli, such as light or sound waves or chemical signals, into electrical signals.

Photos: Getty Images (left), image from: Karl von Frisch, Tanzsprache und Orientierung der Bienen, 1965 (right, 2)