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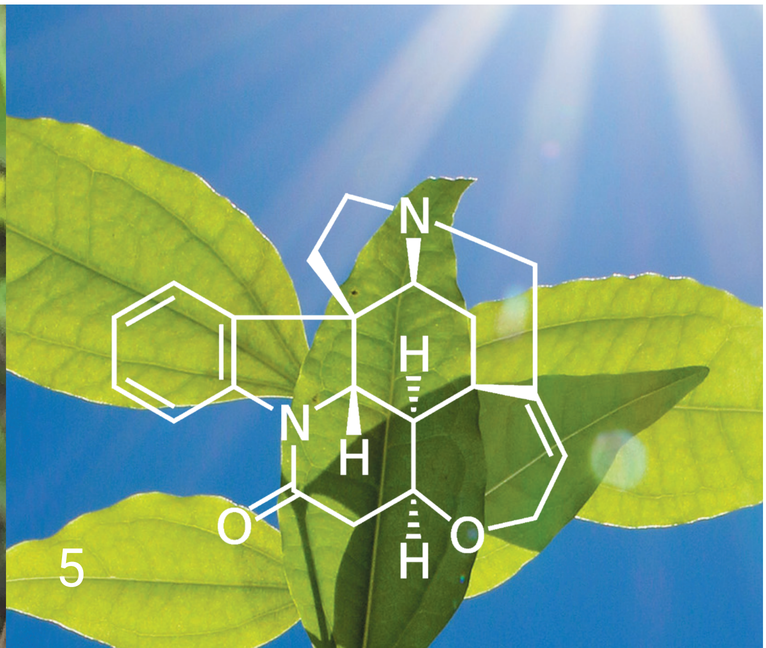
PULS/CE 40

MAX-PLANCK-INSTITUT
FÜR CHEMISCHE ÖKOLOGIE

NEWSLETTER / NOVEMBER 2022



MAX PLANCK
GESELLSCHAFT

EDITORIAL

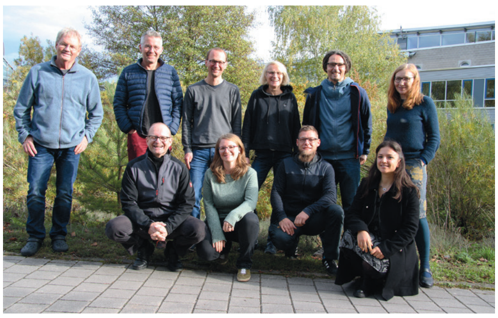
The switch to energy-efficient LED lamps has not only resulted in significant electricity savings, the lighting can also be optimized for plant growth. The advantages of LEDs for plant cultivation have been scientifically evaluated at the institute.

Photo: Benjamin Hermann

We want to become more sustainable!

Dear Readers!

In this, the 40th issue of our newsletter, we would like to focus on a topic that has been becoming increasingly important: sustainability. Since the end of 2021, we have had a Sustainability Commission at our institute. Moreover, we have identified various areas in which we can act more sustainably as individuals and as a team: saving resources, reducing waste, reducing paper consumption by creating paperless workflows, reducing the carbon footprint when traveling to conferences and meetings, supporting biodiversity on the institute's premises, and supplying more sustainable food by offering vegetarian and vegan options. The commission, which currently consists of 12 members, meets once a month to discuss concrete measures and ways to implement them. Since February 2022, we as an institute have also faced an energy crisis caused by the war in Ukraine, and the need and urgency to implement energy-saving measures have come into even greater focus.



Members of the Sustainability Commission at MPI: Johan Brandenburg, Markus Knaden, Martin Kaltenpoth, Karin Groten, Danny Kessler, Angela Overmeyer (back row f.l.t.r.), Thomas Melzer, Sarah Heinicke, Roy Kirsch, Marianna Boccia (front row, f.l.t.r.).

Photo: Evelyn Claußen

With the May presentation by Una Fitzgerald of the University of Galway, a pioneer of the "green lab" initiative, we aimed to provide food for thought on how to reduce the environmental footprint of lab work. Sustainable options in the lab as well as a wide range of resource-saving actions in everyday life or on business trips were identified in a specially prepared survey conducted at the institute, which also helped to increase awareness among the nearly 200 participants.

We have already implemented a number of measures, both large and small. For example: We now use only recycled paper for printers. Since spring, the facade has no longer been lit up in the evening, and lights in laboratories, offices and other shared rooms are switched off automatically at 9 p.m. At the same time, air exchange at night in most labs is kept to a minimum until morning. Shading measures during the summer months have enabled us to significantly reduce electricity consumption in the greenhouse, and settings in our climate chambers have been optimized for energy efficiency.

Our efforts are already bearing fruit: a comparison of electricity consumption in September 2022 with the average electricity consumption of the past eight years showed savings of around 15%. In addition, biodiversity is close to our hearts, and we are working on a concept for the green spaces on the entire Beutenberg campus to protect insects and increase biodiversity by reducing mowing.

Everyone should do what they can to act sustainably, because the time we have left to achieve climate goals is running out. As scientists, we see ourselves as having a special responsibility to contribute.

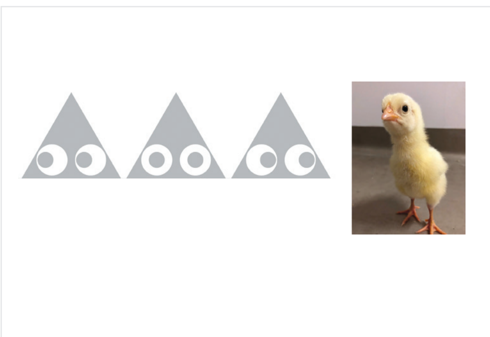
Martin Kaltenpoth

The Mona Lisa effect

Visitors to an art gallery may be familiar with this effect: they feel watched or even followed everywhere in the room by the eyes in a portrait on the wall. This so-called Mona Lisa effect is created when the painter precisely centers the pupils of the subject.

Nature seems to use the Mona Lisa effect as well. Some animals, including many fish and butterflies, have paired circular spots on their bodies that closely resemble eyes. Eyespots have an intimidating effect and are meant to discourage predators from attacking, as they mistake the spots for the eyes of their own enemies.

To test the Mona Lisa effect and rule out the possibility that conspicuous patterns are generally deterrent, Hannah Rowland and her colleague John Skelhorn from Newcastle University developed a behavioral experiment with newly hatched domestic chicks that they trained to attack artificial moths for a mealworm reward. When the chicks had learned to attack the prey, they were presented with one of three different artificial moths: one with so-called eyes whose middle circles (pupils) looked to the left, one with eyes that looked to the right, and one with perfectly concentric circles; thus, the moths appeared to gaze straight forward or to one of the two sides. Then the researchers built mini catwalks (chickwalks!) that either led straight to the food or approached from the side.



The results of the behavioral experiments were unambiguous: The chicks approached more cautiously from the left when the eyespots appeared to look to the left. Chicks approaching from the right showed similar caution when the eyespots were shifted to the right. However, when the chicks approached the artificial eyes from the direction opposed to the perceived line of vision, they attacked the artificial moth quickly to eat the mealworm award. Chicks approached moths with concentric circular eyes only with great caution, regardless of the direction of those eyes. Apparently, chicks perceive the artificial eyespots as eyes. This probably also explains why, in nature, eyespots have evolved independently in different animals to successfully deter enemies.

Hannah Rowland leads the Max Planck Research Group Predators and Toxic Prey. Her focus is on predator-prey relationships, which have long served as models for studying adaptation and fitness in natural environments.

A peacock butterfly (Aglais io) has eyespots on the upper side of each forewing and hindwing.

Bottom left: Predatory chicks and artificial peacock butterflies in a behavioral experiment. The direction of the artificial eyes influenced the birds' behavior: If the eyes looked at the bird, it approached the food more cautiously.

Photos: Anna Schroll (above), Hannah Rowland (middle and bottom left)

Original Publication:

Skelhorn, J., Rowland, H. M. (2022). Eyespot configuration and predator approach direction affect the antipredator efficacy of eyespots, **Frontiers in Ecology and Evolution**, 10:951967.

RESEARCH HIGHLIGHT

Key to pectin digestion

Roy Kirsch loading a third-generation sequencer: So-called nanopore sequencing made it possible to decode the genome of the leaf beetle Phaedon cochleariae.

Mustard leaf beetle (Phaedon cochleariae) feeding on cabbage. Beetle lines that no longer had pectinases after CRISPR-Cas9 genome editing were not able to degrade plant cell wall pectins. Their growth and survival was severely impaired.

Photos: Anna Schroll

Fossil findings of damage to plants by feeding insects provide evidence that insects have been using plants as food for more than 400 million years. Researchers led by Roy Kirsch and Yannick Pauchet from the Department of Insect Symbiosis are investigating how herbivorous insects are able to break down plants' hard-to-digest components. They want to understand how herbivorous insects deal with the plant cell wall that makes up the bulk of their diet. Pectin must be digested first so that the enzymes cellulase and hemicellulase can reach their substrates, and the plant cells are finally freed from their protective cell wall. In this context, pectinases, pectin-degrading enzymes, are the keys to the leaf beetle's efficient digestion.

To test the role of pectinases, the researchers created beetle lines in which these enzymes were no longer present. Using CRISPR/Cas9 genome editing, they succeeded in completely silencing the pectinase-encoding genes in the beetles. The larvae of these pectinase-null mutants turned out to have a low survival rate. A further question was whether the degradation products of pectin digestion improved the survival rate of these beetles when administered orally to the beetle larvae. However, feeding experiments showed that this was not the case. Although surprising, this result showed that leaf beetles do not digest pectin to take advantage of the degradation products. Instead, the decomposition of pectin and probably other plant cell wall polysaccharides facilitates access to the protein-rich cytoplasm of plant cells.

Research in recent years, including from Yannick Pauchet's group, has shown that the acquisition of microbial enzymes via horizontal gene transfer contributed to the species richness not only of leaf beetles but also of insect groups, such as weevils, bark beetles and stick insects. The acquisition of enzymes from microbial organisms could be considered an evolutionary shortcut; in any case, it created the preconditions for insects to turn to pectin-rich plants as a food source in the first place.

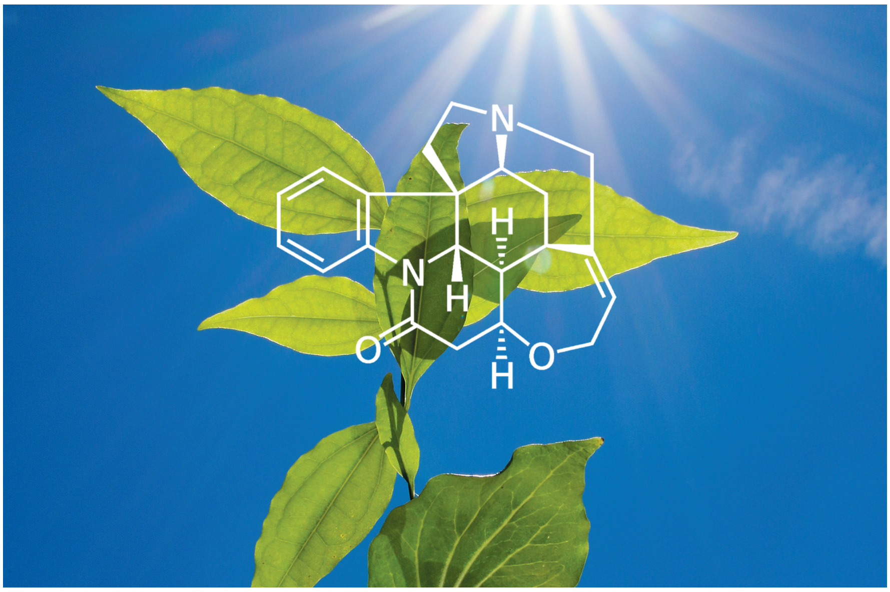
The work of Roy Kirsch, Yannick Pauchet and their team illustrates that an insect's survival on a host plant is not just a matter of adapting to plant defenses such as toxins, feeding inhibitors and other secondary metabolites. Rather, these scientists are focusing on primary metabolism, which has been neglected in research on plant-insect interactions. Their results show that the ability of an insect to digest products of plant primary metabolism is as important to its evolutionary success as its adaptation to plant secondary metabolites.

Original Publication:

Kirsch, R.; Okamura, Y.; Häger, W.; Vogel, H.; Kunert, G.; Pauchet, Y. (2022) Metabolic novelty originating from horizontal gene transfer is essential for leaf beetle survival. **Proceedings of the National Academy of Sciences of the United States of America** 119 (40), e2205857119.

Strychnine biosynthesis elucidated

Many of us know strychnine from crime reports, novels or films. Agatha Christie described what is probably the best-known fictional murder case involving the highly toxic alkaloid used as rat poison in her first novel, "The Mysterious Affair at Styles." The final clue to solving the case was found by the famous detective character Hercule Poirot in his first-ever literary appearance. In science, too, investigative instinct and detective work are sometimes required. Researchers led by Benke Hong and Sarah O'Connor from the Department of Natural Product Biosynthesis not only had to find the one missing link, but they also had to elucidate the entire chain of biosynthetic events that lead to the formation of strychnine in the poison nut tree. To stay in the realm of crime literature: They've solved the case!



Poison nut tree Strychnos nux-vomica with a strychnine molecule. Remarkably, only a single amino acid change in one of the biosynthetic enzymes is responsible for the accumulation of different alkaloids in the poison nut and other Strychnos species.

Photo: Danny Kessler

Surprisingly, it has not yet been possible to find out how plants produce this natural substance, whose molecular structure has a particularly complex architecture. To explore how plants produce strychnine, the scientists first had to find the genes responsible for its biosynthesis. Led by Hong, researchers compared the expression of genes from two species of the genus *Strychnos*, of which only the poison nut produces strychnine. Then they selected candidate genes for each step based on the proposed chemical transformation. The upstream genes of strychnine biosynthesis leading to the formation of a key intermediate have been fully elucidated in the medicinal plant *Catharanthus roseus* (Madagascar periwinkle), and the homologous genes have been identified in the poison nut. "Chemical logic" was required to further solve the task. Based on chemical structures and mechanisms, each step in the metabolic pathway yielded a proposed chemical transformation. As evidence that the identified genes were responsible for the proposed biosynthetic steps, the researchers modified tobacco plants to temporarily produce the enzymes. Adding the appropriate feed materials, they then examined whether the transformed tobacco plant formed the hypothesized product. This method allowed for high-throughput testing of multiple genes simultaneously. Chance came to the rescue in elucidating the final step of strychnine biosynthesis, as it turned out that this transformation occurs spontaneously and does not require an enzyme. Thus, the complete biosynthetic pathway of strychnine, as well as the related molecules brucine and diabolin, could be elucidated. While brucine is also produced by the poison nut, diabolin is formed by a related species of the genus *Strychnos*, which produces neither strychnine nor brucine.

The elucidation of plant metabolite biosynthesis and the biotechnological use of knowing the genetic basis for the formation of medically important compounds are promising research fields. The current study opens up new possibilities for the production of previously unknown plant natural products using metabolic engineering.

Original Publication:

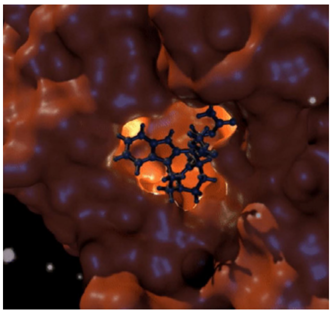
Hong, B., Grzech, D., Caputi, L., Sonawane, P., Rodriguez Lopez, C., Kamileen, M. O., Hernandez Lozada, N. J., Grabe, V., O'Connor, S. E. (2022). Biosynthesis of Strychnine. **Nature**, 607, 617-622.

Expansion of a catalytic repertoire in plant metabolism

Researchers from the Department of Natural Product Biosynthesis, together with partners from the John Innes Centre, UK, and the Chinese Academy of Sciences, have discovered how the catalytic repertoire of alcohol dehydrogenases in plant metabolism has been expanded. Normally, medium-chain alcohol dehydrogenases carry out a reversible 1,2-reduction of aldehydes to the corresponding alcohols. Now the scientists have outlined how the active site of these dehydrogenases can be modified to perform atypical carbonyl reductions. The study also provides information on how chemical reactions in plant metabolism can be altered.

Original Publication:

Langley, C.; Tatsis, E. E.; Hong, B.; Nakamura, Y.; Paetz, C.; Stevenson, C. E. M.; Basquin, J.; Lawson, D. M.; Caputi, L.; O'Connor, S. E. (2022). Expansion of the catalytic repertoire of alcohol dehydrogenases in plant metabolism. **Angewandte Chemie, International Edition**, e202210934.



Active site of the studied alcohol dehydrogenase from the iboga shrub (Tabernanthe iboga) binding to precondylocarpine acetate.

Animation: Chloe Langley

Nepetalactone biosynthesis in catnip and pea aphid

Pea aphid (Acyrthosiphon pisum) on a broad bean (Vicia faba).

Photo: Anna Schroll

In a study published in PNAS, scientists from the Department of Natural Product Biosynthesis have shown that catnip and the pea aphid independently evolved the ability to biosynthesize the iridoid nepetalactone. Although the individual biosynthetic steps appear identical, the enzymes that catalyze these steps are different. For the first time, researchers have succeeded in resolving the biosynthetic pathway of such a complex molecule in an animal. Of particular interest is the comparison of the iridoid biosynthetic pathways in plants and insects, i.e., different kingdoms of living organisms. When organisms evolve comparable solutions independently, scientists call it "convergent evolution." Here, researchers report on the convergent evolution of metabolic enzymes in both an insect and a plant. These enzymes control complex biochemical processes in completely different organisms that biosynthesize the same natural product.

Original Publication:

Köllner, T. G., David, A., Luck, K., Beran, F., Kunert, G., Zhou, J.-J., Caputi, L., O'Connor, S. E. (2022). Biosynthesis of iridoid sex pheromones in aphids. **Proceedings of the National Academy of Sciences of the United States of Amerika**, e2211254119.

Symbiotic bacteria protect the larvae of Lagria beetles from pathogens

Beetles of the genus *Lagria* have developed unusual physical features to protect their offspring: On the backs of the larvae are small invaginations colonized by bacteria. These symbiotic bacteria protect the beetles against pathogenic fungi during their development and also during the sensitive phase of molting. A research team from the universities of Mainz and Copenhagen and the Department of Insect Symbiosis has shown that the beetles' bacterial symbionts inhabit the folds on the insects' backs throughout larval development. The small pockets that are formed remain open to the outside via a narrow channel and intact even during molting.

Original Publication:

Janke, R. S.; Kaftan, F.; Niehs, S. P.; Scherlach, K.; Rodrigues, A.; Svatoš, A.; Hertweck, C.; Kaltenpoth, M.; Flórez, L. V. (2022). Bacterial ectosymbionts in cuticular organs chemically protect a beetle during molting stages. **ISME JOURNAL.**

The Lagria villosa beetle on a soybean plant.

Photo: Rebekka Janke

Enzyme of bacterial origin promoted the evolution of longhorned beetles

Larvae of longhorned beetle species develop primarily in woody tissues, which are difficult for most animals to digest. However, the beetles' larvae possess special enzymes to break down the various components of the plant cell wall. Researchers from the Department of Insect Symbiosis have now taken a closer look at a group of digestive enzymes found only in this beetle family. They were able to recover the ancestral enzyme, which first appeared in a common ancestor of longhorned beetles. Horizontal gene transfer from bacteria to beetle as well as ancient and new gene duplications promoted the evolution of this family of digestive enzymes and enabled longhorned beetles to degrade the major components of the plant cell wall that make up most of their diet.

Na Ra Shin, first author of the publication, studies the enzyme activity of insect cells.

Photo: Anna Schroll

Original Publication:

Shin N.R., Doucet, D., Pauchet, Y. (2022). Duplication of horizontally acquired GH5_2 enzymes played a central role in the evolution of longhorned beetles. **Molecular Biology & Evolution**, 39 (6), msac128.

Tobacco hawkmoths always find the right odor

A research team from the Department of Evolutionary Neuroethology has discovered how tobacco hawkmoths detect odors that are important to them from a complex olfactory background. Their sharp sense of smell enables them to perceive not only the intense floral scent of nectar sources but also the rather unobtrusive smell of their host plants on which their larvae thrive. The researchers showed this by looking at the specific activity patterns that the odors triggered in the moths' brains. What is especially amazing is that tobacco hawkmoths can reliably detect the odors of their host plants despite the multitude of background odors emitted by many other plants in the vicinity.

Original Publication:

Bisch-Knaden, S., Rafter, M. A., Knaden, M., Hansson, B. S. (2022). Unique neural coding of crucial versus irrelevant plant odors in a hawkmoth. **eLife** 11:e77429.

To collect the nocturnal odor of agave flowers, individual flower umbels were enclosed in foil bags and connected to a mobile odor collection system.

Photo: Sonja Bisch-Knaden

Higher brain regions are crucial in evaluating a scent

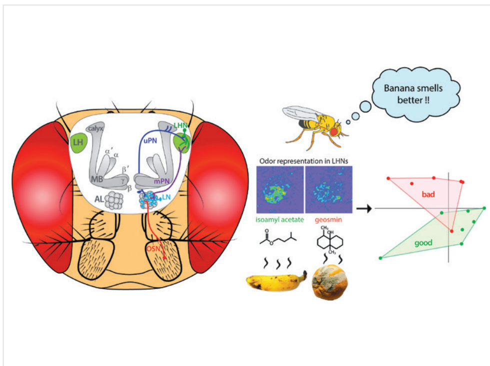
On the right: Schematic of odor representation and evaluation in the lateral horn

Graphic: Sudeshna Das Chakraborty

Original Publication:

Das Chakraborty, S., Chang, H., Hansson, B. S., Sachse, S. (2022). Higher-order olfactory neurons in the lateral horn support odor valence and odor identity coding in *Drosophila*. **eLife** 11:e74637.

In the vinegar fly *Drosophila melanogaster*, specific neurons in the lateral horn, a higher brain region, process odor information and enable behavioral decisions based on the valence of the odors. A research team from the Olfactory Coding Research Group has taken a closer look at a subgroup of these neurons, the glutamatergic neurons, and shown how different odors are processed in these neurons and how the strength of neuronal activity in turn determines the flies' behavior. Higher brain centers are thus able to filter odor information from the environment.



Moreover, they can transform the fly's outside world into a neuronal representation in the brain. The resulting behavior ensures the fly will survive and reproduce.

WE CELEBRATE 25 YEARS OF RESEARCH AT OUR INSTITUTE

For us, the year 2022 was distinguished by the ongoing 25th anniversary celebrations of our institute. On June 1, we organized a ceremony with representatives from politics, the city and the University of Jena, together with our neighboring institute, the MPI for Biogeochemistry, which also celebrated 25 years of research. On September 29 and 30, we held our scientific anniversary symposium with many alumni, which we rounded off with a party and the performance of our institute band. Here are some impressions.

1 – Jonathan Gershenzon and Susan Trumbore, Director of the MPI for Biogeochemistry, moderate the ceremony. 2 – Audience at the ceremony. 3 – The band Jezmer performing a musical interlude. 4 – Keynote speaker Antje Boetius on the impact of climate change on marine biodiversity. 5 – Reunion at the ceremony. 6 – Former colleagues. 7 – The ICE Breakers. 8 – SpeedInforming with Alumni,-9 – Sarah O'Connor. 10 – Martin Kaltenpoth. 11 – Bill Hansson with staff. 12 – New and old colleagues.

Photos: Anna Schroll (1-5), Angela Overmeyer (6-12)

www.ice.mpg.de

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