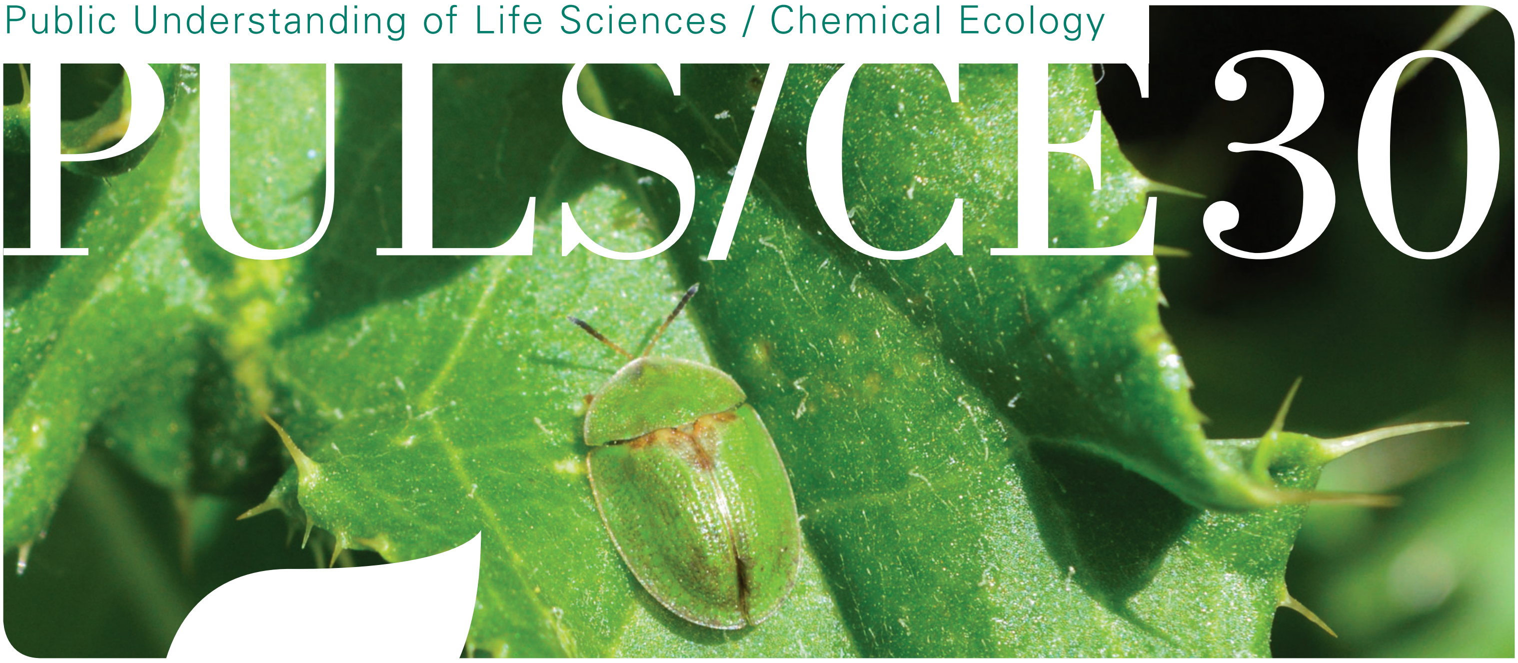
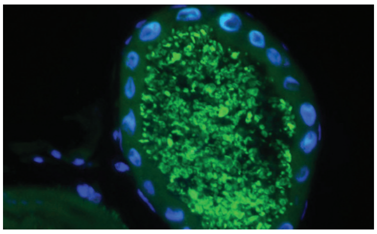
Public Understanding of Life Sciences / Chemical Ecology

PULS/CE 30



Max Planck Institute for Chemical Ecology

Newsletter November 2017



Microbial resident helps digest leaves

Symbiotic bacteria provide tortoise beetles with the enzymes required to break down certain components of the plant cell wall. Without the microbial symbionts, the beetles could not gain access to the nutrients inside the plant cells and hence would be unable to survive … **p. 3**

Smell of vinegar enhances flies' attractiveness

When virgin female flies smell their favorite food, they become more receptive to courting males. Researchers discovered the neuronal mechanism in the brains of Drosophila flies responsible for the fact that males are perceived as more attractive when vinegar is nearby... **p. 4**

Understanding the language of trees

If a poplar is attacked by gypsy moth larvae, the tree responds by producing a variety of aromatic volatile compounds. Jan Günther wants to find out why the trees produce certain compounds and not others and to learn what these mean in the language of the trees ... **p. 5**

MAX-PLANCK-GESELLSCHAFT

The backbone of excellent science

In the basement of the institute, a labyrinth of tubes, cables, and pipes lies waiting to be mastered. From there, the items that are essential for research, such as heat, cold, gases, ultra-pure water and electrical energy, are distributed to the laboratories. A team of six makes sure that the systems function at all times and that supply is not interrupted. *Photo: Angela Overmeyer, MPI-CE*

On September 22, 2017, Daniel Veit received the Excellent Service Award. *Foto: Danny Kessler*

Dear Readers!

No research without service! Rarely on center stage, the service units of the institute nevertheless do a great deal for science: the co-workers in our administration, IT, building service, the gardeners, and the librarians. All these service units have one common goal: to support the scientists, allowing them to concentrate entirely on their research. For 20 years, since the MPI-CE was founded, the number of scientists in the institute has grown steadily, while the size of the service units has hardly changed. At this point, we would like to highlight the many and for the most part uncelebrated achievements of our service staff:

Each year, the administrative team prepares approximately 300 personnel contracts and handles reimbursement applications for more than 600 business trips. In accounting alone, on average more than 12,000 bookings are made every year, and in 2016, almost 16,000 single items were ordered. For many orders, staff in the purchasing department must invite competitive offers and observe complicated import regulations. With only five fulltime people and two trainees, the IT group oversees more than 800 computers and maintains an extremely valuable asset: the research data of the institute in a terabyte scale on the institute's server clusters and backup systems. Gardeners grow up to 90,000 plants each year, relying on biological controls in the greenhouses and growth chambers, and also take care of the outside grounds, which include a beautiful show garden. House technicians make sure that the institute is provided with a functional supply of energy and utilities (see photo on the left). Power consumption in the institute is equivalent to that of 1,800 three-person households; 8,000 electrical devices need to be inspected and maintained regularly in order to ensure they comply with safety standards. Librarians spend less time on handling conventional book orders or interlibrary loans than on introducing scientists to strategies for conducting efficient literature searches, overseeing all aspects of Open Access, and ensuring that institute publications are collected in a repository correctly and in a standardized way.

When everything runs smoothly, we often forget that our colleagues in service are responsible. Unfortunately, what happens behind the scenes is usually noticed only when there is a problem. In order to better honor the achievements of those who work in the background, this year a prize for excellent service was awarded during the institute's 20th anniversary celebrations: the honor went to the head of the workshop, Daniel Veit, who has been instrumental in the practical implementation of many experiments and whose work has been indispensable to the scientific success of the institute. His workshop has created numerous odor collection systems and experimental setups for behavioral assays with insects. Obviously not every service activity is as visible and directly related to research as is the custom-built scientific equipment constructed under Daniel Veit's management, but this does not make the achievements of other service employees any less important. In the future, this prize for excellent service will be awarded annually.

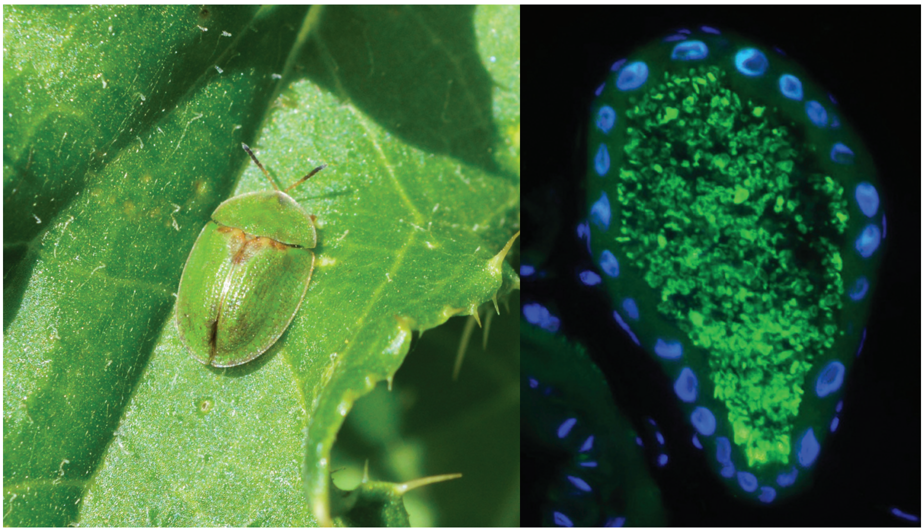
Karin Groten und Angela Overmeyer

Microbial resident helps digest leaves

An international research team has described a bacterium which resides in thistle tortoise beetles and provides the insects with the enzymes required to break down certain plant cell wall components. The genome of the bacterium is the smallest ever sequenced of any organism living outside a host cell. It contains genes that are responsible for the production of pectinases, the enzymes that break down pectin, an essential component of the plant cell wall.

The study is built on the histological descriptions and drawings of the beetle's symbiotic organs that were first published by the German zoologist Hans-Jürgen Stammer more than 80 years ago. The symbiotic bacteria reside in sac-like reservoirs associated with the gut of the beetles. Female beetles transfer the symbionts through vaginal tubes to their offspring by applying a tiny symbiont caplet to each egg. The hatching larvae eat through the eggshell and then consume the caplets containing the symbiotic bacteria.

Leaf beetles are able to degrade components of the plant cell wall, such as cellulose and pectin, with the help of digestive enzymes. However, genetic analysis showed that the thistle tortoise beetle lacks the genes that are responsible for the production of the respective pectinases. This deficit is compensated for by a close partnership with the bacterium. When the researchers compared enzyme activity in tortoise beetles with and without symbiotic bacteria, they found that beetles without symbionts were not able to digest pectin in order to gain access to the nutrients in the cell.



Left: The thistle tortoise beetle (*Cassida rubiginosa*) feeds on thistle leaves. Right: The cross-section shows the symbiotic organs. These sac-like reservoirs house the symbiotic bacteria (green). The researchers named the symbiont "*Candidatus* Stammera capleta" in memory of H.-J. Stammer. Photo (left): Hassan Salem, Emory University. Fluorescence *in situ* Hybridization (FISH, right): Benjamin Weiss, University of Mainz, and Hassan Salem, Emory University.

Genetic analyses revealed that the genome of the microorganism is reduced to only a few hundred genes, among these, some genes that regulate the production and transport of pectinases. Containing only ~270,000 base pairs, the genome of the bacterium is the smallest ever described for an organism that exists outside a host cell. Only a few bacteria that are housed inside their hosts' cells are known to have smaller genomes than the beetle symbiont. This is the first description of a specialized bacterial symbiont whose primary function is pectin degradation.

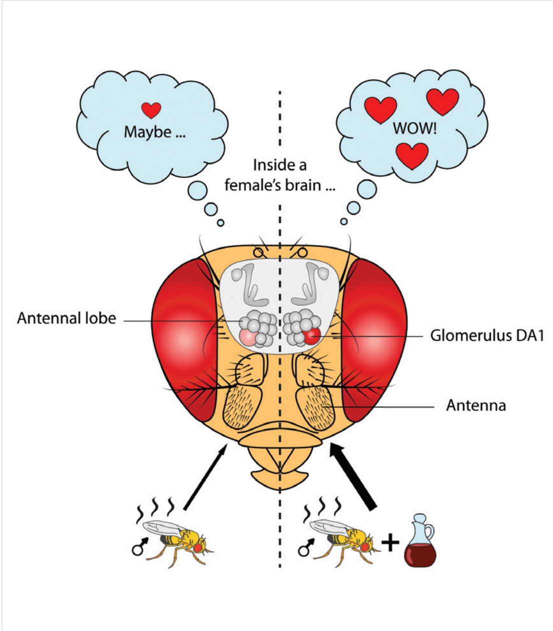
In many leaf beetle species, the genes that activate digestive enzymes in order to degrade plant cell walls originated from fungi and bacteria, and were introduced into the genomes of the beetles' ancestors via horizontal gene transfer. Why some insects have acquired genes from microbes horizontally, while others maintain symbionts to do the same job, remains to be answered in future studies. [AO/KG]

Original Publication:

Salem, H., Bauer, E., Kirsch, R., Berasategui, A., Cripps, M., Weiss, B., Kogy, R., Fukumori, K., Vogel, H., Fukatsu, T., Kaltenpoth, M. (2017). Drastic genome reduction in an herbivore's pectinolytic symbiont. **Cell** 172, DOI: 10.1016/j.cell.2017.10.029

Smell of vinegar enhances flies‘ attractiveness

Original Publication:
Das, S., Trona, F., Khallaf, M. A., Schuh, E., Knaden, M., Hansson, B. S.. Sachse, S. (2017). Electrical synapses mediate synergism between pheromone and food odors in *Drosophila melanogaster*. **PNAS**, Early Edition, DOI: 10.1073/pnas.1712706114



Above right: What happens in the brain of a virgin *Drosophila melanogaster* fly when it smells the male pheromone cis-vaccenyl acetate? Glomerulus DA1 (pink, on the left) is activated. The odor of vinegar intensifies this olfactory signal and the activation of the glomerulus DA1 is enhanced (right: red, instead of pink). Also enhanced is the odor-guided behavioral response of the fly: the odor of vinegar in combination with the sexual attractant significantly increases female receptivity during courtship. Image: Silke Sachse, MPI-CE

Below: Female flies find a little “eau de vinegar” makes males more appealing. Photo: Benjamin Fabian, MPI-CE

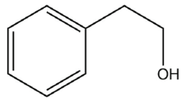
“The way to a person’s heart is through the stomach” is a popular saying. But it is not only in humans that romance and a good dinner go hand in hand. In the vinegar fly *Drosophila melanogaster*, scientists from the Department of Evolutionary Neuroethology have now identified the underlying neuronal mechanism in the fly’s brain. When vinegar is nearby, male flies are perceived as more attractive and the receptivity of virgin females towards courting males is increased.

Previous experiments had revealed that the male pheromone cis-vaccenyl acetate activates the glomerulus DA1 in the brains of female flies. Glomeruli are spherical functional units in the antennal lobe, the olfactory center of the fly brain. The scientists were able to show that the odor of vinegar significantly enhances the reactions of female flies to the male sex pheromone. Together, both odors intensify the activation of DA1. This effect was observed only in unmated virgin flies; it was absent in males and mated females.

The neurobiologists were able to elucidate how the odor signals were processed in the fly brain and determine which brain areas were activated. They used functional imaging techniques to monitor and visualize brain activity induced by the sex pheromone, by vinegar, and by both odors together. The enhanced activation of the glomerulus DA1 is mediated by the process of so-called lateral excitation in a particular class of neurons: Neighboring glomeruli in the brain respond to the odor of vinegar, and the excitation from those glomeruli is transmitted to DA1 via electrical synapses. The male sex pheromone, in contrast, activates DA1 directly through the specialized olfactory receptor Or67d. Thus, both odors activate the same olfactory glomerulus, just through different neuronal pathways.

The results are also ecologically relevant, because the described neuronal mechanism accelerates mating when sufficient food is available for the females and for their offspring. In nature, female flies perceive only small amounts of the male sex pheromone. From an evolutionary point of view, it makes sense to have a mechanism which enhances the effect of the pheromone; then the concentration of the males’ contribution does not need to be increased. *Drosophila* flies have a pretty short lifespan, during which they are constantly threatened by predators, infections or toxic food. Accelerated mating and reproduction is therefore extremely important for their survival. [AO/KG]

Understanding the language of trees



Unlike animals, plants cannot run away from their enemies and have to stand up to attacks. However, they are by no means defenseless. In fact, over the course of evolution, trees have developed complex defense strategies to fend off a plethora of herbivores interested in feeding on their tasty foliage. Trees have evolved particularly versatile and effective mechanisms to protect themselves. When a poplar is attacked by the larvae of a gypsy moth (*Lymantria dispar*), the tree responds by producing and emitting various aromatic volatile compounds.

For many reasons, the western balsam poplar (*Populus trichocarpa*) is an optimal model for studying how trees interact with their environment. Poplar trees are of economic interest because they produce wood so rapidly, and, in addition, they possess a relatively compact genome for such a complex organism. Knowledge of the genome facilitates basic research in molecular and evolutionary biology.

In our studies, we focus on odor-producing enzymes, which are derived from the essential amino acid, phenylalanine. These aromatic fragrances are biosynthesized via a few intermediate steps and combined with the production of several other defensive compounds in order to minimize expenses for the plant while maximizing benefits. By using only one precursor, the plant is able to produce many similar products, all of which may have completely different defensive functions, both directly and indirectly.

Direct defenses directly target the attacker, causing it to avoid the plant. Indirect defenses, which can be compared to a "cry for help," attract predatory insects. A poplar tree can attract the enemies of its enemies; these may rid the tree of troublesome pests and in return get a meal. One such attractant is 2-phenylethanol. Roses and petunias are known to be able to synthesize this compound via different pathways.

Different biomolecular experiments have helped us discover that the poplar is able to produce 2-phenylethanol in at least three different ways. Why the production of 2-phenylethanol is biochemically conserved and which function the aromatic compound has in poplars are the focus of my current research project.

Above: A gypsy moth larva is feeding on poplar leaves. The insect attacks not only fruit trees, but also oaks, beech and poplar trees (right). Mass attack can lead to the defoliation of entire tree populations.
Below: Jan Günther with his test plants in the greenhouse.
Photos Franziska Eberl, MPI-CE

IMPRS
Exploration of Ecological Interactions with Molecular and Chemical Techniques

Jan Günther is a PhD student at the International Max Planck Research School. In his research project in the Department of Biochemistry (under the supervision of Tobias Köllner and Jonathan Gershenzon), he wants to find out why poplar trees emit specific volatile compounds as a response to attack by gypsy moth larvae and what these compounds mean in the language of trees.

„Attention, I'm toxic!" - The chemical ecology of predation

Hannah Rowland in Madingley Wood, a forest which is used by the University of Cambridge for research and education: Each year birds are collected, fitted with transponders, and set free. *Photo: private*

The Monarch butterfly *Danaus plexippus* warns enemies with its bright orange colour. In fact, the insect contains glycosides that can make birds seriously ill and cause vomiting. *Photo: LyWashu, CC BY-SA 3.0*

Since July 2017, Hannah Rowland has been a Max Planck Research Group leader at our institute. She is currently establishing her group, "Predators and Prey". Since November, the British native has also been a fellow at the "Wissenschaftskolleg zu Berlin," an interdisciplinary institute which annually awards such fellowships to only 40 scientists, all of whom are of high academic standing in the natural and social sciences and humanities. Recently, we asked Hannah Rowland a couple of questions:

How and when did you become interested in science?

I've always liked being outdoors especially in woodlands, and I've always been drawn to watching and caring for animals. My earliest memory of being interested in science was being told that dogs didn't see in colour. Of course, I now know that this is incorrect (dogs are dichromatic and have two colour receptors involved in colour vision)! But, as a six or seven year old this idea, that our family dog didn't see like I did, made me want to know how he experienced the world.

How would you describe your current research projects?

I research aposematism. This describes an animal with eye-catching coloration that defends itself with chemicals. The monarch butterfly is a good example: it is bright orange and is toxic. Aposematism works because predators learn that eye-catching prey are best avoided. Predators learn faster when the visual signal is always the same. Bright orange means "it would be a bad idea to eat me". But some aposematic prey are brighter than others, some have larger patches of colour, and some are not eye-catching at all. I'm interested in discovering whether aposematic prey, like monarchs, should stick to the script if they don't want to end up as lunch. I want to understand why warning signals vary, and how signals and receivers evolve. To do this, my group will have to answer two questions: 1. Do warning signals vary because different species of predators behave differently towards aposematic prey? We will research this in the laboratory and the field looking at their genotypes and their phenotypes. 2. Do warning signals vary because they are expensive? Animals don't buy their warning signals with money, but pigments and chemical defences might be expensive to produce, and this is what we'll be quantifying.

Hannah Rowland as a kid with the family dog: When she learnt that her four-legged friend has a different perception of the world, she decided to become a researcher. *Photo: private*

What has been your most amazing finding so far?

The collaborative work I've done with Johanna Mappes' group (University of Jyväskylä), and with John Skelhorn (University of Newcastle) are highlights for me. Together we found that accurate mimicry is more likely to evolve in simple prey communities. We also studied masquerade (when insects disguise themselves as twigs, stones, or even bird poop to hide from their predators), and found that it works because predators misclassify prey, rather than not detecting them. I'm especially proud of the most recent research with Liisa Hämäläinen (University of Cambridge) and Rose Thorogood (University of Helsinki). During my time at Cambridge I established a system of individually identifiable predators at the Madingley Woodlands. I fitted most of the songbirds in the wood with passive integrated transponder (PIT) tags that trigger recording devices when the birds interact with feeders and artificial prey. We have also taken these birds into captivity where we show them videos of other birds foraging. We are doing this to understand whether social information is used by predators to learn about novel warning signals, and how this influences selection and rates of evolution.

What is especially exciting in your research field?

I think that the technological advances in the field are most exciting. We are using digital imaging, computational neuroscience, genomics, innovative laboratory and field experiments, and large-scale comparative analyses to understand the genetic and physiological changes that underlie antipredator defences. These are advances that Charles Darwin and Alfred Russel Wallace could only have dreamt of when they established this field of science.

Why did you decide to come to the MPI?

Because this is the world's best centre for chemical ecology research! Trying to understand the interrelations of ecology, sensory physiology, and animal behaviour is at the heart of my research. The opportunity to collaborate with the diversity of experts who fill the corridors here in Jena working on similar themes was attractive.

What will you research focus on in Jena?

Together with my group, I will continue researching chemically defended organisms that communicate their unprofitability to predators with conspicuous warning signals. We will explore the idea that there is a profitability spectrum among chemically defended organisms because this may be important in shaping ecological communities and interactions among species. What constitutes unprofitability, and how important is it in shaping interactions among species? We will research the effects on consumers of attacking chemically defended prey so that we can understand the processes that have selected for critical sensory abilities in consumers, and how chemical defences change organism behaviour and physiology.

Hannah Rowland loves being outdoors in the woods, where she likes watching animals, espcecially birds, like this Great Tit nestling (below). *Photos: private*

Recent Publications:

Rowland, H. M., Fulford, A. J. T., Ruxton, G. D. (2017). Predator learning differences affect the survival of chemically defended prey. **Animal Behaviour**, 124, 65-74.

Hamalainen, L., Rowland, H. M., Mappes, J., Thorogood, R. (2017). Can video playback provide social information for foraging blue tits? **PeerJ**, 5, 21. doi:10.7717/peerj.3062

Parasitic *Cuscuta australis* plant connecting two soybean plants. *Photo: Jingxiong Zhang, Chinese Academy of Sciences*

Dodder: a parasite spreads the alarm among neighbors

A team of scientists from the Kunming Institute of Botany in China and the Department of Molecular Ecology in Jena has discovered that parasitic plants of the genus *Cuscuta* (dodder) not only deplete their host plants' nutrients, but also function as important "information brokers" among neighboring plants, when insects feed on these. Dodder vines connect host plants to form a network. If any plant in the network is attacked by herbivores, the expression of defense genes in unattacked neighboring plants is up-regulated. Once alerted, the plants become more resistant to their enemies. [AO/KG]

Original Publication:

Hettenhausen, C., Li, J., Zhuang, H., Sun, H., Xu, Y., Qi, J., Zhang, J., Lei, Y., Qin, Y., Sun, G., Wang, L., Baldwin, I.T., Wu, J. (2017). The stem parasitic plant *Cuscuta australis* (dodder) transfers herbivory-induced signals among plants. **PNAS**, 114 (32), E6703–E6709

A pathogen manipulates sick vinegar flies so that they smell particularly attractive to their conspecifics. *Photo: Anna Schroll*

The irresistible fragrance of dying vinegar flies

Vinegar flies should normally try to avoid their sick conspecifics to prevent becoming infected themselves. Nevertheless, as researchers from the Max Planck Institute for Chemical Ecology and Cornell University recently found out, the flies are irresistibly attracted to the smell given off by sick flies. A dramatic increase in the production of the sex pheromones responsible for the attractive odor of the infected flies is caused by pathogens: this strategy is used by the deadly germs to infect healthy flies and spread even further [AO/KG]

Original Publication:

Keesey, I. W., Koerte, S., Khallaf, M. A., Retzke, T., Guillou, A., Grosse-Wilde, E., Buchon, N., Knaden, M., Hansson, B. S. (2017). Pathogenic bacteria enhance dispersal through alteration of *Drosophila* social communication. **Nature Communications**, 8: 265

The desert ant *Cataglyphis fortis* is a master navigator. *Photo: Markus Knaden, MPI-CE*

Desert ants cannot be fooled

Cataglyphis fortis desert ants can learn visual or olfactory cues to pinpoint their nest, but only if these cues are unique to the nest entrance. Scientists from the Department of Evolutionary Neuroethology discovered that the ants do not consider visual landmarks or odors as nest-specific cues, if these occur not only near the nest but also along the route. Hence, ants are able to evaluate the informative value of such cues and are not fooled by ubiquitous, unreliable cues. [AO]

Original Publication:

Huber, R., Knaden, M., (2017). Homing ants get confused when nest cues are also route cues. **Current Biology**, DOI: 10.1016/j.cub.2017.10.039

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