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PULS/CE 44

MAX-PLANCK-INSTITUT
FÜR CHEMISCHE ÖKOLOGIE

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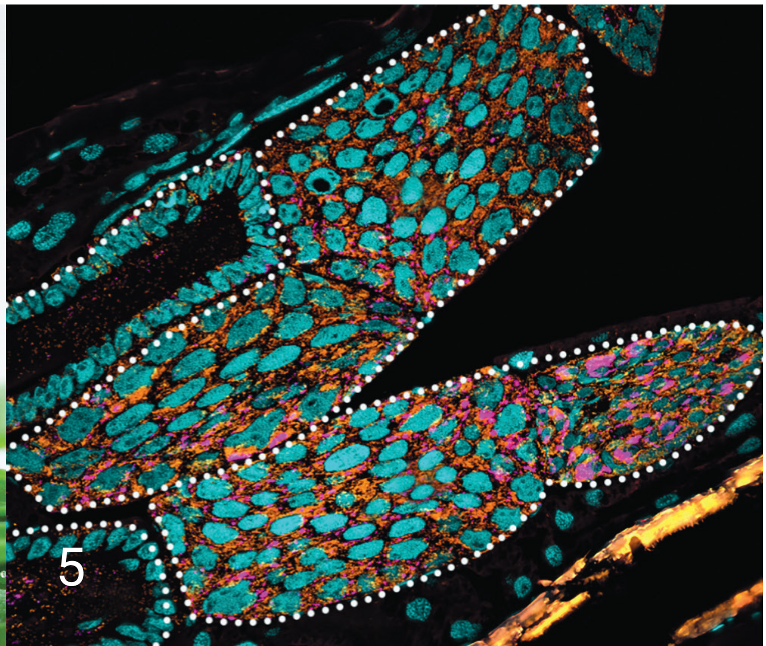

MAX PLANCK
GESELLSCHAFT

EDITORIAL

Our research for society

Above: Our foyer during the Long Night of the Sciences 2022, when almost 2,000 visitors came to learn about our research.
Below: Part of the research team at the Long Night of the Sciences 2022.
Photos: Angela Overmeyer, MPI-CE

Dear readers!

On November 22, it's time again: our institute opens its doors for the Long Night of the Sciences. For the ninth time, we would like to introduce everyone to the fascinating world of chemical communication between living organisms. This event is not only an opportunity for us to present our research on plants, insects and microorganisms, but also an expression of our commitment to a society that supports us with public funds. Research does not take place in a vacuum. It is closely linked to the values of democracy and world openness, values that we live and breathe in an active way. In a world increasingly marked by tensions and the need to find common answers to global crises such as global warming or the extinction of species, we see it as our responsibility to build bridges and promote dialogue.

The majority of our researchers come from abroad. International diversity enriches our scientific approaches and perspectives, and strengthens the intercultural exchange that is essential for an open society. Science thrives on diversity - of origin, of thought, of experience, of methodology. Only together can we meet the great challenges of our time. It is also important that research takes place within democratic structures. Democracy promotes freedom of research and ensures that scientific knowledge is transparent and accessible to all. By sharing our research results with the public, we want to contribute to informed decision-making and to strengthen trust in scientific processes. Therefore we cordially invite you to learn more about our research projects, results and ideas during the Long Night of the Sciences. We are driven by your interest and your questions. On page 8, you can learn more about our program on November 22. Join us and become part of our dialogue!

Angela Overmeyer

LANGE NACHT DER WISSENSCHAFTEN JENA 2024

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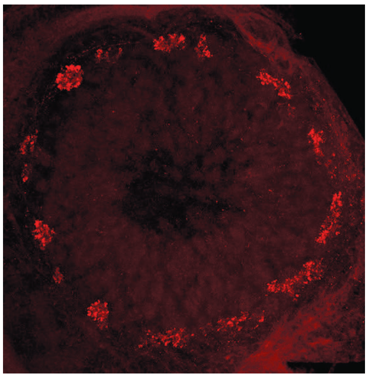
RESEARCH HIGHLIGHT

Ring-shaped odor coding

The European migratory locust, *Locusta migratoria,* is considered a major crop pest and is mentioned in the Old Testament as the eighth of the ten biblical plagues of Egypt. Despite its name, it is rare in Europe, but causes massive crop failures in Africa and Asia, threatening the livelihoods of many people. The insects occur in two phases: as localized individuals in the solitary phase and in the dreaded gregarious or swarming phase. A unique feature of migratory locusts is the structure of their olfactory brain, the antennal lobe. It has more than 2,000 spherical olfactory units called glomeruli, unlike most other insects which have only 20 to 300.

Using the CRISPR/Cas9 method, Xingcong Jiang from the Olfactory Coding Research Group and the Department of Evolutionary Neuroethology has succeeded for the first time in developing transgenic migratory locusts that express a special calcium sensor in their olfactory neurons. This protein fluoresces when the cells are activated, ennabling scientists to analyze the details of odor processing. Using functional 2-photon calcium imaging, the researchers were able to visualize the activation patterns for different odors in all developmental stages of the locust. The results show a ring-shaped arrangement of glomeruli in the antennal lobe of locusts, which the research team led by Silke Sachse and Bill Hansson, was able to confirm through the targeted genetic expression of a well-characterized olfactory receptor.

The pattern of odor coding within the glomeruli is consistent in all developmental stages, from the first nymph stage to the adult locust. Interestingly, the spatial coding of odors in the antennal lobe reflects the chemical structure of the odors, but not their valence. Pleasant and unpleasant scents activate different regions of the olfactory brain in flies; migratory locusts, in contrast, do not show a valence-specific activation coding in higher brain centers.



The ring-shaped structure of the olfactory coding could be specific to migratory locusts. Future studies will need to show whether other locust species show similar coding patterns.

Knowing how insects perceive and process odors and how this ultimately affects their behavior is important in order to better understand the ecological interactions of insects with their environment. This could improve the control of pests, such as the migratory locust, and increase our understanding of the neural mechanisms underlying swarm formation.

Above: European migratory locust (*Locusta migratoria*) feeding: Scientists at the Max Planck Institute for Chemical Ecology want to understand how the perception of odors affects the animals' dangerous swarming behavior and have now studied the olfactory coding in the locust brain.
Photo: Benjamin Fabian

Center: Ring-shaped glomerular arrangement in the outer region of the antennal lobe of a migratory locust. The region receives input from olfactory sensory cells that respond to the cannibalism-inhibiting pheromone phenylacetonitrile (PAN), first described by Bill Hansson's team in a study published in Science in 2023.
Fluorescence microscopic image using mCherry immunostaining: Xingcong Jiang / Veit Grabe

Original Publication: Jiang, X. et al. (2024). Ring-shaped odor coding in the antennal lobe of migratory locusts. **CELL**, doi: 10.1016/j.cell.2024.05.036

RESEARCH HIGHLIGHT

Key protein for plant defense

First author Marianna Boccia investigates black nightshade plants. Photo: Anna Schroll

Colorado potato beetle* Leptinotarsa decemlineata *on black nightshade. Feeding experiments with plants lacking GAME15 and wild-type plants revealed the role of steroidal saponins in leaf defense. Photo: Danny Kessler

The biosynthesis of specific steroidal compounds in Solanaceae plants, such as potatoes and tomatoes, starts with cholesterol. Although the genes for the basic structures are known, it has not been possible to reconstitute these processes in other plants. Prashant Sonawane, head of the Specialized Steroid Metabolism in Plants Group in the Department of Natural Product Biosynthesis, and his team set out to find the missing piece of the puzzle. They wanted to find out which gene or protein in the biosynthetic pathway was still unknown.

The research team used the wild plant *Solanum nigrum* (black nightshade), which forms various steroid molecules from cholesterol. The leaves are dominated by the saponin uttroside B, the berries contain steroidal glycoalkaloids, such as α-solasonine. Through biochemical analysis, researchers discovered the gene GAME15, which encodes a protein that belongs to the family of cellulose synthase-like proteins but has no function in cellulose production. Instead, it plays a crucial role in the production of steroidal compounds. GAME15 interacts with other enzymes involved in the hydroxylation of cholesterol. Plants in which the GAME15 gene was knocked out were unable to produce steroidal glycoalkaloids or saponins.

Steroidal saponins and steroidal glycoalkaloids have promising medical applications, including anti-cancer properties. By identifying GAME15, the research team was able to reconstitute the metabolic pathway of these compounds in heterologous hosts, such as the tobacco plant *Nicotiana benthamiana*, up to the scaffold of furostanol, a precursor of steroidal saponins, and solasodine, a direct precursor of steroidal glycoalkaloids. This method, also known as 'pharming', uses genetically modified plants to produce low-cost medicinal substances.

Observations in the greenhouse led researchers to discover the ecological role of steroidal saponins in black nightshade. They had noticed that genetically modified plants that could no longer produce saponins were more susceptible to leaf pests. In experiments with leafhoppers and Colorado potato beetles, the insects preferred the GAME15 knockout plants. This is the first demonstration of the importance of steroidal saponins in plant defense.

The new findings, published in the journal *Science*, open new opportunities for breeding pest-resistant plants and for producing steroidal compounds of medical interest.

Original Publication: Boccia, M. et al. (2024) A scaffold protein manages the biosynthesis of steroidal defense metabolites in plants. **Science**, doi:10.1126/science.ado3409

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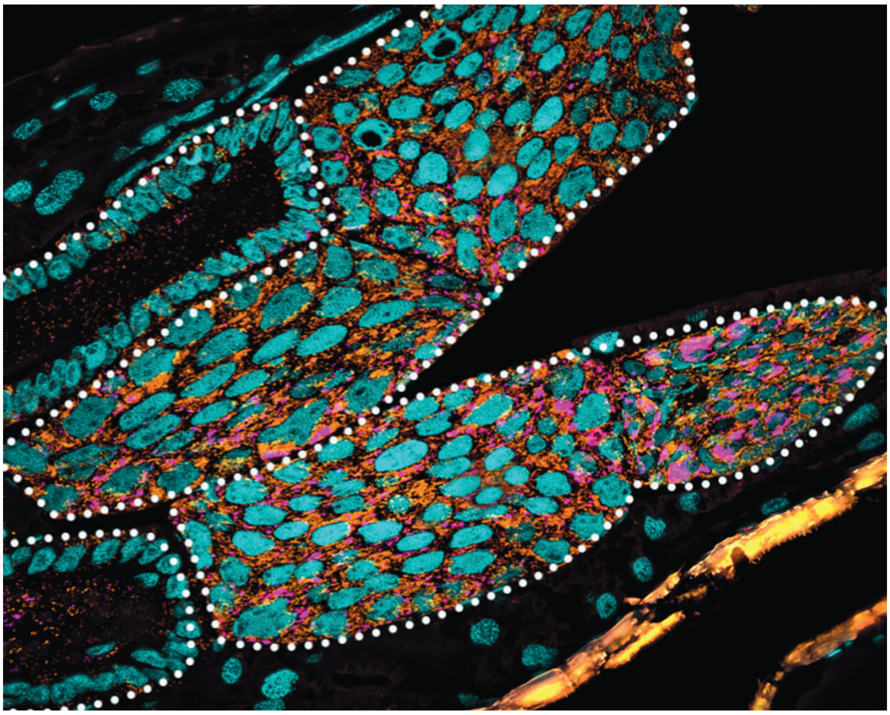
RESEARCH HIGHLIGHT

Hidden partners



Symbiodolus ***bacteria in the reproductive tissue of the cereal leaf beetle*** **Oulema gallaeciana.** ***These are yellowish-orange in color, whereas the nuclei of the host are blue.*** **Symbio** ***in the name of the symbiont refers to a symbiotic partnership;*** **dolus** ***refers to the deceptive way in which the bacterium infiltrates the host. The Greek-Roman deity "Dolus" as the personification of deception and fraud was the inspiration. The species name*** **clandestinus** ***means "secret." The name refers to the symbiont's ability to penetrate the host's tissues and remain hidden from the host's immune system.***
Fluorescence *in-situ* hybridization: Jürgen Wierz / Benjamin Weiss

Living organisms are always part of an ecosystem and interact with each other. There are both harmful interactions, such as parasitism, and beneficial ones, such as mutualistic symbioses, where both partners benefit. Harmful and beneficial interactions occur on a continuum, and the effect on the host is often dependent on the ecological context.

A team of researchers led by Jürgen Wierz and Martin Kaltenpoth from the Department of Insect Symbioses is the first to describe the newly discovered insect symbiont *Symbiodolus clandestinus*, which is found in numerous insect species and may have far-reaching effects on insects and ecosystems.

The discovery of *Symbiodolus* in various insect species was made independently by several members of the group. Discussions within the group and searches of DNA databases revealed that *Symbiodolus* is a widespread bacterial symbiont about which little in known. One reason for this could be that *Symbiodolus* does not appear to have a clear impact on its hosts and is often found in low numbers.

Jürgen Wierz wanted to find out more about the symbiont, in particular how widespread it is, in which insect tissues it occurs and what influence it has on its hosts. Using genome sequencing, he was able to identify *Symbiodolus* in 23 insect species from six different insect orders, including beetles, dipterans, butterflies and fleas. In the species with *Symbiodolus*, almost all the individuals studied carried the symbiont. However, the amount of *Symbiodolus* bacteria in the individual insect species varied greatly. Fluorescence *in situ* hybridization showed that *Symbiodolus* can spread in different insect tissues and penetrate cells, especially in reproductive organs. That the symbiont was found in all life stages of the insects, including eggs, suggests parents may transmit it to offspring. These findings show that the symbiont is well adapted to life in insects.

To study the interactions between symbionts and host insects, the research team assembled the symbiont's genome and discovered several secretion systems of *Symbiodolus*. These systems allow the bacteria to efficiently transport molecules and control biological processes. Several secretion systems were identified, including T1SS, T3SS and T6SS. The diversity of these systems may explain why *Symbiodolus* is so successful in different hosts and can invade their cells.

Symbiodolus also produces amino acids and vitamins that could benefit the host, but may also be dependent on nutrients from the host. Although the interactions are not yet fully understood, *Symbiodolus* provides important insights into the symbiotic relationships between insects and bacteria. Understanding these strategies could help elucidate the evolutionary origins and success of insect-microbe symbioses and explore their role in nature.

Original Publication: Wierz et al. (2024). Intracellular symbiont *Symbiodolus* is vertically transmitted and widespread across insect orders. **ISME Journal**, doi: 10.1093/ismejo/wrae099

Pit-building venom mixers

Researchers from the Department of Insect Symbiosis, together with colleagues from the University of Giessen, report that the adaptation of antlions to their ecological niche has also changed their venom. They compared the venom system of antlions, the larvae of antlion lacewings, with that of the closely related lacewing larvae. The antlions produce a much more complex venom from three different venom glands than do their relatives. All of the identified venom proteins come from the insect larvae themselves and not from symbiotic bacteria. Analyses using fluorescence *in situ* hybridization to visualize bacteria in the tissue showed that antlions are apparently free of symbiotic bacterial partners. Some of the toxins are new and appear to be unique to antlions. Antlions, which wait for their victims in funnel-shaped traps in the sand, can also immobilize large prey with their venom.

The results show that different habitats and prey spectra strongly influence the venom composition and venom systems of lacewings, and that their dynamics could impact the evolution of predator-prey relationships. Antlions produce a complex venom mixture that enables them to overwhelm even large, defensive insects in their prey-poor habitat. They have also developed evolutionarily unique structures that allow them to inject either venom or digestive enzymes into their prey through their mouthparts in separate systems.

Original Publication: Fischer, M. L. (2024). Divergent venom effectors correlate with ecological niche in neuropteran predators. **Communications Biology**, 7: 981, doi: 10.1038/s42003-024-06666-9

An antlion (Euroleon nostras) waits in its sand funnel for prey insects to fall or walk into the funnel. Usually all you can see are its sickle-shaped pincers sticking out of the sand. Photo: Benjamin Weiss

A bitter aftertaste: How nitrogen gets into the bitter substances of *Solanum* plants

Dagny Grzech with black nightshade plants, which serve as a platform for developing the production of steroidal glycoalkaloids. Photo: Anna Schroll

A team of researchers from the Department of Natural Product Biosynthesis, in collaboration with colleagues from the University of York in the UK and the Weizmann Institute of Science in Israel, has succeeded in characterizing the crucial biosynthetic step in the production of steroidal glycoalkaloids, important defence substances in several plants of the genus *Solanum* (family Solanaceae). Solanaceous plants, such as tomatoes and potatoes, produce nitrogenous defense compounds called steroidal glycoalkaloids to protect themselves from herbivores and plant diseases. Nitrogen uptake is a key factor in the toxicity and hence bioactivity of steroidal glycoalkaloids.

The scientists have now discovered how the transaminase enzyme GAME12, which plays an important role in basic plant metabolism, controls the production of steroidal glycoalkaloids in *Solanum*. The research provides a basis for the biotechnological production of steroidal glycoalkaloids in other plant species. The researchers were able to show that the transfer of the GAME12 enzyme into the leaves of black nightshade (*Solanum nigrum*) is sufficient to produce nitrogen-containing steroidal glycoalkaloids that would otherwise not be present in the leaves. This metabolic detour may also be possible in other agriculturally relevant plants that produce non-nitrogenous defense compounds such as saponins.

The study illustrates the high plasticity of biosynthetic pathways, which is reflected not only in changes in enzymatic activity but also in their spatial organization. This metabolic plasticity leads to an enormous diversity of specialized pathways in plants.

Original Publication: Grzech, D. et al. (2024). Incorporation of nitrogen in anti-nutritional *Solanum* alkaloid biosynthesis. **Nature Chemical Biology**, doi: 10.1038/s41589-024-01735-w

New research group investigates how evolution happens as a process

Shabnam Mohammadi will head the Max Planck Research Group Evolutionary and Integrative Physiology at the Max Planck Institute for Chemical Ecology starting in November 2024.
Photo: Alfonso Aceves Aparicio

Our institute has a new research group starting in November: The Max Planck Research Group Evolutionary and Integrative Physiology investigates how evolution works by analyzing similar evolutionary outcomes in different species. Research questions focus on the predictability and accessibility of adaptations. The scientists hope to find answers to the question of whether function-altering mutations are gained predominantly by chance or are influenced by molecular factors. They will also investigate the phenomenon of negative pleiotropy, whereby beneficial mutations can also have disadvantageous effects. The group hopes to find out how compensatory mutations and gene duplications can counteract these negative effects in order to better understand the dynamics of evolution as a whole. One example is the resistance of various vertebrates to toxic cardiac glycosides.

The group is led by Shabnam Mohammadi. The American completed her PhD at Utah State University in 2017, focusing on the molecular and physiological mechanisms of toxin resistance in toad-eating snakes. In 2018, she came to Germany on a scholarship from the Alexander von Humboldt Foundation to work as a postdoc at the University of Hamburg. Since 2022 she has been a postdoctoral researcher in Hannah Rowland's Max Planck Research Group Predators and Toxic Prey, at our institute. In her new group, she aims to investigate large-scale evolutionary patterns and adaptative mechanisms at different hierarchical levels of biological organization. Her research will focus on genomic evolution, and the molecular function and physiology of living organisms. This interdisciplinary approach will be used to investigate how some vertebrates have become resistant to cardiac glycosides.

https://www.ice.mpg.de/481968/evolutionary-and-integrative-physiology

Honors for Jonathan Gershenzon

Right: Jonathan Gershenzon receives the Silver Medal of the International Society of Chemical Ecology (ISCE) from ISCE President Ted Turlings. The award winner gave the first plenary lecture at the 39th Annual Meeting of the International Society of Chemical Ecology in Prague entitled "The other half of the story: How insects circumvent plant chemical defenses."
Photo: Markus Knaden

Jonathan Gershenzon, head of the Department of Biochemistry, has been elected a member of the European Molecular Biology Organization (EMBO). His election as EMBO member underlines his pioneering research in the field of chemical ecology. As an EMBO member, Jonathan Gershenzon joins a community of more than 2,100 outstanding researchers, including 92 Nobel Laureates.

Jonathan Gershenzon was also awarded the Silver Medal of the International Society of Chemical Ecology (ISCE) in July. The medal recognizes Gershenzon's outstanding contributions to the study of the interactions between plants and herbivorous insects. His research has supported the development of new, more sustainable methods of pest control in agriculture, the ISCE said in announcing the award. His work has shown how insects can evade plant defenses through detoxification reactions or by altering the target site of the toxin.

The ISCE also highlighted his recent research into the defense mechanisms of woody plants, particularly poplar and spruce species. The continuing heavy bark beetle infestation in central European spruce forests prompted him to investigate possible preventive measures based on a better understanding of the natural defense mechanisms of spruce.

LONG NIGHT OF THE SCIENCES

Did you know that the devastating damage caused by bark beetles in our forests is also due to their successful cooperation with fungi? Or that insects have very sensitive noses or antennae and depend on their sense of smell for survival? Or have you ever heard of beewolves? They live in an amazing defense symbiosis with bacteria to protect their offspring. We look forward to your visit during the Long Night of the Sciences on November 22, 2024, and to sharing with you the secrets of how insects, plants and microbes live together.

https://www.lndw-jena.de/

www.ice.mpg.de

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