PUBLIC UNDERSTANDING OF LIFE SCIENCES / CHEMICAL ECOLOGY

PULS/CE

41

MAX-PLANCK-INSTITUT
FÜR CHEMISCHE ÖKOLOGIE

NEWSLETTER / MAY 2023

MAX PLANCK
GESELLSCHAFT

EDITORIAL

Empowering women in science

Female staff members of the Department of Evolutionary Neuroethology celebrate Diversity Day. We have no shortage of excellent young female researchers at our institute. The proportion of female PhD candidates is over 60 percent, and the overall proportion of women among researchers is 46 percent. However, we have a long way to go before there is equal representation in top positions in science.
Photo:Jürgen Scheere

Dear readers!

We are very proud to be able to present new results again this year that have been published in high-ranking journals and received a lot of public attention. Please read our research highlights on pages 3-5. On top of that, several awards for our researchers have caused a lot of joy and jubilation. Yuko Ulrich, head of the Lise Meitner Group Social Behavior, became the first awardee of the Zukunftskolleg Research Award of the University of Konstanz in 2022. You can read a detailed interview with her on pages 6-7. Silke Sachse, head of the Olfactory Coding Research Group, will receive the Certificate of Merit at the International Congress of Entomology, an award for outstanding mid-career entomologists.
The director of our Department of Natural Product Biosynthesis, Sarah O'Connor, was even awarded the most important German research prize, the Gottfried Wilhelm Leibniz Prize, which is endowed with 2.5 million euro. In May, she was also elected as a new Fellow of the Royal Society. The most recent awards to researchers at our institute have almost all gone to women. And that is long overdue.

Although the proportion of our female doctoral researchers compared to their male colleagues is now over 60 percent, this is not the case when we look at female scientists at the higher stages of their career paths. Only 35 percent of group leaders are currently women, and Sarah O'Connor is so far the first and only female director at our institute. According to data from the German Federal Statistical Office, Germany ranks among the lowest in the EU in terms of the proportion of women in research, at 28.1 percent; this is below the European average of 32.9 percent (source: German Federal Statistical Office (Destatis) 2022).

Why women in Germany are still significantly underrepresented in top positions, including in science and technology, is not easy to answer. In most cases, the reasons are manifold and there are no easy solutions. In 2017, a study by the Institut der Deutschen Wirtschaft was able to show that still far too few females applied for leadership positions, though plenty of women qualified. There is still a lack of role models to support young female scientists and give them the confidence to assume leadership. We are therefore particularly pleased that we have top female scientists at our institute whose achievements are recognized worldwide.

Angela Overmeyer

The call of the fungi

Researchers have known for some time that chemical communication plays an important role in massive outbreaks of bark beetles. The beetles first select a suitable tree and then release so-called aggregation pheromones. These pheromones attract nearby conspecifics to join a mass attack. Spruce trees, whose defenses are already weakened by various stress factors, fall victim to the beetles more easily than do healthy trees.

An international research team led by Dineshkumar Kandasamy and Jonathan Gershenzon from the Department of Biochemistry now reports that the spruce bark beetle finds its fungal partners based on the volatile chemical compounds the fungi release when they break down the components of spruce resin. Spruce bark beetles are associated with fungal partners of different genera. For the study, the researchers focused on the species *Grosmannia penicillata*. They observed that the bark beetles are attracted to odors released by their symbiotic fungi when the fungi grow on a medium that contains a powder made from spruce bark. The fungi convert terpene compounds from spruce resin into oxygenated derivatives that are particularly attractive to bark beetles. Fungal partners not only attracted the beetles, but also stimulated them to tunnel.

Further evidence of the importance of chemical derivatives from fungal metabolism in making spruce trees already infested by the fungi even more attractive to bark beetles was provided by electrophysiological studies of the beetles' olfactory perception of these odors. This involved testing the response of individual sensilla, the hair-like sensory organs on the beetle antennae, to different fungal odors. The researchers were able to show that bark beetles possess specific olfactory sensory neurons, which are housed in the sensilla; these specialize in the perception of oxygenated monoterpenes emitted by fungi.

Mass outbreaks of bark beetles have caused shocking levels of forest damage across Germany, as seen here on the Brocken in the Harz Mountains. One of the main pests is the spruce bark beetle* Ips typographus. *The beetle encountered spruce monocultures that were already weakened by high temperatures and prolonged droughts. Attacks are intensified by symbiotic fungi that convert defense compounds from spruce resin into attractants.
Photo: Angela Overmeyer

The newly hatched young adult is still in the so-called pupal chamber at the end of the tunnel it created as a larva. It is surrounded by spores of a symbiotic fungus.
Photo: Dineshkumar Kandasamy / Veit Grabe

The results of this new study could help improve the control of bark beetle outbreaks. For example, it may be possible to optimize pheromone traps by adding the oxygenated monoterpenes from fungal metabolism. An important goal for the research team is to learn more about the metabolism of the compounds of spruce resin in the fungi and to determine whether this is a detoxification reaction for the fungus, for the beetle, or for both.

Original Publication: Kandasamy, D., et al. (2023). Conifer-killing bark beetles locate fungal symbionts by detecting volatile fungal metabolites of host tree resin monoterpenes. **PLOS Biology**, doi: 10.1371/journal.pbio.3001887

RESEARCH HIGHLIGHT

Air pollution impairs mating

Copulation attempt of two* Drosophila *males.

Courting chain of four male* Drosophila *flies. Male flies exhibited unusual courting behavior towards other males that had been exposed to the increased ozone levels that are nowadays often found in cities in the summer.
Photos: Benjamin Fabian

Most insect pheromones are odor molecules that contain carbon-carbon double bonds. Such double bonds are known to be easily destroyed by ozone. To study the effects of ozone on the mating behavior of *Drosophila* flies, researchers led by Nan-Ji Jiang and Markus Knaden from the Department of Evolutionary Neuroethology developed an way to expose flies to ozone that could mimic the slightly elevated levels of ozone in the air that are often measured in cities today during the summer. In the experiments, male flies were exposed to these slightly elevated ozone concentrations.

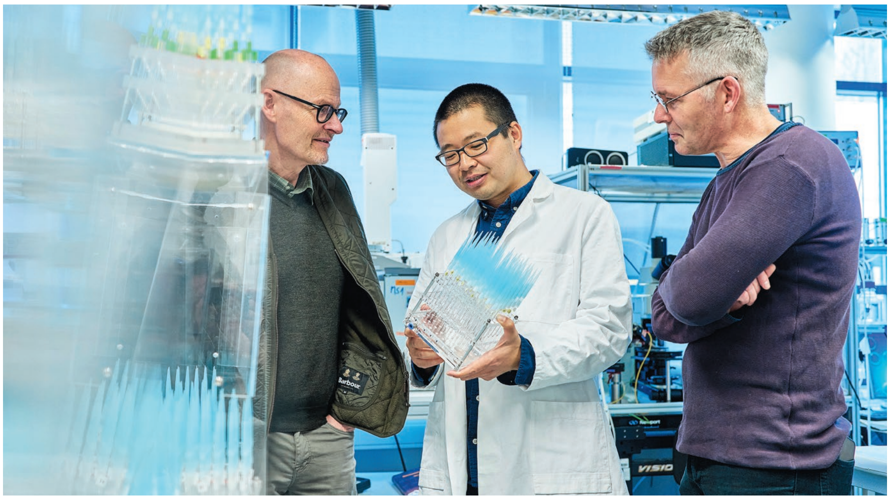
In addition to males of the model fly *Drosophila melanogaster*, the researchers also tested male flies of eight related species and checked their attractiveness to conspecifics. The observations they made were disturbing, which may be mainly due to the role pheromones play in attracting the opposite sex and mating. *Drosophila* sex pheromones are emitted by males and increase the attractiveness of males to females. At the same time, males use the odor signal to distinguish females from other males.

Although their pheromone attracts females, it repels other males. During mating, males transfer the pheromone to females. Freshly mated females that smell of the pheromone are no longer attractive to other males for the time being. Consequently, increased ozone concentrations not only resulted in females being no longer attracted to males; moreover, males exposed to ozone were suddenly interesting to their male conspecifics. Ozone-exposed males lined up in long courtship chains. In eight of the other nine species studied, the research team observed unusual courtship behavior by males toward other males exposed to ozone.

As most insect pheromones contain carbon-carbon double bonds, ozone can also be expected to interfere with sexual communication in many insect species as well. High ozone levels are not only harmful to human health; the current lifestyle of industrialized nations comes at very high costs to the environment and climate. The current study provides another plausible explanation for why insect populations are declining dramatically worldwide. If chemical communication is disrupted by pollutants in the air, insects may no longer be able to reproduce at a sufficient rate. This could also affect pollinating insects such as bees and butterflies. The fact that 80% of our crops need to be pollinated by insects highlights the scale of this problem in the future, should we not succeed in drastically reducing air pollution.

Original Publication:
Jiang, N-J., Chang, H., Weißflog, J., Eberl, F., Veit, D., Weniger, K., Hansson, B. S., Knaden, M. (2023) Ozone exposure disrupts insect sexual communication **Nature Communications** 14:1186,

Stop signal for cannibalism



Bill Hansson, Hetan Chang and Markus Knaden with a collection of odors emitted by locusts.
Photo: Anna Schroll

Huge swarms of migratory locusts take on the scale of natural disasters and threaten the food supply of millions of people, especially in Africa and Asia. Migratory locusts occur both in the solitary phase (the insects live alone and dispersed), and in the gregarious phase, which is when they exhibit the typical swarming behavior that fits their designation as migratory locusts.

Behavioral experiments with the migratory locust *Locusta migratoria* showed that cannibalism rates increased when more gregarious insects were kept together in a cage. Thus, there is a direct relationship between population density and cannibalistic behavior. To find out if gregarious locusts emit particular odors that are not produced in the solitary phase, a research team led by Hetan Chang, Markus Knaden and Bill Hansson from the Department of Evolutionary Neuroethology analyzed and compared all the odors emitted by solitary and gregarious locusts in the juvenile stage. Of the 17 odors produced only in the gregarious phase, only phenylacetonitrile (PAN) turned out to be an odor signal that deterred other locusts in behavioral tests. As population density increased, not only did the level of cannibalism increase, but the insects also produced more PAN. Using genome editing, the researchers succeeded in switching off an enzyme responsible for the production of this compound. This allowed them to confirm its strong anti-cannibalistic effect, as cannibalism was again significantly increased when the insects were no longer able to produce the compound.

The biggest challenge was finding the olfactory receptor that recognizes PAN. Because locusts have more than 140 odor receptor genes, the research team had to clone as many genes as possible and test one at a time. Tests on 49 different odorant receptors using more than 200 relevant odors eventually led to the identification of the odorant receptor OR70a as a highly sensitive and specific detector of PAN in *Locusta migratoria*.

Behavioral experiments with genetically modified locusts whose OR70a receptor was no longer functional again showed a greatly increased rate of cannibalism. This increase was attributed to the fact that the signal to an insect to stop cannibalism could no longer be perceived by the locusts without the responsible receptor.

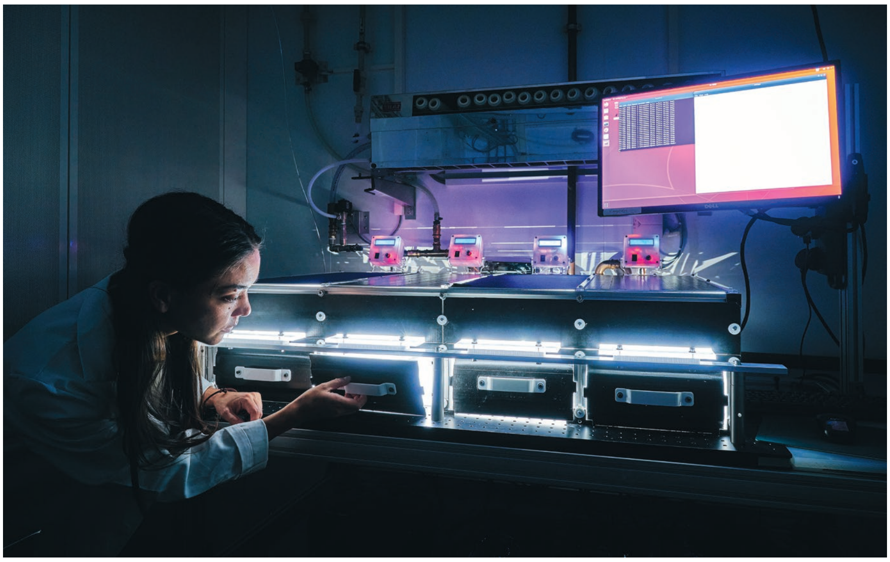
A pheromone that controls cannibalism is an absolutely new discovery. Since cannibalism has a major impact on the swarm dynamics of locusts, a fundamental understanding of the population ecology of these animals, and in particular the effect of PAN, provides new opportunities to curb the spread of locust swarms.
By inhibiting locusts' PAN production or receptor function, researchers could induce the insects to behave in a more cannibalistic manner and thus fight themselves.

Original Publication: Chang, H., Cassau, S., Krieger, J., Guo, X., Knaden, M., Kang, L., Hansson, B. S. (2023). A chemical defense deters cannibalism in migratory locusts. **Science**, 380 (6644), 537-543

Cannibalistic feeding attack: A migratory locust Locusta migratoria *eats a conspecific. Cannibalism is considered one of the main drivers of the devastating swarming behavior of locusts.*
Photo: Benjamin Fabian

INTERVIEW WITH YUKO ULRICH

Science is the best way to understand the world



Yuko Ulrich at the MPI for Chemical Ecology: Her research includes behavioral experiments with many ant colonies simultaneously. She uses software to analyze individually marked individuals in each colony.
Photos: Anna Schroll

Almost two years ago, Yuko Ulrich joined our institute as the first head of a Lise Meitner group. The Max Planck Society's Lise Meitner Excellence Program is aimed at highly talented young female scientists; the program's goal is to increase the number of female scientists in leadership positions. With her research group, Yuko Ulrich is studying the behavior of clonal raider ants. Interdisciplinary collaboration with other groups at the institute allows her to focus on the chemical communication that underlies this behavior.
We asked her a few questions:

Why are you fascinated by science?
I have wanted to be a biologist for as long as I can remember. So I had no hesitation when it came to choosing a major at university. To me, science is the best way to understand and satisfy one's curiosity about the natural world. To do this as a job feels like an incredible privilege: you get to learn all you can on any topic, pick an interesting unanswered question, and then step into the unknown. Beyond this, you get to interact with brilliant people at all career stages on a daily basis, and you constantly learn from them. It is hard for me to think of a more satisfying line of work.

Why do you study ants?
Ants and other social insects are endlessly fascinating. Their colonies show remarkable traits, including extreme forms of cooperative behavior and phenotypic plasticity, as well as sophisticated forms of communication. All these interesting traits are tied to their social lifestyle, which they have pushed to such extremes that it often makes sense to think of the colony as a superorganism, rather than a collection of individuals.
For all these reasons, people have been studying ants for a long time to address big questions in evolutionary biology, behavioral ecology and chemical ecology, and we can ground our work in this rich body of knowledge.

What has been your most exciting discovery so far?
During my postdoc in Daniel Kronauer's lab at The Rockefeller University, my colleagues and I studied division of labor in the clonal raider ant, a queenless species where colonies are made up of genetically near-identical workers. We found that these identical workers develop stable differences in behavior in response to their social environment. In other words: they develop individuality in each other's presence. The more ants in the colony, the more they specialized in certain tasks like brood care or foraging. This was exciting because it showed that division of labor, a fundamental property of insect societies, can emerge naturally among a small number of identical individuals.

Why did you decide to come to our institute?
For the research and the people. The unique knowledge and expertise present at this institute provide new opportunities for us to identify some of the chemical cues that drive social behavior. Because I am not a chemist, this requires lots of input from people with different expertise and a really collaborative environment. Right from my first visit to the institute, I felt the institute would provide a supportive, collaborative, and welcoming environment for a young research group. And this has definitely proved true!

Which research projects did you bring to Jena?
All our projects use the clonal raider ant *Ooceraea biroi* to address questions about social behavior. In the main research project I brought to Jena, which is funded by the ERC, we investigate how social organization affects disease transmission. This project has already grown in directions that are very much influenced by our new scientific environment. For example, we have started looking at whether parasites disrupt the chemical communication of their hosts and whether this could have something to do with the behavioral changes we observe in infected individuals.

Which new projects are you looking forward to?
One project is a collaboration with the Mass Spectrometry group headed by Rayko Halitschke, where we hope to identify a key larval pheromone in our ants. Together with Tobias Koellner from the Department of Natural Product Biosynthesis, we are starting to characterize and localize some of the chemicals produced by the clonal raider ant and other ants. With Markus Knaden and Nan-Ji Jiang from the Department of Evolutionary Neuroethology, we are working on the chemical ecology of parasitic infections. Finally, in collaboration with the Department of Insect Symbiosis, we plan to start testing some generalist insect symbionts in our ants. All these collaborative projects could not easily have happened anywhere else, and I cannot wait to see what we find.

What does it mean to you to be leading a Lise Meitner group?
It's a real honor to be part of the Lise Meitner Excellence Program, which gives people at my career stage an incredible opportunity with a long-term perspective. In practice, being a Lise Meitner group leader also means I am part of a growing, supportive community of brilliant young female principal investigators. I am excited to see what that community achieves. My advice to young female scientists would probably be to apply for this or a similar program, even if you do not feel 100% ready yet, or are not sure you satisfy all criteria perfectly. It is also hard to overstate how important creating and maintaining a network of supportive people in academia can be; this will help you throughout your career.

Diversity is a matter close to your heart. Why is it important?
I think diversity is simply good for science. It is pretty clear to me that talent is distributed equally, it is opportunity that is not. If academia and research institutes want to attract and retain the best talent, they need to be more diverse and inclusive than it has traditionally been. There is also a lot of empirical evidence that diverse groups of people perform better overall. At a more basic level, I personally had the chance to work at several different institutions, and I find that working in a diverse, inclusive environment is intellectually more stimulating, interesting, and fun.

The Lise Meitner Group Social Behavior in May 2023: Baptiste Piqueret, Xiaohua Chu, Sarah Rogoz, Lai Ka Lo, Qi Wang, Bhoomika Bhat, Antje Schmaltz, Yuko Ulrich, Tim Zetzsche, Luis Wirsching, und Zimai Li (from left to right).
Photo: Angela Overmeyer

Below: A group of clonal raider ants of the species* Ooceraea biroi*. The colored markings are used to track the behavior of individual workers from a colony.
Photo: Anna Schroll

RESEARCH NEWS / AWARDS

The dark side of being toxic

Original Publication:

Blount, J. D.; Rowland, H. M., et al. (2023). The price of defence: toxins, visual signals and oxidative state in an aposematic butterfly. **Proc. R. Soc. B.** 29020222068

Monarch butterfly *Danaus plexippus*. Photo: Hanna Rowland

Hannah Rowland, head of the Max Planck Research Group Predators and Toxic Prey, together with an international research team, has found that the striking orange and black wings of monarch butterflies, known to signal to predators that these butterflies are highly toxic, has a down side. Monarch butterflies that had ingested high amounts of toxic food as caterpillars exhibited high levels of oxidative damage and were less conspicuous in their coloration after storing these toxins in their bodies. Thus, the storage of toxins and the formation of the colorful wings come at a cost, even for insects that are highly specialized on their food plants.

Gottfried Wilhelm Leibniz Prize awarded to Sarah O'Connor

Sarah O'Connor and DFG President Katja Becker. © David Ausserhofer/dfg

This year's Leibniz Prizes were awarded in Berlin on March 15, 2023. Among the 10 awardees was Sarah O'Connor, head of our Department of Natural Product Biosynthesis. The chemist is being honored with Germany's most prestigious research award, endowed with 2.5 million euros, for her fundamental discoveries in the area of plant natural product biosynthesis. Sarah O'Connor studies metabolites in plants, particularly alkaloids and iridoids, which are often of interest as medicinal agents. Her research focuses on how plants produce these complex compounds from simple building blocks, and how metabolic pathways have developed in the course of evolution. Her findings are of great importance for the possible synthetic production of plant natural products for medical use. She is also developing new biological platforms to produce high-quality plant-derived natural products cheaply and quickly.
In May, Sarah O'Connor was also elected as a new Fellow of the Royal Society.

Certificate of Merit for Silke Sachse

Silke Sachse. © Nives Kramberger

The Council of the International Congress of Entomology will honor Silke Sachse with the Certificate of Merit, a new award for outstanding mid-career entomologists, at the 27th International Congress of Entomology 2024 in Kyoto, Japan. Silke Sachse joined the Department of Evolutionary Neuroethology in 2006 as a project group leader. Since 2008, she has led the independent Olfactory Coding Research Group. Using the model fly *Drosophila melanogaster*, she has been investigating the neural basis of olfactory perception in insects.
By combining neurogenetic tools with state-of-the-art techniques such as *in vivo* two-photon microscopy, anatomical tracing, neuronal reconstructions, optogenetics, and variety of behavioral assays, her group has identified crucial neuronal mechanisms that enable an insect to encode, process and interpret the wide array of environmental odors to accomplish odor-guided decisions.

www.ice.mpg.de

Impressum: PULS/CE is published semi-annually and can be downloaded free of charge on the homepage of the MPI for Chemical Ecology and is distributed electronically as PDF to subscribers. A print version will be sent on request. **Editor:** MPI-CE, Jena / **Managing Director:** Prof. Dr. Jonathan Gershenzon (viSdP) / **Editorial Staff:** Dr. Karin Groten, Research Coordination; Angela Overmeyer M.A., Information and Communication; Emily Wheeler, Editing / **ISSN:** 2191-7507 (Print), 2191-7639 (Online)

MAX PLANCK GESELLSCHAFT