C3E NEWSLETTER 2017/18

CENTRE OF COMPETENCE IN CHEMICAL ECOLOGY

UNIVERSITÉ DE NEUCHÂTEL

FACULTÉ DES SCIENCES

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Cover illustration

Wood ants carrying a piece of tree resin into their nest, where they spray it with formic acid to protect the colony from fungi and bacteria (see Page 5). Photo credit Simon Williams, Nature Picture Library

IMPRESSUM

Centre of Competence in Chemical Ecology (C_3E)
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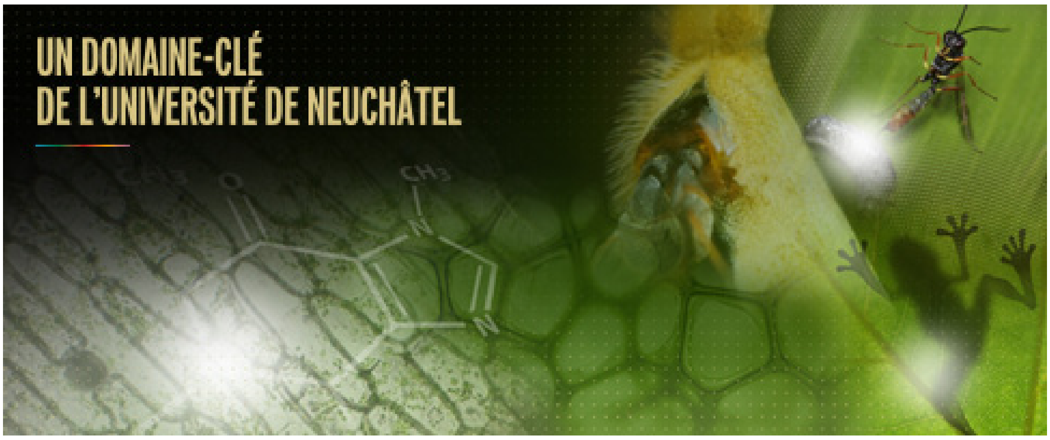
CENTRE OF COMPETENCE IN CHEMICAL ECOLOGY

UNIVERSITÉ DE NEUCHÂTEL



Fruitful collaborations


Ted Turlings


Felix Kessler


Stephan von Reuss

We are finally back with a new newsletter of our Center of Competence in Chemical Ecology (C$_3$E), based at the University of Neuchâtel. It has been a while since we last reported on our research activities, but as you will see, we have not been sitting still. The studies that are highlighted cover a wide range of topics including pharmacology by ants, pesticide residues in bee honey, the importance of oxytocin levels for collaboration among humans, and new roles for herbivore-induced plant volatiles. We are also particularly happy with our successes in obtaining research funds. One of the consistent reasons for this success has been the excellent "chemistry" among the collaborators within our university, an inherent advantage of a small university, where everyone knows each other, and we can literally count on the personal support from the janitors up to the rectorate. Most of our research projects involve multiple research groups, sometimes even entirely different disciplines. Not all the required expertise is represented at our university, and the collaborations therefore extend to many institutions inside and outside Switzerland.

A common denominator is the contribution of the Neuchâtel Platform for Analytical Chemistry (NPAC), which conducts thousands of analyses per year for a great diversity of projects, local, national, and international. As announced in this newsletter, the NPAC has been successful in obtaining third party funding and with further financial support from the university will soon expand its analytical capabilities with new state-of-the-art equipment.

In previous newsletters, we have already addressed the importance of fruitful and constructive collaboration without borders. We would like to stress this once again in a world where we are confronted with increasing divisiveness at the political level. Luckily this is not the case in science, where it has been most evident that progress can only be made by joining forces. Our New Year's resolution is to do even better in this respect and, in our own modest way, continue our collaborative efforts to advance the field of chemical ecology.

All our best wishes for 2019.

STEERING COMMITTEE

Ted Turlings (director C$_3$E) *fundamental and applied research in chemical ecology (FARCE)*
Felix Kessler (vice-rector research UniNE) *plant physiology*
Stephan von Reuss (director NPAC) *bioanalytical chemistry*

COORDINATION

Thomas Degen *chemical ecology*

NPAC

Gaétan Glauser *mass spectrometry and metabolomics unit*
Armelle Vallat *mass spectrometry and metabolomics unit*
Sylvain Sutour *nuclear magnetic resonance unit* **(new)**

PARTICIPANTS UNINE

Betty Benrey *evolutionary entomology*
Redouan Bshary *behavioural ecology*
Daniel Croll *evolutionary genetics* **(joined in 2017)**
Patrick Guerin *animal physiology* **(retired in 2017)**
Fabrice Helfenstein *evolutionary ecophysiology* **(left in 2018)**
Edith Joseph *microbiology*
Pilar Junier *microbiology*
Jacob Koella *ecology and epidemiology of parasites* **(joined in 2017)**
Brigitte Mauch-Mani *molecular and cell biology*
Sergio Rasmann *functional ecology*
Gregory Röder *chemical ecology*

EXTERNAL PARTNERS

Consuelo De Moraes & Mark Mescher *ETH-Zürich*
Matthias Erb *University of Bern*
Ted Farmer *University of Lausanne*
Cris Kuhlemeier *University of Bern*
Jean-Pierre Métraux & Felix Mauch *University of Fribourg*
Heinz Müller-Schärer *University of Fribourg*
Philippe Reymond *University of Lausanne*
Urs Schaffner *CABI, Delemont, Switzerland*
Florian Schiestl *University of Zurich*
Jean-Luc Wolfender *University of Geneva*

By adding acid, ants amplify antimicrobial activity of arboreal amber (aka tree resin)

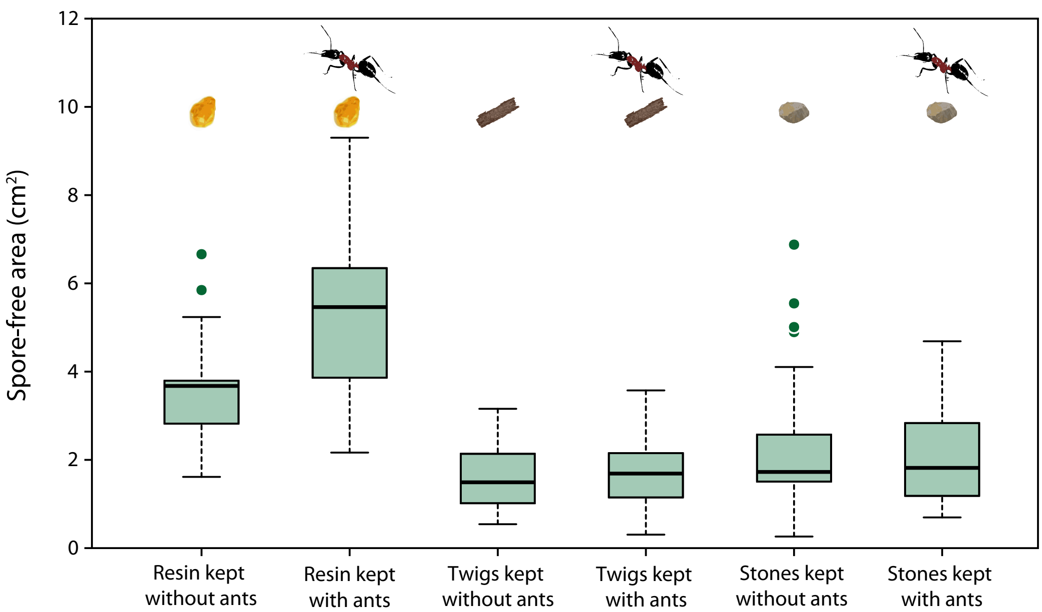
Geoffrey Jaffuel

Armelle Vallat

Together with researchers from the University of Lausanne, Geoffrey Jaffuel and Ted Turlings from the FARCE lab and Armelle Vallat from the NPAC published an article in *Ecology and Evolution*. It demonstrates that ants can achieve effective protection against an infectious micro-organism in their nest by mixing endogenous and plant-acquired chemical defences.

Ant nests provide a favourable environment for microbial growth, such as the deadly fungus *Metarhizium brunneum*. To fight this and other pathogens, wood ants, *Formica paralugubris*, collect pieces of resin from coniferous trees and place them in their nests. By spraying the resin with formic and succinic acid from their venom glands, they enhance the disinfecting properties of the resin. The researchers observed that tree resin had much higher inhibitory activity after having been in contact with ants, while no such effect was detected for other materials commonly found in nest such as twigs and stones. They could reproduce this result by experimentally applying synthetic formic acid to resin.

The mixture of resin and formic acid was found to provide greater antimicrobial activity than expected from the separate effects of the individual components. The authors conclude that the ability to synergistically combine antimicrobial substances originating from different sources is not restricted to humans and may play an important role in the health of insect societies. The paper received a lot of interest and positive responses, for example in an article published in *Science* (doi:10.1126/science.aal0915), and the study was featured in the episode "Attenborough and the Empire of the Ants" of the BCC series *Natural World*.



Antifungal activity of pieces of resin, twigs, and stones that had been kept without or with ants, respectively. The boxplots show the median values of spore-free areas around the tested items, as well as the upper and lower quartiles. The whiskers encompass 1.5 times the interquartile range. Outliers are indicated by circles.

Brütsch T, **Jaffuel G**, **Vallat A**, **Turlings TCJ**, Chapuisat M 2017. Wood ants produce a potent antimicrobial agent by applying formic acid on tree-collected resin. ***Ecology and Evolution*** 7: 2249-2254.

Neonicotinoid residues in honey

Gaétan Glauser

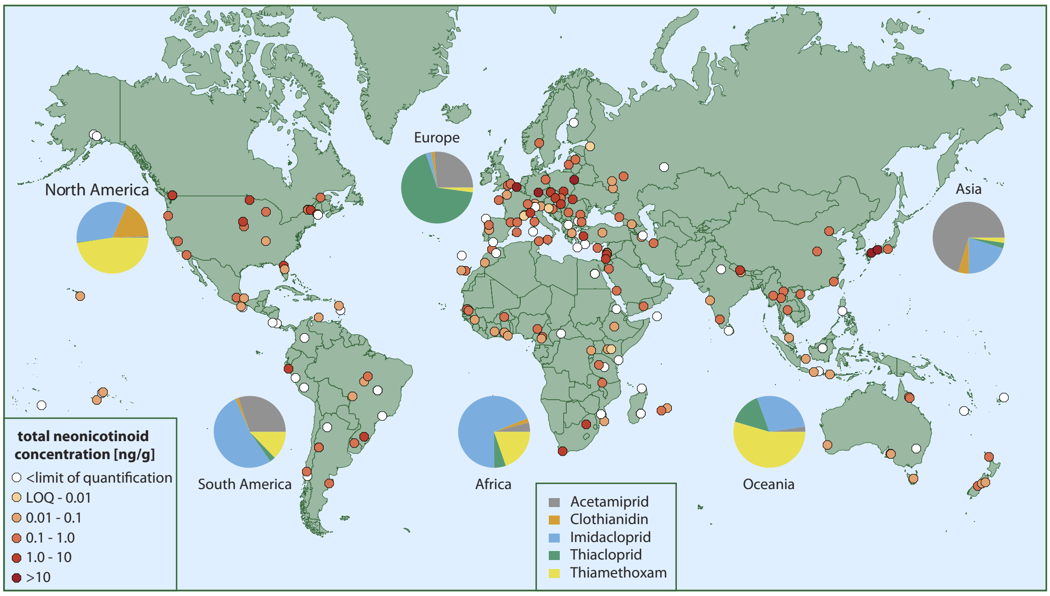
Edward Mitchell

Alexandre Aebi

A *Science* paper co-authored by Gaétan Glauser of the NPAC, Edward Mitchell and Alexandre Aebi of the Soil Biodiversity Group of the Institute of Biology as well as collaborators of the botanical garden of Neuchâtel has stirred quite some buzz in the scientific community and the media all around the globe. The researchers assessed the exposure of pollinators to neonicotinoids, a group of insecticides suspected to be involved in general pollinator decline, by analyzing honey samples from across the world.

Between 2012 and 2016, the botanical garden of Neuchâtel organized a citizen science effort, which resulted in a vast collection of honeys from all continents. The NPAC examined 198 representative samples for residues of five different neonicotinoid pesticides (acetamiprid, clothianidin, imidacloprid, thiacloprid, and thiamethoxam). In 75 % of them at least one of these compounds was found; 45% contained two or more, and 10% even four or five. While the concentrations detected remained well below the maximum residue level authorized for human consumption, the study shows that pollinators are globally exposed to neonicotinoids, partly at concentrations shown to be harmful to bees. The researchers argue that the fact that many of the samples showed multiple contaminations is worrying. It indicates that bee populations throughout the world have to cope with a cocktail of neonicotinoids. The combined exposure to neonicotinoids and other pesticides may further increase harm to pollinators.

The authors were quite overwhelmed by the media attention the article attracted. It was prominently featured in the international press and it appears to have even prompted the UK government to reverse its position on the usage of neonicotinoids. With the expertise gained in the detection of trace amounts of neonicotinoids in complex matrices such as honey, the NPAC has placed itself in an excellent position to carry out forthcoming studies on the topic.



Worldwide distribution of honey contamination by neonicotinoids. The color shade of the dots indicates the total neonicotinoid concentration (nanograms per gram; LOQ = limit of quantification). The pie charts represent the relative proportion of overall concentration of each neonicotinoid by continent.

Mitchell EAD, Mulhauser B, Mulot M, Mutabazi A**, Glauser G,** Aebi A 2017. A worldwide survey of neonicotinoids in honey. ***Science*** 358: 109-111.

Endogenous oxytocin influences cooperation and conversation as a function of group membership

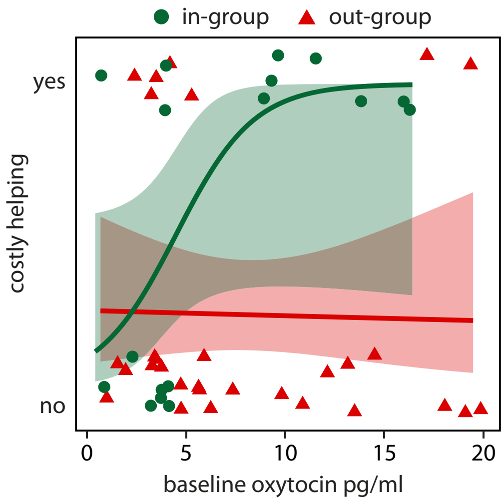
Jennifer McClung

Zegni Triki

Redouan Bshary

The laboratory of behavioural ecology directed by Redouan Bshary participates in two centres of competence of UniNE, namely in chemical ecology (C$_3$E) and in cognitive sciences, thereby building a bridge between science and humanities. Within the wider context of a current SNSF project (see below), two members of Redouan Bshary's group, Jennifer McClung and Zegni Triki, jointly with a researcher in communication science and another in work psychology, demonstrated for the first time the involvement of naturally occurring oxytocin in social interactions among humans, specifically in the context of cooperation and conversation.

Cooperation with unrelated individuals is far more widespread among humans than among other animals, but the readiness to cooperate is also highly variable. The neurohormone oxytocin, famous for its role in pair bonding and maternal behaviour, is one candidate mechanism that could explain this variation. To study the effect of the hormone in social interaction, the researchers did not rely on the traditional approach, the artificial application of a known amount of oxytocin with a nasal spray, but instead quantified the natural hormone levels in the saliva of volunteers before and after participating in the experiment. The experiment consisted of an "egg hunt" for objects representing a reward. Before the start of the game, the participants were randomly assigned to a specific group, and this group membership was visibly displayed. The hunt took place in teams of two, and the pairs formed were either composed of members of the same group or of two different groups. No further instructions were given. Each player could then spontaneously choose to cooperate with the other person, which was costly in terms of time invested, or to collect only eggs for its own reward.



Baseline oxytocin levels predicting costly helping as a function of group membership with 95% confidence intervals. Logistic regression lines shown for each condition ($p \leq 0.01$).

The researchers found that higher baseline levels of oxytocin predicted increased helping, but interestingly this effect was only present between in-group players. Higher baseline oxytocin also predicted less discussion about individuals' goals between in-group players, whereas more of such discussion occurred between out-group players. Furthermore, out-group members who did not help showed a decrease in oxytocin from baseline levels after the experiment. In conclusion, these results show that endogenous oxytocin predicts both helping behaviour and conversation, importantly as a function of group membership.

McClung JS, **Triki Z**, Clément F, Bangerter A, **Bshary R** 2018. Endogenous oxytocin predicts helping and conversation as a function of group membership. ***Proceedings of the Royal Society B*** 285: 20180939.

Project Title	**How proximate factors underlying decision making may affect the evolution and maintenance of cooperation**
Funding Organization	Swiss National Science Foundation
Funding Scheme	***Regular grant, Project funding (Div. I-III)***
Budget	783'575 CHF
Start	1.5.2017 - 30.4.2020

New evidence for unusual roles of herbivore-induced volatiles in direct and indirect plant defence

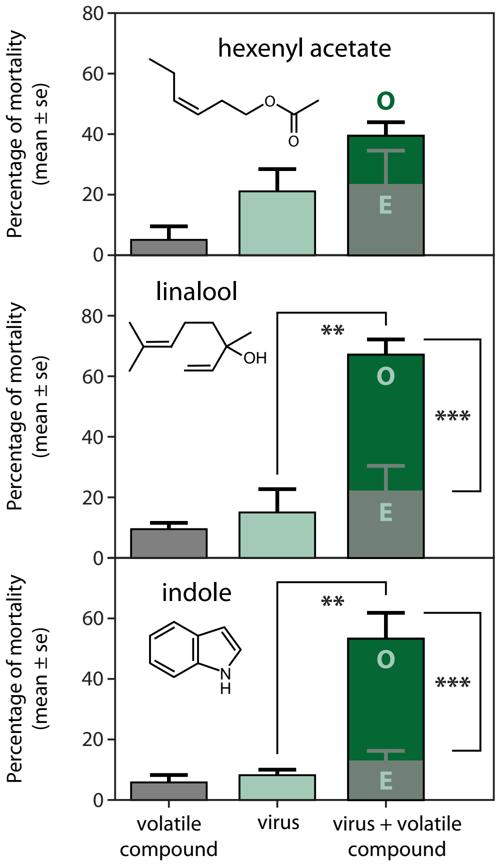
Nathalie Veyrat

Hao Xu

It is well established that herbivore-induced plant volatiles (HIPVs) that can serve as signals to alert undamaged plant tissues and to attract natural enemies of the herbivores. Members of the Farce group have coauthored two recent publications demonstrating that HIPVs can exert a direct effect on the herbivores, specifically on two noctuid caterpillars, *Spodoptera littoralis* and *Spodoptera exigua*, respectively.

The first paper, published in *Science Advances*, resulted from a collaboration with the research group of Matthias Erb at the University of Bern, and involved two former PhD students of Ted Turlings, Nataile Veyrat and Hao Xu. The researchers confirmed that indole produced by maize plants in response to feeding by *Spodoptera* caterpillars, increases the recruitment of the parasitoid wasp *Microplitis rufiventris*. Surprisingly, however, they also observed that indole exposure renders the caterpillars less attractive to the wasps and also decreased parasitization success. The caterpillars are repelled by indole in the absence of wasps, but specifically stop avoiding the volatile, when the wasps are present.

The second paper, published in the journal *Applied and Environmental Microbiology*, again involved the laboratories from Bern and Neuchâtel and was the fruit of a joint study with two laboratories from Valencia, Spain. The researchers found strong support for their hypothesis that exposure to HIPVs can render insects more susceptible to natural pathogens. They could show that indole and linalool, but not (*Z*)-3-hexenyl acetate, increased the susceptibility of *Spodoptera exigua* caterpillars to a specific nucleopolyhedrovirus in a synergistic manner. Indole also increased the pathogenicity of *Bacillus thuringiensis*. These results suggest a novel defensive role for plant volatiles by influencing insect interactions with natural pathogens, probably mediated by an altered composition of insect gut microbiota.



Effect of the three HIPVs on susceptibility of *Spodoptera exigua* caterpillars to viral infection. O = Observed mortality; E = expected mortality, when assuming additive effects only.

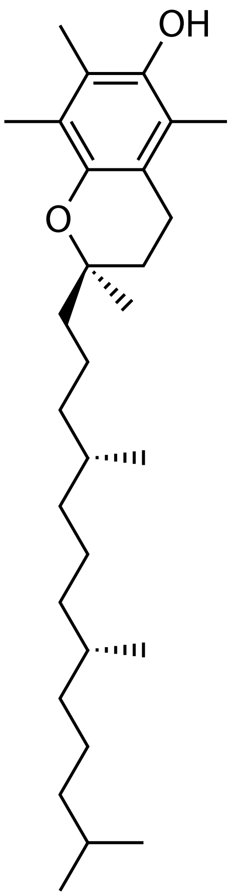
Both studies revealed that certain HIPVs can modulate tritrophic interactions via physiological changes in the herbivores, by changing their odour or making them more susceptible to diseases. These findings add a new dimension to the role of HIPVs as mediators of tritrophic interactions.

Ye M, **Veyrat N**, **Xu H**, **Turlings TCJ**, **Erb M** 2018. An herbivore-induced plant volatile reduces parasitoid attraction by changing the smell of caterpillars. ***Science Advances*** 4: DOI: 10.1126/sciadv.aar4767.

Gasmi L, Martínez-Solís M, Frattini A, Ye M, Collado MC, **Turlings TCJ**, **Erb M**, Herrero S 2019. Can herbivore-induced volatiles protect plants by increasing the herbivores' susceptibility to natural pathogens? ***Applied and Environmental Microbiology*** 85: DOI: 10.1128/AEM.01468-18

The functions of plastoglobuli in plastid metabolism, developmental transitions and environmental adaptation

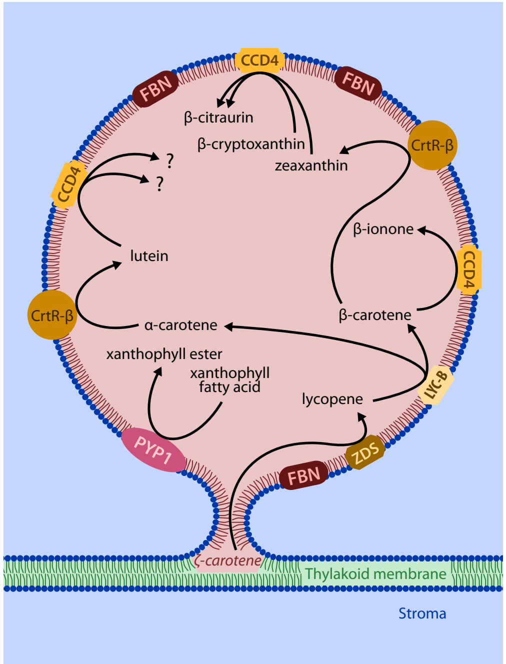
Felix Kessler



α-Tocopherol, one of eight forms of vitamin E

Felix Kessler, head of the laboratory of plant physiology, has co-authored a review article about plastoglobuli, his area of expertise, in *Annual Review of Plant Biology*. Plastoglobuli are lipoprotein particles surrounded by a membrane lipid monolayer that occur in different types of plant plastids, e.g. in chloroplasts, chromoplasts, elaioplasts, and gerontoplasts. The review summarizes the present understanding of features and functions of plastoglobuli. It provides a conceptual framework for future research on this topic and outlines opportunities for crop improvement that might arise from this research.

Plastoglobuli are characterized by small, specialized proteomes and metabolomes and respond dynamically in shape, size and number to abiotic stress and developmental transition of the plants. Associated with the thylakoid membranes, plastoglobuli in chloroplasts have a function in photosynthetic regulation, plastid biogenesis and senescence, including recycling of phytol, remobilization of thylakoid lipids, and the production of jasmonates. They play an important role in the metabolism of prenyl lipids such as tocopherol, membrane soluble antioxidants that limit the damage inflicted by excessive light to the photosynthetic apparatus. The research group of Felix Kessler has collaborated regularly in the past with the NPAC to qualitatively and quantitatively analyse lipid composition of plastoglobules and photosynthetic membranes. The functional connections between plastoglobuli and chloroplast carbon metabolism are still poorly understood, and the function of several proteins contained in plastoglobuli remains to be elucidated. Plastoglobuli in chromoplasts (see Figure) are involved in the synthesis and storage of carotenoids and therefore are highly enriched in carotenoid esters and enzymes participating in carotenoid metabolism.



Chromoplast plastoglobulus specialized in carotenoid metabolism. CrtR-β, LYC-β, and ZDS are recruited and support carotenoid biosynthesis and accumulation in PGs. CCD4 cleaves carotenoids, thereby contributing to fruit chromoplast pigmentation and volatile emission. PYP1, a PES homolog, participates in carotenoid ester synthesis in tomato petal chromoplasts. Abbreviations: CCD4, CAROTENOID CLEAVAGE DIOXYGENASE 4; CrtR-β, β-carotene β-hydroxylase; FBN, FIBRILLIN; LYC-β, lycopene β-cyclase; PES, PHYTOL ESTER SYNTHASE; PG, plastoglobule; PYP1, PALE YELLOW PETAL 1; ZDS, ζ-carotene desaturase.

Since plastoglobuli store and metabolize various nutritionally and commercially important molecules, including vitamins E and K1 as well as carotenoids, it is envisioned that engineering the corresponding pathways in plants can lead to the accumulation of these important products. The enhanced production of biofuels by algae and land plants constitutes another potential field of application of plastoglobulus-related research.

van Wijk KJ, **Kessler F** 2017. Plastoglobuli: Plastid Microcompartments with Integrated Functions in Metabolism, Plastid Developmental Transitions, and Environmental Adaptation. In: Merchant SS (ed.) ***Annual Review of Plant Biology*** 68: 253-289.

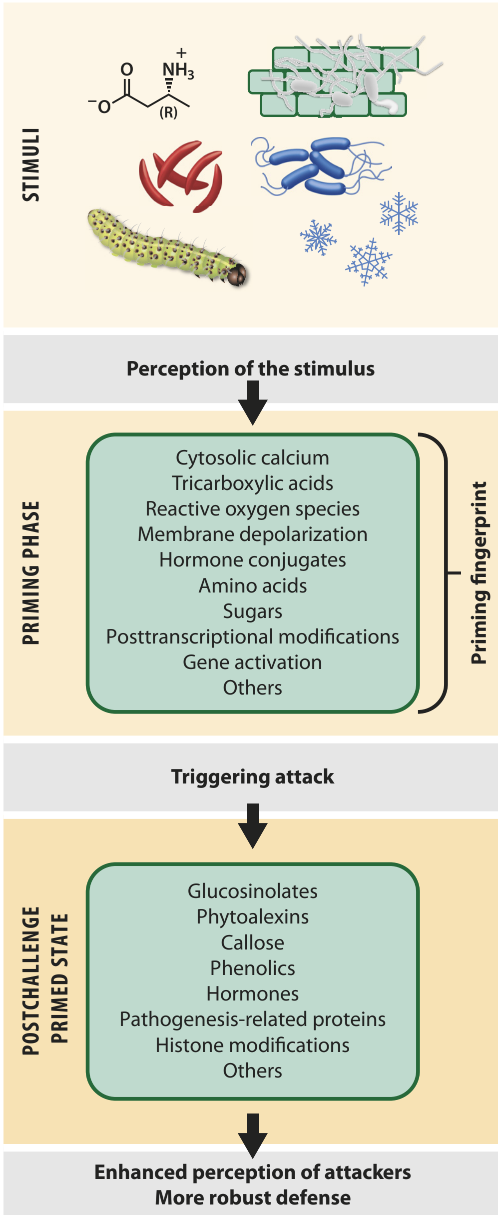
Defense priming: an adaptive part of induced resistance

Brigitte Mauch-Mani

Ivan Baccelli

With her group at the laboratory of cell and molecular biology, Brigitte Mauch-Mani has conducted pioneering research in the field of defense priming in plants. Together with her former post-doctoral student Ivan Baccelli she was invited to co-author a paper in the *Annual Review of Plant Biology* series.

In plant defense, priming is the physiological process by which a plant, after having experienced a stressful situation, prepares to more quickly or aggressively respond upon renewed exposure to any such stress. The review article covers all the consecutive steps from the stimulus that induces priming over the various changes that happen following the stimulation during the priming phase to the enhanced responsiveness of the plants after a challenge and the duration of this postchallenge primed state. A whole range of stimuli, derived from pathogens, beneficial microbes, or arthropods, as well as chemicals and abiotic cues can act as warning signals and trigger the establishment of priming. Once the plant has perceived the stimulus, the so-called priming phase sets in, which involves manifold changes at the physiological, transcriptional, metabolic, and epigenetic levels. When the plant faces a new challenge, it effectively mounts a faster and/or stronger defense response, which results in increased resistance and/or stress tolerance. Priming can be durable and maintained throughout the plant's life cycle and can even be transmitted to subsequent generations, and has therefore been considered a type of plant immunological memory. The review article closes with some remarks about the potential significance of priming to enhance plant protection in agricultural systems, given that transgenerational immune resistance does not seem to be limited to short-life model species, like *Arabidopsis thaliana*, but has also been reported for economically relevant crop plants with longer life spans such as tomato.



The sequential steps of defense priming. Stimuli stemming from pathogenic or beneficial fungi, bacteria, rhizobacteria, arthropods, and abiotic stresses are perceived by the plant, leading to a slight induction of various compounds and activities in the priming phase.

Mauch-Mani B, **Baccelli I**, Luna E, Flors V 2017. Defense Priming: An Adaptive Part of Induced Resistance. In: Merchant SS (ed.) ***Annual Review of Plant Biology*** 68: 485-512.

Tritrophic interactions mediated by herbivore-induced plant volatiles: mechanisms, ecological relevance, and application potential

Matthias Erb

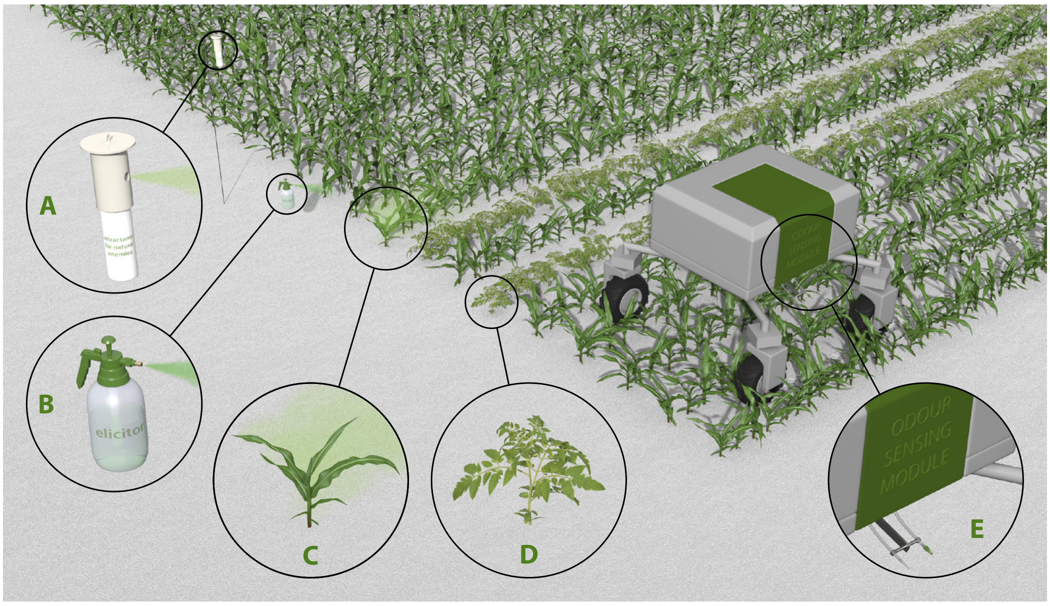
Ted Turlings

Thirty years ago, Ted Turlings was involved in the discovery that herbivore-induced plant volatiles (HIPVs) play a key role as cues that allow predators and parasitoids to locate their herbivorous prey and host, respectively. Now he was commissioned together with Matthias Erb, a former PhD student of his and now professor at the University of Bern, to write a review article about the topic, which covers the wealth of knowledge since generated and the many remaining open questions.

The authors first provide a brief overview of the history and main research questions in this still booming interdisciplinary research field, before reviewing the latest progress and new directions. They summarize the current knowledge on the role of HIPVs in tritrophic interactions from an ecological as well as a mechanistic perspective. They argue that the ecological importance of the phenomenon has become widely recognized, while the primary evolutionary function of HIPVs is still debated. There is evidence that plants can gain fitness benefits by releasing attractive volatiles, but functions other than the indirect defence might have played a more important role in the evolution of HIPVs, such as signalling within and between plants and direct defences against herbivores and pathogens.

In the last section the authors propose five possible strategies (Figure A-E) to exploit the volatile signals that mediate tritrophic interactions for pest control in agriculture:

- **A** Dispense attractants or repellents to affect arthropod foraging behaviour.
- **B** Treat plants with inducing agents to alter their attractiveness.
- **C** Breed crop plants with enhanced HIPV emissions attracting natural enemies.
- **D** Use companion plants that affect the attraction of pests and beneficials (e.g. push-pull strategy).
- **E** Develop odour sensors to monitor for pests and diseases.



Schematic overview of strategies to enhance, manipulate, and exploit HIPVs in agriculture. **A** odour dispensers, **B** elicitor sprays, **C** enhanced crop emissions, **D** companion or sentinel plants, and **E** odour-sensing devices.

Turlings TCJ, **Erb M** 2018. Tritrophic Interactions Mediated by Herbivore-Induced Plant Volatiles: Mechanisms, Ecological Relevance, and Application Potential. ***Annual Review of Entomology*** 63: 433-452.

This *Arum* smells like shit, and psychodid flies fall for it

Nadir Alvarez

Sergio Rasmann

Adrienne Godschalx

Mark Szenteczki

Opened chamber of an *Arum maculatum* inflorescence full of moth flies, *Psychoda phalaenoides*, collected in alcohol.

Nadir Alvarez was junior lecturer at the institute of biology of UniNE between 2005 and 2010, before becoming an SNF professor at the University of Lausanne. He teamed up with Marc Gibernau (Università di Corsica) and Sergio Rasmann to study the ecology and evolution of olfactory signalling in the deceptive pollination of *Arum maculatum*. Their project is funded by the Swiss National Science Foundation and involves both a postdoctoral fellow, Adrienne Godschalx, and a PhD student, Mark Szenteczki. Since Nadir accepted the position of Head of Research and Collections at the Natural History Museum of Geneva in 2017, the team has been based within the laboratory of functional ecology in Neuchâtel.

Arum maculatum, also known as *lords-and-ladies*, belongs to the minority of flowering plants that are deceptively pollinated. It signals the presence of a reward without providing any. Its dung-like odour during anthesis mimics the smell of the natural oviposition sites of moth flies belonging to the family Psychodidae, which are lured in by the scent and temporarily caught inside the floral chamber. *Psychoda phalaenoides* is almost exclusively trapped across most of the distribution of *Arum maculatum*, but another species, *Psycha grisescens*, is predominantly found as pollinator across southern Europe and parts of the Atlantic fringe. The researchers seek to explain these differences in attraction: are they related to pollinator availability, or are plants adapting to the most efficient local pollinator? They aim to characterize geographic variation in chemical communication between *Arum maculatum* and psychodid flies, and to investigate the evolutionary mechanisms underlying floral scent production. To this end, ecological data on plants (e.g. floral scent variation) and pollinators (e.g. pollination efficiencies) will be combined with data on genetic variation of the plants at the level of genome and transcriptome. Ultimately, this will provide further insight on how biotic interactions can lead to local adaptation, ecological and genetic diversification, and eventually speciation in a fascinating deceptive pollination system.

Title	**Ecology and evolution of olfactory signalling in the deceptive pollination of *Arum maculatum*: mimicry and local adaptation**
Funding Organization	Swiss National Science Foundation
Funding Scheme	***Regular grant, Project funding (Div. I-III)***
Budget	CHF 351'780
Start/End	1.3.2017 - 29.2.2020

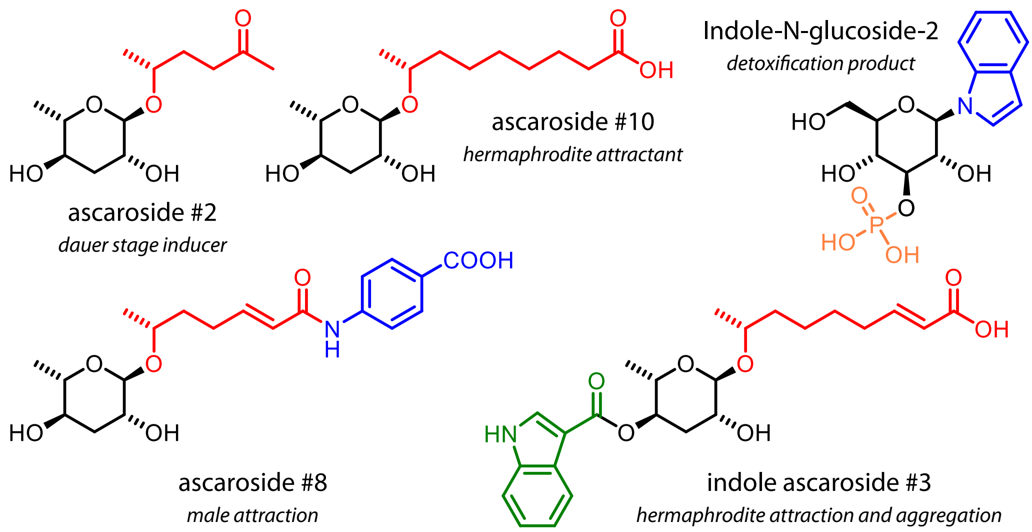
Nematometabolomics

Stephan von Reuss

Siva Bandi

In his "*Diversity of Life*" lecture presented in 2014 at Duke's Nicholas School of the Environment, Edward O. Wilson gave the following recommendation, based on the observation that nematodes are the most abundant animals on earth: "*And if you want a future, students in the audience here, and you want to do something completely new and would like to be a world authority in practically no time at all, making discoveries right and left that are important, please plan on being a nematologist*". Stephan von Reuss, professor in bioanalytical chemistry at the Institute of Chemistry since 2016 and director of the Neuchâtel Platform of Analytical Chemistry (NPAC), is a young scientist who has indeed chosen to devote his research to the study of nematodes. At the beginning of 2018 he launched his first SNSF-funded research project to explore chemical space in free-living bacterivorous nematodes.

Together with Dr. Siva Bandi, his postdoctoral fellow, Stephan von Reuss analyzes secondary metabolites in nematode metabolomes, while focusing on a selection of closely related *Caenorhabditis* species including *C. elegans*, an extremely successful model organism in biology. Undoubtedly representing the most well understood animal on earth with regard to its genome, transcriptome, and proteome, our knowledge about its metabolome and chemical ecology is very limited. Preliminary results revealed that bacterivorous nematodes produce a large diversity of complex multimodular components that combine structural units from various primary metabolic pathways. Using a combination of MS/MS and NMR based comparative metabolomics, these species-specific modular components will be structurally identified and their potential biological functions be investigated.



Examples for modular components identified from the *Caenorhabditis elegans* metabolome that incorporate structural units from carbohydrate (black), fatty acid (red), amino acid (green), and bacterial (blue) metabolism.

Title	**Comparative analysis of secondary metabolism in *Caenorhabditis* nematodes**
Funding Organization	Swiss National Science Foundation
Funding Scheme	***Regular grant, Project funding (Div. I-III)***
Budget	300'000 CHF
Start/End	1.1.2018 - 31.12.2020

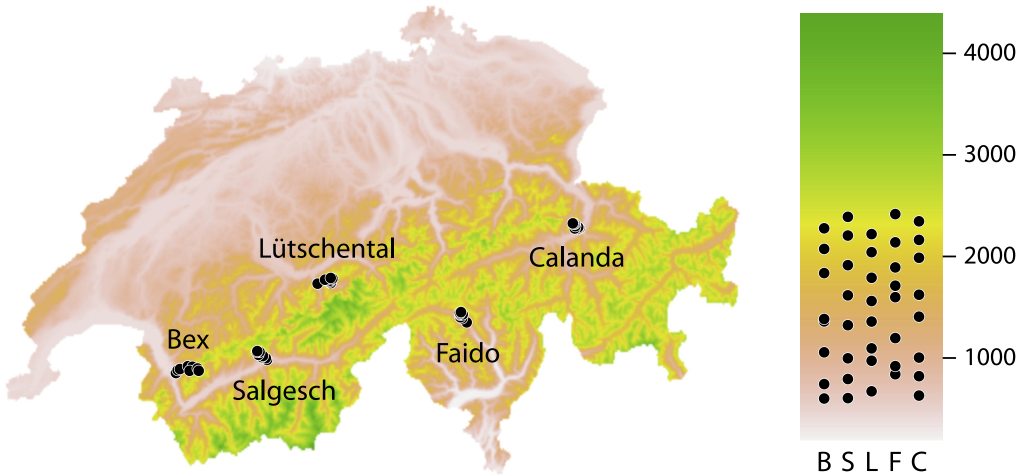
Elevational gradients revisited for a broader understanding of phytochemical diversity

Sergio Rasmann

With his Functional Ecology group, Sergio Rasmann has studied altitudinal gradients as a tool for determining the adaptive role of plant defences for some time. In his new SNF-funded project he will continue this successful approach trying to adopt a holistic view to understand how abiotic and biotic conditions influence the diversity of secondary metabolites in plants.

The researchers will sample vegetation along five mountain transects in the Swiss Alps that cover several biomes and a large range of climatic and soil conditions. The study will involve the assessment of a combination of different parameters. Common garden experiments will be performed at different elevations to establish the relative effect of herbivory, soil nutrients and climate on phytochemical production and, in turn, how phytochemical diversity influences the surrounding animal and microbial communities. Also molecular phylogenetic trees are to be created for the studied species to address questions on the macroevolution of phytochemistry along elevation gradients.

Of course, chemotyping of entire plant communities growing at different altitudes is a central part of the project. High-throughput and efficient metabolomics techniques will be developed in close collaboration with Gaétan Glauser of the NPAC. The study will greatly benefit from the newest analytical technologies becoming available there (see page 16). It will allow for building molecular networks from MS/MS data at the plant individual or species level, which will make it possible to discriminate among plant communities and will facilitate the identification of the most discriminating molecules. Such an approach might eventually become the new standard in phytochemical diversity research.



Geographical location and elevation of the five alpine elevation transects studied in Switzerland.

Title	**PhytoChemAlp: Assessing the causes and consequences of phytochemical diversity**
Funding Organization	Swiss National Science Foundation
Funding Scheme	***Regular grant, Project funding (Div. I-III)***
Budget	800'000 CHF
Start/End	1.6.2018 - 31.5.2022

Agriscents – Scents and sensibility in agriculture

Wenfeng Ye

Carla Arce

Arooran Kanagendran

Ted Turlings has been given the opportunity to explore one of the potential applications of inducible plant volatiles that was outlined in the review article presented on page 11. In the article it is proposed that the specificity in herbivore- and pathogen-induced plant volatiles might be exploited for crop monitoring. Now, Ted has been awarded an ERC advanced grant to investigate the feasibility of this approach, and several postdoctoral researchers (see pictures) will conduct the research, which will also involve several external partners, e.g. at the University of Bern and at the Max Planck Institute in Jena.

Plants typically release large amounts of volatiles in response to an attack by herbivores or pathogens. The resulting odour blends are in general characteristic for a given inducing antagonist. Using maize as main model plant, the ERC project has the aim to improve our understanding of this signal specificity. This knowhow will then be used to develop a novel odour-detection device.

A first goal is to create an inventory of "odour-prints" for a wide range of herbivore-plant and pathogen-plant combinations including simultaneous infestations. Herbivore-induced volatiles will be collected in assays comprising both leaf-sucking and leaf-chewing insects, e.g. several lepidopteran species. The researchers will also try to find solutions to survey belowground insect pests such as larvae of *Diabrotica* beetles based on plant-produced scents. The latest sensor technologies, developed by industrial and academic partners, will be evaluated. It is envisioned that the implemented sensor will permit real-time monitoring of pests and thus enable farmers to precisely apply crop protection treatments at the right time and in the right place.

Spodoptera littoralis **caterpillar feeding on maize.**

Title	**Scents and sensibility in agriculture: exploiting specificity in herbivore- and pathogen-induced plant volatiles for real-time crop monitoring**
Funding Organization	European Research Council (ERC)
Funding Scheme	***Advanced Grant***
Budget	2'498'086 EUR
Start/End	1.9.2018 - 30.8.2023

The NPAC will upgrade its machine park with an UHPLC-High Resolution Tandem Mass Spectrometer

NPAC
Neuchâtel Platform of Analytical Chemistry

The Swiss National Science Foundation has awarded a Research Equipment (R'Equip) grant to Gaétan Glauser and Ted Turlings. Together with matching funds of the University of Neuchâtel, it will enable the purchase of an ultra-high performance liquid chromatography-high resolution tandem mass spectrometer (UHPLC-HRMS/MS) to supplement the existing machine park of the Neuchâtel Platform for Analytical Chemistry (NPAC).

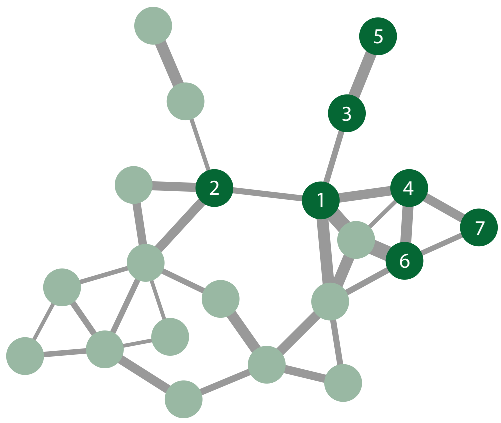
The NPAC provides chemical analytical services for universities, federal research institutions and industries in Switzerland as well as for clients and partners abroad. Since its creation in 2014, it has performed more than 100'000 analyses and has made important contributions to numerous research projects in biology, chemistry and hydrogeology, resulting in more than 90 peer-reviewed publications.

So far, the NPAC's machine park comprised two triple quadrupole and one quadrupole time-of-flight mass spectrometers. These instruments have reached a certain age and begin to show clear limitations for the challenging metabolomics applications that collaborators and clients request more and more frequently. The acquisition of a new state-of-the-art UHPLC-HRMS/MS system will allow the NPAC staff to drastically increase sensitivity, speed of acquisition, selectivity and identification rate. Thus, the analytical capabilities will be expanded to a much higher level of performance, which opens the door for new research opportunities. Data dependent analysis (DDA) becomes an additional option for acquisition. Molecular networks can be generated, a recently emerged powerful approach to facilitate metabolite annotation. The two C_3E research projects presented on page 13 and 14 will largely benefit from these new possibilities as will any other future study relying on the analytical services of the NPAC.

The NPAC is recognized as an infrastructure of national importance and enjoys an excellent reputation among the plant and animal science communities for its performance. The purchase of the UHPLC-HRMS/MS instrument is expected to further strengthen the NPAC's competitive position in bioanalytical chemistry.

GNPS annotation

1 Quercetin-3-O-glucoside
2 Quercetin-3-O-robinobioside
3 Quercetin-3-D-xyloside
4 Quercetin-3-O-alpha-L-rhamnopyranoside
5 Kaempferol-3-O-alpha-L-arabinoside
6 Kaempferol-3-O-glucoside
7 Kaempferol-3-rhamnoside



Schematic depiction of a molecular network, showing an example of glycosylated flavonoids with GNPS annotation (Global Natural Product Social Molecular Networking platform), adapted from Olivon et al. (2017, Analytical and Bioanalytical Chemistry 409: 5767–5778; DOI 10.1007/s00216-017-0523-3)

Project Title	**Ultra High Performance Liquid Chromatography-High Resolution Tandem Mass Spectrometry (UHPLC-HRMS/MS) for metabolomics and identification of bioactive molecules**
Funding Organization	Swiss National Science Foundation
Funding Scheme	***R'Equip***
Budget	310'000 CHF
Start	1.12.2018