Public Understanding of Life Sciences / Chemical Ecology

PULS/CE 31

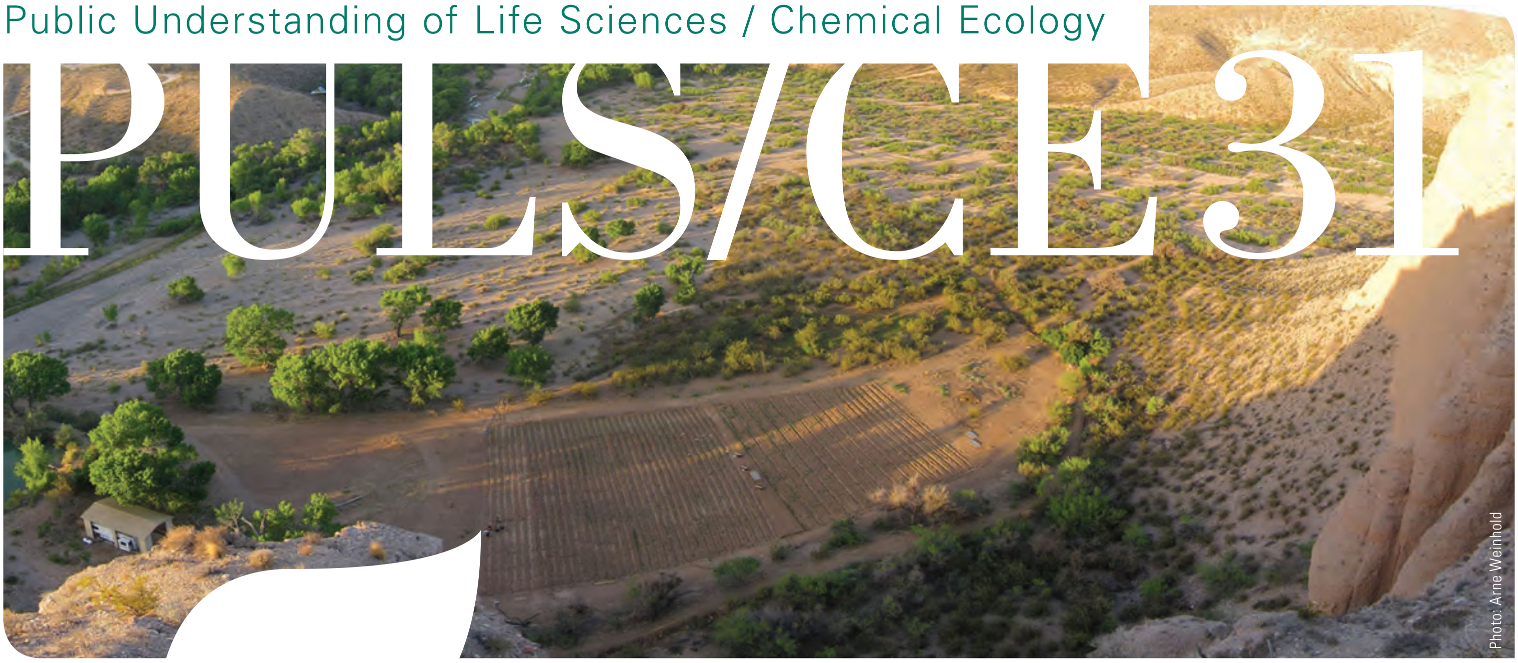


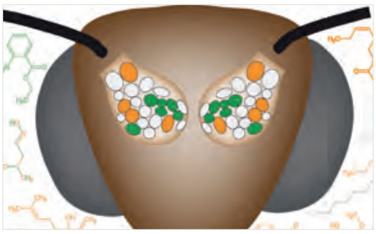
Photo: Arne Weinhold

Max Planck Institute for Chemical Ecology

Newsletter May 2018

Resilient Microbiome

Field experiments with tobacco plants that produce antimicrobial peptides (AMPs) in order to manipulate the plants'microbiomes reveal that the enormous bacterial diversity residing in natural soils may account for the stability of the plant-microbiome relationship … **p. 3**



Specialized brain structures

A team of researchers studied 80 environmental odors that are ecologically relevant to tobacco hawkmoths and discovered where these odors are processed in the moths' brain. Behavioral assays and physiological analysis showed that certain areas in the antennal lobe are associated with feeding, others with egg-laying...**p. 4**

How does white spruce respond to drought?

Erica Perreca studies the effect of drought on the methylerythritol phosphate (MEP) pathway in white spruce, the most common tree species in the boreal forest. One product of this metabolic pathway, isoprene, helps the plant cope with drought stress ... **p. 5**

MAX-PLANCK-GESELLSCHAFT

Jerrold Meinwald (1927-2018), one of the "fathers of chemical ecology," authored more than 400 publications. As a member of the editorial board of the journal PNAS, he edited numerous articles from the field of chemical ecology, many from our institute. In 2012 he received the National Medal of Science for his achievements. *Screenshot from his video message to our institute, September 2017, Cornell University*

"All those who consider themselves chemical ecologists, as well as all scientists who have been inspired by and stand on Meinwald's foundational research discoveries owe him the gratitude of their professions. He also had a major impact on the founding of our institute." Ian Baldwin

"Jerry will be remembered as a person of many talents, a gentleman with a sweet smile and an inspirational scientist shaping the field of chemical ecology together with his memorable colleague Tom Eisner for more than 50 years." Aleš Svatoš

Thank you, Jerry!

Together with ecologist Thomas Eisner, he is considered the founder of the research field, chemical ecology: chemist Jerrold Meinwald from Cornell University. While Eisner was fascinated by insects and observed how beetles, moths and grasshoppers used chemical substances to defend themselves, attract sexual mates or protect their offspring, Meinwald's contribution as a chemist was to isolate and identify these substances.

A beautiful example of their joint research is the investigation they led into the chemical defense of the colorful moth *Utetheisa ornatrix*. Eisner discovered that spiders removed moths of this species from their webs. Then Meinwald and his colleagues found out that alkaloids - plant toxins that the insects had sequestered from plants on which they had been feeding - made the insects indigestible for spiders. Moreover, while mating, male moths transferred these substances to females, which then transferred them to their eggs.

Numerous fascinating stories about the role chemistry played in the interactions between organisms and their environment inspired many young scientists to become interested in the field of chemical ecology.

In the early 1990s, the young research discipline attracted the attention of the Max Planck Society, which wanted to establish institutes in the new federal states. Meinwald was a key contact for the society because of his experience in the field. Our institute would not exist as it is now without him. His expertise was extremely important for evaluations and recruitments. Meinwald gave a keynote lecture when the institute's new building was officially inaugurated in 2002 and showed great interest in the development of our institute.

He sent his good wishes in a video message when the institute celebrated its 20th anniversary in September 2017. In this message, he summarized what chemical ecology means to all of us:

"Most of us are doing chemistry and biology now because of an early attraction to the beauty of beetles or butterflies, or perhaps jellyfish. The chemists among us probably fell in love with fireworks or dyes, or exotic aromas. These interests have let us to our concerns about how molecular structures are determined, how molecules are synthesized, how organisms have evolved, how behavior is controlled, how organisms interact with one another, not only through sound and light but also via chemical exchanges. We all try to understand the world around us and we are relevant to apply this understanding to improvements in medicine, agriculture, forestry, and maintaining a sustainable environment for life on earth."

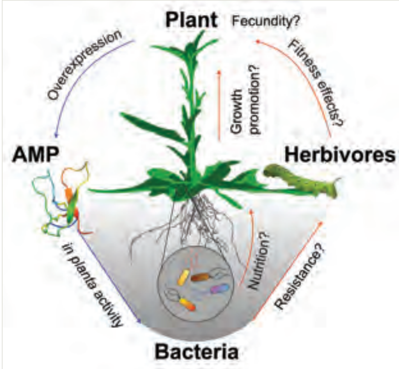
On April 24, 2018, Jerrold Meinwald died at age 91. The Max Planck Institute will always remember him with gratitude and respect.[AO]

Resilient microbiome

The microbiome, which consists of all microorganisms that live on or in plants, animals and also humans, is important for these species' health and development. In a new study, scientists from the Department of Molecular Ecology investigated how a plant responds to manipulations of its microbial associations. For their field experiments, the researchers used plants of the wild tobacco species *Nicotiana attenuata*, which produce antimicrobial peptides (AMPs). AMPs show activity against different beneficial microbes of the genus *Bacillus*, and the scientists wanted to use them to show how important microbes are for the plants' health. However, to their surprise, the transgenic plants appeared rather unimpressed by the presence of AMPs when compared to controls in the field. They took a close look at the results of further experiments and saw that different strains of the same bacterial species differed in their sensitivity to antimicrobial peptides. The scientists believe that the antimicrobial peptides target only single bacterial strains. Yet, the enormous diversity of bacteria in the soil provides a vast potential of beneficial bacteria for new partnerships. The negative effects that AMP expression has on a transgenic plant are less than previously thought.

Animals and plants produce natural antimicrobial peptides, as does the human gut. For medical purposes, these peptides may even be considered as potential alternatives to antibiotics in the fight against drug-resistant pathogens. While antimicrobial peptides may be very potent against single bacterial strains under laboratory conditions, their effect on an entire bacterial community in a natural environment is unknown. This is why it is so important to study plants not only in the greenhouse but also under natural conditions, in the natural soils of their ancestral habitat. Laboratory experiments, in which humans control the variables, will provide only limited results. Experiments conducted in the real world, in nature, deliver results, which, although sometimes challenging to interpret, are not bound by human imagination.

Studying the microbiome of a plant and its effects on the plant's development and the health turns out to be much more difficult and complex than expected. The researchers are now planning further experiments with tobacco plants in order to find out how these plants recruit soil bacteria, how they maintain relationships with their bacterial partners and how they keep the bacteria from morphing into deleterious pathogens. [AO/KG]

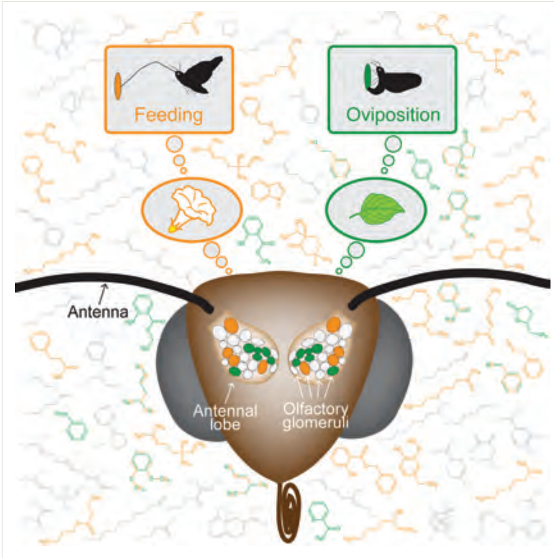


Right above: What is the function of the microbiome? What impact do bacteria, which have been recruited by a plant from the soil, have on plant performance in nature? Can they improve nutrient uptake, and do they increase growth and fecundity? Can they provide resistance to attack by herbivores? And what happens if plants express antimicrobial peptides (AMPs) which target specific bacterial partners? *Graphic: Arne Weinhold, MPI-CE*

Left below: On their field site at Brigham Young University's Lytle Ranch Preserve, scientists of the Department of Molecular Ecology study ecological interactions of the wild tobacco species *Nicotiana attenuata* in the plant's native habitat. *Photo:Arne Weinhold, MPI-CE*

Original Publication:
Weinhold, A., Dorcheh, E. K., Li, R., Rameshkumar, N., Baldwin, I.T. (2018). Antimicrobial peptide expression in a wild tobacco plant reveals the limits of host-microbe-manipulations in the field, **eLife** 2018;7:e2871

Specialized brain structures



Original Publication:
Bisch-Knaden, S., Dahake, A., Sachse, S., Knaden, M., Hansson, B. S. (2018). Spatial representation of feeding and oviposition odors in the brain of a hawkmoth. **Cell Reports** 22, 2482-2492.

Right above: Plant odors elicit different activity patterns in the antennal lobe (the olfactory center) of female hawkmoths (*Manduca sexta*). The stimulation of different glomeruli (subunits in the antennal lobe) may result in different behaviors. Glomeruli represented in orange correlate with feeding, glomeruli represented in green, with oviposition behavior. *Graphic: Sonja Bisch-Knaden, MPI-CE*

A female *Manduca sexta* moth lays eggs on the leaves of a *Nicotiana attenuata* plant. *Photo: Danny Kessler, MPI-CE*

Nocturnal moths, such as the tobacco hawkmoth *Manduca sexta*, rely on their extremely sensitive sense of smell in order to locate flowers that contain nectar. After feeding, female insects lay their eggs. Although the moths drink the nectar of flowers of different plant species, their larvae thrive only on the leaves of plants from the nightshade family, such as tobacco. Additionally, female moths also find the best host plants for their offspring via olfactory cues. A team of researchers from the Department of Evolutionary Neuroethology has investigated whether neural activity patterns linked to either feeding or egg-laying behavior can be observed in the antennal lobe, where scents are first processed in the insect brain. The scientists analyzed the responses of the olfactory center of the moths to 80 important plant odors. They measured the concentration of calcium ions in nerve cells to visualize the ions' activity when moths were stimulated with an odor. Identifying which olfactory glomeruli became active in response to which odor was the goal. Olfactory glomeruli, spherical structures in the antennal lobe of insects, are considered the primary subunits of the olfactory center. When the antenna of a moth is stimulated by an odor, an odor-specific pattern in the antennal lobe is activated. Such patterns are similar in all moths of the same species.

Next, the researchers tested the 80 odors in behavioral experiments with female *Manduca* moths; in behavioral assays using a wind tunnel, they compared neural activity patterns in the moths' brains in response to certain odors to the attractiveness of those same odors. Responding to odors that had been applied on filter paper, the insects unrolled their proboscis and tried to drink nectar or bent their abdomen and laid eggs on the paper. Surprisingly, a single chemical compound could be as attractive to hungry moths searching for food as a complex flower bouquet would be. A few odors even caused virgin females to lay their eggs on the filter paper, although it obviously had not been fertilized. When the scientists compared behavior (feeding or egg-laying) to the activity patterns in the antennal lobe, they noticed that activity in specific brain areas correlated with one or the other of the behaviors. The activity level of certain glomeruli determined whether female moths extended their proboscis to feed or whether they tried to grab the paper with their feet and curl their abdomen to lay eggs.

In their natural habitat, *Manduca sexta*, a moth species found throughout North and South America, feeds on a variety of nectar-producing flowers. The offspring of *Manduca sexta*, however, survive on only a few host plant species, such as tobacco. The odor of a host plant provides a moth with crucial olfactory cues. [AO/KG]

How does white spruce respond to drought?

Rising global temperatures coupled with reduced precipitation will lead to longer and more frequent dry periods, resulting in more frequent and intense drought episodes. Drought stress reduces the photosynthesis of trees, lowering their capacity for growth and ability to invest energy into defense against biotic stress. As a consequence, the ecological performance of trees is compromised and their mortality rate increases. For this reason, scientists hope to develop the ability to predict how trees will perform and how the composition of the forests will change in response to increasing episodes of drought.

The plastidial methylerythritol phosphate (MEP) pathway plays a key role both in the biochemistry of plants and trees, because it synthesizes compounds involved in primary metabolism, and in defense against biotic and abiotic stress. Since the first substrates along the pathway come directly from photosynthesis, we want to study the effect of reduced photosynthesis and carbon starvation on the MEP pathway during drought stress.

Many studies about drought stress have been carried out in the past in angiosperms. Therefore, we chose a conifer species, the white spruce *Picea glauca*, for our experiment. We are particularly interested in the production of the first product of the pathway, the volatile compound isoprene, which is believed to play an important role in plants against abiotic stress such as drought.

Moreover, isoprene has a central role in atmospheric chemistry. In fact, through its ability to produce aerosols, isoprene is hypothesized to have an effect on the climate and on the environment.

For my PhD project, I subjected 3-year-old white spruce trees to a period of drought and used a real-time system to measure photosynthesis, and a real-time mass spectrometer to measure isoprene emission. I also use the $^{13}CO_2$ labelling technique in order to measure the carbon flux in the pathway. Carotenoid, chlorophyll and monoterpene pools were also analyzed. Currently, I am improving analytical tools to better understand how the MEP pathway is regulated.

Erica Perreca

Erica Perreca studies drought resistance in white spruce (*Picea glauca*). This conifer species is the most common tree in the boreal forest which contains 35% of the world's carbon reserves. This makes this species a very important study object. Improving knowledge about the regulation of the MEP pathway and how the synthesis of its products can change in *Picea glauca* could help predict the performance of this tree species during drought stress.
Photo: Angela Overmeyer MPI-CE

IMPRS Exploration of Ecological Interactions with Molecular and Chemical Techniques

Erica Perreca is a doctoral student from Italy at the International Max Planck Research School. For her project in the Department of Biochemistry, she is investigating the effects of drought stress on the metabolism of white spruce (*Picea glauca*). She is especially interested in the methylerythritol phosphate (MEP) pathway and how it is affected during drought stress.

The western corn rootworm (Diabrotica virgifera virgifera), originally from Central America, has been found more and more frequently in Europe and is causing great concern among farmers. *Photo: Nowlan Freese, MPI-CE*

Maize pest exploits plant defense compounds to protect itself

As a team of researchers from the University of Bern and the Max Planck Institute for Chemical Ecology has learned, attempts to biologically target this crop pest by applying entomopathogenic nematodes have often failed. Maize plants store defense compounds known as benzoxazinoids in their roots in a non-toxic form. The scientists showed that the western corn rootworm stabilizes a toxic benzoxazinoid by adding a sugar molecule. This modified molecule is used directly to fend off nematodes, used as a biological control. Moreover, rootworms can stabilize a second plant-derived benzoxazinoid, sequester its non-toxic form in their bodies and activate it in response to attack by the nematodes. Hence, the rootworm has a two-pronged strategy for protecting itself using plant defenses. The study provides an important basis for further investigation into attempts to better control this major agricultural pest in the future. [AO]

Original Publication: Robert, C. A. M., Zhang, X., Machado, R. A. R., Schirmer, S., Lori, M., Matéo, P., Erb, M., Gershenzon, J. (2017). Sequestration and activation of plant toxins protects the western corn rootworm from enemies at multiple trophic levels. **eLife** 2017;6:e29307

A female of the beewolf species *Philanthus basilaris* at its nest entrance, Utah, USA. Three genera of these solitary wasps cultivate *Streptomyces* symbionts that protect the wasps' offspring from pathogenic fungi by producing a mixture of up to 45 different antibiotic compounds. *Photo: Martin Kaltenpoth, Universität Mainz*

Beewolves have been using the same antibiotics for 68 million years

The discovery of penicillin about 90 years ago and the widespread introduction of antibiotics to combat infectious diseases have revolutionized human medicine. However, in recent decades, the increase in multidrug-resistant pathogens has confronted modern medicine with massive problems. Insects have their own antibiotics, which provide natural protection against germs. Beewolves are solitary digger wasps that carry paralyzed bees into their underground brood cells; these serve as a food supply for their offspring. To protect their young, beewolves also rely on the chemical arsenal of microorganisms. Adult females breed bacteria of the genus *Streptomyces* in their antennae and deposit these bacteria onto the walls of the brood cells in which their larvae develop. When a larva spins its cocoon, it weaves the *Streptomyces* into the cocoon silk. The bacteria produce a cocktail of different antibiotic substances that form a protective layer, preventing mold fungi from entering the cocoon and infecting the larva. A team of scientists from the Johannes Gutenberg University in Mainz and the Max Planck Institute for Chemical Ecology have now found that the antibiotic cocktail consists of up to 45 different substances. The number of antibiotic substances is not only much higher than previously thought, but the cocktail has also remained surprisingly stable since the symbiosis emerged, about 68 million years ago. TE/AO]

Original Publication: Engl, T., Kroiss, J., Kai, M., Nechitaylo, T., Svatoš, A., Kaltenpoth, M. (2018). Evolutionary stability of antibiotic protection in a defensive symbiosis. **PNAS**, 115 (9) E2020-E2029

Alcohol used as a „weed killer" optimizes the harvest of ambrosia beetles

An international team of researchers including Peter Biedermann, who was a scientist at the Max Planck Institute for Chemical Ecology until recently and is now heading a group at the University of Würzburg, has studied the black timber bark beetle (*Xylosandrus germanus*) and its fungal „crop." This beetle species belongs to the so-called ambrosia beetles, which are characterized by their ability to cultivate fungi. When weakened trees produce alcohol, they are targeted and colonized by the beetles. The new study showed why alcohol is so attractive to these insects: An increase in the activity of alcohol-degrading enzymes makes the wood alcohol-rich, and the insects' fungi grow optimally in such wood. More fungi mean more food for the beetles, and more food means more offspring. The fungi grow best at an alcohol concentration of about two percent. At this level, the omnipresent molds, which can also be considered the „weeds" of fungal agriculture, grow only weakly and cannot overgrow the fungal gardens. For more than 60 million years, the animals have successfully and sustainably practiced agriculture. Unlike human farmers, the insects seem to have had no problems with resistance to "weed killers." [JMU]

Original Publication: Ranger, C. M., Biedermann, P. H. W., Phuntumart, V., Beligala, G. U., Ghosh, S., Palmquist, D. E., Mueller, R., Barnett, J., Schultz, P. B.,, Reding, M. E., Benz, P. (2018). Symbiont selection via alcohol benefits fungus farming by ambrosia beetles. **PNAS**, 115 (17) 4447-4452.

The fruit-tree pinhole borer (*Xyleborinus saxesenii*) is a so-called ambrosia beetle. These bark beetle species cultivate fungal gardens in the tunnels they have excavated in the wood of trees. The fungi, their sole source of nutrition, are referred to as ambrosia ("food of the gods"). *Photo: Gernot Kunz*

Drosophila larvae have food odor preferences that differ from those of adult flies

Scientists from the Department of Evolutionary Neuroethology and the Mass Spectrometry Research Group have compared the odor preferences of larvae of the vinegar fly *Drosophila melanogaster* to those of adult flies. The researchers collected odors from 34 different fruits and used them to stimulate the odor receptors of flies and larvae. The responses revealed that the "noses" of flies and their offspring process odors differently. Whereas 90% of the odor receptors in larvae were involved in evaluating food odors, only 53% of adult flies' odor receptors responded to the smell of food sources. Larvae were particularly attracted to the odors of strawberry, passion fruit and pineapple, whereas flies found these odors minimally or not at all attractive. Flies were more interested in the odors of red currant and kiwi, odors which the larvae cared little about. Obviously, larvae and flies have evolved odor-processing mechanisms that mirror their different developmental stages. [AO]

Original Publication: Dweck, H. K. M., Ebrahim, S. A. M., Retzke, T., Grabe, V., Weißflog, J., Svatoš, A., Hansson, B. S., Knaden, M. (2018). The Olfactory Logic Behind Fruit Odor Preferences in Larval and Adult *Drosophila*. **Cell Reports**, DOI: 10.1016/j.celrep.2018.04.085

Flies and larvae of the common vinegar fly *Drosophila melanogaster* have evolved different fruit odor preferences: Whereas adult flies like red currant and kiwi (photo) most, their offspring considers strawberries and passion fruit a special treat. *Photo: Anna Schroll*

Hannah Rowland (right) explains why she wants to study the blue tits' feces to find out how the birds digest toxic insects. *Photo: Angela Overmeyer*

First "cake-networking" event at the institute

On May 4, the first "cake-networking" event was organized at the institute. Initiated by Hannah Rowland, leader of the Max Planck Research Group Predators and Prey, group leaders at the institute met to test a new format for exchange. Hannah served the participants a cake she had baked and then gave a short overview of the field work she had planned for the next months: Together with another scientist from her group, she wants to collect the feces of blue tits to find out which insects the birds feed on and how they digest the toxins sequestered in their food. Her talk resulted in a lively discussion and ideas for new collaborations within the institute. The format may be extended to postdocs and PhD students in the future. [KG]

Bill Hansson. *Photo: Anna Schroll*

Bill Hansson: new member of Leopoldina

BOn May 23, 2018, Bill Hansson, director of the Department of Evolutionary Neuroethology, was officially appointed a new member of the German National Academy of Sciences Leopoldina in Halle/Saale. He is now a member of the Section of Organismic and Evolutionary Biology. Membership in the oldest society of natural scientists in the world is a great honor and shows that research topics in chemical ecology and neuroethology play an important role in the scientific world. [AO]

On February 26, 1948, the Max Planck Society was officially founded in Göttingen (on the left: the minister of culture of Lower Saxony, Adolf Grimme, and the first president of the MPG, Otto Hahn). In 2018, the MPG also commemorates the 100th anniversary of Max Planck's (on the right) Nobel Prize. The first German-wide Max Planck Day will celebrate these events and highlight the role of science in society. *Banner: MPG*

First Germany-wide Max Planck Day on September 14 - also in Jena!

The year 2018 is of special relevance for the Max Planck Society. In February, the society celebrated the **70th anniversary of its founding**. **Max Planck (1858-1947)**, the physicist and discoverer of the quantum theory after whom the society is named, was awarded the **Nobel Prize 100 years ago**. The institutes in the new federal states have an additional reason to celebrate, as 25 years ago, in autumn 1993, the Max Planck Society decided on new guidelines for the establishment of a unified research landscape. These resulted in the foundation of 20 new institutes, including ours. During the research festival on September 14, 2018, the more than 80 Max Planck institutes will present their future research directions in many different areas and discuss their relevance for society.

In Jena, the three Max Planck institutes invite all who are interested to come to the Science Pub Quiz in the **Paradiescafé**, Vor dem Neutor 5, 07743 Jena, from 7:00 pm At 8:00 pm, teams of up to five members can help demonstrate that science is fascinating and fun too. Everybody is welcome to participate. You can register under phone 03641-572110 or via e-mail to **quiz@ice.mpg.de**.

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www.ice.mpg.de

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