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Max Planck RESEARCH

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Language

THE HISTORY OF SCIENCE
Leaves of Truth

CHEMISTRY
Trio with an Extensive Repertoire

ASTRONOMY
A Dark World of Ice

ENVIRONMENT
Thaw in the Climate Model

SIEMENS

Pictures of the Future

The Magazine for Research and Innovation

Dossier – Innovation at Siemens
How Innovations are generated – from initial idea to market launch.

siemens.com/pof-innovations

Photo: Michael Gebhardt / Environmental Research Station Schneefernerhaus

High above the Clouds?

No – right in the middle is the place to be! This is because both the global climate and local weather events are extremely dependent on cloud formation. Located just under the peak of the Zugspitze mountain and frequently cloaked in dense cloud, the Schneefernerhaus provides the perfect conditions for scientists of the Max Planck Institute for Dynamics and Self-Organization to study clouds from a direct and immediate perspective. Operating as a hotel until the early 1990s, the Schneefernerhaus is now Germany's highest environmental research station. Here, the researchers from Göttingen aim to measure how, in the turbulent flows of a cloud, tiny droplets of water collide with one another before combining to form larger droplets and, ultimately, rain. It is precisely this phase of droplet formation that is very difficult to reproduce in laboratory conditions or to numerically simulate.

After four years of preparatory work, 6.5 tons of equipment were transported from Göttingen to Garmisch-Partenkirchen, at the foot of the Alps, and, using a special heavy-load helicopter, installed on the tower terrace of the Schneefernerhaus. The heart of the measurement apparatus is the "seesaw," which basically allows a sled to "ride along" in the main flow of a passing cloud. Four high-speed cameras photograph the cloud particles, which are illuminated with a powerful laser. This makes it possible to track the path of a single droplet over a relatively long time interval.

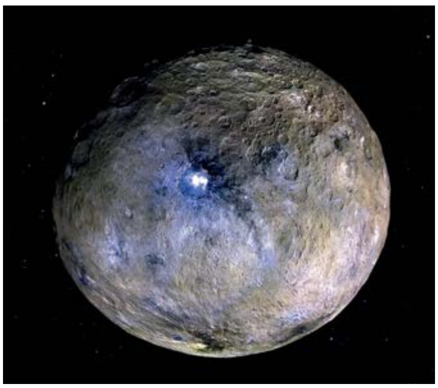
In the high-pressure wind tunnel in the laboratory in Göttingen, the scientists can generate models of virtually any type of turbulent flows, while their work on the Zugspitze allows them to precisely observe natural turbulences. It is hoped that the combination of these approaches will help unlock the secret of clouds – for a better understanding of these nebulous beauties that are so important for the climate.

https://www.youtube.com/watch?v=Y4KFgg4OMQY

Contents

ON THE COVER Even if we sometimes talk past one another, natural language is our central means of communication. But how did this instrument develop over the course of evolution? And what goes on in our minds when we hold a conversation? Language is proving to be an extraordinarily complex topic – and one that holds great interest not only for classical linguists and computer scientists, but also for psychologists and behavioral researchers.

Cover illustration: Dorothea Pluta; photos this page: Valentin Rodriguez/agefotostock/Avenue Images (large photo), Sven Döring (right)



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SPECTRUM

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REGULAR FEATURES

Photos: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA, Leif Riemenschneider, Frank Vinken (left to right)

Chancellor Pushes the Red Button

High-level visit to the control room of the Wendelstein 7-X nuclear fusion reactor: Chancellor Angela Merkel, a physicist herself, visited Greifswald in early February to switch on the first hydrogen plasma at the fusion reactor. “Every step we have taken toward the fusion power plant over the course of a century represents a success,” underscored Merkel before a large audience from the realms of science and politics before getting down to action. For the all-important push of the button, employees from the Max Planck Institute of Plasma Physics had a glass cube structure with the silhouette of the fusion reactor specially constructed and positioned on a steel column. Shortly after Angela Merkel spiritedly pressed the button, a bright light flickered on the monitors. These screens provided a glimpse inside the plasma vessel, where the brief fusion reaction the Chancellor had set in motion via the 2-megawatt pulse of microwave heat could be seen. Reaching a temperature of 80 million degrees and lasting a quarter of a second, the first hydrogen plasma in the system fully met the expectations of scientists and engineers at the Institute.

Before the start: Project manager Thomas Klinger, Managing Director Sibylle Günter, Helmholtz President Otmar Wiestler, Chancellor Angela Merkel, Max Planck President Martin Stratmann and Erwin Sellering, Minister President of Mecklenburg-Vorpommern (from left).

New Network for Alumni

Former Max Planck scientists join together

Every year scientists from many different countries visit the Max Planck Institutes and, conversely, many head off to all parts of the world as alumni. For some time now, the Max Planck Society has endeavored to cooperate with them in establishing a global, cross-disciplinary network. The alumni work has thus far focused on former working locations. “Max Planck alumni feel an affinity primarily with their institute,” said Filippo Guarnieri, who previously worked at the Max Planck Institute for Gravitational Physics. But he also emphasizes that: “Their skills are nevertheless important to the Max Planck Society as a whole, across institute boundaries.”

This was reason enough for him and five other alumni from different institutes to establish the Max Planck Alumni Association e.V. This new union will enable all alumni to work on independent projects autonomously and for the benefit of the entire organization and its scientists – for instance to foster knowledge sharing, career development and recruiting.

Photo: Norbert Fellechner/IPP

"The end product is what matters"

Detlef Weigel, Director at the Max Planck Institute for Developmental Biology, explains why genome editing offers a targeted way of breeding better crops

Greater resistance to pests, less sensitivity to drought, higher yields – this is just a small selection of the requirements that crops will have to fulfill in the future. Humanity needs new crops that can withstand the changes arising from global warming and meet the growing demand for food. With the help of a new method called genome editing, scientists are seeking to develop new crop varieties more efficiently than before. If no foreign genes are inserted into these plants, they can't be distinguished from plants that have been bred using traditional methods. For this reason, Detlef Weigel from the Tübingen-based Max Planck Institute for Developmental Biology, together with colleagues from the US and China, is asking for genome-edited plant varieties of this kind not to be classified as genetically modified plants.

Mr. Weigel, how are new varieties bred from crops today?

Detlef Weigel: It's important to realize that traditional breeding also aims to alter the DNA of the plants. For example, if you would like to obtain a new plant that can withstand drought and produce high yields, you can cross existing varieties that are resistant to drought or produce particularly high yields. The genes for these traits are newly mixed in the descendants' DNA, and some plants receive the genes for both traits. Chemical substances or radiation can also be used to generate mutations somewhere in the genetic code. Plants with new traits can also arise in this way. However, it is very time-consuming and complicated to seek out plants with the desired traits from thousands of mutants.

What is the difference between genome-edited and genetically modified plants?

With traditional genetic engineering, genes are often introduced into a plant's DNA that do not arise naturally in the species, for example genes for resistance to a herbicide. Different processes exist for this: for example, the genes can be "shot" into the plant cells using a kind of "gene gun." With genome editing, we cut the DNA with a protein at a predefined location. The genome editing method known as CRISPR/Cas9 has become the most common method. We can then modify the DNA at the interface or insert new sections. So genome editing should be viewed as a variant of mutation breeding, with the difference that the generation of particular mutations is targeted.

The major advantage here is that these modifications can be obtained in the same way as they are made in traditional breeding and crossing experiments. For example, individual letters of the genetic code can be exchanged. This corresponds to a modification that can also arise through natural mutation. Short sections of DNA can also be inserted and, in this way, genes from a species can be replaced with genes from its other varieties or from closely related species – something that is also done in traditional cross-breeding.

The criticism regarding genetically modified plants is aroused by the aforementioned "foreign genes" in particular. Do genome-edited plants also contain such foreign DNA?

The genetic information for the cutting protein is usually inserted into the plant's DNA so that it can be formed in the plant cells. This gene doesn't arise naturally in plants and is, therefore, foreign DNA. Following the successful modification of the genome, however, it can be completely removed. Using the analysis methods available today, it is possible to ensure that a genome-edited plant no longer contains any foreign DNA. Genome editing can also be used to insert completely foreign genes into the genome – as is the case in traditional genetic engineering. However, this kind of genome editing should be subject to different regulations than the kind that is used to make minor modifications.

Is it possible to distinguish at all between genome-edited and traditionally bred plants?

If no foreign genes are inserted, then, no, it isn't possible. A plant that has been modified using genome editing doesn't differ in any way from a plant whose genome was altered through breeding. At the end of the process, there is nothing to indicate how the new variety arose.

Detlef Weigel is in favor of classifying genome-edited plants as traditionally bred plants.

Photo: Jens Abendroth for the MPI for Developmental Biology

So genome-edited plants shouldn't be treated like genetically modified plants if they don't contain any foreign DNA?

Exactly! This is why we are asking for them to be classified as traditionally bred plants. In our view, how a plant variety came into being doesn't make any difference; the end product alone is what matters. In my view, it doesn't make any sense to classify plants as different if it isn't possible to say how they came into being.

Is this possible from a legal point of view, or would it require a change in the law?

The German Genetic Engineering Act states that the descendants of a genetically modified plant must also be classified as genetically modified. So the fact that genome-edited plants temporarily contained the gene for the cutting protein would make them and their descendants genetically modified plants forever – despite the fact that the foreign gene was removed without trace. This was certainly not the intention of the legislator, as genome engineering didn't yet exist when the Genetic Engineering Act was passed. So we suggest that the Genetic Engineering Act should not be applied to genome-edited plants. Interview: Harald Rösch

Leibniz Prizes Awarded to Three Max Planck Researchers

Prestigious award presented to Marina Rodnina, Emmanuelle Charpentier and Benjamin List

Great honor: The winners of this year's Leibniz Prizes include Max Planck Directors Marina Rodnina, Emmanuelle Charpentier and Benjamin List.

The Gottfried Wilhelm Leibniz Prize, awarded annually by the German Research Foundation, is one of the most prestigious scientific prizes in Germany. The prize is endowed with up to 2.5 million euros, and once again, three Max Planck Directors received the award in March 2016.

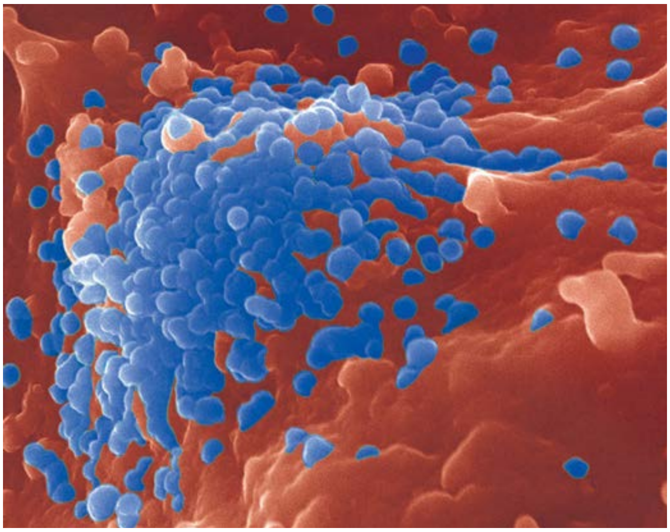
Marina Rodnina from the Max Planck Institute for Biophysical Chemistry was honored for her pioneering efforts on understanding the function of ribosomes. She succeeded in shedding light on the fundamental principles of how ribosomes – the protein factories of living cells – function. Emmanuelle Charpentier, Director at the Max Planck Institute for Infection Biology, was presented the award for developing the CRISPR/Cas9 technique. This mechanism, which stems from bacteria, can be deployed as a high-precision tool to investigate the function of genes and to manipulate genetic material. Benjamin List, Director at the Max-Planck-Institut für Kohlenforschung (Coal Research), received the prize for establishing an entirely new field of catalysis research. List discovered one of the foundations of organocatalysis, which allows natural substances rather than metals to be used as catalysts for the first time.

HIV Scissors to Combat AIDS

Enzyme removes the genome of the AIDS pathogen from infected cells

To date, no cure has been found for infection with HIV. The drugs that infected patients must take for the rest of their life suppress the spread of the virus and thus the outbreak of the disease. In 2007, a team of researchers headed by Joachim Hauber from the Heinrich-Pette Institute in Hamburg and Frank Buchholz from the Max Planck Institute of Molecular Cell Biology and Genetics in Dresden succeeded for the first time in cutting out HIV genetic material from human cell cultures using an enzyme. Scientists have now taken an important step forward: they have developed the gene scissors to the point where over 90 percent of the HIV genotype can be removed from the human genome.

The scientists have proven the effectiveness of their technique in cell cultures and animal research. The number of viruses fell below the detection limit in animals receiving this treatment. Frank Buchholz, now a professor at the Technische Universität Dresden, believes this represents a medical milestone: "The creation of molecular scalpels will change medicine. It's not just HIV patients who will benefit from this development, but also many others with genetic diseases."



Burgeoning HIV: Up to ten billion virions are newly formed from activated T-cells every day. After a short time, these virus particles are ready to infect the next cells.

Photos: MPI for Biophysical Chemistry, Hallbauer & Fioretti, Jörg Baumann (top, left to right), Olivier Schwartz, Pasteur Institute, Paris (bottom).

Exchange of Talent with Dutch University

Max Planck Society and Radboud University agree on joint program

Soon, up to 100 master's degree students from Radboud University in the Netherlands will be able to undertake internships each year at the Max Planck Institutes. Gerard Meijer, the University's President, and Martin Stratmann, Max Planck President, concluded an agreement at the beginning of March. "This presents us with a great opportunity to establish ties with young talent who will become the cutting-edge scientists of the future," emphasized Stratmann when signing the agreement. Meijer highlighted the opportunities for students to gain research experience at one of the prestigious Max Planck Institutes.

The internships will last 6 to 12 weeks, with the participating institutes providing supervision, workplaces and equipment. The remaining costs will be covered by Radboud University and the Erasmus program. A further framework agreement between the two scientific institutions also enables Max Planck scientists to obtain lecturing experience at Radboud University. This will be particularly beneficial to young researchers seeking a university career. Research cooperation is also to be stepped up. The collaborative program will initially run for five years.

Invaluable cooperation: Max Planck President Martin Stratmann (left) and University President Gerard Meijer seal the launch of new joint activities between the two institutions with their signatures.

Photo: Radboud University

On the Net

CV of Failures

We all experience failures in our careers, but we tend to keep quiet about them. Not so Johannes Haushofer, a 36-year-old assistant professor from Princeton who recently shared his "CV of failures" for all the world to see on his Twitter account. The CV includes sections entitled "Degree programs I did not get into," "Research funding I did not get," and "Paper rejections from academic journals." Haushofer's intention was to provide some perspective on failure by making it visible – and with great success, as his post very quickly went viral.

www.princeton.edu/~joha/Johannes_Haushofer_CV_of_Failures.pdf

A Quantum Future

Researchers are seeking to make quantum communication tap-proof, enabling message recipients to determine whether a transmission has been tapped. This is made possible by the uncertainty principle that Werner Heisenberg described back in 1927. Our new educational video ("Quantum physics – tap-proof through randomness") for upper secondary school students clearly explains what lies behind this principle and how it can be applied to copy protection.

www.youtube.com/watch?v=3sheEy1rNGI

Fascinating Insights

The Wellcome Image Awards for the best scientific photographs of the year in the field of biology and medicine were presented on March 15. Twenty spectacular images were honored, including a submission by Alfred Anwander from the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig. Wellcome Image is an extensive image database that provides unrestricted access to photographs and illustrations from the history of medicine to current biomedical research. A team of scientists, artists and journalists select the best scientific photographs each year.

www.wellcomeimageawards.org/2016

Leaves **of Truth**

Objectivity ranks as one of the highest ideals in research, but that wasn't always the case. It wasn't until the 19th century that it began to vie with the centuries-old principle of natural truth. Even today, the two concepts still come into conflict. As the author explains, some scientific controversies are more easily understood through a closer look at the history of science.

TEXT **LORRAINE DASTON**

Why does society need the history of science? And why does science, in particular, need the history of science? In the fast-moving, pressurized world of present-day research, scientists often wish for something that the history of science can't deliver: they want to know where and when the next breakthrough is coming, and which research program will fulfill its promises and more besides. These things can't be prophesied – fortunately. Science that relies on its past to extrapolate its future would lack creativity.

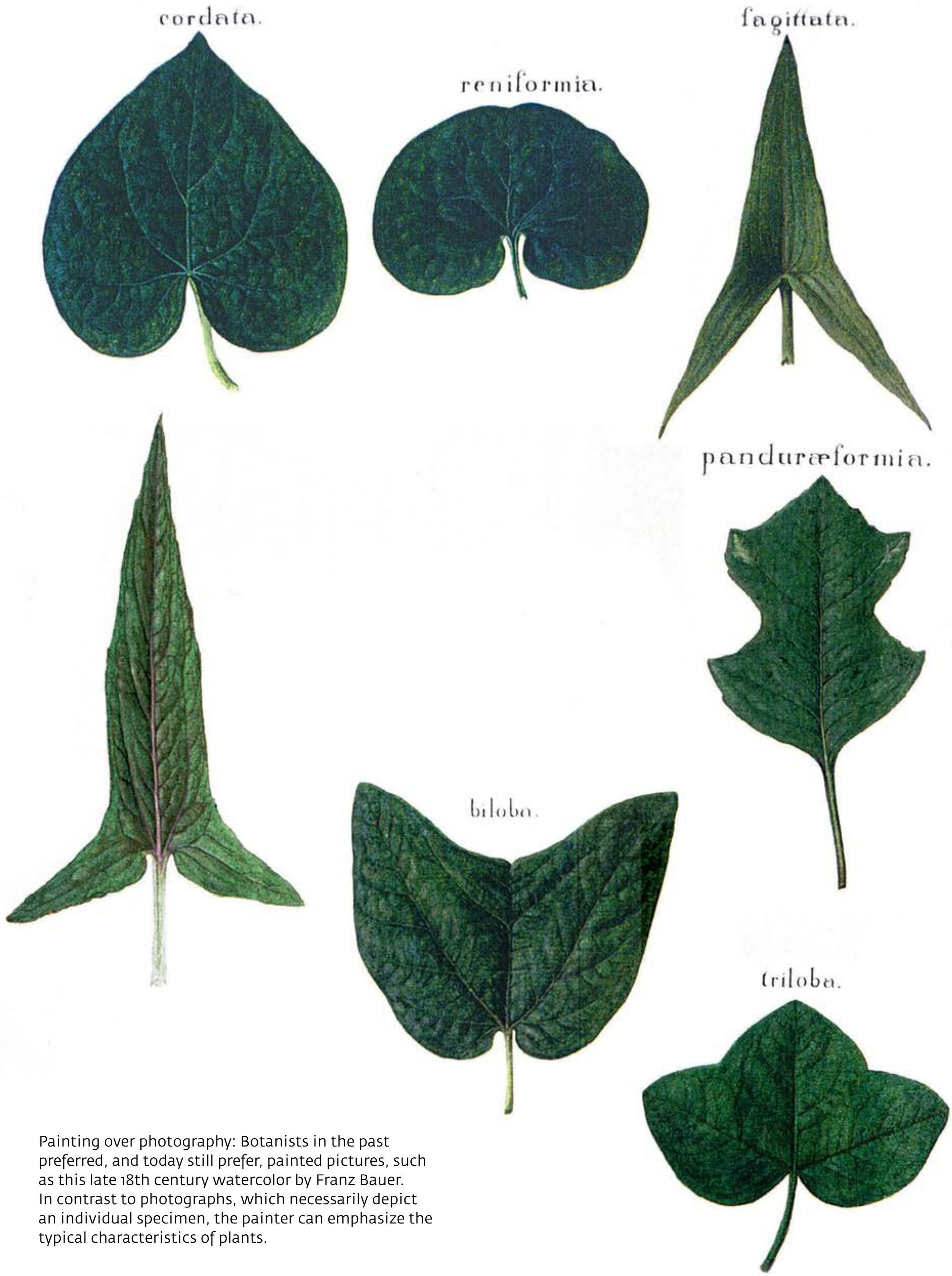
Science has different time scales, each with its own tempo

What the history of science can provide is an explanation of why present-day research is devoted to certain issues (and not to others); why certain methods (and not others) have become indispensable; why some discoveries are hailed immediately while others languish in obscurity for decades, or even centuries; why one discipline flourishes while another is neglected; why a scientific career follows certain stages (and not others); and ultimately why scientific careers exist – something that, from a historical perspective, is anything but self-evident.

Above all, the history of science provides an explanation of the varying time scales of science, each with a tempo of its own – and each with transformative potential.

There are three clocks that measure the pace of science. Empirical discoveries move at the fastest pace – the research results that appear in the next issue of SCIENCE, NATURE and other journals. This clock is calibrated in weeks and months; it ticks *allegro*.

The tempo of the climate for empirical research, on the other hand, is *andante*. By climate, I mean the synthetic theories – the different questions embodied within a theory – but also the material con-



Painting over photography: Botanists in the past preferred, and today still prefer, painted pictures, such as this late 18th century watercolor by Franz Bauer. In contrast to photographs, which necessarily depict an individual specimen, the painter can emphasize the typical characteristics of plants.

ditions for science: the invention of new instruments, the level of social support and appreciation of research, the ability to attract the finest minds to this career rather than any other. This clock ticks slower, in units of years and decades.

The third clock is *legato*, advancing in units of centuries or even millennia. It measures the pace of the fundamental epistemic virtues of science, the particular characteristics that define the science of a specific era as science (as opposed to knowledge, opinion or belief): certainty, truth, precision, objectivity. It is this third clock, the history of the seemingly self-evident in science, that I focus on in my research.

Only experienced observers are capable of distinguishing signal from noise

Given that these categories develop so slowly and are anchored so deeply in the identity of science, they appear to have no history. But let us take an example – certainty: For almost 2,000 years, from antiquity until the end of the 17th century, this was the sine qua non of science. *Episteme* in ancient Greek, *scientia* in Latin, the concept was defined as certain knowledge that not only accorded with the facts, but could be proven by *axiomata*, in the same way as a syllogism in logic or a mathematical proof.

Even Isaac Newton still clung to this vision: he described his laws of motion as *axiomata sive leges motus*. Redefining the concept of science as probable and even revisable knowledge was a slow but revolutionary transformation.

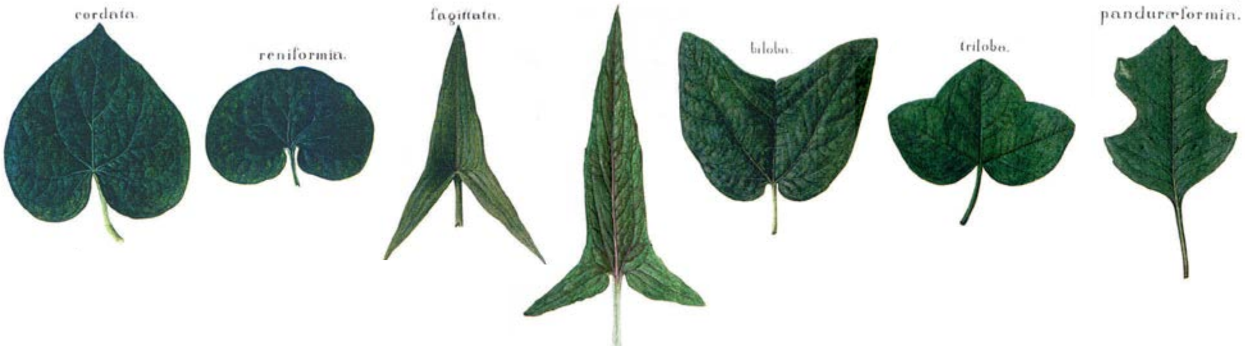
Certainty, truth, precision, objectivity – they all sound so abstract. In reality, however, these goals are tangibly expressed in scientific practice. Error bars for measurements, Monte Carlo simulations, idealized graph curves and techniques of illustration are all examples of how the abstract-sounding categories take on concrete form in everyday scientific practice.

The three time scales of science – *allegro, andante, legato* – are interwoven like a triple fugue. Taking one of these concrete forms, imaging, I would like to flesh out two of these epistemic virtues – natural truth and objectivity – and the resulting potential for conflict. Let us consider two illustrations of leaves, one a watercolor dating from the late 18th century and the other a so-called nature print from the mid-19th century. Both were created for botanical purposes.

The leaves in the watercolor were depicted very naturalistically by a master of botanical art named Franz Bauer. However, the painting doesn't depict real leaves, but rather idealized leaf types: *cordate* (heart-shaped), *trilobate* (having three lobes) and *sagittate* (arrow-shaped).

The leaf in the nature print, in contrast, is an imprint of an individual oak leaf, pressed between copper and lead plates until it made an impression in the soft lead. Although this process was lauded by its originator as the third great moment in cultural history – following the invention of writing and Gutenberg's movable type – botanists remained unconvinced. Neither the meticulously accurate reproduction of details nor the immediacy of the method impressed them. Photography also found little use in tomes devoted to plants. Botanists preferred, and still prefer, natural truth over accuracy and objectivity.

What, exactly, is natural truth? Under which circumstances is this epistemic virtue better suited to scientific purposes than any other? Particularly in the sciences given to classification – botany, zoology, anatomy, crystallography – natural truth aims to capture the typical: not this or that human skeleton with all its idiosyncrasies, but *the* human skeleton – or *the* gladiolus, *the* elliptical galaxy or *the* isometric crystal.



Natural truth fights not only against natural variability, but also against the spread of all kinds of data. Astronomers, physicists or psychologists, suddenly confronted with a data point that refuses to fit the pattern, must decide whether or not it is meaningful to include it in their calculations. If an astronomer, for example, is trying to determine the orbit of a comet, and all of his observations bar one single exception point to a parabola, does it make sense, is it right and proper, to ignore this aberration?

Natural truth would say "yes," whereas objectivity would say "no." Natural truth recognizes symmetries and regularities among a seething mass of variability, thus opening the way for classification and mathematical models. Even though natural truth is inclined to idealize, it promotes the highest empirical efforts.

Only the most experienced observers are capable of distinguishing the typical from the atypical – the signal from the noise. This ability requires mature powers of judgment. And assertive intervention in images and data.

Natural truth is an age-old epistemic virtue and is still regarded as an ideal any time scientists in a wide variety of disciplines attempt to recognize symmetries, regularities and types (such as the genera of organisms) under conditions of variability, data spread, and noise of all kinds.

However, it was probably from the mid-16th to the mid-19th century that natural truth experienced a golden age, in the era of Vesalius' Canon of the Human Body and Linnaeus' "plant archetypes." From the early to mid-19th century, natural truth came into increasingly frequent conflict with a new epistemic virtue: objectivity.

At first glance, it seems surprising that objectivity, perhaps the central epistemic virtue of modern science, should be so late in making an appearance.

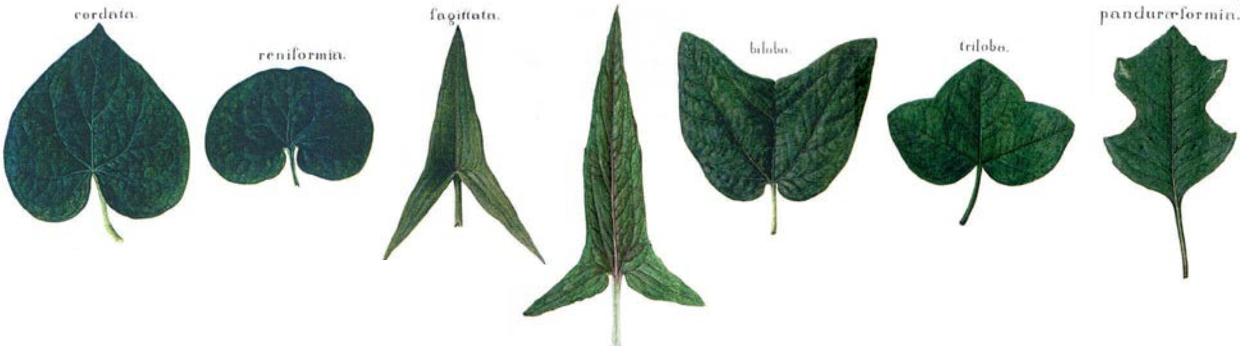
The word objectivity is indeed much older, deriving from the late scholastic Latin term *objectivus*, frequently paired with *subjectivus*. These familiar-sounding terms, however, signify the precise opposite of what we understand the words to mean today: "objective" referred to things as they appear to the conscious mind, whereas "subjective" referred to things themselves.

But it wasn't just the meaning of the words that turned 180 degrees around the year 1840. Objectivity and subjectivity, once of purely philosophical interest, became increasingly relevant for the empirical sciences in some very specific cases. From the middle of the century, scientists in a wide variety of disciplines – physiology, astronomy, chemistry, physics, bacteriology and even philology – were becoming concerned about a new obstacle on the path to knowledge: the obstacle that they themselves presented.

An objective researcher must resist the temptation to embellish nature

The researchers feared that their subjective self was inclined to embellish, idealize and, in the worst case, regularize observations in order to make them fit theoretical expectations – to see what it hoped to see. For the adherents of the new epistemic virtue of objectivity, the interventions by the proponents of natural truth were scandalous – they were the subjective projections of the researchers themselves.

What form did the difference between natural truth and objectivity take? Often it was a contrast between drawing and photography, as in the case of British physicist Arthur Worthington, who, after 20 years studying the splashes of drops, was forced to admit that his earlier drawings were too fine, too symmetrical – a projection, he felt, of his expectation that he would indeed find nature to be perfect. It was only with the introduction of photographic



methods that Worthington recognized that his ideal, the "autosplash of his mind's eye," didn't exist.

Photography, however, can serve both natural truth and objectivity. There are, for instance, some microphotographs of snowflakes dating from the end of the 19th century that are quite revealing in this regard. They were taken in Vermont around 1885 by Wilson Bentley, who edited the pictures to eliminate any irregularities. Richard Neuhaus also published images of snowflakes in Berlin in 1893, but his show asymmetries, broken or missing arms, and other deviations from geometric perfection.

While scientists since Kepler had regarded snowflakes as proof of the mathematical structure of nature and very openly removed "damaged" or "abnormal" examples as being atypical, Neuhaus criticized Bentley's embellishment of his photos as "entirely gratuitous." The objective researcher had to exercise self-discipline and resist the temptation to portray nature as more beautiful, more symmetrical or more regular than it actually was.

There is no mistaking the moral overtones of the accusations Neuhaus leveled at Bentley. Objectivity wasn't only a methodological dictate, but also a moral one. Almost all epistemic virtues have a similarly moral tone. How could it be otherwise? This is determined not only by practical considerations – whether, for example, an aberration may be discarded or not – but also by a professional ethos that must be internalized. The ethos of natural truth doesn't always coincide with that of objectivity: all scientists serve the cause of truth, but they have differing assessments of the obstacles.

Where is the risk of misjudging the truth greater: in the variability of nature or in the subjectivity of the scientist? Given that differing epistemic virtues such as natural truth and objectivity also have different histories, it's no surprise that these histories sometimes collide. But precisely because the differences in the course of history aren't apparent to scientists, such collisions are frequently interpreted as scientific misconduct, even to this day.

The consequences can be devastating. Let me cite just one example from the US – without mentioning any names, although biologists will probably immediately recognize the case. A young postdoctoral student was working with an experienced scientist in the laboratory of a Nobel laureate. The student was unable to replicate the scientist's results despite adhering meticulously to the textbook methods; she also noticed that the published measurements didn't always coincide with those recorded in the scientist's lab diary.

Misconduct proves to be a case of colliding epistemic virtues

The student became a whistleblower and accused her colleague of falsifying data. Because the research was being funded by the National Institutes of Health, this episode became a national scandal, with hearings in congress, secret service investigations and ruined careers. After more than ten years of investigation, the scientist was exonerated by the Office of Research Integrity.

Other experienced scientists were ultimately able to replicate her results: precisely because they were experienced, they were willing – as the accused researcher had been – to sometimes refrain from including aberrant data in their published analyses. What the press and congress had interpreted as a case of scientific misconduct appears in retrospect to have been an example of colliding epistemic virtues: the objectivity of the postdoc who followed the methods precisely and wanted to include all of her measurements in her analysis, versus the natural truth of the scientist who modified her methods on an ad hoc basis and ignored implausible data.

Please don't misunderstand me: genuine cases of data falsification and scientific misconduct do, unfortunately, exist. But there are also genuine collisions between epistemic virtues – just as ethical virtues sometimes collide. Justice and mercy aren't always reconcilable, any more than honesty and courtesy.

The initial reaction on both sides is frequently an outburst of moral indignation directed at the other party, as if virtue were to be found on one side only. But the historic perspective shows that both parties have virtue on their side – albeit different virtues, with different histories. Because the third clock that measures scientific development ticks so slowly, these histories remain invisible for most scientists.

This is where the history of science can facilitate a completely different discussion that doesn't focus on who is right and who is wrong, but instead asks: which goals do we wish to pursue in this specific case, and where does the greatest risk of failure lie? ◂

THE AUTHOR

Lorraine Daston (born in 1951) is a Director at the Max Planck Institute for the History of Science in Berlin, a visiting professor on the Committee on Social Thought at the University of Chicago, and an honorary professor of the history of science at Humboldt University in Berlin. She was born in the US, where she was awarded a doctorate at Harvard University in 1979 and taught at Harvard, Princeton and Göttingen Universities, among others. The main focus of Professor Daston's research is on the ideals and practices of rationality. She has also published papers on numerous topics relating to the history of science, such as the history of probability and statistics, wonders in early modern science, and the history of scientific objectivity.

Photo: Skúli Sigurdsson

Education Is a Valuable Commodity

Scientists from 55 countries around the globe work at the Max Planck Institutes. Here they relate their personal experiences and impressions. Suhrid Ghosh from India spent considerable time in the Himalayas researching hoverflies, and recently took up a doctoral position at the Max Planck Institute of Molecular Cell Biology and Genetics in Dresden. The 24-year-old hopes to one day return to his home country as a teacher.

I love hiking and camping, and living and working in nature. If I had the choice, I'd always prefer field work in the jungle to working in the lab. But some things just can't be studied in the jungle, which is why I came to the Max Planck Institute of Molecular Cell Biology and Genetics a couple of months ago as a Ph.D. student.

Education is a privilege in the tiny Himalayan village where I was doing field work for my master's degree: I frequently saw the children gathering in front of their teacher's house in the early morning hours to pick her up for the hike to the schoolhouse – a cumbersome journey over hill and dale. They marched 12 kilometers uphill in the morning and back down in the evening just to be able to go to school. Curiosity was their sole motivation – and maybe the hope for a better life.

In the afternoons, they would visit us researchers, asking about our experiments. We were studying hoverflies and how they orient themselves in the mountains to find their flowers. The village children intuitively knew why this is important, and had their own unspoiled perspective on the topic – much better than grown-ups.

Graphic: iStockphoto

Suhrid Ghosh, 24, studied microbiology (MSc) in Vadodara, India from 2012 until 2014 before conducting project studies on hoverflies with Shannon Olsson at the National Centre for Biological Sciences in Bangalore, India from 2014 to 2015. Since 2015, he has been conducting doctoral research with Suzanne Eaton at the Max Planck Institute of Molecular Cell Biology and Genetics in Dresden.

It is indeed a great gift when nature is so tangible for kids. I grew up on a small farm close to Calcutta. My ancestors were traditional dairy farmers. I knew exactly how to wash a cow, how to milk her and how to keep the barn in check. At the same time, however, I was very lucky to have had direct access to education, which is not the norm in populous India. There are so many people here with great ideas, but many of them have never actually attended school, despite education being one of the most fundamental human rights.

When my time as a scientist is over, I'd like to get involved in this very issue and work as a teacher in India – I imagine this to be very fulfilling, because teachers have an important function in Indian society. After all, it was a teacher at my high school who told me about the Max Planck Society as a research organization. He had once had a very bright student, named Rupak Majumdar, he said, who is now even a Max Planck Director.

So Rupak became sort of a role model for me, since he came from the same city and was now an internationally recognized scientist. Many years later, when I was doing my master's degree, I remembered the name Max Planck and I applied in Dresden. Of course it was a big transition for me, but my colleagues at the Institute are very friendly and helpful. And they told me that there are really great opportunities for hiking and climbing in the Elbe Sandstone Mountains, also known as Saxon Switzerland. I hope to try that out very soon.

Photo: Private collection

Without a **Sound**

During language acquisition, gestures seem vital to learning how to speak. They help us emphasize and structure what we say. **Simone Pika** from the Humboldt Research Group at the **Max Planck Institute for Ornithology** in Seewiesen wants to know whether gestures were an evolutionary precursor of human language and how they develop. To investigate this question, the researcher studies the communication strategies of great apes in natural environments, but also corvids and human infants.

TEXT **CATARINA PIETSCHMANN**

An incredible cacophony of vocalizations echoes through the rainforest, followed by hectic scurrying. Chaos is in the air. Baboons have hunted down a small antelope, but a group of chimpanzees immediately snatches away their prey. As Bartok, the alpha male, lugs the carcass around, some members of his group beg him to share some of the meat.

Bartok, however, wants to be the first to eat, so he settles down with the dead animal less than four meters away from the blonde woman. Simone Pika has been following the chimpanzees for quite some time during her daily treks through Uganda's Kibale National Park, and she can hardly believe that Bartok is sitting so close to her now.

Two males have the courage to approach Bartok and the scientist. While one of them simply sits down next to the alpha male, opens up his outstretched hand and then gently starts plucking at the antelope, the other male is less self-confident. Although he also sits down next to Bartok, he then starts making begging and appeasement gestures: he ducks down, sways backwards and forwards, whimpers like a chimpanzee child, and makes a facial expression called a fear grin. The message: Don't hurt me, but give me some of that delicious stuff. And it works! Bartok tears the antelope apart and shares small pieces of the meat with both of them.

RESEARCHERS KEEP THEIR DISTANCE

"When you actually get to see something like this in the wild, you can't help sitting in the camp that night and just smiling from ear to ear," says Pika, thinking back to that day. Because unlike in the days of the young Jane Goodall, scientists no longer lure wild chimpanzees with food, but instead track them down in the rainforest day after day, guided by the animals' nests, feeding grounds and calls, all the while making sure to keep an observer distance of at least seven meters. Only in very rare and specific contexts, such as the highly-aroused situation of hunting, do they not increase their distance from the animals when it falls below this minimum.

Yet Pika doesn't need to get any closer to film the gestures that are exchanged between the animals. The 43-year-old is the Leader of the Humboldt Research Group "Evolution of Communication" at the Max Planck Institute for Ornithology in Seewiesen. She wants to solve one of evolution's biggest mysteries: how did human language evolve?

According to one theory, our ancestors initially gesticulated with each other before using speech. That means they could have communicated simple information using gestures. "But, like many of my colleagues, I now believe this to be a rather unlikely scenario, because individuals use gestures to communicate with each other mainly

Like all great apes, gorillas also communicate via gestures. The animals use this form of communication mainly in relaxed settings and across short distances.

Photo: Simone Pika/MPI for Ornithology

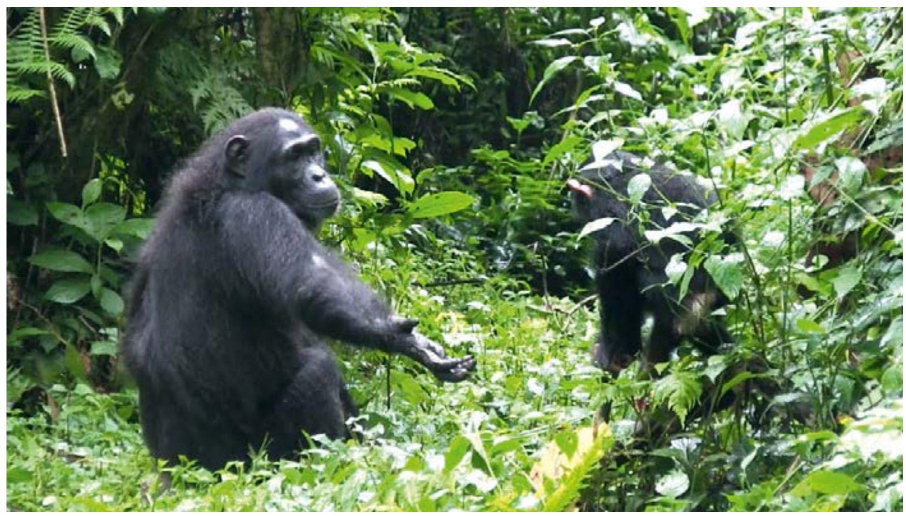
when they are in a relaxed setting and can touch or at least see each other," says Pika.

But what if an animal wants to warn other members of its group of a predator, and the group is far away in the dense rainforest? "Then vocalizations are, of course, much more effective than gestures." That is why most researchers now believe that calls and gestures evolved in parallel.

While writing her doctoral thesis under the supervision of Michael Tomasello at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Pika studied the gestures used by gorillas and bonobos in various wildlife parks and zoos across Europe. But is their behavior similar to that of their fellow apes living in the wild? Or do animals in captivity gesticulate primarily because they lack a natural environment and are constantly in each other's presence?

To find answers, the young researcher had to observe her subjects in their natural habitats. "In 2005, when I was given the opportunity to study a group of chimpanzees in Kibale National Park, nothing could hold me back. I will always remember that very first day: Not a single chimpanzee anywhere in sight, but the forest was filled with their calls, which are known as pant-hoots and can be heard hundreds of meters away. The wild chimpanzees called out much more frequently than their counterparts in captivity, indicating to us that calls play a very different role in natural habitats," Pika explains.

Pant-hoots let chimpanzees know who is in which part of the forest and with whom. The animals also use these characteristic calls to claim rich feeding grounds for themselves. When greeting each other, they use quieter pant-grunts. Pika has observed that some animals also accompany these grunts with



gestures. In a new study being conducted with her postdoctoral fellow Dr. Eva Luef, the researcher is therefore aiming to find out whether chimpanzees, like humans, have certain greeting customs, and if so, whether these greetings vary depending on an individual's social rank within the group. Consequently, gestures would be relevant in situations in which humans, too, would talk to each other: in direct exchanges, when individuals are in very close proximity to each other.

In 2010, Pika received the Alexander von Humboldt Foundation's Sofja Kovalevskaja Award, which is endowed with 1.65 million euros. She uses these funds to study the evolution and development of communication in three different model groups: in children growing up in different cultures; in great apes, our closest living relatives; and in species that have a similarly complex social structure – corvids. Using this approach, Pika aims to determine the degree to which our ancestors had developed communication skills, and which factors are responsible for the fact that only humans are capable of speech.

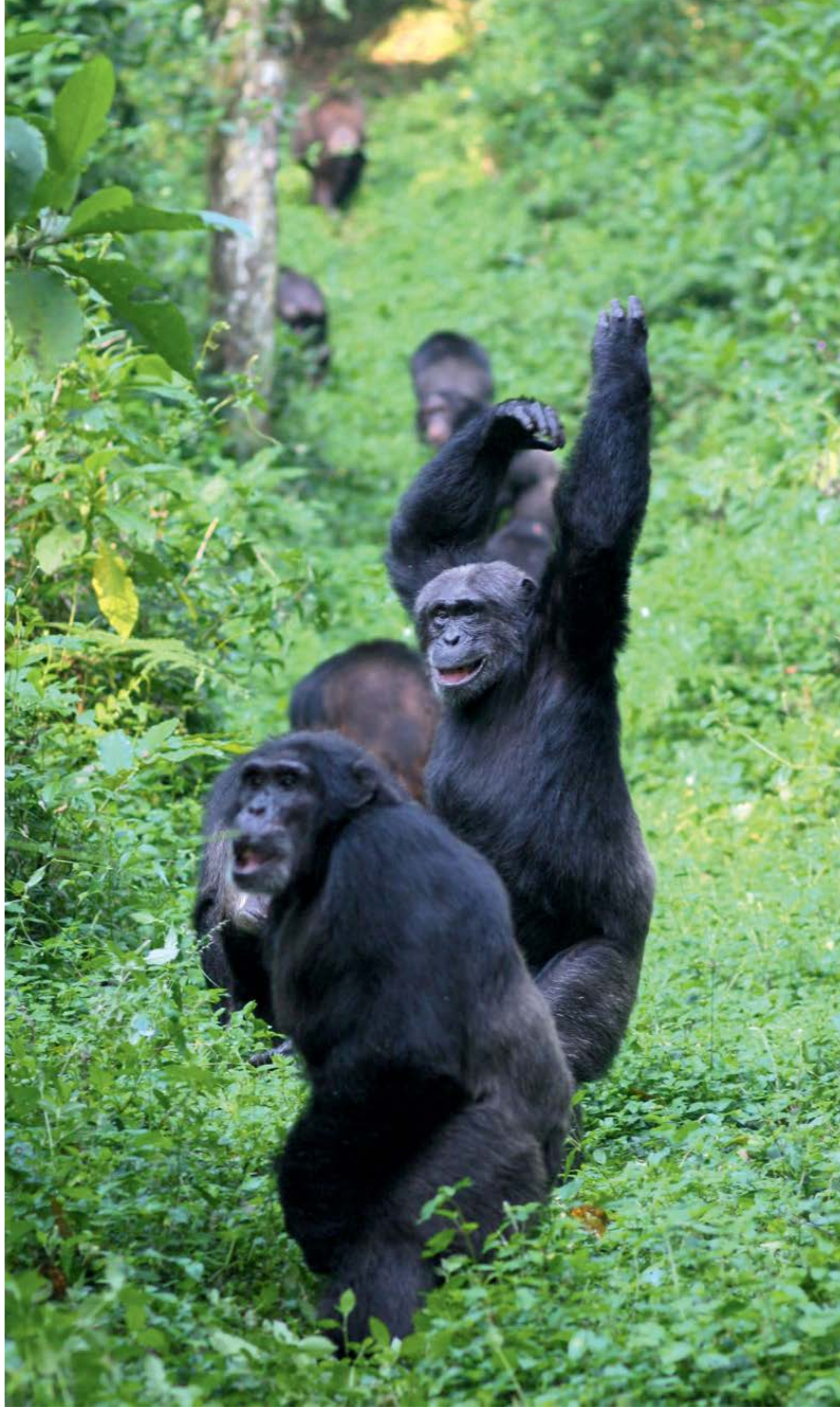
Today, there is a scientific consensus that apes use gestures to communicate with each other. Pointing gestures, however, were considered to be an exclusively human trait until recently. Yet chimpanzees living in zoos have been observed to clearly point to highly desirable food, such as grapes and bananas, indicating to their keepers: I want that! It appears that chimpanzees and bonobos in captivity learn that they can bring a human's attention to a particular object by pointing at it, and that they will ultimately receive the object. This kind of exchange has only rarely been observed in nature, and only between friends or between mothers and their offspring.

GROOM ME HERE!

The pointing gestures that have been observed in chimpanzees living in their natural environments mostly occur in the context of animals grooming each other. Grooming is more than just a hygienic behavior: it plays an important role in establishing and maintaining social relationships. Simone Pika dis-

Left The more independent young chimpanzees become, the less their mothers carry them around. By stretching out her arm and making eye contact, this chimpanzee mother is telling her child that it's time to go to one of the safest places in the rainforest of Uganda's Kibale National Park: onto mom's back.

Right Chimpanzees use more than 100 different types of gestures. Some gestures are used by only one single member of a group. The male chimpanzee Dolphi, for example, raises his arms vertically above his head to signal to the alpha male (front) that he should follow the group.



covered that chimpanzees use distinct scratching gestures to let others know that they want to be groomed, but more importantly, they use them to signal where. "This means chimpanzees know that their counterpart understands the meaning of the gesture," says the Max Planck researcher.

Many species of birds also use referential gestures when performing courtship displays – despite the fact that birds and humans sit on two very divergent branches of the evolutionary tree. Ravens are a prime example: not only are they intelligent and capable of learning, but they also use objects as pointing tools. Pika discovered that ravens pick up objects with their beaks with the intention of offering or showing them to other group members, or to attract the attention of a potential mate. And sometimes they just want to scuffle with each other for it.

"Children do that too – and chimpanzees, surprisingly, don't. They do scuffle for things, but they don't hold up objects to show or offer them to others. In the case of chimpanzees, most gesture-based interaction doesn't involve objects," says Pika. This indicates that apes use pointing gestures only to attract the attention of conspecifics, but never to inform them of something going on in their immediate surroundings.

Just like apes, ravens also groom each other – called preening – but only on the body parts that are out of their own reach. They do so by scooting closer to their partner and presenting the part of their body that itches. Young birds also enjoy spreading their wings and sliding down a snowy slope on their backs. Normally, birds only lie on their backs when they are dead. Yet a raven lying on its back is sending a dif-

ferent message: I can afford to lie in this crazy position because I am strong and healthy! Ravens are also known to make kicking gestures with their feet.

The pointing gestures displayed by ravens and apes are therefore a typical case of parallel evolution, because the two different species can't have learned this behavior from a common ancestor. "Studying ravens helps us uncover such examples of similar yet independent evolution and understand the reasons why gestures evolved. After all, not everything that humans and apes do was necessarily done by our common ancestors," says Simone Pika.

Humans use vocalizations to communicate from the day they are born – sometimes much to the chagrin of exhausted parents. But even for babies and toddlers, gestures are a key communication tool before they learn to speak. To date, though, very little research has been conducted in this area. Pika, now the mother of an almost two-year-old daughter, was sensitized to this topic as a result of her work with great apes and wanted to find out more.

PARENTS, JOIN IN THE RESEARCH!

First sounds, then gestures, and then finally the first words! Simone Pika and her assistant Monika Krug developed a speech calendar for parents who wish to record the stages of their child's language development from the ages of 0 to 24 months. Parents interested in participating in this study have the option of anonymously taking part in the "Milestones of Language" study, which started in November 2015 and runs until the end of 2017.

For more detailed information and the download version of the language calendar, please visit **www.orn.mpg.de/milestones**

That's why, four years ago, when she started to work at the Max Planck Institute in Seewiesen, she set up a playroom for toddlers in a lakeside building that legendary behavioral scientist Konrad Lorenz once used to observe wild geese. Together with the members of her working group, Pika studied how toddlers communicate with their parents from the age of five and a half months until the time at which they are capable of saying three words.

Very early on, children utter sounds that appear to be questions. At the age of nine to twelve months, most toddlers start using pointing gestures. "Initially, they point at something without making sure that others attend to their gestures. Maybe they do it because the gesture helps them internalize something and structure their thoughts," says Pika. Only later in their development do children also establish eye contact with their parents when pointing to an object they want, as if to say: This teddy bear, I want, Mommy!

Gestures help children learn to speak. But why do adults gesticulate? For one

Photo: Valentin Rodriguez/agefotostock/Avenue Images

Left Ravens are very social animals. Similar to apes, these birds also strengthen and nurture social relationships by preening distinct body parts.

Right Simone Pika studied the gestures used by individually marked ravens living in a raven colony at the Cumberland Wildlife Park in Grünau, Austria. In Seewiesen, she works with captive and hand-raised ravens to find out more about how their communicative signals evolve.

Photo: MPI for Ornithology

thing, we talk with our hands to help our conversation partner visualize what we're saying. "But we also do it for ourselves. This is evident from the fact that gestures are always formed before or while the respective word is being uttered. Our hands communicate an idea faster than our mouth does," the scientist explains. Gestures help us structure our thoughts. This is commonly observed in toddlers: the more difficult the subject, the more illustrative gestures they use.

From 2003 to 2005, Simone Pika studied an interesting phenomenon at Edmonton University in Alberta, Canada: gestures used by bilingual adults. Do people gesticulate differently in their mother tongue than they do in their second language? Yes – especially when they are more fluent in their native language. In that case, people tend to use more visual gestures when speaking their second language. The study also revealed that, when learning a language that traditionally uses a lot of gestures, a person will soon start gesticulating more in his or her mother tongue, as well.

The first researcher to compare the evolution of communication in humans and apes was Russian scientist Nadezhda Ladygina-Kohts. She discovered that a child's first attempts at speaking include gestures and facial expressions that are surprisingly similar to those of baby chimpanzees. At that time, several attempts were made to raise baby apes like human children in a normal household. A gorilla named Toto, for example, lived with a family in Central Africa for nine years. Yet all efforts were in vain – none of the animals ever learned to speak. Today we know that the anatomy of the larynx and its neural connections with the tongue prevent monkeys and apes from producing complex sounds, let alone words.

PIONEERS OF THE FIELD

In the late 1960s, scientists were able to teach a female chimpanzee named Washoe more than 300 signs in American Sign Language. Washoe used sign language to communicate not only with her trainers, but also with her adopted son. And she combined signs on her own to form new meanings: the first time she saw a duck, for example, she signed "water" and "bird."

The gorilla Koko and the orangutan Chantek also learned sign language. A bonobo named Kanzi is able to use a keyboard with symbols that stand for – but do not resemble – particular objects. When he is in the mood for pizza, for example, he presses the pound symbol. The key with the triangle on it stands for "banana."

"But these are isolated cases. Very rarely did the animals create new words using the basic vocabulary they were taught. Furthermore – and I believe this is highly significant – most of their communication dealt with themselves in the present moment in time: I want to eat, I want to play, let's go out to the garden," says Pika. Unlike humans, she explains, chimpanzees and other great apes don't communicate their thoughts about what happened yesterday or what will happen tomorrow.

So anatomical features aren't the only reason apes are incapable of speech. They don't seem to possess a world of thought that they can or want to pass

» A comparison of the complexity of vocalizations and gestures produced by great apes doesn't help explain the evolution of language.

on using language. For them, gestures are thus an efficient form of communication without symbolism. However, it does bear a certain resemblance to human language and human communication in terms of the underlying structure of communication, which includes cooperation, turn-taking behaviors and negotiation.

In the animal kingdom, it is birdsong that comes closest to the complexity of human language, especially as regards the ability to learn and form new combinations: Songbirds and parrots are able to recombine individual notes and note sequences to create new verses. Moreover, they imitate notes, voices and sounds, such as mobile phone ringtones or the noise of a revving engine.

However, birds don't appear to use their songs to communicate something new to their conspecifics. "The main message of birdsong is: 'This is my territory!' and 'Look how impressive I am!'" says Pika. Consequently, this is another communication structure that differs significantly from human language in many respects.

BONOBOS COMMUNICATE FASTER THAN CHIMPANZEES

Back to gestural signaling of great apes: in a comparative study into the communication strategies of wild chimpanzees in Uganda and Ivory Coast and bonobos in the Democratic Republic of the Congo carried out with her doctoral student Marlen Fröhlich and other colleagues, Pika discovered that there are even differences in the way closely related species – such as chimpanzees and bonobos – communicate. The scientists discovered that bonobo mothers and their children exchange information faster and more fluently than chimpanzee mothers and their offspring.

Temporal relationships between social actions involved in bonobo gestural sequences are more similar to social actions in human conversations than to those of chimpanzees. For example, when a bonobo mother wants to get up and leave, she turns toward her child and holds out her outstretched arm in the child's direction. Almost simultaneously, the offspring walks up to her and climbs onto her back. In other words, the recipient of the gesture responds even before the entire message has been conveyed.

In the case of chimpanzees, in contrast, communication between mother and child is often characterized by longer negotiations: the mother turns toward her child and extends her arm in its direction. They both look at each other. The mother moves her arm in the offspring's direction once again, but this time faster and using a shorter range of motion. Only now does her child walk up to her and climb onto her back.

These observations may indicate that bonobos anticipate their counterpart's actions much more quickly than chimpanzees. Or that they can simply afford to react more quickly, thus possibly choosing a "wrong" response, because their society is more tolerant and less aggressive. Furthermore, the females have greater influence. These different communication styles correspond to the results of comparative studies that focus on the structure of the brain: the regions that play an important role in the ability to feel empathy are more developed in bonobos than in chimpanzees.

In light of her findings, Simone Pika concludes that, "The similarities and differences between the vocalized sounds and gestures of our closest extant relatives won't help us solve the mystery of how language evolved. Language is based on a range of cognitive skills that already existed before the advent of speech."

One of the prerequisites for acquiring language is what is known as interactive intelligence. When we talk to each other, we continuously alternate: one person speaks, the other listens, then the listener replies, and so on. A conversation is like a game of ping-pong, where questions and answers fly

When toddlers point at something, they initially do it for themselves. A little later in their development, they learn that gestures can convey distinct messages to others. They then start making eye contact with their parents to make sure they have their attention.

Photo: Catherine Delahaye/Mauritius Images

Simone Pika studies the development of communication in individuals from three model groups: human children from different cultural backgrounds, several species of great apes (bonobos, chimpanzees and gorillas) and corvids (crows and ravens). Her findings show that gestures are particularly developed in social animals that cooperate with members of their own species.

back and forth; a game based on a specific set of rules as regards the roles of the participants and the temporal sequence. The speaker and the listener cooperate with each other – otherwise, their communication would fail.

Can precursors of this type of cooperation be observed in apes? "Clearly, yes," says Pika. When a mother plans to leave and wants her child to come with her, she must make it clear that the gesture is directed at her infant, and also make sure that her offspring understands what she intends to communicate. Without such communicative cooperation between mother and child, such an interaction would not work.

So animal communication is essentially not all that different from human communication with regard to the type and purpose of the exchange. Yet animals appear to manage just fine without language. Would it even be advantageous for chimpanzees if they could speak? Simone Pika nods. "Of course. Language has virtually catapulted us into a new universe: We can think about symbols and exchange information about objects that aren't in our immediate vicinity or that don't even exist, about things that happened yesterday or that might happen tomorrow."

Moreover, language is the foundation of writing. Writing allows us to record our experiences and pass them on to our descendants. This ensures that our knowledge doesn't get lost, and that it grows from generation to generation. "There's no doubt about it: language makes us humans one of the most powerful species on earth," Pika emphasizes.

But what if evolution had taken a slightly different course? What if gorillas and chimpanzees had acquired this skill before we did? Is the thought of a distant planet in another galaxy where apes actually are in charge really just science fiction? If not, we can only hope that they treat their closest relatives with greater respect than we treat them here on earth. ◂

TO THE POINT

- **Gestures foster human language: they help babies learn to speak. Adults use gestures to emphasize what they say and to structure their thoughts.**
- **Gestures alone are not the precursors of human language.**
- **Many different species of animals also communicate using gestures. Great apes and ravens even point at things to draw the attention of other members of their species to particular objects.**

GLOSSARY

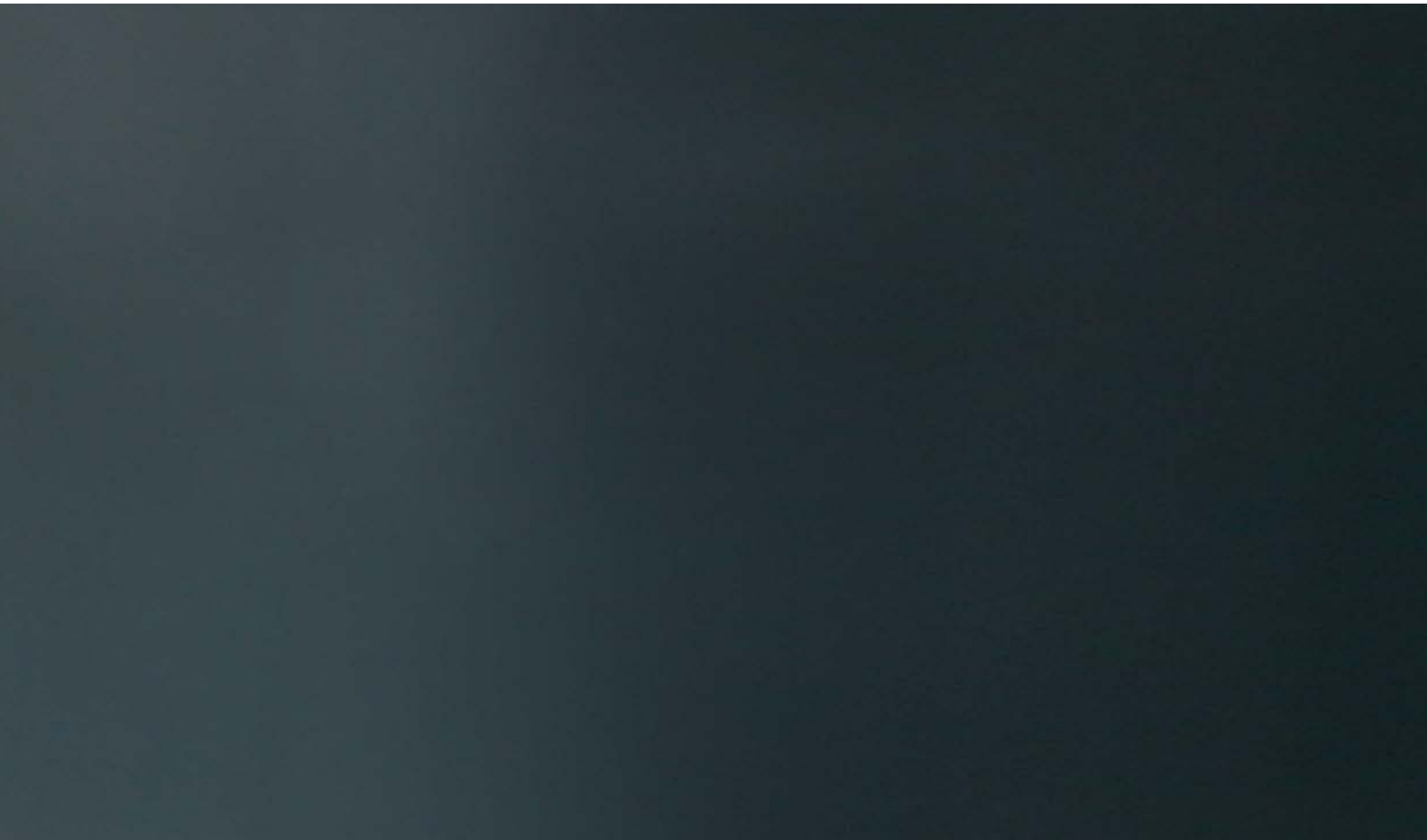
Bonobos: Along with chimpanzees (*Pan troglodytes*), bonobos (*Pan paniscus*) are our closest extant relatives. Although they are also called pygmy chimpanzees, they are almost the same size as chimpanzees. However, their body and head are more graceful, their face is darker, and the mouth of bonobo children has a more reddish hue than that of young chimpanzees. Bonobos are found only in the Democratic Republic of the Congo, south of the Congo River.

Pant-hoots: These particularly loud calls emitted by chimpanzees can be heard in the rainforest from miles away. The calls generally consist of several elements, which can vary in their structure. Chimpanzees can recognize each other by their pant-hoots and use this distinct call in different contexts, such as when traveling through the rainforest or arriving at rich feeding grounds.

Talk First, Think Later

During everyday conversations, we often begin to speak before we have decided exactly what we want to say. **Antje Meyer** and her team at the **Max Planck Institute for Psycholinguistics** in Nijmegen are investigating how we plan sentences and what obstacles may stand in the way. To this end, the researchers test volunteers on a treadmill, construct virtual environments and travel to India to study whether illiterate individuals process language differently.

Photo: Mauro Rodrigues/Fotolia



TEXT **STEFANIE REINBERGER**

A cartoonish sketch flickers on the monitor. The image shows a dog biting a mailman. Click. Next image: this time, a girl is pushing a boy on a sled. Then: a woman giving a boy a cookie. The volunteer stares intently at the screen and tries to describe the brief, changing scenes as quickly as possible. Her head rests on a chin support to prevent it from wobbling. While the volunteer describes the images, a scientist, using a special eye-movement camera, follows her gaze as it scans the drawings. In this way, Antje Meyer and her team in the Psychology of Language Department at the Max Planck Institute for Psycholinguistics hope to discover how people plan sentences.

During a conversation, questions and answers often follow each other seamlessly. We appear to form sentences effortlessly – evidently without taking much time to plan them beforehand. In fact, many speakers start their sentences before they know precisely what they want to say. This is possible because we plan speech faster than we're able to articulate the words. For example, as one says "The young girl ...," there is ample time to prepare the second part of the sentence in the background: "... throws the ball."

"UMS" AND "ERS" HELP IN PLANNING SENTENCES

But how does this work exactly? Do we have general strategies for language planning that help us formulate answers without having to give them much thought? The scientists are seeking to answer this question with the help of experiments using an eye-movement camera. The device determines precisely, to within a millisecond, where the viewer's gaze lingers. For example, while the volunteer is looking at the picture of a dog biting a mailman, the camera system detects which section of the image she is gazing at most intensely before expressing the scene in words. This, in turn, reveals what information she has given the most attention to while preparing her sentence.

In simple situations such as "The dog is biting the mailman," the eye movements of most subjects follow the same pattern: after a brief orientation phase, during which the subjects often look at the center of the image, they gaze at the sections of the image in the order in which they appear later in the sentence. In other words, the eye wanders from the dog to the place at which the dog sinks its teeth into the mailman's leg, and finally, to the mailman's face.

However, when subjects are called upon to describe more complex situations, or when descriptions are longer, their eye movements increasingly vary.

The very same person may then proceed extremely flexibly in describing different scenes – and variations are particularly pronounced between different speakers. Ultimately, a certain amount of flexibility probably helps people plan and choose their words in order to express themselves quickly and appropriately.

But not everyone is able to describe a scene or answer questions with equal speed and fluency. “Many factors come into play, such as how well an individual masters a particular language,” Meyer says. Those speaking a foreign language will have to break sentences into smaller bits while planning them. This reduces the speech rate, forcing the speaker to introduce brief pauses that are then often filled with “ums” and “ers”.

“We should therefore never conclude that non-native speakers (speakers not using their mother tongue) are unable to take in a situation just because they take longer to formulate their answer,” the researcher cautions. “The delay is not in their thought process but in their ability to express themselves in a foreign language.”

Antje Meyer cites another real-life example: “In school, pupils are expected to process sentences they’re unable to comprehend because they don’t have the requisite vocabulary and language skills.” Textbooks for vocational schools, for example, are often formulated in a style normally found in scientific papers – replete with long, convoluted sentences, technical terms and the like. “So it’s no wonder that a young woman who wants to be a hairdresser mentally blocks out the material,” the Max Planck Director says, with a note of criticism. Yet vocational students probably wouldn’t have any trouble following relevant material if it were expressed using words they’re familiar with.

Such findings may sound mundane, but that’s precisely what piques Antje Meyer’s interest. The psychologist

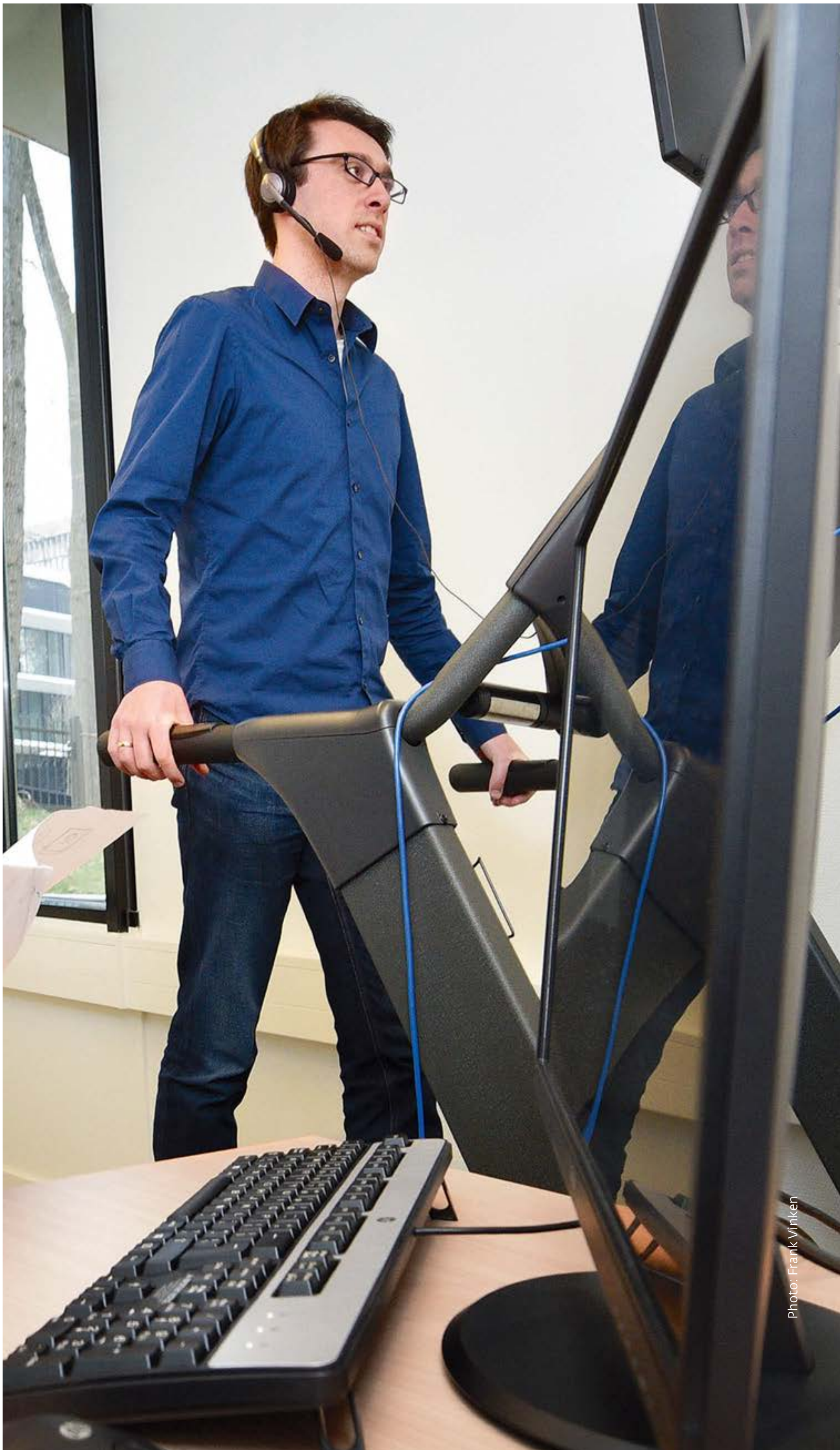
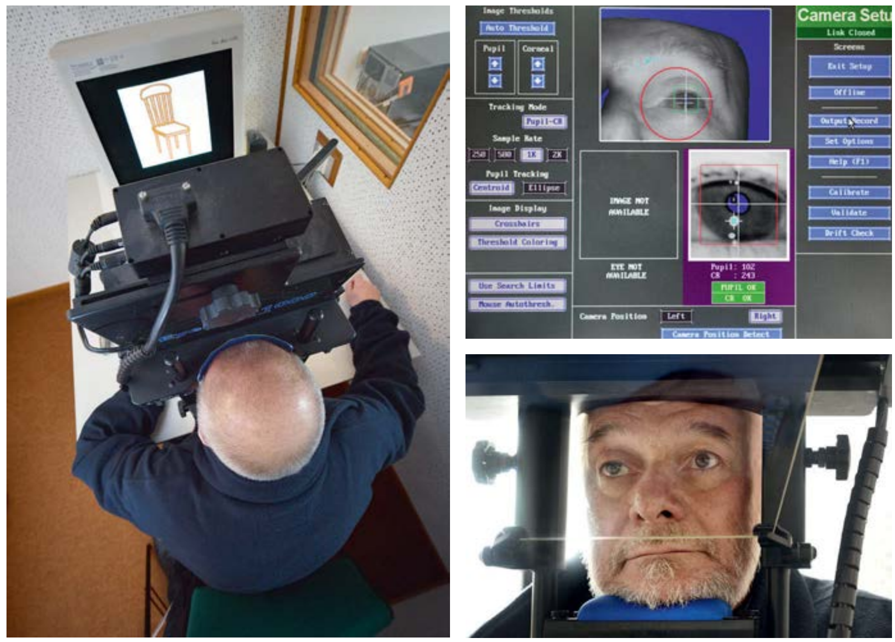


Photo: Frank Vinken



Speaking time in the laboratory: An eye movement camera (right) pinpoints exactly where the subject looks before speaking. Normally, any distraction should be avoided while speaking. However, experiment participants on a treadmill (left) are able to name images more quickly than participants who are sitting.

wants to know how language works in natural contexts, such as in normal conversational situations when an individual responds to what has just been said. “You might think that listeners use the time during which their counterparts are speaking to prepare their own response,” the researcher says. “That may be possible sometimes, but comprehension suffers as a result.”

To prove it, the team in Nijmegen again uses an eye-movement camera. This time, two volunteers sit in front of a monitor on which two rows of objects are displayed. The task is simple: the first speaker names the objects in the upper row, and the second, those in the lower row, doing so one after the other, as in a question-and-answer pattern.

While subject number one is “reading out” the first line, the researchers track the eye movements of the “responder.” If he were preparing his utterances early on, his eyes would tend to dwell on the bottom row – but that is not the case. The listener first dutifully follows the speaker through the top row and then jumps to the lower row just before the end of the first speaker’s utterance. The temporal overlap of listening and preparing one’s own articulations is less than half a second.

THE RESEARCHER THINKS LITTLE OF MULTITASKING

Another experiment provides the explanation. When volunteers are shown images of objects to name while listening to words read aloud through headphones, they are usually unable to remember later what they heard. The only exceptions are words that are played back while the subjects are looking at “scrawled” images containing no identifiable objects. When the speaker then – necessarily – inserts a pause, their mind registers the auditory input. This means that our capacity for listening is severely hampered while planning our own speech.

“It’s not a good idea at all to encourage our students to think of clever questions during a lecture,” Meyer says. Instead, the motto should be: listen before formulating your own thoughts and questions. Anything else will be to the detriment of our ability to assimilate the information. “In fact, you shouldn’t write anything down either,” says Antje Meyer, looking at the journalist diligently taking notes during this conversation.

In general, the psycholinguist thinks little of multitasking, because it’s impossible to give one’s full attention to more than one activity. The only exception is moderate exercise. Subjects walking on a treadmill were able to name images faster than subjects sitting on a chair. “That surprised us,” says the scientist. “We had originally assumed that running would distract people from verbal tasks and that the subjects would therefore do more poorly.”

But exercise appears to act as a stimulus and thus enhances alertness. “It’s

Photos: Frank Vinken (3)

The search for variety: Antje Meyer and her team make a point of seeking out a variety of participants for their experiments. One study is investigating how reading affects speech among members of the Dalits, the "untouchables," in India. This allows the researchers to compare illiterates and literates from the same social class.

also likely that the subjects notice the distraction and therefore try harder to solve the task well," says Meyer, adding with a smile: "That's also why we're standing here while we're talking."

But be careful: not all types of movement are equal, and they don't always enhance concentration. The team in Nijmegen is currently carrying out a series of tests in which the treadmill rotates at a slower rate than the subjects' normal walking pace. They have to pay attention in order not to stumble and are therefore forced to divert capacities from the verbal task.

However, tests with human subjects in front of monitors and on treadmills model only a relatively artificial situation in the laboratory. And while it's true that this can answer basic questions about attention and language planning, a real dialogue consists of far more than a string of objects named sometimes simultaneously and sometimes in succession. Conversation partners interact and have to respond spontaneously to what has been said. On the one hand, the speaker commands the listener's attention, so that she is unable to consider her response during this time. On the other hand, sentence planning is supported by what was said before, because the responder can refer to thoughts and phrases the previous speaker used. For example, when one person asks: "What's your favorite food?", the other buys time by responding: "My favorite food? It's pizza."

A virtual reality laboratory is currently being built in the basement of the Max Planck Institute for Psycholinguistics to simulate situations that more closely approximate the natural conditions of interactive conversation. Here, instead of speaking to a monitor, subjects will talk to projected 3-D avatars in as natural an environment as possible – for instance in a virtual cafe. This has the advantage that the scientists can control the speech patterns of the avatars down to the smallest detail, and the virtual actors never act unpredictably.

To study speech in its natural context, it's important to involve as broad a range of subjects as possible. "Most of what we believe we know about the psychology of language has only been investigated with students, most of whom were female," says Antje Meyer. It's virtually impossible to extrapolate findings from such an elite group to the general population.

READING AFFECTS VISUAL CONCENTRATION

The scientist has therefore taken great pains to set up heterogeneous groups of subjects – for example in the NEMO Science Museum in Amsterdam. The participants were mainly parents with their children. This was an opportunity to conduct dialogue experiments with people of various ages and from various social groups. The data has not yet been fully analyzed, but regardless of the scientific result, Meyer is heartened by the enormous interest the museum's visitors have shown in the research.

Another research field of the Psychology of Speech Department largely requires participants outside universities: studies on cognitive processing in illiterates. Falk Huettig, who heads his own research group in the department, is focusing on this topic. Specifically, he is delving into the question of whether and, if so, how literacy affects the brain, speech and cognition.

One of the pioneers in this field is French neuroscientist Stanislas Dehaene from the Collège de France in Paris. Together with international colleagues, Dehaene published a highly acclaimed paper in the journal SCIENCE in 2010. In the paper, the researchers compared the brain activity of illiterates with that of literate participants. Using imaging techniques, the researchers observed that reading influences the network in the brain that is responsible for spoken language.

They also discovered that, with readers, certain areas in the brain are more strongly activated – not only by written words, but also by images and symbols – than is the case with illiterate individuals. However, the region responsible for recognizing faces appeared to be diminished in literate participants compared with their illiterate counterparts. Could this mean that reading has an adverse effect on facial recognition?

The problem with Dehaene's study is that the participants came from diverse cultural and socioeconomic backgrounds – even from different continents. Moreover, the study compared a relatively small group of illiterate individuals with individuals who only learned to read and write as adults. The control group was also very mixed and largely comprised of academics. "Too many potentially confounding variables are at work, such as significant differences in all areas of general education, as well as the participants' social background," Huettig criticizes. "Differences in vocabulary, for instance, as well as poverty and poor access to basic healthcare, can have an impact on networks in the brain."

The psychologist therefore set out to find study participants from the same social group. This would allow him to investigate the influence of reading skills more directly. And he was successful: in a small village in the In-

Photos left page: Frank Vinken (top), brianindia/Alamy/Mauritius images (bottom)

dian state of Uttar Pradesh, among members of the Dalits – often referred to as “untouchables” in the West – a traditionally disadvantaged class in Indian society. “In this group we find both people with reading and writing skills and illiterates, but all from the same social and cultural background,” says Falk Huettig and adds: “On top of that, we have the opportunity to carry out longitudinal studies on a large sample to test how speech, cognition and the brain are influenced when illiterates learn to read.”

These studies are possible only through collaboration with scientists at Lucknow University in the capital of Uttar Pradesh. Huettig and his colleagues can also use functional magnetic resonance imaging (fMRI) there to investigate processes in the participants’ brains.

Spoiler alert: Falk Huettig’s team was unable to confirm Dehaene’s hypothesis that literacy adversely affects facial recognition. Nor was the alleged positive effect of literacy on the phonological processing of speech verified. On the other hand, the scientists discovered a number of other differences between the two groups – including effects on visual attention. For example, participants with reading and writing skills scored better in certain search tasks than illiterates.

PREDICTIONS HELP US SPEAK EFFICIENTLY

For instance, when participants were asked to select the green or the thin chicken from a flock of dissimilar chickens, the literate individuals proved to be significantly faster. They scored particularly well when the animals sought were located in a section of the image to the right of the center. Huettig suspects that this could have something to do with the horizontal left to right direction in which Indian script is read.

Stanislas Dehaene, too, had already found that literate subjects are able to process visual stimuli better horizontally, namely in rows, than illiterates.

In addition, Huettig discovered that literacy has had a direct impact on his participants’ ability to anticipate upcoming language input. For example, illiterates are evidently less able to predict what their conversation partner will say next. To arrive at this conclusion, the researchers once again used a camera system to record eye movements. The participant hears the beginning of a sentence and looks at a monitor showing images representing how the sentence might be continued. For his Hindi-speaking volunteers, Huettig chose a sentence construction that accounted for the specific syntax of this language.

Applied to an English example, the experiment might look as follows: The subject hears “The boy will eat …” while a cake and a chair appear on the screen. Those who predict the continuation of the sentence in their mind are more likely to look at the cake than the chair. Whereas the gaze of literate participants does indeed tend to move to the cake before the word is spoken, the researchers found no such tendency in the group of illiterates. The latter’s eye movements only moved to the cake when it was mentioned. Although the illiterate participants were able establish a link between the spoken sentence and the displayed symbols, they had great difficulty predicting the continuation of the sentence.

Moreover: further investigations by the Max Planck researchers showed that the ability to predict increases with literacy skills. They compared people with dyslexia, a reading disability, with participants with average reading skills, or second graders who could read well

Photo: Frank Vinken

First listen, then discuss: Antje Meyer follows this principle when conducting meetings with her team. Their experiments have shown that people are unable to follow a lecture and formulate their own thoughts simultaneously.

with second graders with reading difficulties. The effect was significant, even among students: those who could read well were also able to predict spoken language faster and more reliably.

However, this difference is barely noticeable in everyday life. Poorer readers do not necessarily respond more slowly to a question than adept readers – as long as they understand the content. And illiterates are not necessarily limited in their everyday conversation. It appears that prediction is just one of many strategies the brain uses to make language and speech as efficient as possible.

In any case, Falk Huettig's investigations have confirmed that reading has a significant impact on information processing and networks in the brain. He hopes to shed further light on the phenomenon with the help of brain imaging studies, which he is currently carrying out with colleagues in India among illiterate individuals who are learning to read.

The scientist is already convinced of one thing: "Our research and findings have revealed great potential for dyslexia research." So far, he says, much has been reported about what people with dyslexia can do worse or better than literate individuals. But it's almost impossible to determine the cause and effect of the reading disability with this approach. However, if you compare illiterates with individuals with reading and writing difficulties, it's possible to identify the characteristics the two non-reading groups share. This can then be used to narrow down the search for causes.

"The first outcome of our research is that we can advise dyslexics to practice reading as much as possible, even if they find it difficult," Huettig says. "The more one reads, the more his or her visual attention, for example, improves." And so scientific curiosity and basic research merge again at the heart of everyday life – where speech occurs under natural conditions. ◂

TO THE POINT

- **People are unable to listen and plan a response simultaneously when conversing. Instead, the content of what is said often emerges only during the act of speaking.**
- **The ability to read has a significant influence on information processing in the brain.**
- **Those who can read score better in image search tasks and are better able to predict the content of conversations.**

GLOSSARY

Imaging methods: In the neurosciences, these special techniques allow researchers to watch the brain at work. The most commonly used techniques include positron emission tomography (PET), which uses a weakly radioactive substance distributed in the body to provide sectional images of the brain, and functional magnetic resonance imaging (fMRI).

Dyslexia: International term for an intelligence-independent reading disability. It is usually used synonymously with legasthenia. It is characterized by severe, persistent problems with reading and writing at the word level.

Functional magnetic resonance imaging (fMRT): This technique is used to visualize perfusion changes in areas of the brain. Based on such changes, scientists can identify which areas of the brain are activated during specific tasks.

Digital **Storytellers**

Movies with audio descriptions help blind people understand the storyline. Could computers take over the task of transforming moving images into natural language? Anna Rohrbach, a scientist at the Max Planck Institute for Informatics in Saarbrücken, and her husband, Marcus Rohrbach, who conducted research at the same Institute until recently, have made it their mission to make that possible. They aim to develop a computer that can automatically generate and read out film descriptions.

TEXT **TIM SCHRÖDER**

The Pianist," "Gandhi," "Men in Black," "X-Men" – Anna Rohrbach owns a sizeable collection of movies and blockbusters. Her office shelf is filled with around 200 DVDs, neatly sorted in rows. While most people collect DVDs with the intent of spending a cozy movie night on the couch, for Anna Rohrbach they mean, above all, a lot of work.

Anna Rohrbach is a computer scientist. Together with her husband, Marcus, she is trying to teach computers something that might sound impossible at first: to watch videos and describe what is happening on screen. This is a trivial task for humans; at some point or other, we have probably all called out to the next room: "Honey, come quick! It's about to get really exciting!" When a gangster in a movie raises his weapon or the police chase a killer through dark alleyways, human viewers know exactly what's going on.

But a computer? First, a computer would have to be able to tell that a gun in a person's hand is a weapon and not a TV remote, that a hug has nothing to do with hand-to-hand combat, and that a fencing match isn't a matter of life and death. That in itself is a challenge. Then the moving images would need to be translated into comprehensible and grammatically correct natural language.

Anna and Marcus Rohrbach are experts in computer vision, which deals with automatic image recognition and analysis. Significant progress has been

Cooking on screen: Marcus Rohrbach set up a kitchen at the Max Planck Institute for Informatics and equipped it with video cameras. A computer program he developed is able to describe the cooking scenes being filmed here.

Software that learns: Marcus Rohrbach taught the computer program to recognize different activities being carried out in the kitchen by having assistants first describe the scenes. Here he is being assisted by doctoral student Siyu Tang.

made in this field over the past decade. Computers today can recognize faces in photographs and match them with different people. They can even correctly interpret pictures of landscapes. Reddish light, sails, horizontal lines? Sure thing: a sunset on the ocean. "But using clear words to correctly describe moving images in a movie scene is something else entirely," says Anna Rohrbach.

ONE APPLICATION IS IMAGE DESCRIPTIONS FOR THE BLIND

The scientist conducts research at the Max Planck Institute for Informatics in Saarbrücken. Marcus Rohrbach worked there too, before his recent switch to the University of California in Berkeley for a postdoc position, where he remains in close contact with his colleagues back in Saarbrücken. Yet the Rohrbachs aren't the only ones involved in this project. The idea originated from a collaboration between the Max Planck working group led by Bernt Schiele, in which Anna and Marcus Rohrbach work or worked, respectively, and the Department of Computational Linguistics at Saarland University, which is headed by Manfred Pinkal.

The researchers envision several applications for their project. In the future, computers could automatically generate and read out film descriptions for blind people. By today's standards, this is still a pretty costly and time-consuming process, because the voice-overs for movies need to be recorded by professional voice actors. A second possible application could be to automatically describe videos posted on online platforms. With the help of these short texts, Internet users could find relevant videos more quickly without first having to click through numerous clips.

A third application seems a bit more futuristic. If a computer is able to interpret movie scenes and describe them in natural language, then it can also comprehend events unfolding in the real world and render them in spoken words. That's why the Rohrbachs believe that, in just a few years, service robots or smartphone apps will be able to understand human actions and converse with humans using natural language. They could answer a user's question as to where he left his glasses, for example, or discuss what he should cook for dinner – after all, they observed which meals were served over the past few days.

Around five years ago, Marcus Rohrbach began teaching computers how to describe videos – a major goal that requires many small steps. "After all, you can't expect a software program to recognize the entire world with all its imaginable scenarios," the scientist explains. "That's why we decided to start out by limiting ourselves to one easily understandable scene – a kitchen, where we filmed people as they cooked." To this end, Marcus Rohrbach had a modern kitchen with a ceramic-glass cooktop and elegant cabinets specially set up at the Max Planck Institute.

Unlike a normal home kitchen, this one is fitted with several cameras that record what goes on in the room. The first step was to film volunteers as

Photo: MPI for Informatics

» The most important step: Marcus Rohrbach had to link the knowledge about movements and objects with activity descriptions – a complex process that is carried out in several stages.

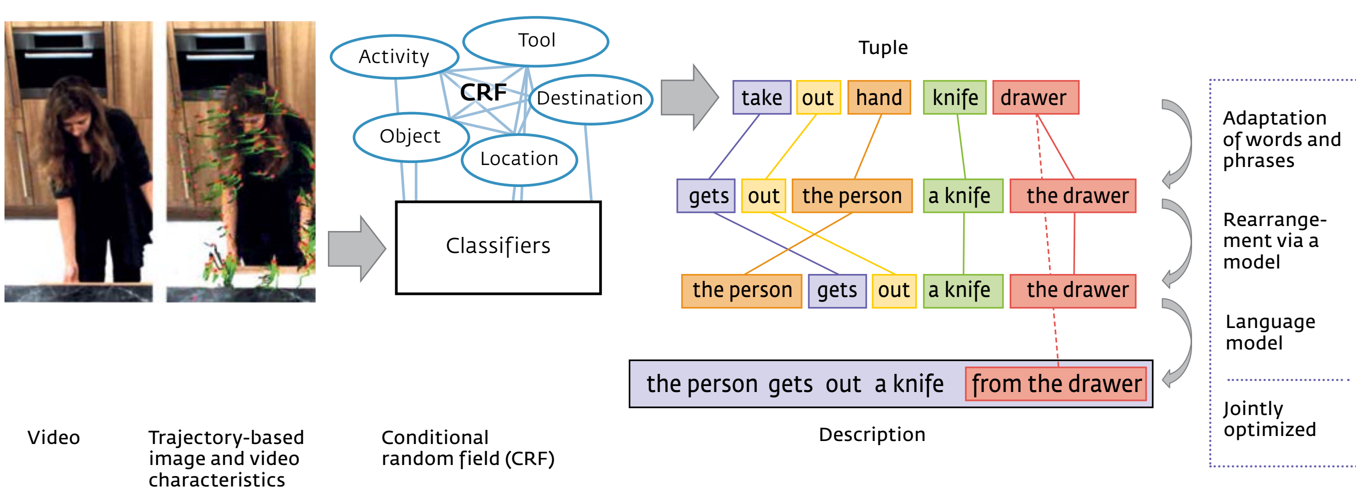
they performed different tasks – peeling an orange, cooking spaghetti or slicing a cucumber. Next, he gave his assistants the task of describing these film sequences using natural words – for example: "A man is standing in the kitchen and slicing a cucumber with the knife."

Since these descriptions are freely worded and have no fixed structure, the data then had to be annotated with comments that follow a fixed pattern. For example, the assistants noted down information pertaining to the following categories: object (such as a cucumber), activity (for instance peeling or slicing), tool (knife), location (countertop) and destination (salad bowl). "These categories are essential if you want to comprehensively describe an activity," Marcus Rohrbach explains, "because they contain the key elements of a sentence, such as the verb or object; for example: man – knife – slice – cucumber."

SOFTWARE TRACKS THE MOVEMENTS

Yet before a computer can describe objects, it first needs to learn what they look like. For this, Marcus Rohrbach used a software program that automatically learns the different parameters. The software is based on algorithms that are fed with a set of training data – in this case the video clips recorded in the kitchen. Step by step, the algorithm learns what an object looks like and can later recognize it accordingly. In the end, it computes probability values, such as, "This is 94 percent consistent with a banana."

Of course recognizing a video sequence also requires correctly identifying and interpreting movements. A rhythmically moving hand could be cutting, peeling a carrot or beating egg whites. The computer must be able to distinguish between these different actions. Marcus Rohrbach taught it such activities using tracking software. This software tracks the movement of individual pixels in a video image, essentially "freezing" the entire motion sequence. The researcher then fed this tracking data



The software developed by Marcus Rohrbach analyzes a video by first determining the image and video characteristics along the trajectories. Classifiers then identify objects, activities and tools as well as locations and destinations. Next, a model known as a conditional random field (CRF) creates a correlation between these parameters. This results in a tuple containing words and phrases that are first adapted to common wordings, for example by adding articles. The words and phrases are then rearranged before a language model adds any missing prepositions to form the final description.

Graphic: MPI for Informatics

Left Anna Rohrbach has collected around 200 DVDs in order to teach a software to describe the content of any given video.

Right In order to correctly describe a scene, a software must also be able to detect the subtext of the images. Otherwise it will mistake a hug for a wrestling match or the other way around, and it won't be able to distinguish between an Olympic fencing match and a historical duel.

into the algorithm as well, so that the computer learned to differentiate between cutting and peeling.

"These types of algorithms are known as classifiers," says Marcus Rohrbach. Depending on the probability value, they weigh different options to decide which action is being performed – for example cutting or stirring – or which object is involved – a cucumber or a banana. In order to do this, the classifier already has to take a range of characteristics, such as color, shape and size, into account when identifying the object.

A CONDITIONAL RANDOM FIELD PREDICTS THE ACTION

It's also important to model the interaction between various objects and activities. It's unlikely, for instance, that a person would peel a cucumber in a pot using a spoon; rather, you'd expect someone to stir zucchini in a pot using a wooden spoon, even though both scenarios might appear similar at first glance.

In order to predict which motion or activity is most likely being carried out, Marcus Rohrbach uses what is known as a conditional random field. This probabilistic model learns a correlation between the object, activity, tool and location. In other words, it predicts a group of categories, called a tuple; in this case, an object-activity-tool-location tuple. As with the other methods, the conditional random field model is also taught using training data.

The next step is the most important one. Marcus Rohrbach had to link this knowledge about movements and objects with activity descriptions – a complex process that is carried out in several stages. First, the classifier identifies the probability of individual elements. When a person puts an onion on the cutting board, the classifier will conclude that the following elements are the most probable: "hand", "put", "onion", "board", "countertop". The classifier excludes concepts that appear less probable, such as "spoon" or "pot". Next, the conditional random field computes which tuple best describes the given scenario – in this case, for instance: hand, put, onion, board.

"In order to then transform these tuples into natural language, we used an approach that translates texts, for example from English into German," says Marcus Rohrbach. As a first step, the software rearranges the concepts linked in the tuple to create a reasonable sequence, such as: "Hand put onion board."

Next, a language model adds any missing articles or prepositions to the words and phrases to form a semantically correct construct – in other words a sentence with a reasonable structure, such as: "The hand puts the onion on the board." In addition, it replaces certain terms with more commonplace wording that the language model is more familiar with – for instance "person" instead of "hand." Each computational step put together ultimately leads to the formation of a grammatically correct sentence, such as: "A person puts an onion on the board."

DETAILED DESCRIPTIONS VS. SHORT SUMMARIES

"The kitchen project was actually the topic of my Ph.D. thesis a while ago," Marcus Rohrbach explains. "This video description technique worked pretty well and correctly translated the scenes into natural language." Anna Rohrbach then expanded the model in such a way that it was able to describe scenes using different degrees of detail

Photo: Oliver Dietze

Photos: gruizza/iStockphoto, PaSta77/shutterstock, katatonia82/shutterstock (from left to right)

or abstraction – a feat that no other working group had accomplished before her. This method is thus capable of both describing the individual steps of an activity in detail, such as: "A woman takes spaghetti out of a cupboard, gets a pot out of the drawer and fills it with water," and summarizing the entire action in one concise sentence: "A woman cooks spaghetti."

Yet this first project had its limitations, says Marcus Rohrbach. After all, the video analysis system was limited to the kitchen setting. The whole system was also much too complex, in his opinion. The entire process of analyzing scenes, creating tuples, semantically correlating concepts and finally forming the finished sentence just seemed to take too long. "That's why we've set ourselves two new goals: we want to be able to analyze scenes in any given setting, and we want to reduce the whole process of turning a scene analysis into natural language output down to a single step."

This is where Anna Rohrbach's impressive film collection comes into play. She has analyzed 202 movies and 118,000 video clips to date. Each of these clips includes a natural language sentence description. She uses these data sets to train a special software tool: a long short-term memory (LSTM) network.

THREE CLASSIFIERS RECOGNIZE ONE SCENE

This tool is an artificial neural network that, like all software of this kind, mimics the functions of the human brain. Unlike other artificial neural networks, however, an LSTM remembers previously processed data over a longer period of time, which also allows it to process the input data more reliably when key signals (for example during scene recognition or speech) come in at irregular intervals.

Provided that such an LSTM is properly fed with training data, it can draw on its experience to independently decide which information is relevant and must be stored in the system, and which information can be deleted. This means the LSTM is capable of assessing the relevance of information. Today, LSTMs are often used for translating speech or recognizing handwriting.

An LSTM is the centerpiece of Anna Rohrbach's work. It links the visual information – the input – directly with the language generation, thus achieving the goal of reducing the video description process to a single step. The LSTM, too, uses probabilities. Its input is visual data, which in turn is supplied by classifiers. In order to fully recognize an entire scene, the scientist uses three different classifiers, which provide information about the following three aspects: the activity being performed, the objects in view, and the location in which the particular scene is taking place.

Anna Rohrbach also incorporates elements developed by other working groups, such as a classifier created by researchers at the Massachusetts Institute of Technology in the US. By feeding it a lot of data, the classifier was taught to recognize settings and environments – a kitchen, a bathroom, or a restaurant, for example. As usual, the classifiers supply probability values, which are then linked to form a probability vector – a cloud of probability values, if you will – before being fed into the LSTM.

The LSTM converts this visual information directly into natural language descriptions. "One of the strengths of this LSTM is that it can assess a sequence of words to predict which words are likely to follow," says Anna Rohrbach. It is very efficient at deciding which word must follow another

The neural network (LSTM) developed by Anna Rohrbach describes video sequences such as a dance scene more accurately than other computer programs, but not quite as well as a human just yet.

word, and at filtering out irrelevant data. The LSTM adds articles and prepositions, thus generating meaningful, natural language.

"It basically uses the same technique we humans do. We also remember which words we just said and formulate the next part of our sentence accordingly." Anna Rohrbach's LSTM has also developed what you could call a feeling for language. It no longer requires tuples that first string words together and then rearrange them step by step to form a complete sentence.

Ultimately, the LSTM uses probabilities to decide which word will come next. Apparently it does this very well: in a direct comparison, Anna Rohrbach's technique produced better results than other video description methods. Among other things, her LSTM was able to describe a scene with greater accuracy and more nuances than the other methods.

THE LSTM DELIVERS BETTER RESULTS THAN OTHER METHODS

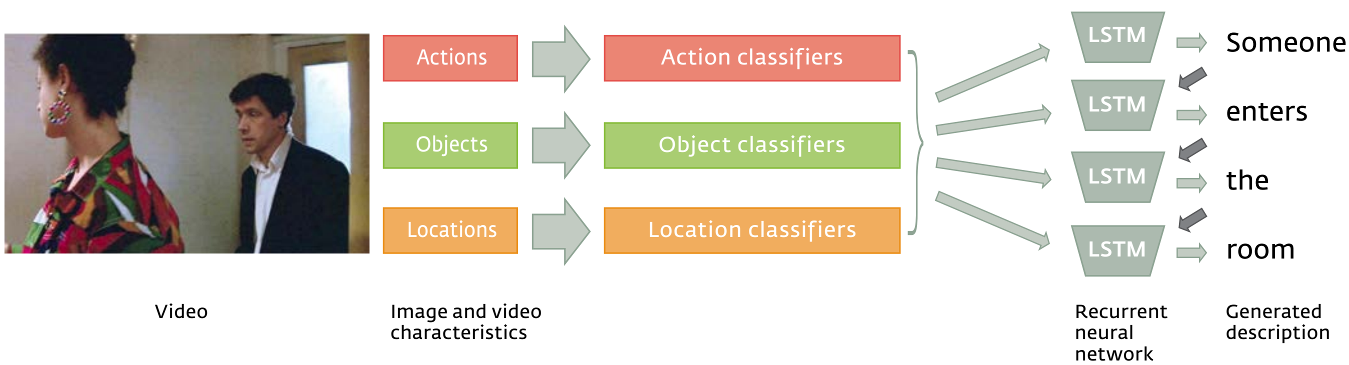
For example, a movie scene depicts a person leading a blonde woman onto the dance floor and then spinning her. Anna Rohrbach's LSTM described the scene as follows: "Someone is in a white dress, smiling with a smile and white hair." A different software offered a considerably less detailed description: "Someone glances at someone." The software developed by a third team against which Anna Rohrbach compared her LSTM even provided an unintentionally comic description of the two actors looking at each other: "Someone glances at someone. Someone glances at someone."

The comparison clearly shows that the LSTM analyzes the scene more accurately than other methods. At the same time, however, this example also exposes the weaknesses of Anna Rohrbach's system. After all, the LSTM didn't reveal that this scene took place in a ballroom. "It's true that this method isn't one hundred percent reliable yet. Grammar mistakes keep slipping in. And in some cases it doesn't correctly recognize scenes, especially when they are particularly complex," says the researcher.

One such example is a video sequence showing a young person in sports clothing running away. This scene was manually described for blind people as follows: "He runs up the steps of the stand and away." The LSTM interpreted: "Someone is running in the middle of the road."

This shows that the LSTM still has certain limitations, especially when it comes to recognizing abstract content. The LSTM wasn't able to make out that the young person is running away, and it also ignored the fact that he is running up a set of steps. "In other cases the system wasn't able to recognize that a person was fleeing from the police," says Anna Rohrbach.

Photo: Oliver Dietze



Anna Rohrbach's software learns to recognize actions, objects and locations depicted in a video using different classifiers, each of which is specific to one of these three categories. In a series of cycles, a recurrent neural network (LSTM) then uses these image characteristics to create a word-for-word description of the video.

"It's difficult to teach a computer to establish such thematic relationships between different pieces of content." Yet that is exactly what Anna Rohrbach has set out to achieve in the near future. She would also like to teach the computer to interpret actors' emotions. That would significantly improve the analysis method and bring video descriptions to a whole new level.

Rohrbach can't yet say exactly when her video description system will be ready to market. "But remarkable progress has been made in the field of image recognition over the past few years. So sometimes things can happen very quickly," she says. But she doesn't want to commit to anything just yet. The benefit for users would be substantial. Videos could be enhanced with text for the blind in no time at all. And Internet users could quickly skim through the content of online videos using either the concisely summarized description – "A woman cooks spaghetti" – or the extended, fully detailed text version. ◂

TO THE POINT

- **Over the past decade, significant progress has been made in the field of computer vision, which deals with automatic image recognition. For example, today's computers are able to recognize faces in photographs and attribute them to different people.**
- **Describing film scenes, on the other hand, is a much more complex process.**
- **Nevertheless, scientists hope to enable computers to automatically generate and read out video descriptions.**
- **To achieve this goal, researchers at the Max Planck Institute for Informatics are using a special software tool known as a long short-term memory (LSTM).**

GLOSSARY

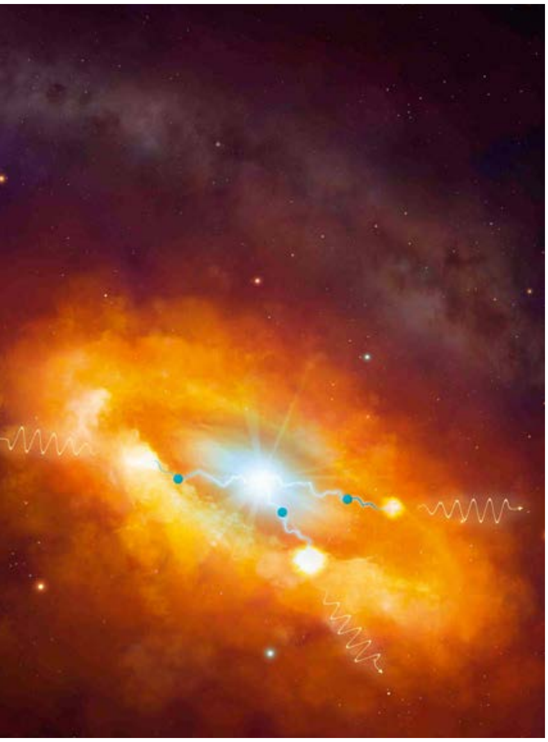
Algorithm: A clear set of operations to be performed in order to solve a problem or class of problems. Algorithms consist of a finite number of individual steps and can be executed by being implemented in a computer program, for example.

Computer vision: The computer-aided approach of solving problems relating to the abilities of human vision. Possible applications include industrial production processes and traffic engineering.

Long short-term memory (LSTM): An artificial neural network that mimics the functions of the human brain and remembers previously processed data over a comparatively long period of time. When fed with training data, an LSTM can independently decide which information is relevant and must be stored in the system.

Extreme Energy Source at the Heart of the Milky Way

H.E.S.S. telescopes observe cosmic radiation accelerated by giant black hole



The Earth is constantly bombarded with high-energy particles from space. The particles in question are protons, electrons and atomic nuclei, and are referred to as cosmic radiation. Energy-rich gamma light is generated when the particles are accelerated. This process also takes place in the central area of our Milky Way. With the help of the H.E.S.S. telescopes in Namibia, researchers – including scientists from the Max Planck Institute for Nuclear Physics – have been observing the gamma rays transmitted in this way for a decade. They had already detected a highly compact point source and extended band of diffuse gamma radiation with energy levels in the teraelectron volt range (TeV = 10^{12} eV) some years ago, but now they have identified for the first time a source capable of radiating energy in the petaelectron volt range (PeV = 10^{15} eV). The scientists suspect that what is involved here is the Sagittarius A*, a supermassive black hole at the heart of the galaxy; this monster mass would be identical to the compact point source in the teraelectron volt range. Moreover, its gamma rays could interact with molecular clouds and thus also generate the diffuse band of gamma rays. The astronomers have eliminated other objects, such as a supernova remnant, a pulsar wind nebula and a compact cluster of massive stars, as possible energy sources in the petaelectron volt range. (www.mpg.de/10390310)

Extraterrestrial particle accelerator: This artist's depiction illustrates the processes that contribute to the formation of the high-energy gamma radiation. Protons (blue spheres), which are accelerated by the Sagittarius A* black hole (bright source in the center), interact with molecular clouds in the surroundings. This generates pions, among other things, which almost immediately disintegrate into gamma radiation photons (yellow waves). An image of the Milky Way in visible light is shown in the background.

Blood Test for Tuberculosis

Biomarkers may one day be able to predict the risk of developing tuberculosis. Between 1.5 and 2 million people die of tuberculosis every year, making it one of the infectious diseases with the highest global mortality rate. However, not everyone infected with tuberculosis becomes ill: fewer than 10 percent of those infected with the pathogen actually contract the disease. Up to now, it has not been possible to identify which of those infected would develop the disease. An international team of scientists, including researchers from the Max Planck Institute for Infection Biology in Berlin, have now developed a tuberculosis test that can predict with a reliability rate of around 75 percent whether an infected individual will go on to develop the disease. The results show that certain genes are active in the immune cells in the blood of those infected with tuberculosis who then later develop the disease. The blood test is expected to detect the activity pattern typical of potential tuberculosis patients, and could predict the onset of the disease as early as over a year before it develops. The researchers now plan to carry out clinical trials to test whether, once predicted, the onset of the disease can be prevented with the help of targeted treatment. (www.mpg.de/10377384)

Early prognosis: It is hoped that molecules in the blood will one day indicate to doctors whether a patient will develop tuberculosis.

Photos: Dr. Mark A. Garlick/H.E.S.S. Collaboration (top), Jonas Steengaard (bottom)

Compass in the Eye

Some mammals may be able to use the Earth's magnetic field for orientation, similar to birds

Foxes are more successful at catching mice if they pounce on their prey in a northeasterly direction. Scientists from the Max Planck Institute for Brain Research may have found an explanation for this extraordinary observation. They discovered light-sensitive molecules in the retinas of several mammalian species that can also register changes in the Earth's magnetic field. Dogs, wolves, bears, foxes and badgers have the molecule cryptochrome 1, while feline predators, such as cats, lions and tigers, do not. In primates, the molecule is found in the eyes of orangutans and some macaque species, for example. The researchers presume that, like some bird species, the animals in question use the cryptochrome 1 to sense the Earth's magnetic field. Migratory birds also have cryptochrome molecules in their eyes, allowing them to perceive the inclination of the magnetic field lines relative to the Earth's surface. However, the molecules react to the magnetic field only if they are simultaneously excited by light. In addition, birds also have microscopic ferrous magnetic particles in their cells to enable them to orient themselves based on the magnetic field. This kind of magnetite-based magnetic sense is also found in some mammals, such as *Fukomys*, a genus of common mole rats. (www.mpg.de/10319591)

Telltale magnetic field: Foxes may be able to locate their prey based on minute changes in the Earth's magnetic field.

Extortioners at the Negotiating Table

Participants in major political conferences could write a book about it: negotiations consistently fail due to the uncooperative and selfish behavior of individual participants. This can be observed in the often fruitless attempts to reach an international climate agreement over the years, as well as the current difficulties in getting the EU countries to agree on quotas for the acceptance of refugees. According to scientists from the Max Planck Institutes for Meteorology in Hamburg and for Evolutionary Biology in Plön, this is due to the fact that people prefer to have representatives who use extortion as a negotiating strategy. Such representatives keep their own contribution to the attainment of a collective target to a minimum, force others to compensate for any deficits through steadfast stonewalling and ultimately benefit most when the collective target is reached. The researchers discovered this with the help of a climate game and a model derived from game theory. In the experiment, 40 percent of the participants resorted to extortion. The findings give grounds for cautious optimism: extortion ultimately leads to a successful outcome in negotiations. All of the parties involved benefit when the objective of the negotiations is reached – the extortioners a great deal and their victims only marginally, but still. Despite the Machiavellian nature of this strategy, it could help in mitigating climate change. (www.mpg.de/10347602)

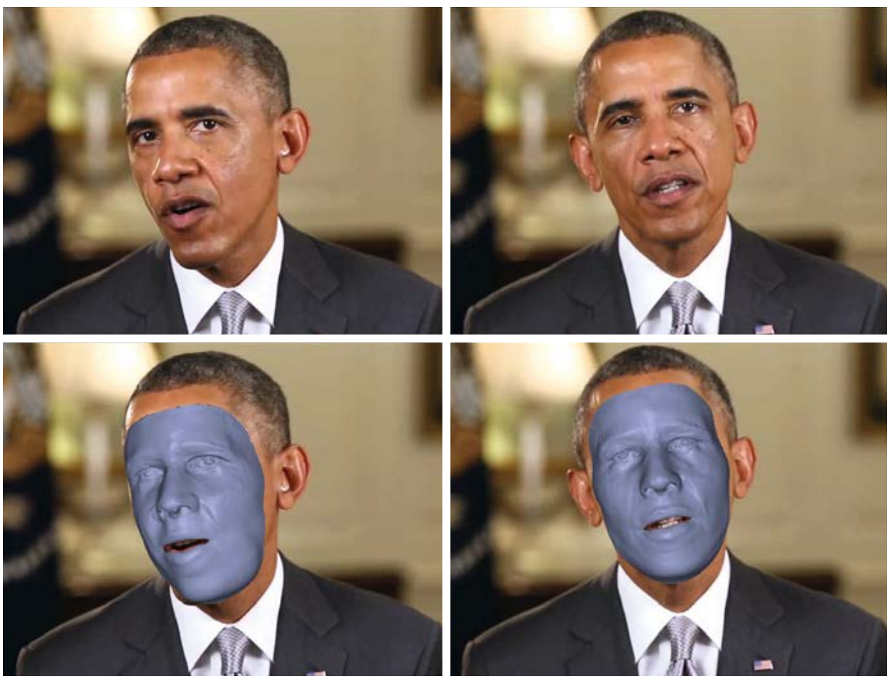
Political conferences are often the scene of fierce negotiations, with agreement often reached only at the last minute.

Photos: David Havel/shutterstock (top), dpa-picture alliance (bottom)

Animation Made Easy

Computer scientists in Saarbrücken produce realistic face models for films from video recordings

Today's film industry no longer relies solely on the skills of actors – when shooting has finished, the images of their faces are often edited on a computer. Such computer animation requires three-dimensional facial models known as face rigs, which, up to now, have been created using complex measuring techniques and manually inserted into the film scenes. Together with his team, Christian Theobalt, Leader of the "Graphics, Vision and Video" Research Group at the Max Planck Institute in Saarbrücken, has developed a new method that speeds this process up considerably. All the team needs are recordings from a standard video camera. The researchers use mathematical models to estimate the required parameters, such as facial geometry, reflection characteristics and scene lighting. Based on this, they can reconstruct an individual face on the computer so faithfully that it works like a complete face rig. With mathematical processes alone, the computer scientists can then give the actors different facial expressions. (www.mpg.de/10364192)

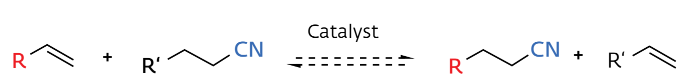


Suitable expressions: Based on ordinary video recordings like these images of US President Barack Obama, researchers at the Max Planck Institute for Informatics can create realistic facial models for computer animation and avatars. With the help of the models, they can also make the faces express emotions that were not shown in the original video.

A Hammer for Molecule Swapping

Chemists develop a versatile tool using a safe variant of hydrocyanation

Chemistry is like a toolbox. To synthesize drugs, plastics and dyes, chemists reach for various reagents in the same way that tradespeople reach for their tools. Scientists from the Max-Planck-Institut für Kohlenforschung (Coal Research) now present a new chemical tool that facilitates an important step in the synthesis process – hydrocyanation – and is less dangerous than the current standard method. What they have done is akin to inventing a hammer that can't hit the user's thumb. With the help of a suitable catalyst, the researchers succeeded in transferring one cyanide group – a functional group that creates numerous possibilities for the further processing of a substance – from one molecule to another. The donor molecule receives a double bond from its partner in the reaction. Up to now, this step in the synthesis process, which arises in the production of nylon, for example, required the use of toxic prussic acid (hydrogen cyanide). The new reaction is also easily reversible. The new hammer in the chemical toolbox not only prevents bruised thumbs, it also doubles as a pair of pliers. (www.mpg.de/10325265)



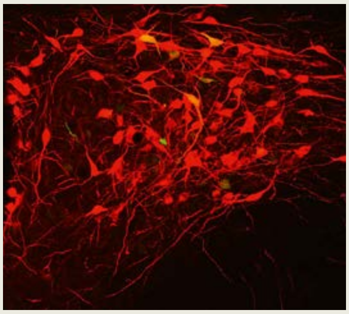
Molecular swap: Chemists from the Max-Planck-Institut für Kohlenforschung (Coal Research) have found a safe way to transfer the cyanide group (CN) from one molecule (R') to another (R). The donor molecule receives a double bond (=) from its partner in the reaction.

Photos: MPI for Informatics

Cuddle Hormone Relieves Pain

The name of the hormone oxytocin, which is derived from the Greek for quick birth, reflects one of its important functions: during childbirth, oxytocin triggers the contraction of the uterine muscles and initiates labor. Because oxytocin also plays a role in the regulation of social bonds, it is generally referred to as the cuddle hormone. The hormone is formed exclusively in the hypothalamus in the brain and is released into the bloodstream via the pituitary gland. Researchers from the Max Planck Institute for Medical Research in Heidelberg have now discovered, in the hypothalamus of rats, a small group of around 30 neurons that coordinate the release of oxytocin into the blood and also stimulate cells in the spinal cord. The nerve endings of the cells extend into the spinal cord, where they release oxytocin as a neurotransmitter. As the scientists have now established, the hormone reduces the sensation of pain in this way. They assume that these cells also exist in the human brain. The human oxytocin system, however, probably consists of more cells. (www.mpg.de/10353789)

Targeted release of hormones: A small group of oxytocin-producing neurons (red) coordinate the release of oxytocin into the blood and spinal cord.

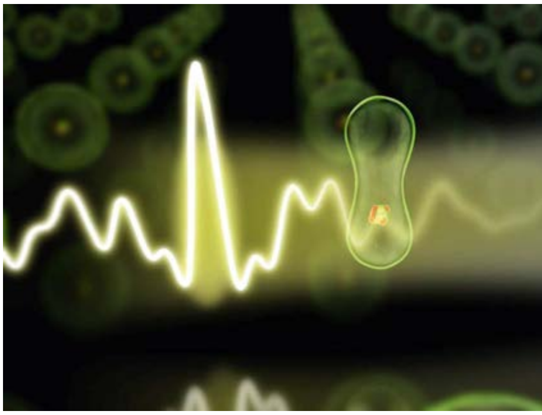


Photos: Christian Hackenberger (top), Eliava et al., 2016 (bottom)

Testing the Response Time of Electrons

Visible attosecond pulses can be used to measure the delayed reaction of electrons to light

Light could be the driving force that soon makes electronic components operate even faster. Physicists are therefore aiming to control electric currents in circuits in time with the light frequency. Insights gained by Eleftherios Goulielmakis and his research team at the Max Planck Institute of Quantum Optics may soon make it possible to control electrons more accurately using light. As the scientists discovered, electrons don’t follow the electromagnetic forces of light immediately, but with a delay of 100 attoseconds. They determined this response time by exciting electrons in krypton atoms using attosecond pulses of visible light. By taking this delay into account, it may be possible to develop even more precise optical-electrical components. (www.mpg.de/9978880)



Electronic response time: Attosecond-long flashes of light make it possible to measure the delay with which electrons respond to the stimulating light due to their inertia. The characteristic form of the light wave arises because the attosecond pulse is formed from light of different wavelengths.

Immune Genes from Neanderthals

Early humans boosted the immunity of *Homo sapiens*

People who travel in foreign countries often find themselves fighting infections. This is because the immune system encounters pathogens there that are still unknown to it. The same principle applied to modern humans when they migrated from Africa to Europe around 50,000 years ago. The migrants clearly benefited from the local inhabitants who had lived there long before them: they mixed with the Neanderthals who had already been living in Europe for 200,000 years and adopted from them gene variants that gave them greater resistance to the local pathogens. Genetic analyses carried out by researchers from the Max Planck Institute for Evolutionary Anthropology in Leipzig have shown that people living outside Africa today inherited three immunoproteins from other early humans: two from Neanderthals and one from Denisovans, another early human species. The immunoproteins in question are known as toll-like receptors, which are expressed on the surface of immune cells and can detect components of bacteria, fungi and parasites. The gene variants of early humans reacted particularly sensitively to contact with pathogens. As a result, the migrants’ descendants benefited from better protection against infection. However, the genetic legacy of early humans also makes us more susceptible to allergies today. (www.mpg.de/9819763)

Dark Taiga Lightens Up

Researchers predict that more deciduous trees will grow in boreal forests due to global warming

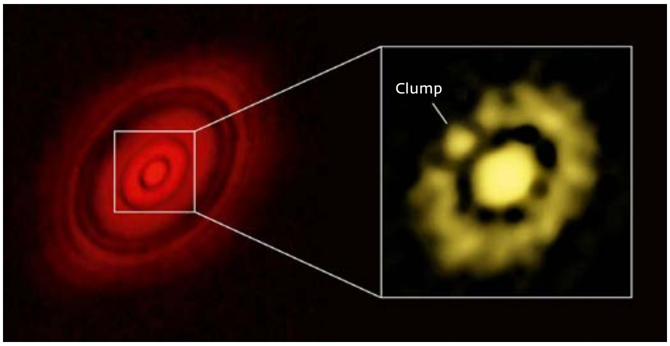
An international team headed by Susanne Tautenhahn from the Max Planck Institute of Biogeochemistry examined how boreal forests are changing as a result of global warming. "Due to climate change, fires caused by lightning, for example, are becoming more common and severe, and natural regeneration processes are being thrown off balance," explains Tautenhahn, who now works at the University of Jena. This sets a chain of events in motion: After a fire, it is difficult for coniferous trees to recolonize, as their relatively large seeds are limited in their capacity to disperse. Deciduous trees, in contrast, have relatively small seeds that are easily dispersed by the wind. This means that they can recolonize burn zones after large-scale fires considerably faster and, over the long term, become the dominant species in these areas. The reduction of the typical conifers, which store high levels of moisture at ground level, in turn further increases the likelihood of forest fires – a self-perpetuating cycle that results in lasting change in the ecosystem. (www.mpg.de/10315240)

The taiga transforms: Forest fires in boreal coniferous forests are set to increase due to global warming. Deciduous trees, which are currently found there only as pioneer species, could dominate in the long term.

Speedy Birth of a Planet

Astronomers observe a clump of dust in the disk around star HL Tauri

Planets form in disks of gas and dust. Images recorded using the VLA radio telescope array in New Mexico show the innermost parts of a planetary birthplace around the young star HL Tauri in unprecedented detail. A gigantic clump of dust with three to eight times the solar mass of the star is clearly visible. In the opinion of researchers from the Max Planck Institute for Astronomy, the existence of this clump of dust provides an answer to a fundamental question: How can planets form in the relatively limited period of time available for their growth? The new images point to a considerably faster birth process, as regions with a particularly high density of dust arise from certain flow patterns of the disk gas. Thus, planetary formation can unfold much faster there than in a homogeneous disk. The dense dust rings in which fragments like the aforementioned clumps can form are external indicators of this process. (www.mpg.de/10400125)



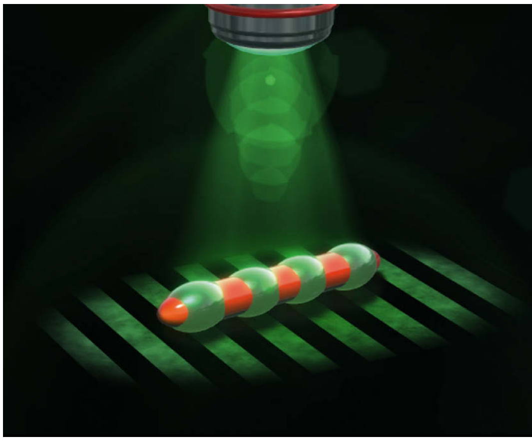
Cosmic delivery room: The protoplanetary dust disk around the young star HL Tauri. Left: earlier observations with the ALMA Observatory, which showed bright areas separated by gaps. Right: the new VLA images, in which additional structures of the inner rings are visible. The object marked as a clump is probably a region in which a planet is currently forming.

Photos: S. Tautenhahn/MPI of Biogeochemistry (top), Carrasco-Gonzalez et al.; Bill Saxton, NRAO/AUI/NSF (bottom)

Ciliates as Models

Swimming microrobots move through water like single-celled organisms

Ciliates can do amazing things: Because they are so tiny, the water in which they live appears to have the consistency of thick honey to them. Despite this, they are able to propel themselves through water thanks to the synchronized movement of thousands of extremely fine filaments, called cilia, on their outer skin. Researchers from the Max Planck Institute for Intelligent Systems in Stuttgart have now developed minute robots that, like the organisms on which they are based, are barely visible to the naked eye and can move through liquids in a similar way. In constructing their swimming microrobots, the scientists working with Peer Fischer used liquid crystal elastomers that expand when exposed to green light: a peristaltic movement results that propels the artificial ciliate when slivers of green light move over it. Although a mini-submarine that can navigate autonomously through the human body and detect and treat diseases may still be the stuff of science fiction, the use of a more developed version of these robots as tiny medical assistants at the end of an endoscope is entirely conceivable. (www.mpg.de/10327369)



Light-driven microswimmers: The material used in the nearly one-millimeter-long swimming body was specifically chosen for its ability to expand when exposed to light. This causes wave-shaped protrusions to form along the microswimmer and drive it in the opposite direction when green slivers of light move over its surface.

Hardship Linked to More Risk-Taking in Old Age

In most Western countries, people's propensity to take physical, social, legal or financial risks decreases with age. In countries like Nigeria, Mali and Pakistan, in contrast, risk behavior remains constant into old age. This is the finding of research carried out by scientists from the University of Basel and the Max Planck Institute for Human Development in Berlin. A comparison of data from 77 countries revealed a clear correlation between risk behavior and such factors as low per-capita income, greater income inequality and a high murder rate. The researchers suspect that this is because people in countries where resources are scarce have to compete more fiercely with each other than people in wealthy countries and countries with good social welfare provisions. (www.mpg.de/9818736)

Fighting for the Host

With the exception of the intrepid Jerry in the "Tom and Jerry" cartoons, no mouse would ever dream of voluntarily remaining in the immediate vicinity of a cat. Some mice, however, do just that, and even appear to be drawn to cats. Behind this strange behavior lies a parasitic protozoan called *Toxoplasma gondii*, which alters the mouse's behavior to its own ends: foolhardy mice are more likely to fall victim to predators, and this boosts the spread of the parasite. Other parasites also manipulate the behavior of their host. But what happens when parasites at different stages of development, or even different species of parasites with competing objectives, infect a single host? Scientists from the Max Planck Institute for Evolutionary Biology in Plön have discovered that parasites sabotage each other and disable the other's manipulation programs – even if they originate from different species. According to the researchers, in the case of conflicts of interest, the parasite that is in the infectious state and needs to change hosts has the upper hand. The researchers discovered this by studying parasitic tapeworms and threadworms, which first infect copepods and then fish. This behavior could also have medical consequences, for instance if parasites circumvent the manipulation programs of pathogens, thus hindering their spread. (www.mpg.de/9958046)

Conflicting goals: Several parasites often infect one and the same host, as shown here in a copepod, which is infected with the tapeworm *Schistocephalus solidus* (green) and the threadworm *Camallanus lacustris* (blue). If the parasites are at different stages in their development, they try to influence the behavior of the crustacean in opposing ways.

Graphic: Alejandro Posada (top); photo: N. Hafer/MPI for Evolutionary Biology

A Trio with an **Extensive Repertoire**

It is frequently only the development of new materials that makes technological advances possible, whether in the areas of energy supply or information technology. With the Heusler compounds, **Claudia Felser**, Director at the **Max Planck Institute for Chemical Physics of Solids** in Dresden, uncovered a rich source of materials that offer promising properties for a variety of applications.

TEXT **PETER HERGERSBERG**

Whether Germany can successfully achieve a turnaround in the energy sector depends on more than just its utility companies, consumers and politicians. To a certain extent, the Chinese government, too, must display its good will – at least as regards the current state of technology. After all, China exports around 90 percent of the rare earth metals. These metals, which bear archaic-sounding names like promethium, samarium, neodymium and dysprosium, are used in numerous high-tech applications. Some of them are responsible, for instance, for the particular attraction of the strongest known permanent magnets. The generators in modern wind turbines, especially those in offshore installations, use these powerful magnets to produce the electricity Germany is using to counter climate change.

The manufacturers of these wind generators were therefore understandably agitated when the Chinese government placed limits on rare earth exports in 2010. Even though the quota has since been lifted again, the industry has undertaken a global search for new sources. Better still, it would like to find alternatives so that it will no longer be at the mercy of exporters' whims. Moreover, while the metals are not as rare as their name would suggest, the process by which they are obtained is complex and harmful to the environment – the official reason cited for China's export limits.

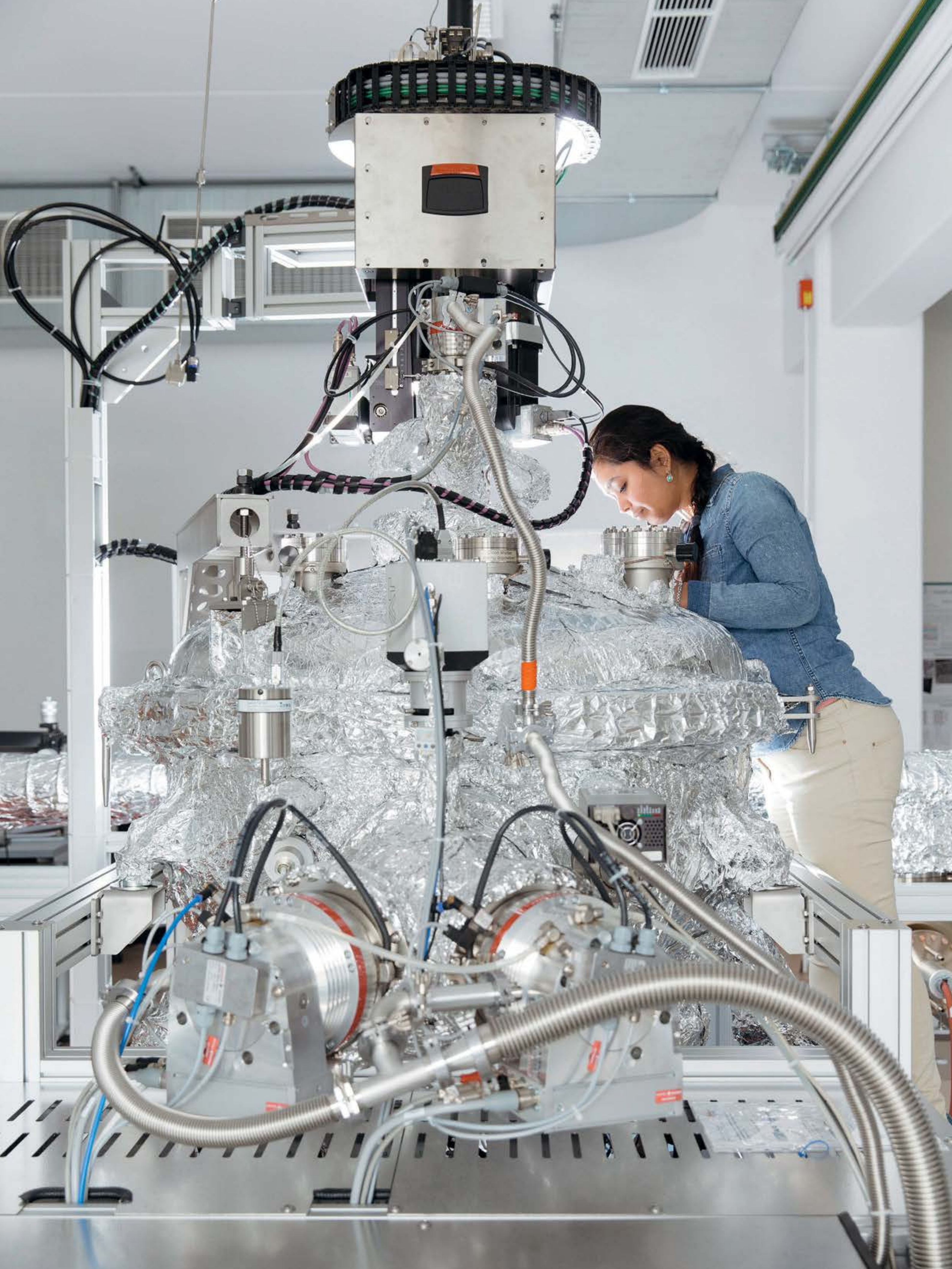
COMBINING RESOURCES LIKE BUILDING BLOCKS

Claudia Felser may be able to offer a solution, at least as far as permanent magnets from these controversial metals are concerned. One thing the Director at the Max Planck Institute for Chemical Physics of Solids in Dresden aims to achieve with her research into Heusler compounds is to find permanent magnets that don't include rare earths. These compounds usually comprise three metals and crystallize in a characteristic structure. They are named after Fritz Heusler, a German mining engineer and chemist. Back in 1903, he determined that a compound comprising copper, manganese and aluminum behaves like a magnet, or more precisely, a ferromagnet, despite its components not exhibiting at least this form of magnetism.

Thereafter, for many years, hardly anyone paid any attention to the compounds. It wasn't until the 1980s that someone took interest again, as it was then gradually becoming clear that they offer much more than just magne-

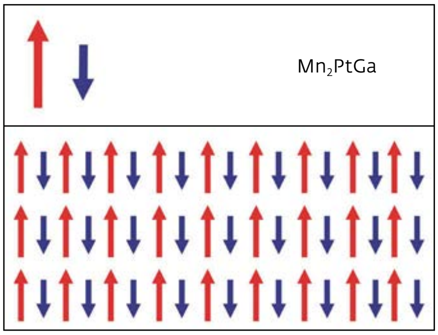
Versatile apparatus: Roshnee Sahoo examines the sputtering system that she and her colleagues use to produce thin films of various materials.

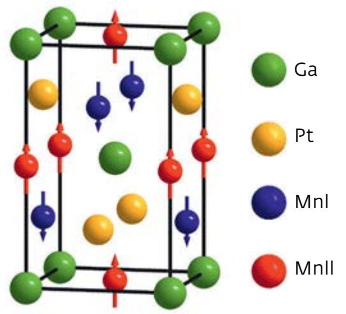
Photo: Sven Döring



Above Claudia Felser and Gerhard Fecher continually develop ideas for new Heusler compounds.

Below In the crystal of a compound comprising manganese (Mn), platinum (Pt) and gallium (Ga), manganese atoms occupy a variety of positions (right). The magnetic moments at the different manganese positions have opposing orientations and essentially hold each other in place, making it very difficult to reverse the polarity of this substance. Since there is more of one kind of manganese (red) than of the other (blue), the substance ends up having a low magnetic moment (left).





tism. Around 1,500 of these compounds are known, in which 52 – and thus the majority – of the existing metals are combined in various ways.

"The good thing about Heusler compounds is that we can combine all kinds of elements like building blocks," says Claudia Felser. And because the properties of the individual chemical components can largely be derived from their positions in the periodic table of the elements, this chart – the basic law of her work – adorns the wall behind the desk of the Max Planck Director, where it is easily visible for referencing.

Mixing these chemical building blocks together yields materials with a variety of properties that are of interest to both science and technology. As a result, Felser speaks almost as frequently of patents she has applied for – or ought to apply for – as she does of publications in scientific journals.

The metallic trio with the ever-changing composition owes its scientific and technical appeal to its extensive repertoire: some Heusler compounds are metallic conductors and others are semiconductors. Now, it's not as if the industry suffers from a shortage of good conductors or semiconductors. After all, copper, silicon and the like have been doing a fine job for decades. "But the electronics industry is looking for materials with more options for different settings," explains Claudia Felser. And that is precisely what the three-element combinations offer. They also include, for instance, half-metals, which are not to be confused with semiconductors and could be very popular particularly for the electronics of the future – but more on that later.

Furthermore, the different kinds of conductivity in Heusler compounds are coupled with other interesting properties, of which various forms of magnetism are just a few. But some Heusler compounds also have magneto-optical capabilities, meaning they offer the possibility to influence the magnetic properties with light. Others exhibit

Photo: Sven Döring; graphics: nature materials/2015/Macmillan Publishers thermoelectric behavior, where a temperature difference creates an electric potential in the material. A couple of the substances are also materials that remember their shape: if you deform them and then subsequently heat them, they return to their original shape. Some Heusler compounds also offer rather exotic properties – more on this point later, too.

Claudia Felser discovered the chemical toolbox of Heusler compounds in the 1990s when she was looking for a superconductor – which she also found among the Heusler compounds. Superconductors transport electricity with no electrical resistance at all, but to date, unfortunately, only at temperatures well below freezing. As Claudia Felser soon found out, this also applies to the superconducting Heusler compounds she first discovered.

While this didn't offer any prospects for loss-free electricity transport and thus contributed nothing to energy conservation, it opened up a research field for the chemist in which she is still reaping success. "Sometimes I also ask myself whether I can devote my entire research life to the Heuslers," she says. "But there is simply so incredibly much to discover here." Her expertise in this field has even garnered her a nickname among materials scientists: Mrs. Heusler.

BASIC RULES FOR MAGNETIC MATERIALS

Her group has continually added new specialties to the array of capabilities that Heusler materials can take on. Claudia Felser always has her eye on potential technical applications, but she is less concerned with a specific material that she and her colleagues want to position for one application or another. "We are interested in discovering new principles and gaining a deeper understanding," says the researcher. She is most satisfied when, in the end, there is a simple rule that makes it possible to state whether a material will have a certain property or not.

For some properties of Heusler compounds, the simple basic rules work very well – for magnetic materials, for example. "We have been particularly interested in magnetic Heuslers for a few years now," says Claudia Felser. In this context, magnetic can mean many things: ferromagnetic or ferrimagnetic; soft magnetic or hard magnetic; having a low magnetic moment or a high magnetic moment.

What all magnetic materials have in common is that their atoms have unpaired electrons that act like tiny bar magnets. In ferromagnets, which include bar and horseshoe magnets as well as, for instance, magnets for pinboards, the tiny bar magnets of the individual atoms all align the same way with their north and south poles. In this way, a magnetic field develops in them that is outwardly perceptible. This makes it possible to use a bar magnet to magnetize one iron nail after another until, in the end, an entire chain of nails dangles from the permanent magnet.

Whether a Heusler compound is ferromagnetic can be determined based on the number of a certain kind of electrons: valence electrons. These sit closer to the outside edges in the atoms and determine the atoms' chemical and physical behavior. "I'm a chemist," says Felser, "I like counting electrons." Ferromagnetic Heusler compounds have to have more than 24 valence electrons. And the further over this limit the number of valence electrons lies, the greater their magnetic moment is, and the more strongly the material can be magnetized.

In practice, ferromagnetic Heusler compounds contain manganese or cobalt, but they also form with rare earths. The latter, however, are of little use if we want to overcome our dependence on these metals. The ferromagnet with the strongest magnetic moment that Claudia Felser's team has thus far found among the Heusler materials is known as cobalt iron silicon, which is comprised of two parts cobalt, one part iron and one part silicon.

A SOFT MAGNET IS PRACTICAL FOR TRANSFORMERS

However, the magnetization disappears when even a relatively low magnetic field with the opposite polarity of the original field is applied, and then forms in the opposite direction. Such a material is referred to as soft magnetic. It is practical for the core of an AC transformer, where the polarity is reversed in rapid succession. The material is not, however, suitable for a good permanent magnet, which must not only be able to be strongly magnetized, but must also be hard magnetic. Hard magnetic is the term used for materials that can't easily be demagnetized or have their polarity reversed. As a physicist would say, they have a high coercivity.

The best known permanent magnets combine high magnetization and high coercivity: alloys of cobalt and the rare earth metal samarium, as well as of iron and neodymium. But these properties actually appear to be mutually exclusive in materials that don't include rare earths. "The strength of the magnetization and the coercivity determine the overall magnetization energy," explains Gerhard Fecher, who leads a working group in Felser's department. "Although it hasn't yet been possible to prove this, it appears that a material is able to absorb only a limited amount of magnetic energy." Limit or no, the researchers would be happy just to discover a Heusler compound that absorbs as much magnetic energy as the best permanent magnets containing rare earths.

First calculate, then bake: Binghai Yan (left) first uses models to simulate the properties of materials and gives the experimenters suggestions as to which elements they should combine in, for instance, the arc furnace (right).

The maximum magnetization possible can be influenced by the choice of individual elements – manganese and cobalt, in particular, stand out, alongside a couple of rare earths. Coercivity, however, depends on the interaction between all the elements, as it determines, among other things, what crystal structure a compound forms. To obtain a hard magnet, its smallest components – which we can certainly also think of as building blocks – must not be cubic. Unfortunately, they often are. Instead, for a hard magnet, these unit cells, as they are known, must have the shape of an elongated cuboid. "This results in a preferred direction for the magnetization, which leads to high coercivity," explains Gerhard Fecher.

One material the Dresden-based researchers recently presented has precisely the right structure for a hard magnet. It consists of manganese, platinum and gallium, and it is very difficult to demagnetize. This owes, however, not only to its crystal structure, but also to another characteristic – one that additionally gives it a very low magnetic moment. This substance is a ferrimagnet. In these kinds of materials, the basic magnetic moments originate either from different elements or, as in the case of the manganese-platinum-gallium compound, they come from the same atoms, namely those of the manganese, which take up different positions in the crystal structure.

The elementary magnets of the variously positioned atoms don't align their poles in the same direction, or parallel, but rather in opposition to one another, or antiparallel.

HEUSLER COMPOUNDS FOR SPINTRONICS

Since the manganese-platinum-gallium contains more manganese atoms with the one magnetic polarity than with the other polarity, a low magnetic moment results. However, by varying the mixing ratio of the three elements, the researchers can further reduce the magnetic moment and even make it completely disappear. In this case, the scientists refer to a fully compensated ferrimagnet.

Whether fully compensated or not, in both cases, the antiparallel-oriented elementary magnets provide each other support. "This makes it very difficult to change the polarity of ferrimagnets," says Gerhard Fecher. "They're good hard magnets."

Although its low magnetic moment makes a material like manganese-platinum-gallium unsuitable as a candidate for a good permanent magnet, it is virtually predestined for magnetic storage, such as hard drives. While these are gradually giving way to other storage media in laptops, for instance, they still take up enormous amounts of data in the globally distributed cloud computing environment.

"Strong magnetization is problematic in magnetic memory only because it produces a large stray magnetic field that makes it difficult to read out neighboring storage points," explains Claudia Felser. "So with low magnetization, it's possible to pack the individual storage points much closer together." But it will presumably take some time before ferrimagnets like manganese-platinum-gallium find their way into storage media, and along the way, we should surely also find a less expensive alternative for platinum.

But magnetic Heusler compounds are interesting not only for storing information, but also for processing. This is what spintronics does – a forward-looking branch of electronics that has already produced the modern read heads for hard drives.

Spintronics components exploit not only the charge of an electron, but also its spin. This is a quantum mechanical property that we can imagine as an electron's direction of rotation. It turns the electrons into the tiny bar magnets that, working together in a permanent magnet, generate the magnetic field that exerts an irresistible attraction on iron and similar metals. In electronics, the spin provides an additional way to store information: depending on which direction the microscopic bar magnet points in, it stores a zero or a one.

The first promising Heusler compound Claudia Felser brought into play for spintronics consists of four elements: cobalt, chrome, iron and aluminum, or CCFA. The material that Felser discovered back when she was still a researcher at Johannes Gutenberg University Mainz is likewise magnetic and stands out primarily due to its colossal magnetoresistance.

Back in the late 1980s, Peter Grünberg and Albert Fert discovered giant magnetoresistance. It forms in sandwiches comprising two thin magnetic layers and a non-magnetic intermediate layer when the magnetic layers are oppositely polarized. Since each individual magnetic layer allows nearly only those electrons to pass that have the spin direction that matches their polarization, most of them get stuck on their way through an oppositely poled double layer.

Grünberg and Fert were awarded the Nobel Prize in Physics in 2007 for their discovery of giant magnetoresistance. At room temperature, CCFA has a magnetoresistance that is even many times higher than the material in which Grünberg and Fert first detected the effect. This makes it eminently suitable for reading data in magnetic storage points. IBM bought the corresponding patent in 2001.

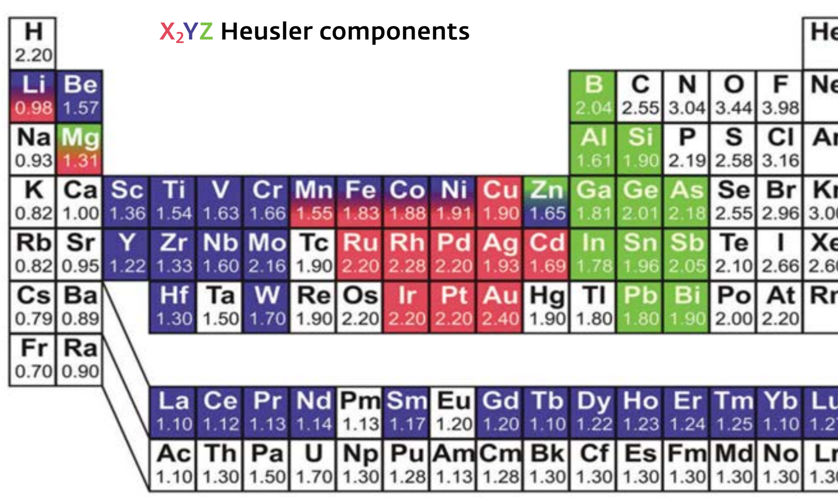
In the future, the researchers in Dresden want to increasingly focus their research on materials in the form in which the electronics industry uses them: in thin films. To this end, in a side wing of their institute building, they have already set up the majority of a new device that would hardly fit in most living rooms. It looks a bit like the International Space Station (ISS) without the solar module, but instead with a visit from a flying saucer. And like the ISS, it, too, will continuously have new components added to it.

A DEVICE FOR MANY EXPERIMENTAL STEPS

The unit stands on a floor in which, here again, the periodic table of the elements is depicted in colorful tiles – the universe in which Claudia Felser's and her colleagues' research takes place. The facility is the showpiece in the equipment fleet of Felser's department. It provides a closed system in which the researchers can carry out many experimental steps that would otherwise take place in separate apparatuses.

In the device's vacuum chambers, they use various methods to produce their specimens from countless combinations of elements in nearly any desired thickness. They can even stack the metals in individual atomic layers to produce Heusler compounds that don't form in conventional synthetic processes. And by maneuvering the specimens to different stations through a long vacuum tube, they can also immediately inspect the new materials with a variety of atomic force microscopes and a scanning tunneling microscope, or use photoelectron spectroscopy to determine the exact composition and the electronic structure of the material.

The electronic structure, which is a product of the composition and the structure of a material, is as important to solid state researchers as the genetic code is to biologists. Just as the genome defines a good portion of our characteristics, how electrons behave determines the features of a material. Knowing and, if at all possible, even being able to predict where and how electrons move through a material provides information on what type of magnetism

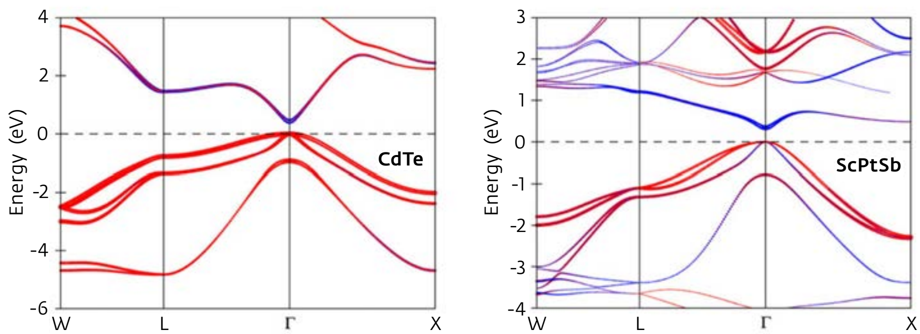


Huge variety: The metals marked in color in the periodic table of the elements can be combined to form countless X_2YZ compounds. The colors stand for the different positions of the elements in the crystal structure that is typical for Heusler materials. The numbers indicate the electronegativities.

Graphic: T. Graf et al./Progress in Solid State Chemistry 39 (2011) 1-50

Above In the spherical sputtering chamber, Gerhard Fecher, Thomas Krüger and Roshnee Sahoo (left to right) first produce different materials that they can subsequently subject to various analysis methods by shuttling the specimens through the system's tubes.

Below A material's electronic properties can be derived from its band structure. The band structures of cadmium telluride (CdTe) and the Heusler compound scandium platinum antimonide (ScPtSb) are similar around the zero energy level because both substances are topological insulators – that is, they conduct electricity only on their surface.



a material exhibits and what else it might be able to do. The paths of the electrons are, of course, particularly important in electronics.

After the researchers in Dresden create a material, they examine its electronic structure as closely as possible. Before that, however, they use sophisticated computer programs to calculate what behavior they can expect from the electrons and thus from the Heusler compound itself – especially when simple electron counting gets them nowhere. In this way, they can at least narrow down a substance with the desired property and spare themselves the effort of synthesizing countless material combinations for testing. But since their calculations are always based on mere approximations – however good these may have since become – and are not always exactly right, there's also no getting around follow-up experiments.

Following a "triple jump" strategy of calculating, synthesizing and measuring, Felser's team is searching, for instance, for new half-metallic Heusler compounds that can likewise be used in spintronics. Half-metallic magnetic materials only conduct charge carriers of one spin direction. This is what gives CCFA, for instance, its colossal magnetoresistance. Another of the few half-metallic Heusler compounds is cobalt iron silicon, which also took center stage as a ferromagnet due to its high magnetic moment.

But the researchers working with Claudia Felser are also searching for other Heusler compounds that aren't magnetic and whose conductivity is nevertheless dependent on the spin direction. This is where the field of expertise of the team in Dresden meets a research field that physicists opened up just about ten years ago: topological insulators, which have since become quite popular in physics.

Photo: Sven Döring; graphics: T. Graf et al./Progress in Solid State Chemistry 39 (2011) 1–50

Inside the crystals of such a material, electrons are just as restricted in their movement as they are in insulating plastics. On their surfaces, however, the electrons can whiz about as freely as they do through metals, and the electrons of the two spin orientations always move in different directions. This makes them interesting for spintronics computing operations. "In spintronic components, topological insulators would require far less energy than other materials," says Binghai Yan, who is Claudia Felser's topological insulators specialist and leads a research group on precisely this subject at the Max Planck Institute in Dresden.

TOPOLOGICAL INSULATORS AMONG HEUSLER COMPOUNDS

The physicist came to the Institute in Dresden after his current boss met his former boss, Shoucheng Zhang from Stanford University, in 2009 – at a spintronics conference. Felser gave a presentation on the prospects Heusler compounds offered for this technology, and Zhang spoke about topological insulators. Afterwards, the two quickly agreed that there must also be topological insulators among the Heusler compounds, and that they could have practical advantages over other materials of their kind. "Only one group of researchers was able to synthesize the original topological insulators – no one else had succeeded," says Binghai Yan. "Heusler compounds, in contrast, are much easier to create."

Binghai Yan's specialty is not limited to synthesizing topological Heusler compounds, though; it also includes the theoretical prediction of which material is most suitable for the task. "To find such materials, we need a treasure map of sorts," he says. "Theory provides good maps." So far, the Dresden-based team has found nearly 100 Heusler compounds that belong to the topological insulators. However, they always contain rare earth metals and, in addition, usually platinum or gold. This doesn't have to stand in the way of practical application if a material simply does its job well enough, as today's high-tech clearly shows: for all of their disadvantages, rare earths and precious metals are frequently indispensable here.

Whether with or without rare earths, in view of the nearly unlimited possibilities the Heusler materials offer and the versatility they have already demonstrated, Claudia Felser's long-term goal doesn't seem too far-fetched: "I would like to bring at least one more material that we develop here to the application stage." ◂

TO THE POINT

- **Heusler compounds involve 52 metals combined in various ways, making it possible to produce materials with a wide variety of properties: semiconductors, metallic conductors, half-metals that can additionally exhibit various forms of magnetism, and also such exotic characteristics as superconductivity, thermoelectricity, colossal magnetoresistance and topological properties.**
- **Heusler materials thus expand the available potential for the electronics industry, for instance, and could even eliminate some industries' dependence on such materials as the rare earth metals, which have finite availability or aren't ecologically sound.**
- **Researchers at the Max Planck Institute for Chemical Physics of Solids have already developed, for instance, a soft-magnetic ferromagnet that, with its high magnetic moment, meets one of the requirements of a good permanent magnet, and a hard-magnetic ferrimagnet with a low magnetic moment for potential applications in memory technology. The researchers have also found half-metals with colossal magnetoresistance and topological insulators for spintronics.**

GLOSSARY

Ferrimagnet: Here, atomic elementary magnets, which we can picture as tiny bar magnets, align themselves oppositely, or antiparallel, to one another rather than parallel, as in ferromagnets (such as iron). However, since in ferrimagnets, the elementary magnets of one of the two opposing orientations outweigh the others, they also exert a weak external magnetic field.

Heusler compounds: Materials that generally comprise three metals. Since there are a total of 52 metals that can combine in various arrangements to form Heusler compounds, there are a great many possible variations. Around 1,500 Heusler compounds are currently known.

Coercivity: The strength of the magnetic field required to completely demagnetize a magnetized substance.

Spintronics: A form of electronics that exploits not only the charge of the electrons, but also their spin, which turns electrons into tiny bar magnets. This makes it possible, for instance, to pack data more densely in today's hard drives.

Topological insulator: A material whose crystals act as electrical insulators in their interior, but conduct electricity on their surface. Since the direction of the electricity is determined by the spin of the electrons, these substances are of interest for spintronics.

A Dark World **of Ice**

A space probe has journeyed to Ceres for the first time. Scientists from the **Max Planck Institute for Solar System Research** in Göttingen are using its two onboard cameras to explore the dark surface of the dwarf planet. They have already discovered signs of frozen water – but is there also an ocean slumbering deep below the craters?

TEXT **THORSTEN DAMBECK**

Some things are relative – a tenet that applies to asteroids as well. Take Ceres, for example, which the International Astronomical Union has listed in the dwarf planet category since 2006. This "dwarf," which is named for the Roman goddess of agriculture and fertility, is simultaneously the largest of the innumerable small bodies that orbit the Sun between Mars and Jupiter.

Geometrically speaking, Ceres is an ellipsoid. At first sight, however, it resembles a sphere with an average diameter of 946 kilometers. Its planetary body is not perfect, of course; stamped on the ellipsoid is a landscape that descends as deep as 7.5 kilometers and towers up to a height of 4 kilometers in other places. This 3.2 percent variation spans a much greater range than that of our own moon (1 percent). Compared with its sister Vesta in the asteroid belt, for which this figure is around 15 percent, the variations in Ceres' topography are merely moderate – relatively speaking.

NASA's *Dawn* space probe traveled to both of these miniature planets after setting off on its journey in 2007. *Dawn's* first port of call was Vesta in summer 2011. The terrestrial scout spent around 14 months exploring this world from its orbit. The probe then ignited its electric ion thruster once again and set off toward Ceres, arriving in March 2015. It has been circling Ceres closely from different orbits ever since.

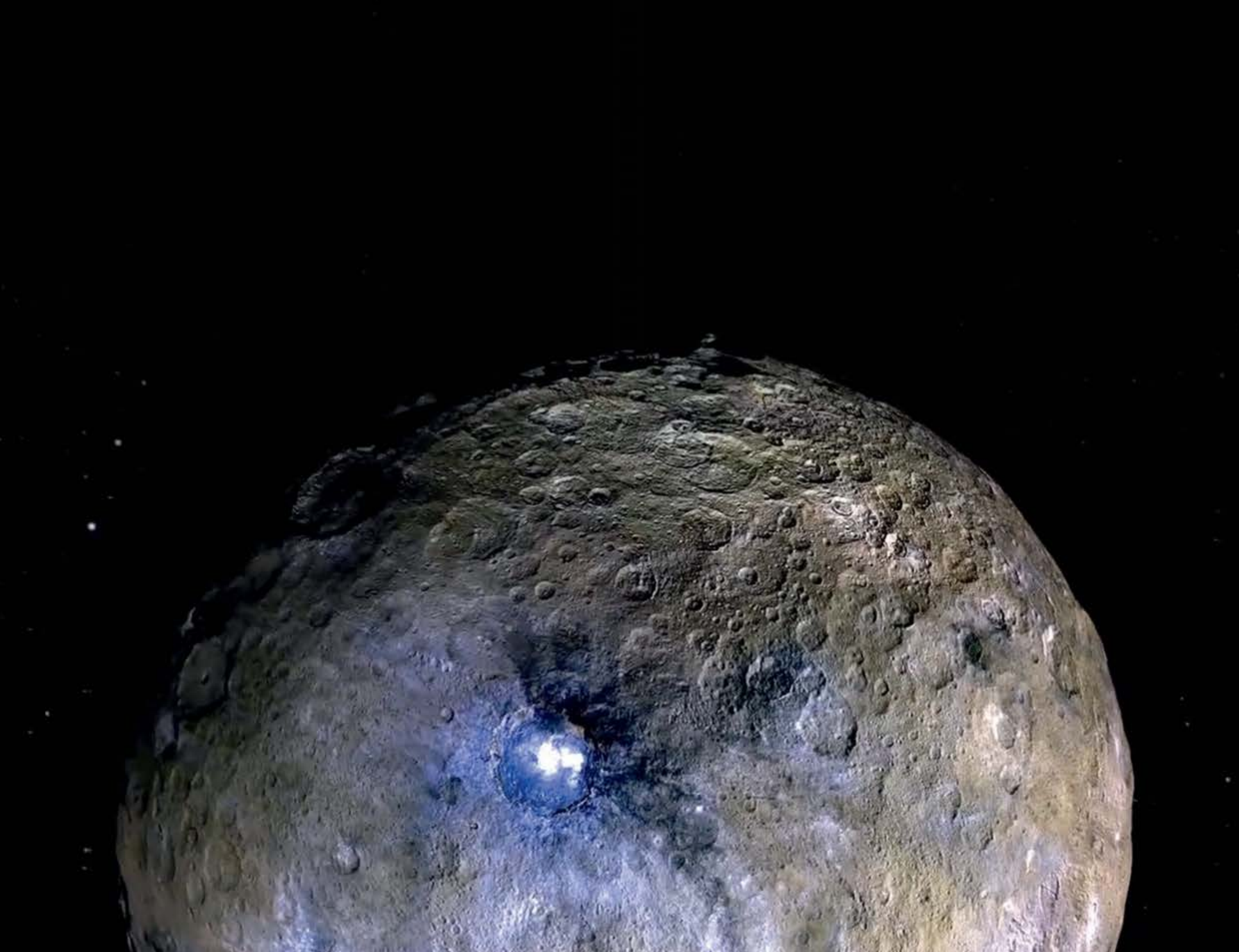
COMPLEX GEOLOGY FASCINATES THE RESEARCHERS

The scientific camera system is one of *Dawn's* high-profile onboard experiments. It comes from the Max Planck Institute for Solar System Research in Göttingen. The two so-called framing cameras are *Dawn's* eyes, so to speak, and they play a key role in the exploration of the two celestial bodies (see box on page 56). Now, their gaze is directed at Ceres. Most of its surface is as dark as fresh asphalt; on average, only 9 percent of incident light is reflected. The researchers are fascinated all the same: the dwarf planet is a world with a complex geology. Although much of what the flood of images is now revealing hasn't yet been evaluated, even the preliminary analyses have unearthed unexpected details.

Dawn is the first visitor to Ceres; last year was the first time a space probe managed to get this far. Although Ceres was discovered more than two centuries ago by Italian astronomer Giuseppe Piazzi, very little exploration had been done there. The story of its discovery is a cosmic cliffhanger: As early as the end of the 18th century, there was widespread skepticism among scientists as to whether the conspicuous gap between Mars and Jupiter really was empty. Could an undiscovered planet be lurking there?

A group of German astronomers – the "celestial police" – systematically hunted down the suspected celestial body in the zodiacal sky. And lo and behold: on New Year's Eve 1801, a previously unknown object was detected – Ceres. This discovery was not, however, attributable to any of the celestial police officers, but was made at the observatory in Palermo. The new "wandering star" was almost the exact same distance from the Sun that had been predicted by the Titius-Bode law for the planet they were searching for. This empirical law, named for the two scholars Johann Titius and Johann Bode, had already correctly reproduced the distance between the Sun and Uranus, which had been discovered two decades earlier. Ceres was now considered to be a planet, just like Uranus. >

Photo: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA



Dwarf in space: This false color image shows different material on Ceres' surface. The bright regions in the Occator crater appear clearly, near the center of the image.

But the discovery of Ceres was only the beginning; there was apparently a whole gang of undiscovered planets beyond Mars: Pallas and Juno were found soon afterwards, and Vesta followed in 1807. In 1850, they were already so numerous that the designation dwarf planet gained acceptance. By the turn of the 20th century, 462 members of Ceres' species had been tracked down, and its status as a planet was now long gone. Today, almost half a million known specimens inhabit the main asteroid belt between Mars and Jupiter. Most of them are relatively small; Ceres alone accounts for around one-third of the total mass of the belt.

EAGLE-EYED CAMERA STUDIES IMPACT CRATERS

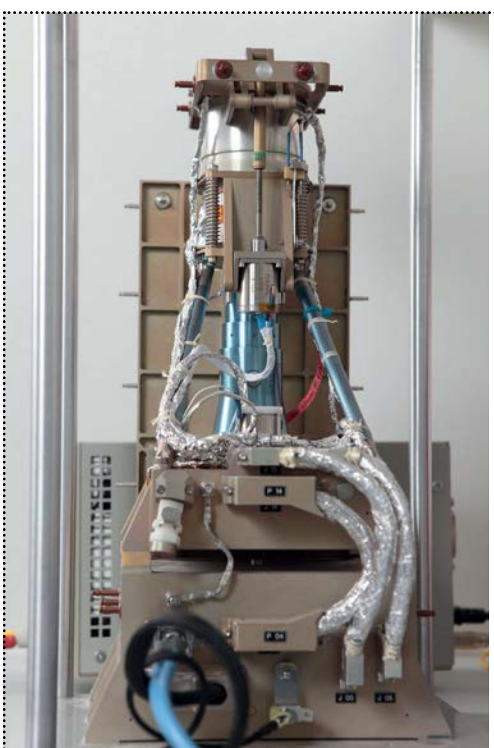
Back to the present: Researchers in the international *Dawn* team have meanwhile presented the first geological maps of Ceres. These, however, are based on observations with the framing cameras that were undertaken from a relatively large distance (4,424 kilometers). Since January, *Dawn* has been directing its eagle eye toward the crater-covered surface. On its new orbit, the probe approaches Ceres to within 385 kilometers.

"Now, with significantly better resolution, we can investigate many of the surface details that we have known about since *Dawn* reached Ceres," says Max Planck researcher Andreas Nathues, who manages the camera experiment from Göttingen. The planet researchers particularly study the different manifestations of the impact craters on Ceres.

A recent image shows Kupalo, an impact crater measuring around 25 kilometers across; it is named for a Slavic fertility goddess and is located in the southern hemisphere. Conspicuous bright stripes spread out radially on the inside of the crater rim. They were presumably formed as a result of landslides on the slopes. Kupalo doesn't have a central peak, as is usually the case with impact craters of this size.

Instead, its center is home to a mountain chain that extends for more than seven kilometers. Several similar mountain chains are repeated near the crater rim, whose shape also deviates conspicuously from a circle. Kupalo's crater bottom is otherwise almost flat and has no subsequently formed smaller craters – an indication of a relatively young age. Several bright spots can be seen in its interior, but more about those later.

The Messor crater (diameter: 42 kilometers) also attracts attention due to its unusual shape. Like Kupalo, its rim also has an irregular shape, and it doesn't have a central peak either. Moreover, the crater bottom has a marked wave-like pattern. Messor is superimposed onto an older crater whose relics are still evident. Messor is



THE EYES OF THE SCOUT

The eyes of NASA's *Dawn* probe are made in Germany: the two framing cameras. Apart from mapping the surface, they are used for probe navigation. Each camera weighs 5.5 kilograms. They can take white-light and color photos and have seven filters in the spectral range from visible light to near infrared for this purpose. The camera system is a collaborative project: it was developed and built by the Max Planck Institute for Solar System Research in Göttingen in collaboration with the DLR Institute of Planetary Research in Berlin, and the Institute of Computer and Network Engineering at the Technical University of Braunschweig.

In addition to the high-resolution photographs, it can record views of the surface with 3-D effect, which can also be made into a montage to create virtual fly-bys. Three further onboard experiments round out the scientific payload: the infrared spectrometer from Italy, with which the researchers analyze the mineral composition and the temperature distribution on Ceres' surface; the gamma and neutron spectrometer from the US, which is responsible for determining the chemical elements in the surface rock; and a radio wave experiment that is used mainly to measure the gravitational field of the celestial body and for position determination.

Photo: Ronald Schmidt

obviously an older crater, because its interior contains almost as many smaller impact craters as are found outside the crater.

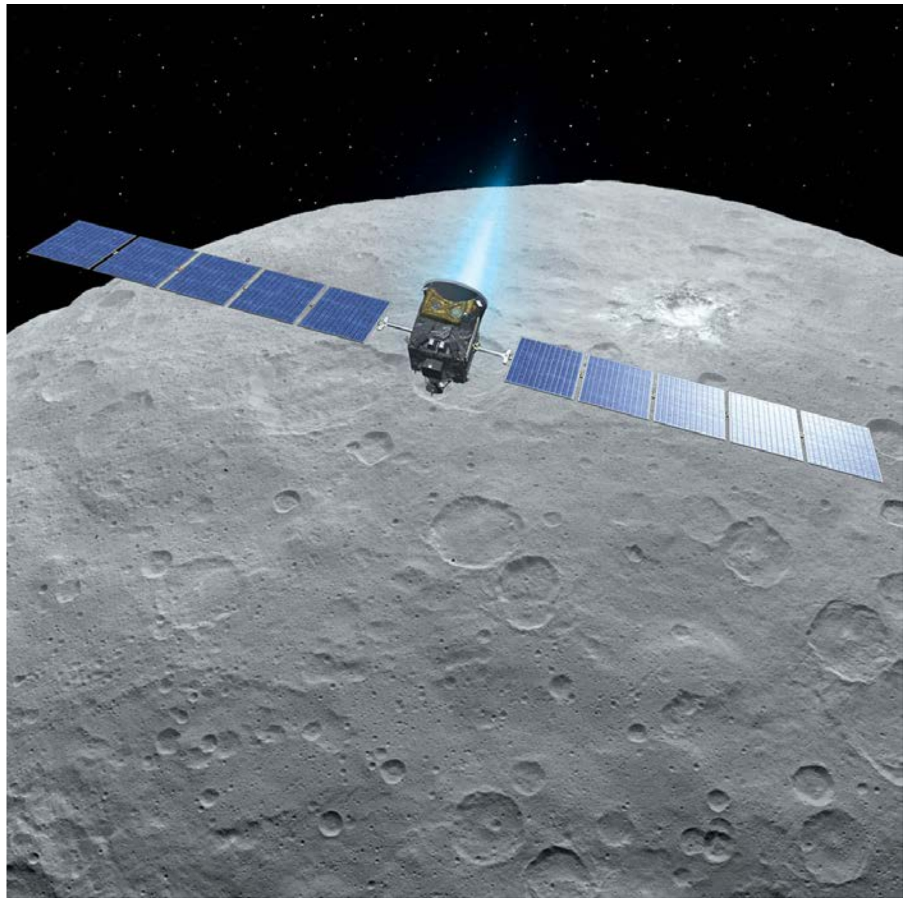
A further crater, around 30 kilometers in diameter and as yet unnamed, has a prominent central peak and distinct terraces that cover the entire crater bottom. These structures also indicate that an asteroid struck material that had a high degree of mobility immediately after the impact. An indication of frozen water in the ground?

OUTER LAYERS ARE NOT MADE OF HARD ROCK

A different crater, the 125-kilometer Dantu, appears on the images to be conspicuously flat with a network of cracks such as those we know in a similar form from lunar craters, for example the young crater Tycho. "The outer layers of Ceres aren't made of hard rock, and this was likely crucial for the formation of these cracks. When the asteroid struck, frozen water below the surface probably melted, at least partially. If it subsequently cools down, it can contract considerably and form many cracks," says Max Planck scientist Martin Hoffmann.

Unlike the situation on our own moon, frozen water has played an important role in the formation of these structures. The fact that Ceres also contains ice had already been expected before the *Dawn* mission. "Ceres' low average density of 2.16 grams per cubic centimeter can't be explained any other way than by a high proportion of frozen water," explains Andreas Nathues. The comparison with Saturn's moon Rhea, which also contains large amounts of ice, is an indication of frozen water in Ceres' surface material.

"The irregular shapes of Ceres' craters resemble those on Rhea," explains Carol Raymond from the *Dawn* team. The craters on Ceres are unlike those on Vesta, the subject of the probe's earlier study. "The craters on Ceres are very dissimilar to those on Vesta, which are bowl shaped," says the researcher from the Jet Propulsion Laboratory in California.



Short-range reconnaissance: The *Dawn* space probe was launched in 2007, flew past the asteroid Vesta in summer 2011 and swung into an orbit around Ceres on March 6, 2015. Since January, the space probe has come to within 385 kilometers of the dwarf planet.

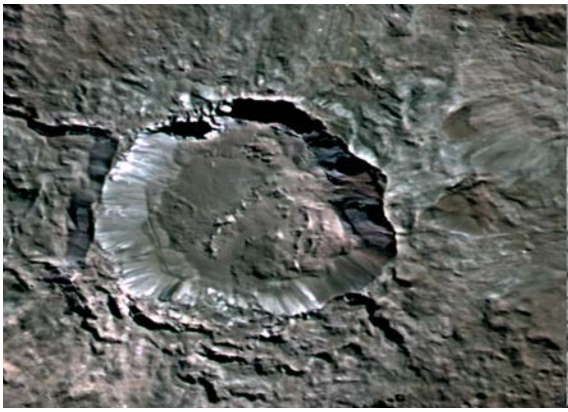
Photo: NASA/JPL-Caltech

Ceres has almost the same surface gravity as Saturn's moon Rhea – the difference between the two celestial bodies is a mere 4 percent. The indications that tell of ice on Ceres, such as the morphology of the impact craters, are only indirect at present. Direct measurements, for example with the onboard infrared spectrometer, aren't yet available. Hoffmann and Nathues are nevertheless convinced that frozen water played a crucial role in the geology: melted by the heat of the impact, it formed many structures as it subsequently froze, structures that are much less pronounced or even lacking completely when objects impact solid rock. "Even though we don't yet understand these processes in detail, they could explain the fracture lines, the terraces, the lack of simple central peaks and the irregular crater rims," says Andreas Nathues.

But back to the unusually bright deposits that were found on Dantu, for example. The Max Planck researchers had already discovered similar ones on other parts of the surface; even on the approach to Ceres, the cameras were dazzled by bright spots on the surface. They initially appeared on the photos as overexposed spots – a completely surprising observation, according to Martin Hoffmann. Last December, a team headed by Nathues and Hoffmann reported in the science journal NATURE that the conspicuous spots weren't rare at all, and that 130 of them had already been identified on Ceres.

SALT DISSOLVED IN WATER IS LEFT BEHIND

With measurements in laboratories in Canada and the US, the researchers attempted to imitate the color signal of these spots recorded with the framing cameras. The result: the bright surface material is likely salt. It presumably



Cornucopia for planetologists: The study of craters provides deep insight into the geology of Ceres. Each of these remnants of asteroid impacts tells its own story, whether it is Dantu, Kupalo, Messor, Occator or Oxo (from left). The bright deposits all over the surface have particularly astonished the researchers. This is apparently material that consists of hydrous magnesium sulfate or other salts. In the Occator crater – shown here in a color-coded topographic view – haze can also form at the crater bottom when the Sun has risen.

consists of hydrous magnesium sulfate or other bright salts as also occur in terrestrial salt lakes, in Torrevieja and La Mata on the Spanish Costa Blanca, for instance. Nathues therefore presumes not only that Ceres' surface conceals ice, but that this ice is partially mixed with salt.

As soon as this mixture is exposed by asteroid impacts or is transported to the surface by internal forces, it can slowly sublime, or transition directly from the solid into the gaseous state. The salt that was originally dissolved in the water is left behind. "Investigating these bright deposits on Ceres' surface will be one of the main objectives for the *Dawn* mission over the coming months," predicts Martin Hoffmann.

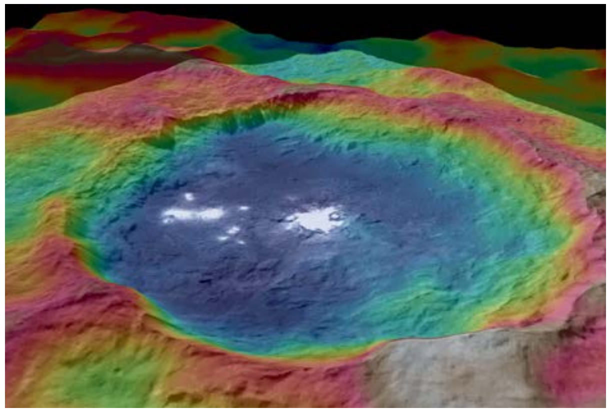
HAZE DEPENDS ON THE POSITION OF THE SUN

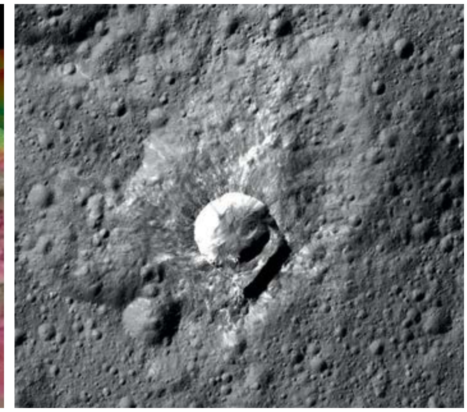
Some of the bright areas have even more to offer, such as the relatively young crater Occator in the northern hemisphere, which is around 80 million years old and has a diameter of over 90 kilometers. Inside its crater walls, which can be as deep as 4 kilometers, the framing cameras have even detected the brightest spots on the whole surface. What's more, the photos show that haze forms on the crater bottom after the Sun has risen. But this mist becomes visible only when Occator is photographed at a very low angle. In the diurnal rhythm, the patches of haze clear as soon as the Sun is near or already below the horizon.

This finding also supports the hypothesis of subsurface frozen water, although it is still not clear how exactly the haze forms. According to Andreas Nathues, it probably happens through openings in the ground, when frozen water sublimes into the vacuum of space. Since dust particles are also entrained in the process, it resembles the outgassings of comets.

The second brightest structure on Ceres' surface, 8-kilometer-wide Oxo crater, is also comparatively young. The photos show bright spots and haze here as well. If the indications for ground ice are confirmed, then the framing cam-

Orientation on a distant world:
Andreas Nathues (left) and Martin Hoffmann inspect a global mosaic of the dwarf planet Vesta. The *Dawn* probe journeyed to it as the first stop on its tour. The two framing cameras on board were developed and built by, among others, the Max Planck Institute for Solar System Research in Göttingen.





eras will have proved for the first time from close up that ice is present in the asteroid belt. Although this region of the solar system is actually too warm for it, ice can evidently remain stable over long periods here when there is a layer of surface rock protecting it against vaporization.

Dawn's observations corroborate measurements taken by the European space telescope *Herschel*, which had already discovered the spectral fingerprint of water vapor in the infrared light of the dwarf planet. One of the two possible sources of vapor discovered by *Herschel* coincides with the position of the Occator crater. According to the analyses undertaken by Nathues' team, so-called hydrated magnesium sulfates – that is, hydrous mineral salts – are an important constituent of the bright ground material. Many of the other bright regions on Ceres, in contrast, probably consist of dried-up salts. The activity that is still ongoing at the Occator crater apparently stopped some time ago at these other locations.

A further current investigation is likewise devoted to Ceres' surface minerals. The researchers used *Dawn's* infrared spectrometer to measure the spectral distribution of the reflected light at wavelengths between 0.4 and 5 micrometers. Cristina De Sanctis from the Istituto di Astrofisica e Planetologia Spaziali (IAPS) in Rome concludes from the measurements that sheet silicates containing ammonium occur widely on Ceres. These substances could possibly have been formed by reactions with organic material or ammonium ice when Ceres was still very young.

DID THE DWARF PLANET MIGRATE TO THE ASTEROID BELT?

The latter, however, is stable only at the very low temperatures found in the outer solar system, which in turn would indicate that pebble-sized objects drifted from regions far from the Sun into the asteroid belt, where they were taken up by the bodies already there. Or did Ceres once migrate from somewhere near Neptune's orbit into today's asteroid belt, as De Sanctis puts forward for discussion? The Göttingen-based researchers have remained rather more cautious here. The evaluation of the measurements is still ongoing; Ceres' origin can be assessed only when this is complete.

And another important question heads the to-do list of the *Dawn* researchers: Does Ceres' solid crust sit atop an ocean like the one planetologists have discovered on Europa? Although Ceres is much smaller than this particular moon of Jupiter, the dwarf planet is relatively large when compared with the even smaller Enceladus, which orbits Saturn and also has such an ocean. Although they don't yet take *Dawn's* observations into account, the latest computer simulations appear to indicate that this could be the case with Ceres as well.

According to the calculations, a zone in which the ice has melted could start 5 to 33 kilometers below the surface; the uncertainty in this figure results from the spread of assumptions that were made for the calculation. If the hypothetical ocean were very salty, it could exist under an even thinner surface layer. *Dawn's* eyes and the other instruments on board have the opportunity to find answers until early 2017. After that, the probe will run out of fuel. ◂

TO THE POINT

- **The *Dawn* space probe has been orbiting the dwarf planet Ceres since March 2015.**
- **Ceres is a world with a complex geology. Some craters have interesting structures; frozen water evidently played a major role in their formation.**
- **White spots appear all over the surface – salt. It presumably consists of hydrous magnesium sulfate or other bright salts as occur in terrestrial salt lakes.**
- **Simulation calculations indicate the possibility that an ocean lies hidden beneath Ceres' surface.**

Photos: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA (3)

Thaw in the
Climate Model

Nowhere does climate change make its presence felt more strongly than in the Arctic. The volume of sea ice there has fallen drastically in recent decades. Climate models have been far from accurate in conveying the full extent of this loss. This is set to change now – not least because **Dirk Notz** and his research group at the **Max Planck Institute for Meteorology** in Hamburg are constantly improving their understanding of the processes that influence the formation and melting of sea ice.

TEXT **UTE KEHSE**

Every year, when the polar night falls over the Arctic Ocean, a wafer-thin solid crust forms on the bitterly cold water. Initially, it consists merely of individual crystals that glide over the surface of the water, forming a sludgy mixture with a slush-like consistency. This mass gradually consolidates to form circular pancake-shaped structures from which meter-thick ice floes eventually form. By the end of the winter, the ice fills almost the entire Arctic Ocean, extending from Canada to Siberia, pushing through the Bering Strait and Baffin Bay and almost fully enveloping Greenland and the Spitsbergen archipelago. By the end of February, the Arctic sea ice covers an area of around 15 million square kilometers every year, an expanse equivalent to one and a half times the area of Europe. During the summer months, in contrast, the vast white expanse retreats considerably.

And it is retreating more and more: The Arctic sea ice has been shrinking rapidly for some years now. In 2012, for the first time since satellite measurements began in 1979, the minimum area of the ice in summer was less than four million square kilometers. "The expanse and thickness of the Arctic sea ice in summer has approximately halved over the last 35 years. Three-quarters of the volume is gone," says Dirk Notz, a sea ice expert at the Max Planck Institute for Meteorology in Hamburg. The melting of the sea ice has reached dramatic proportions: the northeast passage along the Siberian coast is now navigable in most summers and the ice edge

Photo: Thorsten Heller, Arved Fuchs Archive

is shifting further and further north. Most climate models now predict that the Arctic Ocean could be ice-free in summer by the middle of this century.

This has considerable consequences for the global climate. Although sea ice is only a few meters thick, it sits on the ocean like a lid, largely preventing heat from the water from reaching the atmosphere in winter. In summer, in contrast, the bright white ice radiates a large proportion of the incident sunlight back into space. Both effects cool the air in the polar regions. If the ice disappears, the high latitudes will warm up at an even faster rate than is already the case. This would lead to a decrease in the temperature difference between the mid- and high latitudes, a development that could give rise to freak weather conditions in temperate zones.

As recently as ten years ago, many climate models came to the conclusion that ice-free summers could be expected in the Arctic at the end of the 21st century at the earliest. However, the ice has retreated considerably faster than projected by these simulations. In 2007, for example, the ice shrank so much that some researchers suspected a tipping point had already been reached, beyond which the ice could disappear in a matter of just a few years. However, it expanded again over the following two years – again, an unexpected development. In short, the sea ice was behaving

Not stranded: Dirk Notz and Thorsten Heller, a member of the ship's crew, take a sample on an ice floe. On this expedition they joined polar researcher Arved Fuchs, who was travelling on the sailing vessel "Dagmar Aaen" for nostalgic reasons.

Cinematic experience in the sky: The Max Planck researchers enjoyed breathtaking views of the aurora borealis from the Daneborg Research Station in Greenland.

so strangely that it seemed that climate researchers couldn't get a handle on it in their models.

Since then, however, the gaps between the models and reality are far better understood and have narrowed considerably – thanks in part to Dirk Notz's work. He has been head of the Sea Ice in the Earth System research group at the Max Planck Institute in Hamburg for seven years. Notz and his colleagues devote their efforts to finding out what kind of future lies ahead for the sea ice around the North Pole and on the far side of the globe in the Antarctic.

NEW MEASURING INSTRUMENTS FOR FIELD EXPERIMENTS

The team takes a very comprehensive approach to its research: they keep an eye on the overall comings and goings of the sea ice, evaluate satellite data, and model the observed rhythms using complex computer programs. They also investigate the physics of the sea ice in detail: In their laboratory, they observe how the ice changes when it freezes or melts. They use models to describe these physical processes, and they also develop new measuring instruments and use them in field experiments. "The way we combine research on a laboratory scale with general studies and mix different methods is our unique characteristic and the great strength of our group," says Dirk Notz. "We bring the worlds of the modelers and experimental researchers together."

In this way, the Max Planck researchers improve the climate models' simulations of how the sea ice is changing at the global level. "Our measurements enable us to gain a better understanding of the minutiae of the processes that influence the growing and melting of sea ice in nature," explains Notz. Through this understanding, the scientists can then estimate which processes must be incorporated into the global models to obtain reliable answers to the central questions of sea ice research. "Thanks to our work, we know which questions we can reasonably answer using our models – such as why the sea ice is increasing in the Antarctic but melting in the Arctic."

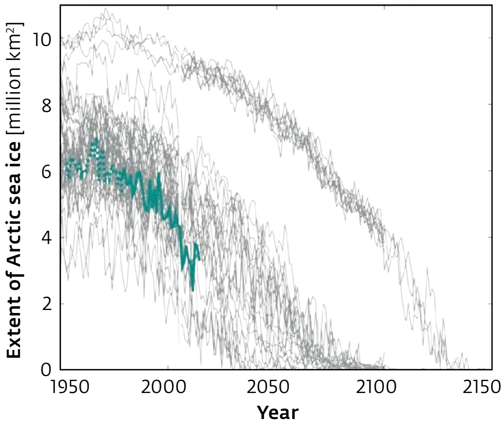
The place where the group's laboratory experiments are carried out is just a short walk away from Dirk Notz's office. On the 13th floor of the neighboring building, the University of Hamburg's Geomatikum, Notz and his colleagues have set up a cold room that's not much bigger than a storeroom. Most of this space is taken up by an ice tank measuring almost two meters long and one meter high. The researchers can grow and study their own sea ice here. They also test prototypes for the measuring equipment they develop themselves and later use in the field.

"In principle, the entire room is a big freezer," explains Dirk Notz. By cooling the air down to as low as minus 25 degrees Celsius, the researchers can reduce the greenish water in the tank from room temperature to negative temperatures within a period of three to four days. After another half day, enough ice accumulates on the surface for them to carry out all sorts of experiments. With the help of several pumps, they can make the water flow in steady circles or generate waves. Heating plates help them simulate thaw conditions. Snow comes from standard spray bottles, and wind from a ventilator.

HOMEMADE SENSORS

It all seems a bit improvised, but that doesn't bother Dirk Notz. "It doesn't matter if it doesn't look pretty, it just has to work," he says. The group has the same attitude to measuring equipment. Because there were no suitable sensors available for many of the parameters they wanted to measure in the ice, the team had to develop suitable measurement sensors themselves. Dirk Notz uses words like "tinkering" and "cobbling together" when he describes the work they did on developing the sensors. "We do almost all of the practical stuff ourselves – it's all

Photo: Leif Riemenschneider



part of our work, so a bit of practical intelligence is needed," he says.

The results of this development work are internationally unique. For example, the Hamburg-based research group has a measuring device with which it can measure the salt content of sea ice at different depths. The sensor resembles a harp. The small version, which is used in the experiment tank, consists of a circuit board and a Plexiglas sheet from which eight pairs of wires protrude at intervals of one centimeter. Electrical conductivity is measured between the wires, and the salt content can be extrapolated from this.

"The salt content of the sea ice is difficult to determine, but it is an extremely important parameter when it comes to characterizing the ice," explains Dirk Notz. When sea water freezes at minus 1.8 degrees Celsius, salt and other dissolved substances are not incorporated into the crystal lattice, but are left over as concentrated brine in tiny pockets and channels within the

Above The models taken into account in the latest global climate report make very different predictions regarding sea ice cover in the Arctic. The measurement data from ships and aircraft (dotted green line) and that from satellites (solid line) are located around the mean of the most reliable simulations.

Below In the laboratory in Hamburg, Dirk Notz (left) takes an ice core, while Niels Fuchs measures the temperature of the ice's surface.

Photo: Tom Pingel, graphic: MPI for Meteorology

Left Leif Riemenschneider (left) and a member of the team install a measuring instrument they use to determine the salt content of the ice by measuring its conductivity as it grows. They are wearing survival suits in case they fall through the ice.

Right To be able to carry out experiments in the youngest sea ice possible, the researchers move around a fjord in northeast Greenland in a hovercraft that can travel over ice and through water.

ice. Thus, sea ice is a mixture of solid freshwater ice and liquid brine. Because this brine has a higher density than sea water, some of it drains out of the ice and into the sea water over time. The researchers deduce from the salt content of the sea ice how much brine remains in the ice. This, in turn, enables them to draw conclusions about almost all of the other physical properties, such as the heat conductivity and mechanical strength of the sea ice, which have to be included in the simulations of global sea ice development.

The brine that drains from the sea ice also plays an important role in the global circulation of the oceans, a process known as thermohaline circulation. Again and again, the heavy liquid increases the density of the surface water in some locations in the polar zones so much that it sinks to the bottom and provides the deep sea with cool, oxygen-rich water. The draining of the brine from the sea ice is thus an important driver of this cycle, which also keeps the ocean currents on the surface in movement.

HOW DOES THE SALT CONTENT DEPEND ON THE AGE OF THE ICE?

So there are plenty of reasons for wanting to gain a better understanding of the complicated processes that influence the salt content of the sea ice and the volume of brine that flows out of it. For example, it was long unclear how the salt content depended on the age or thickness of the ice. To explore these and other correlations, Dirk Notz and Philipp Griewank, his former doctoral student, not only studied the salt content in experiments, they also developed a complex one-dimensional model for describing it. They included all of the physical processes that can change the salt content in their calculations. The structure of the ice, and thus its salt content, develop not only during growth and thawing, but also when it snows or rains or when the sun shines on the surface. The model they developed enabled Griewank and Notz to gain a clear understanding of the measured salt content of sea ice.

Another gap in the research has been closed by meteorologist Ann Kristin Naumann. For her master's thesis, she studied how sea ice freezes in the experiment tank when the water is stirred up by waves or kept in motion by wind and currents. Little was previously known about these processes. Naumann first had to find a suitable method for measuring the solid part of the slushy ice that forms in the agitated water. As she observed, even if the overall mass of ice in the tank increas-

Photo: Leif Riemenschneider

Photo: Leif Riemenschneider

es, the solid proportion of the slushy ice doesn't increase with time. As long as slushy ice is present, only one quarter of it consists of solid ice crystals. This finding is important for understanding the large-scale behavior of sea ice and can now be incorporated into climate models.

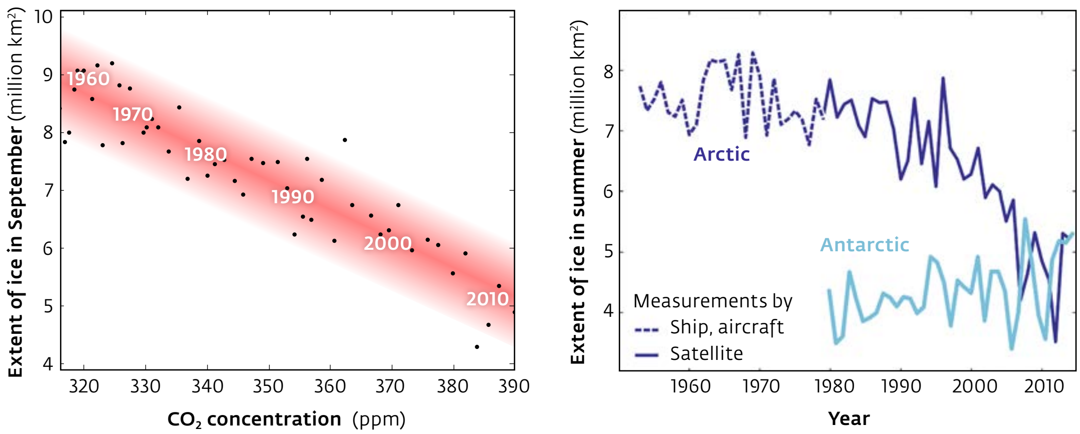
Over the course of the last few years, Dirk Notz and his colleagues have examined numerous other sea ice processes in detail in their experiments, such as the thawing and other developments that arise at the boundary between ice and water. They have also focused on the interaction between snow and sea ice. For example, they examined exactly what happens when a layer of snow pushes the sea ice so far down that the floe is flooded with sea water. The water freezes and forms snow ice, which accounts for up to 40 percent of the volume of sea ice in some parts of the Southern Ocean. Another topic of interest to the scientists is the influence of sea ice on the exchange of CO_2 between the ocean and atmosphere. This is a question of global relevance, as the world's seas and oceans have absorbed around a quarter of the anthropogenic CO_2 emissions to date.

The scientists would also soon like to study some of these processes in field experiments. To do this, they have built a bigger version of the salt measuring device that is buried in the sea ice and transmits data via a satellite connection. An initial test carried out in Greenland in 2013 came to a premature end after just two weeks, but it already provided a lot of valuable data. "We now want to extend the monitoring period and observe for the first time how the salinity in sea ice develops over time," explains Notz. The only information previously available about the salt content of sea ice came from individual measurements taken from ice cores.

To this end, the researchers plan to transport the salt measuring device to a fjord in Spitsbergen as soon as possible, and put it to practical use there for an extended period of time. The team also aims to insert additional sensors into the ice to measure the light conditions, pH value, and oxygen and carbon dioxide concentrations at different depths. In this way, the researchers in Hamburg are collating many important details that help them obtain a better understanding of the peculiarities of the sea ice – and thus ultimately enable them to provide better simulations of its large-scale behavior. Dirk Notz has already achieved some success in this area, too. "By examining apparent contradictions between observations and model simulations, we were able to fill several major gaps in the understanding of sea ice in recent years," he reports.

AN EXPLANATION FOR THE INCREASE IN ANTARCTIC ICE

Together with his colleagues Hauke Schmidt and Alexander Haumann, Dirk Notz discovered, for example, why a slight increase in the extent of the sea ice in the Antarctic is currently being observed – a puzzling effect that is often not apparent in climate models. The study's findings were published in GEOPHYSICAL RESEARCH LETTERS in 2014: Winds blowing from the land have intensified on the Ross Sea, an ocean region on the Pacific side of Antarctica,



Above There is a linear correlation between the retreat of the Arctic sea ice and the increase in CO_2 concentrations in the atmosphere (left). Dirk Notz and his colleagues were able to eliminate all other possible causes for the retreat. While sea ice in the Arctic has retreated over the last 50 years, it is expanding slightly in the Antarctic (right).

Right Dirk Olonscheck, Dirk Notz and Niels Fuchs (from left) discuss the latest measurement data and consider further experiments.

and are driving the ice away from the coast. "The ice is being blown to the north and the ocean south of it freezes over again," explains Notz. As a result, sea ice cover in the Antarctic, particularly the Pacific sector, is increasing – despite global warming.

In another study, Dirk Notz and some colleagues from the Max Planck Institute for Meteorology discovered in 2011 that there is no tipping point beyond which the summer retreat of sea ice in the Arctic would be irreversible. Many climate researchers previously suspected that the Arctic Ocean would enter a new state of being ice-free in summer if the extent of the ice went below a certain limit for the first time. It was feared that the ice loss could accelerate by itself, since sea water absorbs more heat in summer than ice.

The climate simulation created by the Hamburg-based researchers revealed, however, that the sea ice also recovers quickly after a completely ice-free summer. In winter, the ocean quickly releases the previously absorbed heat back into the atmosphere. "Various feedback mechanisms ensure that the former state is re-established after around three years," explains Dirk Notz. This means that the sea ice in the Arctic adapts relatively quickly to the prevailing climate conditions – and it would remain largely stable if climate change were halted.

ONLY THE CO_2 INCREASE CAN EXPLAIN THE SEA ICE RETREAT

However, as revealed by a 2012 study by Dirk Notz and Jochem Marotzke, Director at the Max Planck Institute in Hamburg, the increasing concentrations of greenhouse gases in the atmosphere are already having a very direct impact on sea ice. For this study, the researchers evaluated measurement data on sea ice cover since the 1950s. They concluded that the current sea ice retreat can't be explained by natural fluctuations and must be due to an external cause. The scientists were able to rule out solar radiation, volcanic eruptions and other factors as possible explanations for this, leaving only rising CO_2 values as the cause. "The greenhouse gases increase the incident heat radiation in the Arctic, which has a direct impact on the heat balance of the sea ice: "It melts," explains Notz. As the two researchers have shown, anthropogenic emissions are the direct cause of the sea ice retreat.

Notz also thought about why this retreat is considerably slower in many of the climate simulations than in reality. This discrepancy is often taken as an indication that the climate models fail to realistically register important processes. However, in an article published in the British Royal Society's journal Philosophical Transactions in 2015, Notz concludes that the model simulations can deviate considerably from the measurement data without being fundamentally incorrect. He proves that the expansion of the sea ice is so strongly influenced by chaotic natural fluctuations that even models that realistically describe the key physical processes can deviate strongly from the way things develop in reality.

Thus, even if the climate models failed in part to predict the rapid retreat of sea ice in the Arctic and could still be improved on, this doesn't necessarily mean that they are fundamentally incorrect. "I believe this study is

Graphics: Based on Notz and Marotzke, 2012 (left), Dirk Notz/MPI for Meteorology (right)

Photo: Tom Pingel

one of the most important results of our work, and it has consequences that extend far beyond sea ice," explains Dirk Notz. The conclusion that the natural fluctuations make it difficult to accurately predict a development can also be applied to other parameters in the Earth's climate, such as the amount of precipitation and the frequency of storms and drought.

The Hamburg-based researcher has a lot of plans for the future. He and his colleagues are now increasingly incorporating the insights gained from the group's experiments into global Earth system models so that they can provide better predictions about the ice cover. Another focus of their current work consists in gaining a better understanding of the processes that take place at the boundary between sea ice and sea water – for instance, how the ocean transfers heat to the ice.

But their research object isn't exactly making things easy for them at the moment: a few experiments that the team had planned to carry out in the Van Mijen Fjord on Spitsbergen in January 2016 had to be cancelled due to a lack of ice. There were several weeks of thaw on the Arctic island in December and January – right in the middle of the polar night – and there was no trace of the sea ice that usually has the island firmly in its grasp in winter. And the National Snow and Ice Data Center in the US has just announced that the maximum extent of the winter sea ice in the Arctic this year was the lowest ever recorded since measurements began. The great melt appears to be forging ahead. ◂

TO THE POINT

- **Sea ice in the Arctic has retreated considerably since satellite measurements began in 1979. The extent of the ice there in summer today is only one-fourth of the extent recorded then. Previous climate models failed to reflect both the strong retreat of the sea ice in the Arctic and the increase in the extent of the ice in Antarctica.**
- **Dirk Notz and his Sea Ice in the Earth System research group are improving the simulations created for the climate models by studying all of the processes that affect the extent of the ice in the Arctic and Antarctic, both generally and in detail, using laboratory and field experiments and models. An important parameter here is the salt content of the ice, which depends on different factors.**
- **The researchers have established that there is no tipping point for the Arctic sea ice, beyond which the sea ice would disappear permanently in summer. They also discovered why the sea ice in the Antarctic is increasing: stronger winds from the land are driving the ice away from the coast, so that new ice is forming there.**
- **According to another study, due to chaotic natural fluctuations, climate simulations can deviate significantly from observations without necessarily being incorrect. This insight can also be applied to other climate parameters, such as the amount of precipitation and frequency of storms and drought.**

Mediator between Worlds

Ayelet Shachar wanted to be an architect. She wanted to create spaces and provide homes for people. As a lawyer and political scientist, however, she discovered the spaces of the law – and the possibilities they provide for enabling migrants and locals to find ways of living together. Every community, says the Director at the **Max Planck Institute for the Study of Religious and Ethnic Diversity** in Göttingen, needs the discourse about aims and identity. And every individual has the right to participation and a home.

TEXT **MARTIN TSCHECHNE**

Architecture seems like an obvious place to start. To accommodate the new colleague, a story was added on to the rather simple building that stands opposite the beautiful art nouveau villa where the Max Planck Institute for the Study of Religious and Ethnic Diversity in Göttingen is based. Finishing plaster still crunches underfoot up there, and desks, computer monitors, corner seating, conference rooms and coffee machines have yet to transform the snow-white suite of rooms into a workplace. Not a single book stands in Ayelet Shachar's bookshelves yet.

It's a spring day in 2016. Every impression is a mere snapshot, of course – this one, too. The boxes from Toronto will be unpacked soon, the books arranged, and colleagues will have furnished their rooms upstairs. Today more than ever, perhaps, this kind of insight plays a role in the work and studies of Professor Shachar, who was born in Jerusalem: time is the crucial fourth dimension in her thinking, to which she gives form through political analysis, ethical debate and legal intellectual rigor, citing architecture as a model.

EXPLANATIONS AND SOLUTIONS ALWAYS IN DEMAND

She has been in Germany since last June and in Göttingen since July, after which events unfolded in quick succession; she was increasingly called on to share her expertise, and was overrun with new requests for explanations and solutions, long-term strategies and instantaneous advice for the next day's decisions. The lawyer and political scientist says she longs to finally get back to the everyday life of the world of research, but she doesn't give the slightest impression of being exhausted. "I arrived at exactly the same time as the refugees," she says.

So: architecture. She really was heading in that direction, she explains. For a few years she dreamed of creating spaces, three-dimensional structures and volumes that would house and protect their residents, lend direction to their activities and a dimension to their thinking. "Imagine a cathedral," she says. "People were supposed to perceive how small they are in the face of divine greatness. That was the purpose of architecture then." In her vision of space, it should empower people instead.

In the aftermath of the Vietnam War, it was the boat people whose fate shook the world. Between one and a half and two million people who had escaped Vietnam also faced hostility in neighboring countries. So the refugees were forced onto the sea in rubber dinghies and fishing boats, floating coffins that were always hopelessly overfilled. They would arrive somewhere eventually. The international community ac-

Photo: Frank Vinken

tually responded at the time. Ships were dispatched and many of the homeless Vietnamese were saved and granted asylum in the US, Canada, Japan, and many in Germany, as well. But over 250,000 of them drowned. Ayelet Shachar was an alert and concerned young woman in Israel. The fate of the boat people must have affected her. At some point during this period she decided to study, not architecture, but law. After all, the two disciplines are not so very different.

The images we see today are similar. They portray dramas unfolding off the coast of Greece, at border fences in Hungary and in front of armed police at the gateway to Macedonia. But can

Room for law: As a lawyer and political scientist, Ayelet Shachar is interested in the question of how governments can create a contemporary legal framework for the phenomenon of global migration. Her work in Göttingen is also supported by the Max Planck Foundation.

laws provide a home? Define a home? "They can create spaces," Ayelet Shachar replies. That's already a huge step. They can offer safety, regulate coexistence, protect culture and, by way of a happy ending, lay the foundations for an identity – assignments that any architect would be proud to work on.

Her topic is the study of citizenship and migration, borders and refugees: collapsing systems, merging cultures, biographies without hope, and the fundamental right to a place to live and participation. And when all of that has been sorted out, when dry land has been reached, at least, and a temporary status established, the researcher is interested in how minorities integrate and how they are integrated. How does the tradition and culture of one group rank vis-à-vis the law of the other? How much identity does someone need to survive, and how unavoidable is a new start when all the coordinates have changed? She is interested in the question as to why a woman from Syria thinks it is acceptable to leave her apartment in Hamburg only with her

Right to a homeland: Where a child was born or where its parents come from currently determines its nationality and thus the opportunities it will have in life. In Ayelet Shachar's opinion, this principle is outdated. Instead, she advocates nationality based on a person's reality.

» Laws can offer safety, regulate coexistence, protect culture and, ultimately, lay the foundations for an identity.

husband's permission and in his company. Where should a new way of thinking take over: With her? With the husband? With everyone else? Shachar has no propensity for pathos. She loves light and clear, functional lines – in architecture, too.

The questions come day in and day out. Should women from Afghanistan insist on wearing their veils when they face a judge in Europe? Is it acceptable for states to sell their citizenship, including the right to vote, like a commodity? What should be done when false passports come to light or when Tunisians and Moroccans mix in with the streams of refugees from Syria and Iraq? How much co-education should girls from Muslim families be expected to accept when it comes to physical education? How much special status is needed to make one group understandable to the other?

MILLIONS OF PEOPLE NOT RECOGNIZED

And does the definition of belonging to a community on the basis of a birthplace or the legal status of parents alone reflect the reality of life in a globalized world? The principles of *jus soli* and *jus sanguinis* are so old that they have Latin names: right of the soil and right of the blood. Shachar argues that it is high time that we adopted a *jus nexi*, a right of connection, based on which a person's reality dictates his or her citizenship.

She tells the story of a young man who arrived in the US with his parents when he was just ten days old. *Jus soli* applies there: anyone born on American soil is automatically an American with all of the rights of a US citizen. His parents remained in the country. Their temporary visas lapsed. The entire family was illegal. The boy went to school like everyone else, as American law does not ask about citizenship when it comes to reading, writing and arithmetic. It was only when he applied to go to college that he discovered that, officially, he didn't even exist. He had never lived anywhere except the US. He was bright and curious and ready to take his place in the community – but he was a loser in the lottery for rights defined at birth and based on origin alone. Shachar's work on religious diversity and gender equality, "Multicultural Jurisdictions," had already generated a groundswell of interest. "The Birthright Lottery" is the book with which Shachar cemented her reputation as a combative thinker. "And that," she concludes her example, "is why we need a *jus nexi* to supplement and complement the other two principles." Millions of people are living without recognition.

"Here I am. I come from Canada, the global center of multiethnic, interreligious and multicultural diversity!" This is how she introduced herself to her colleagues from the Max Planck Society. Nor did she forget to mention the special situation in the city of her birth, Jerusalem, where the holy sites of three monotheistic global religions are located against the backdrop of an eternally smoldering conflict, a city dominated by the acute threat posed by almost all of its neighbors, a vital need for coalition and compromise, and a population with highly diverse roots and cultures: what else could she do but reflect on rules and borders and the opportunities offered by coexistence in such a multilayered, complex and conflict-ridden setting?

Sometimes she is impelled to provide an answer; sometimes, when politicians put pressure on her, she gives in and does just that. No, she says, if the scales of justice oblige such a result, of course you must convince the woman to remove her burka in court. After all, democratic discourse is not just about making your arguments heard; it is also about engaging with others while you do it.

MALTESE CITIZENSHIP FOR 650,000 EUROS

She is well able to tell stories and does so like a seasoned reporter. She backs up her findings with stories and anecdotes because people give their reality a structure through narratives comprising images and examples. She ignores the cautionary advice she has received from some colleagues that, in professional circles, it's better to attract attention by publishing a large number of individual articles, and joyfully owns up to the iconoclasm of her books. She's special, and she likes it that way. And such delight in argument and constructive confrontation could well provide fertile ground for the vision of a society that has accepted diversity and mobility as characteristics of its time, and develops opportunities from them. A society in which ideas count more than norms and fostering exchange is more important than sticking to the rules.

She tells about Canada and the US, where immigration and integration were constitutive elements of society from the outset – and where, neverthe-

Photos: Reuters (top), Niels Leiser (bottom)

» Nobody gets into a rubber dinghy to paddle to America. Geographical location, history, economic power: everything has its weight.

less, all negotiations about access and acceptance take place, as far as possible, outside the territorial limits and, ideally, in the place from which the people embark on their journey. Naturally, it is alarming, to say the least, when a country like Malta puts its citizenship up for sale for 650,000 euros. This throws open a back door to the European Union and the Schengen area with no agreement or control. The few cosmetic changes subsequently imposed – the price increase and residency requirement – did nothing to alter the reprehensible nature of this business, especially in the case of people who were up to no good.

A RELATIVITY THEORY OF MIGRATION

Canada is vast, but it has only 35 million inhabitants. And the US, unlike Germany, isn't surrounded by nine different neighbors with nine different ideas about the needs of their citizens. Great Britain is an island and Greece has too many of them to be able to protect them effectively. "True," says Shachar: "Geography matters." Nobody gets into a rubber dinghy with the intention of paddling to America. Geographical location, history, economic power: everything will have its weight in the negotiations. The social obligation of the community to its citizens, the expectations of those who take to the roads and seas, their despair and possible disappointment, the ultimate strength of every detail is tested and each one can become a weakness that puts the entire system at risk. "To my knowledge, this takes effect … immediately, at once," stuttered Günter Schabowski when he was asked in front of the cameras of the Western media when the citizens of the GDR would be able to travel to the West without a special visa. That was on November 9, 1989, and the party official made world history without knowing it or intending to do so. He seemed helpless. The rustling papers in his hand had no better information to give him – but a minor uncertainty in the legal detail sealed the fate of his country.

No solution can be applied to the next case without being verified, and no structure will hold up if it was designed to accommodate a few thousand unfortunate refugees and one and a half million of them suddenly appear on the doorstep. Ayelet Shachar acts in systems whose essence and only constant is change. There were times, she relates from the history of the US, when there were grave doubts as to whether it would ever be possible to integrate Italian or Irish immigrants there. The scientist pauses with relish before reaching her punch line: "Today, Americans of Italian and Irish origin have exactly the same reservations about the Cubans. And who knows, maybe one of them will become the next president, or the one after that … ."

She erects her buildings on agile foundations. And in her expert reports, she recommends making this a feature of their design. Haven't architects in Japan shown that skyscrapers can grow even in earthquake zones? The scientist is also aware of the role of change in her simulations of reality: time is the fourth dimension of her architectural creations. Something akin to a theory of relativity of migration develops and unfolds in this way. The formula is basically simple: each detail alters the whole. Every deported asylum seeker hardens the structures underpinning those who sent him away. Every accepted refugee alters the economy, demography, culture and social network. No one can say when and how critical values are reached and exceeded; no one can be certain which investment will pay off. But change can't be hindered, and every development opens up new opportunities.

The questions about the burka and the trade in citizenship remain important. And yet, Shachar constantly sees a threat to her role when she is expected to express her views in shorthand. Headlines are short, committees have other items on their agenda to get through, and political negotiators seek solutions by cobbling together a few points from each side's list into an acceptable compromise.

OLYMPIC PRIVILEGES FOR A SELECT FEW

Shachar focuses on the whole picture, not the pixels: it's the interaction of the elements that fascinates her, not so much the elements themselves. The scandal that arose around the Archbishop of Canterbury a few years ago was a warning to her. Rowan Williams argued that, in a society in which people of Islamic faith have also found their home, the application of their legal system must also be up for discussion. Sharia law in England? The outcry resounded across the entire country. "He referred to one of my books," says Shachar. But of course the headlines omitted all the analysis, the intricately developed logic of the argument, and the detailed explanation of the systemic relationships.

Renowned expert: Ayelet Shachar is popular as a speaker, but even more so as a political consultant. She began working at the Max Planck Institute in Göttingen in summer 2015 – at the same time as thousands of refugees arrived in Germany via the Balkans.

Politicians act like politicians; Ayelet Shachar is a scientist. She completed her undergraduate studies in Tel Aviv and her doctorate at Yale University. She has held guest professorships at Stanford and Harvard and a prestigious chair in Toronto. She is married to Ran Hirschl, a renowned expert in comparative constitutional law, was appointed a member of the Royal Society in Canada, and was invited to become Director of a Max Planck Institute. “Just don’t look for any straightforward logic in my career,” she says and laughs. “There is none!”

Except, perhaps, the logic that she has always gone where she was needed. Not so much to the individual building sites, but to the places where the master plan, the strategy, the political concept is being developed. The highest court in Canada has telephoned her, as has the World Bank and, more recently, the European Parliament, as well as other instances that prefer to keep such consultations confidential. Is there a better place than Göttingen to reflect on the routes and possible destinations

Photos: Niels Leiser (top), Reuters (bottom)

» No solution can be applied to the next case. Ayelet Shachar acts in systems whose only constant is change.

of the current refugee crisis? A provocatively empty pedestal with no memorial figure on top was recently placed in front of the town's railway station. In the inscription, seven professors from the university scornfully thank King Ernst August for chasing them out of the country in 1837 during the struggle for a liberal constitution. Brothers Jacob and Wilhelm Grimm were among them. The spotlight of their global renown as linguistic researchers, fairytale collectors and fathers of a German identity shines today on nearby Kassel and Berlin. What remains for the people of Göttingen is stubborn mockery – the empty pedestal is also, of course, a reference to the pompous equestrian statue that stands in front of the railway station in the federal state capital of Hannover and bears an inscription proclaiming the people's loyalty as the servants of their sovereign ruler.

Ayelet Shachar has to smile when she hears this story. It is exactly the kind of thing that appeals to her: a terse statement, an image confirming precisely what she gives the hotheads to think about when they try yet again to get her to corroborate a preconceived view. Sometimes, self-interest can also prompt more detailed reflection about a place where people can find a home. The Brothers Grimm weren't the only ones to receive a friendly reception in Kassel: before them there were the Huguenots, the Protestants driven out of France, a capable, ambitious and grateful people. And a good 300 years of history have confirmed the wisdom of that decision.

Shachar has just written a book about such benefits accrued by communities through migration, about the pros and cons of the perhaps shrewd, but maybe also shortsighted importing of skills and competencies. Its title, "Olympic Citizenship," expresses a certain irony, as it is obviously an injustice to keep hundreds of thousands of people out of certain countries with barbed-wire fences while promising others Olympic privileges because they can design complex computer programs or play football with particular skill.

BUILD BRIDGES, NOT WALLS

However, the starter pistol in the race for talent, the competition for highly skilled migrants with a willingness to adapt, has already been fired. Skeptical geopoliticians, demographers and economists have long bemoaned the corresponding loss of workers in countries that urgently need doctors, teachers and engineers. But countries like the Philippines have long been deliberately producing such employees for the global market. And the money the seafarers, building workers and well-trained nurses send back to their families at home is a fixed item on the asset side of their economic balance sheets.

This happens. The migrants pay their price, and it is very high. And governments know the value of people as a resource. In 2000, when Schröder's government failed to attract IT specialists – particularly from India – with generous promises, the reason wasn't just the bad weather in Germany, but the fact that the green card offered wasn't as attractive as the one provided by the competition. The attempt simply came too late and the tide was already in full flow. Large numbers of these employees completed their studies at Harvard or Yale, were accepted at Stanford, Caltech or MIT, and have since found their place on Wall Street or in Silicon Valley.

The world will look different tomorrow – of this Ayelet Shachar is certain. Tomorrow, the boxes from overseas will be unpacked, her books will line the shelves, and her colleagues will have taken their places at the desks in their beautiful white office suite. Sixty million people fled their countries in 2014. Many more have probably since followed them. The problem is spreading – with luck and astute action, it is possible to develop opportunities from it.

And Europe is by no means the only region that must ready itself for the migratory movements of the 21st century. The German federal finance minister travels to China to discuss the roles of both countries in the global banking system and to develop common ground in the area of migration. Everyone has realized that banks and finances are closely intertwined throughout the world. The realization that the operation of nuclear power plants, waste disposal, air pollution, climate change and the weapons trade can't be regulated by national forums alone is also gaining ground as the working basis for international conferences. However, the phenomenon of migration is still waiting for the recognition, analysis and management of its global dimension. The world needs workable ideas; not walls, but bridges – and, if possible, bridges that can be used at different times and in different directions. Good architecture creates the foundations for this. Ayelet Shachar devotes her time to thinking about such future foundations for a world of mobility. ◂

Hunting for Particles Underground

Neutrinos are particles with seemingly magical powers: the different types are able to transform into one another, and thus have a mass. This discovery earned two scientists the 2015 Nobel Prize for Physics. A quarter of a century ago, these ghostly particles also attracted the attention of researchers at the **Max Planck Institute for Nuclear Physics** in Heidelberg for the first time. While conducting their Gallex experiment to hunt for them, they looked deep into the furnace of the Sun.

TEXT **HELMUT HORNUNG**

We can't see them, we can't feel them, yet they're everywhere. They penetrate everything – stars and planets, lead walls measuring light-years across, and even our own bodies. More than 66 billion of them shoot through the nail of your index finger every second. Neutrinos are the most common particles in the universe after photons, or light particles, yet their research history is relatively young.

In a letter written on December 4, 1930, Wolfgang Pauli mentioned such a particle for the first time, calling it a neutron. The Austrian physicist postulated the particle to explain the energetic conditions in the radioactive beta decay of an atomic nucleus. Enrico Fermi, an Italian, studied it in depth and gave the tiny theoretical particle the name "neutrino". Finally, in 1956, Clyde L. Cowan and Frederick Reines at the Los Alamos National Laboratory in the US succeeded in detecting this "mini neutron." The project to search for the neutrino was aptly called "Poltergeist."

Owing to its extremely weak interaction with matter, the fleeting phantom was very difficult to detect. This spurred the physicists on all the more to investigate it in greater detail in the years that followed. So the hunt continued, and in early summer of 1990, European scientists set a special trap for the ghostly particle from the interior of the Sun. To do this, they went underground.

In the spotlight: The media showed a great deal of interest in the results obtained by the neutrino hunters in the 1990s. Here, Gallex spokesperson Till Kirsten from the Max Planck Institute for Nuclear Physics at a press conference.

The Gran Sasso tunnel is a good 10 kilometers long. The A24 *autostrada* that runs through it links the cities of Teramo and L'Aquila as it crosses the Abruzzo region of Italy. After 6.3 kilometers, an exit leads off to a laboratory. Above its halls are 1,400 meters of rock, which forms a natural barrier against cosmic radiation and thus minimizes the "contamination effect" in the – extremely intricate – measurements.

The trap consisted mainly of 30.3 tons of gallium – half of the annual global production at the time. The gallium was delivered in six-packs of containers holding 1,200 liters of gallium chloride solution each. The liquid then had to undergo a 20-hour process to purify it of contaminants created by natural cosmic radiation. Only then was the gallium chloride put into one of two 30-cubic-meter tanks and dissolved in hydrochloric acid.

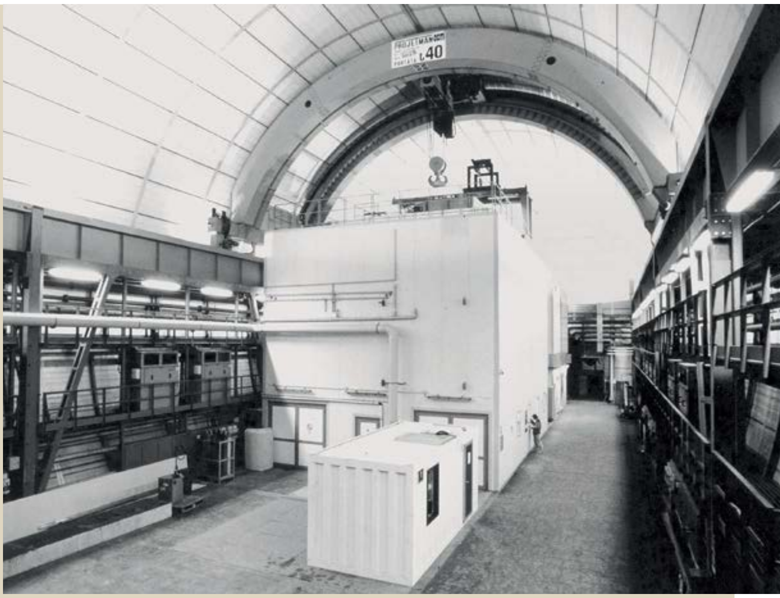
The tanks were made of corrosion-resistant material, glass-fiber reinforced polyester coated on the inside with polyvinylidene fluoride. This material contained extremely small amounts of natural radioactive substances such as radium, thorium or uranium. Only one tank was used for measurements at any one time, with the other kept in reserve as a precaution.

So how did they go about finding the neutrino? One of the researchers involved referred to it back then as a "special challenge for chemistry" – a slight understatement, which is why the media repeatedly reported that the whole project was more difficult than the proverbial search for a needle in a haystack.

The numbers speak for themselves: there were some one quintillion (10^{30}) atoms floating around in one Gallex tank. The scientists set a measurement period of 20 days. During this radiation period, the solar neutrinos were expected to score an average of ten hits – that is, collide with ten (!) gallium atoms and transmute them into germanium. In a nutshell: a hint of radioactive, gaseous and therefore extremely volatile germanium chloride was formed in the liquid gallium chloride.

At the end of a measurement period, these miniscule traces of germanium chloride were driven out of the tank using liquid nitrogen and, after a complex treatment process, were detected by

Photo: MPG Archive



In the depths: In the Gran Sasso subterranean laboratory under 1,400 meters of rock, researchers gazed into the heart of the Sun. The Gallex experiment registered neutrinos generated by the stellar fusion reactor.

means of their radioactivity. The scientists then used the number of germanium atoms detected in this way to draw conclusions about the flow of neutrinos from the Sun.

The unusual location of the Gallex experiment deep below the rocks paid off. The researchers succeeded in reducing the germanium production resulting from the natural cosmic background radiation to a mere two percent of the neutrino-induced signal. In addition, the counting room was also surrounded by a Faraday cage that kept out the stray electric radiation coming from the outside.

The neutrinos that got caught up in the tank originated from the center of the Sun, where there is a gigantic fusion reactor at work converting hydrogen to helium at a temperature of well over 15 million degrees Celsius and a pressure of 200 billion bar.

Bild der Wissenschaft, issue 12/1992

» With their sophisticated trap for the fleeting particles – a tank filled with thirty tons of liquid gallium – the researchers in the Italian mountains have received unambiguous neutrino signals.«

During this proton-proton reaction, as the process is called, two hydrogen nuclei (protons) first fuse to form a deuterium nucleus, releasing a positron (a positively charged electron) and an electron neutrino as they do so. In a second step, the deuterium nucleus fuses with a further proton to create a helium nucleus (^{3}He) and simultaneously emits a gamma quantum. In the final step, two ^{3}He nuclei fuse to form ^{4}He and release two protons.

During the proton-proton reaction, the Sun uses hydrogen to generate not only considerable amounts of helium, but also an inconceivable number of so-called pp neutrinos. These witnesses to the stellar fire leave the interior of the Sun unhindered and reach Earth a good eight minutes later. They account for roughly 90 percent of all solar neutrinos and, at 420 kiloelectron volts, have quite a low maximum energy. But Gallex was sensitive to this type of neutrino. The scientists eagerly awaited the result, having run into a dilemma in the years before the Gran Sasso experiment. They were racking their brains over the mystery surrounding the neutrino.

In the early 1970s, Raymond Davis was the first to detect solar neutrinos using a tank full of perchloroethylene in the Homestake gold mine in South Dakota. The problem was that there was only a third as many of them as the standard solar model predicted. The Japanese Kamiokande detector likewise found this discrepancy. However, the two detectors were sensitive to beryllium-7 and boron-8 neutrinos, which were thought to arise from a side chain of nuclear fusion. So was the theoretical scenario in the core of our Sun wrong?

Gallex entered the scene at just the right time, because the experiment was intended to capture the above-described, much lower-energy pp neutrinos for the first time. The result was published roughly a year after the facility had gone into operation: “First glimpse into the furnace of the Sun” was the title of a press release issued by the Max Planck Society on June 2, 1992. It reported that Gallex had tracked down neutrinos compatible with the predicted number. Till Kirsten from the Max Planck Institute for Nuclear Physics in Heidelberg, who headed the European Gallex collaboration, said, “The foundations of our explanation of nature behave in such a normal way that some sensation-seeking observers may be disappointed at this time.”

From the very beginning of proposal writing and project planning, Gallex defined two major motivations. One was the definite detection of solar pp neutrinos, and the other was the search for neutrino mass, reflected in reduced electron-neutrino fluxes due to neutrino flavor oscillations between electron, muon, and tau neutrinos.

The first data set released in 1992 proved the first item, but the statistical significance concerning the second one was far too low for a positive claim. Ensuring this option required patient solar neutrino data collection for many more years and an elaborate calibration with a man-made megacurie low-energy neutrino source. In 1997, the significance of a neutrino flux deficit due to neutrino oscillations had reached more than 99.9 percent.

In 2001, researchers working with Canadian physicist Arthur B. McDonald published their measurement results, which the team working with Japanese physicist Takaaki Kajita confirmed. As the electron neutrinos travel the 150 million kilometers from the Sun to Earth, they slip into the role of their relatives, instantly changing into tau and muon neutrinos, to which traps like Gallex were blind. For them to convert, they must have a mass, albeit a very low one. And that’s how the two scientists finally managed to detect the ghostly particles – and walk away with the 2015 Nobel Prize for Physics.

The work in Italy’s Abruzzo region goes on. One experiment there, known as Borexino, has also been on the trail of solar neutrinos for the last couple of years. Adjacent to it are the traps that are designed to capture particles of the enigmatic dark matter that makes up one-fourth of the cosmos and whose nature is still completely unknown. The underground researchers apparently specialize in solving the most difficult mysteries in the universe.

Photo: MPG Archive

New Open Access Initiative Launched

An expression of interest made public in mid-March has already been signed by over 40 organizations

At the conference in Berlin: Chairperson Ulrich Pöschl (third from left) with DFG President Peter Strohschneider (second from left) and Gerard Meijer, President of Radboud University (left).

A growing number of international research organizations are endeavoring to convert the majority of scientific journals currently published on a subscription basis to open access (OA) publishing. This goal was discussed at the 12th Open Access Berlin Conference hosted by the Max Planck Society in late 2015. The expression of interest (EoI) was published in mid-March.

The EoI calls on all parties concerned to "work toward a rapid and efficient transition for the benefit of science and society," and has already been endorsed by more than 40 organizations. "Direct access to specialist articles is a key factor in achieving scientific progress in the digital age. The time has come to make open access the publishing standard. Only by coordinating our activities internationally can we succeed in achieving this goal," says Max Planck President Martin Stratmann.

The first signatories include the FWF Austrian Science Fund, the Dutch research organization NWO and the European University Association, which represents more than 800 institutions of higher education in 47 European countries. From Germany, this group includes the German Research Foundation (DFG), the German Rectors' Conference, the Fraunhofer-Gesellschaft, the Helmholtz Society, the Leibniz Society and the Max Planck Society. The European Research Council (ERC), which has no specific publication funds, also supports the initiative in its own position statement.

According to the EoI, the objective is "to convert a majority of today's scientific journals from a subscription model to OA publishing." This transformation is to be achieved by using "funding currently spent on subscriptions to scientific journals to fund sustainable OA business models."

Studies showing that the conversion from traditional scientific publications to the OA model is feasible with the available funding were also discussed at the Berlin conference, which was chaired by Ulrich Pöschl, Director at the Max Planck Institute for Chemistry, who is the scientific open access coordinator at the Max Planck Society. The Max Planck Digital Library (MPDL) – which is coordinating the "OA2020" transformation initiative associated with the EoI – also presented such analyses. The plans also call for the establishment of a network with national points of contact in Europe, Canada, the US, China, Japan, South Korea and other countries. As Ralf Schimmer from the MPDL explains, "All parties concerned will agree on specific steps in the transformation process in the form of a roadmap."

www.oa2020.org

About OA2020

OA2020 is an initiative under the umbrella of the Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities, which has been embraced by more than 540 signatory institutions. Building on the Mission Statement of 2013, OA2020 aims to accelerate the transition to open access by transforming the existing corpus of scientific journals from their current subscription system to open access.

Over the course of the last 10 - 15 years, open access has become a shared vision of many if not most of the world's national and international research councils. Open access as a principle is very well established in the international discourse on research policies; however, open access as a practice has yet to transform the traditional subscription-based publishing system, which is as vigorous and prosperous as ever, despite its inherent restrictions on access and usage and its remarkable detachment from the potentials of a 21st century web-based publishing system.

Kick-off for Cooperation in Hong Kong

Max Planck researchers establish contacts with potential research partners at three-day symposium

Max Planck Society scientists are involved in many projects in China, and traditionally especially with colleagues from the Chinese Academy of Sciences. A total of four Max Planck Directors and twelve Max Planck Research Group Leaders from seven institutes traveled to Hong Kong in early April to share information and ideas on their research work with around forty select junior scientists from five Hong Kong universities. Both the public lectures at the University of Hong Kong (HKU) and the follow-up workshops in small groups focused primarily on topics in physics and the life sciences.

Joachim Spatz, Director at the Max Planck Institute for Intelligent Systems, heads up the initiative for the Max Planck Society. A key partner, in addition to the Hong Kong University of Science and Technology (HKUST), is the Croucher Foundation – a private foundation that applies the Harnack principle and supports outstanding junior scientists from Hong Kong. Following the successful kick-off, the partners now want to further discuss how cooperative projects can be set up on appropriate research topics.

Kicking it off with a handshake: Joachim Spatz, Director at the Max Planck Institute for Intelligent Systems, welcomes King L. Chow from the Hong Kong University of Science and Technology.

Alumni Symposium Holds Premiere in Berlin

New platform for exchange of career ideas

What career path should I pursue after leaving Max Planck? Should I go into research or industry? What have other alumni chosen to do? And how can they be better integrated into the Max Planck Society today? These and other questions will be discussed at Harnack House from August 22 to 24 at the first "Max Planck Symposium for Alumni and Early Career Researchers," which provides a new platform for exchange between alumni, the Max Planck Alumni Association and junior scientists. "International guests will report on their alumni work, and we will build on their experience with all participants, for example by developing joint projects between the Max Planck Society and its alumni," explains Filippo Guarnieri, co-organizer and head of the Max Planck Alumni Association.

To register, visit: www.mpg.de/symposium2016

Photo: HKUST

Diverse Objectives – Diverse Careers

On a visit to Munich, PhDnet presented its 2016 agenda

The PhDnet Steering Group: General Secretary Cátia Crespo, Spokesperson Martin Grund (front, center), Financial Officer Roman Prinz (front, right) and Sections Representatives Yorick Peterse (BMS), José Martinez (CPTS) and Christian Sternberg for the HSSS, (back, from left).

Whenever the Steering Group of PhDnet visits Administrative Headquarters, it is always a little livelier in the corridors – and this visit, when the new members traveled to Munich for discussions with President Martin Stratmann and Secretary General Ludwig Kronthaler, was no exception.

They came from four different federal states, and this broad array also reflected one of this year's main issues: the need for diversity. "And this applies in every respect," says spokesperson Martin Grund from the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig. "A workgroup was set up at our annual meeting specifically to ensure that doctoral students are actively supported regardless of gender, sexual orientation or background, and with consideration for chronic diseases and disabilities – in short, to ensure that the full spectrum of individual life plans is taken into account."

The Steering Group, which represents around 3,500 Max Planck doctoral students, has plenty of ideas about how to champion such diversity. "Bringing the number of vacation days into line with that of the collective agreement for civil service employees would be a step in the right direction, as it would send an important signal to doctoral students from abroad, families and those with disabilities." The PhDnet workgroup is also considering "diversity days" or special soft-skills seminars.

PhDnet advocates more professional and centrally managed career advisory services covering career paths both within and outside of science. This issue will also be the focus of the career fair, which, following its successful premiere last year, will again bring doctoral students into contact with potential employers at the Visions in Science conference from September 16 to 18.

www.phdnet.mpg.de

Photo: Dalija Budimlic/MPG

Research Establishments

- Institute / research center
- Sub-institute / external branch
- Other research establishments
- Associated research organizations

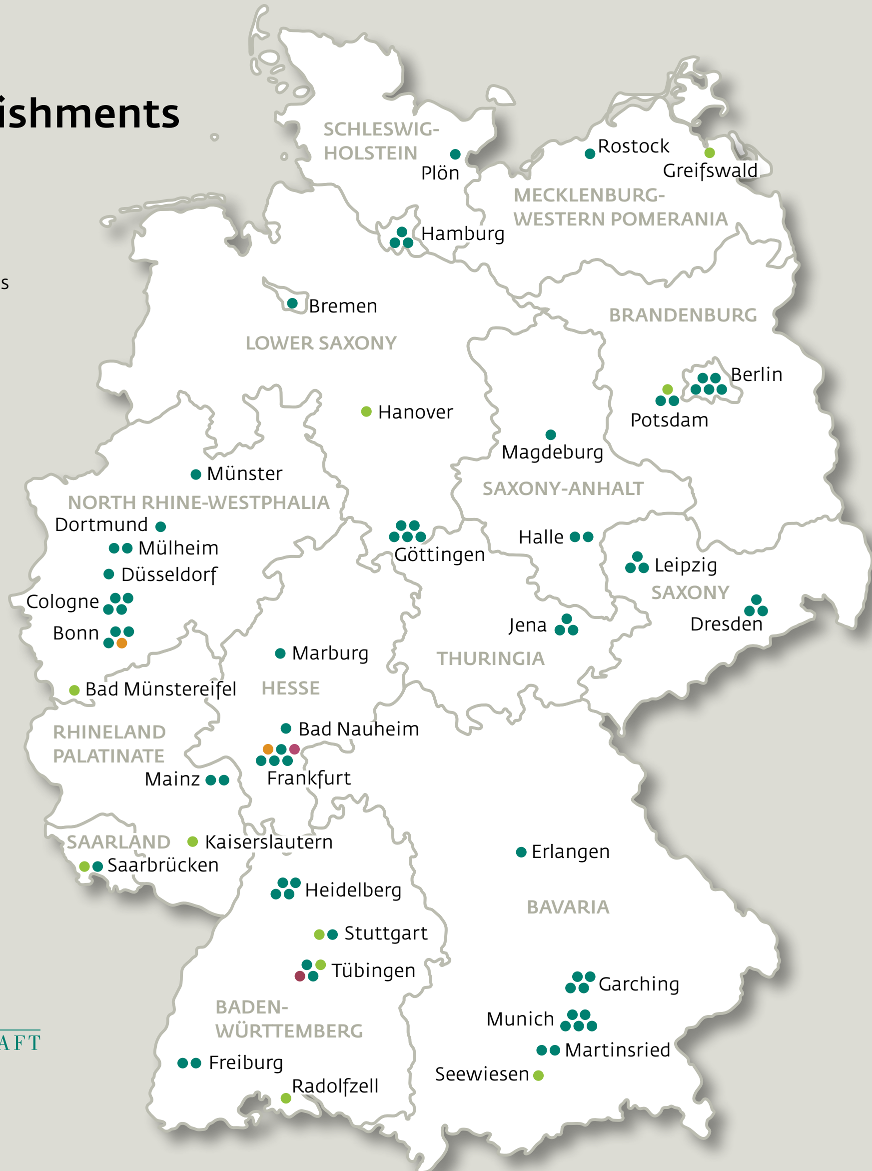
The Netherlands
- Nijmegen

Italy
- Rome
- Florence

USA
- Jupiter, Florida

Brazil
- Manaus

Luxembourg
- Luxembourg



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