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# Desert ants: Earth's magnetic field calibrates their navigation system

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The desert ant Cataglyphis nodus at its nest entrance—an inconspicuous hole in the ground that cannot be seen from the ant's perspective. To find its way back there, the ant uses the Earth's magnetic field during its learning walks. Credit: Robin Grob

They are only a few centimeters tall and their brains have a comparatively simple structure with less than 1 million neurons. Nevertheless, desert ants of the Cataglyphis genus possess abilities that distinguish them from many other creatures: The animals are able to orient themselves to the Earth's magnetic field.

A research team from Julius-Maximilians-Universität Würzburg (JMU) discovered this a few years ago. However, it was previously unknown where in the ants' brains the magnetic information is processed. This has now been resolved.

In a new study published in the journal *Proceedings of the National Academy of Sciences*, the team shows that information about the Earth's magnetic field is primarily processed in the ants' internal compass, the so-called central complex, and in the mushroom bodies, the animals' learning and memory centers.

Professor Wolfgang Rössler, holder of the Chair of Behavioral Physiology and Sociobiology at the University of Würzburg, Dr. Pauline Fleischmann, former scientist at the Chair of Behavioral Physiology and Sociobiology and now a member of the Neurosensorics/ Animal Navigation working group at the University of Oldenburg, and Dr. Robin Grob, who has since moved from Rössler's chair to the Norwegian University of Science and Technology in Trondheim, were responsible for this study.

## First exploratory walks for calibration

"Before an ant leaves its underground nest for the first time and goes in search of food, it has to calibrate its navigation system," says Fleischmann, explaining the background to the work. During so-called learning walks, the animals then explore the immediate surroundings around the nest entrance and repeatedly pirouette around their own body axis with short stops in between. During these pauses, they always look exactly back in the direction of the nest entrance, even though they cannot see the tiny hole in the ground.

Thanks to their field studies in southern Greece, where Cataglyphis ants are native, Fleischmann and her colleagues were able to prove that desert ants orient themselves to the Earth's magnetic field during the learning walk phase. Fleischmann and Grob investigated the ants' orientation behavior while the magnetic field was being manipulated, but also looked for changes in the nervous system of Cataglyphis as an expression of the newly acquired experience.

## A faulty magnetic field disrupts the learning process

The zoologists concentrated on young workers that had not yet undertaken any learning walks. The ants were only allowed to set off as part of the precisely planned experiments—sometimes under natural conditions, sometimes in a permanently manipulated magnetic field that, for example, displayed chaotic directions or did not allow horizontal orientation. This faulty directional information was not a reliable reference system for the ants' behavior to look back to the nest entrance during the learning walks.

"Our neuroanatomical brain analyses show that ants exposed to an altered magnetic field have a smaller volume and fewer synaptic complexes in an area of the brain responsible for the integration of visual information and learning, the so-called mushroom body," explain Fleischmann and Grob. In the central complex, the region of the ant's brain in which spatial orientation is anchored, the same findings were observed under certain conditions.

## The number of synaptic connections increases

Desert ants that were allowed to make their first excursions under natural conditions were clearly different. Their sensory experiences, a combination of information about the magnetic field, the position of the sun and the visual environment, triggered a learning process that was accompanied by structural changes in the neurons and an increase in synaptic connections in the aforementioned brain regions.

According to the scientists, this leads to the conclusion that magnetic information not only serves as a compass for navigation, but also as a global reference system that is crucial for the formation of spatial memory.

## In search of the sensory organ

The results of their experiments prove "that ants need a functioning magnetic compass during their learning walks in order to calibrate their visual compass and at the same time store images of the nest environment in their long-term memory," say Fleischmann and Grob say. At the same time, their research extends far beyond the field of compass calibration in ants.

Rössler emphasizes that "the results provide valuable information on how multisensory stimuli can influence neuronal plasticity of brain circuits for navigation in a critical phase of brain maturation."

As a next step, the team wants to investigate in which sensory organ the desert ant receives the magnetic information and via which sensory pathways it is transmitted and processed. This has not yet been achieved with any animal species that orients itself to the Earth's magnetic field.

Due to their manageable and relatively small nervous system, insects, to which Cataglyphis belongs, offer a unique opportunity to investigate the neuronal basis of magnetic orientation at all levels.

**More information:** Robin Grob et al, Importance of magnetic information for neuronal plasticity in desert ants, *Proceedings of the National Academy of Sciences* (2024). DOI: 10.1073/pnas.2320764121

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