

# Max Planck RESEARCH



The Science Magazine of the Max Planck Society | 2018



# Migration

HISTORY

The Power of Humiliation

QUANTUM PHYSICS

Crystals under Control

EVOLUTIONARY BIOLOGY

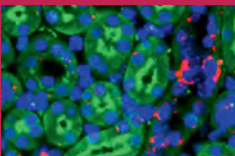
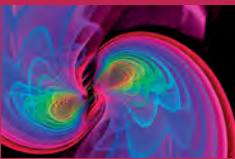
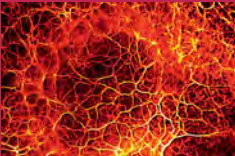
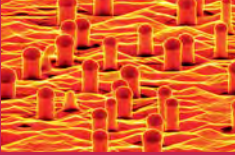
Mice Are Here to Stay

NANOTECHNOLOGY

Biomolecules in Action



Connecting Science and Business.



Max Planck Innovation is responsible for the technology transfer of the Max Planck Society and, as such, the link between industry and basic research. With our interdisciplinary team we advise and support scientists in evaluating their inventions, filing patents and founding companies. We offer industry a unique access to the innovations of the Max Planck Institutes. Thus we perform an important task: the transfer of basic research results into products, which contribute to the economic and social progress.

# Connecting Science and Business



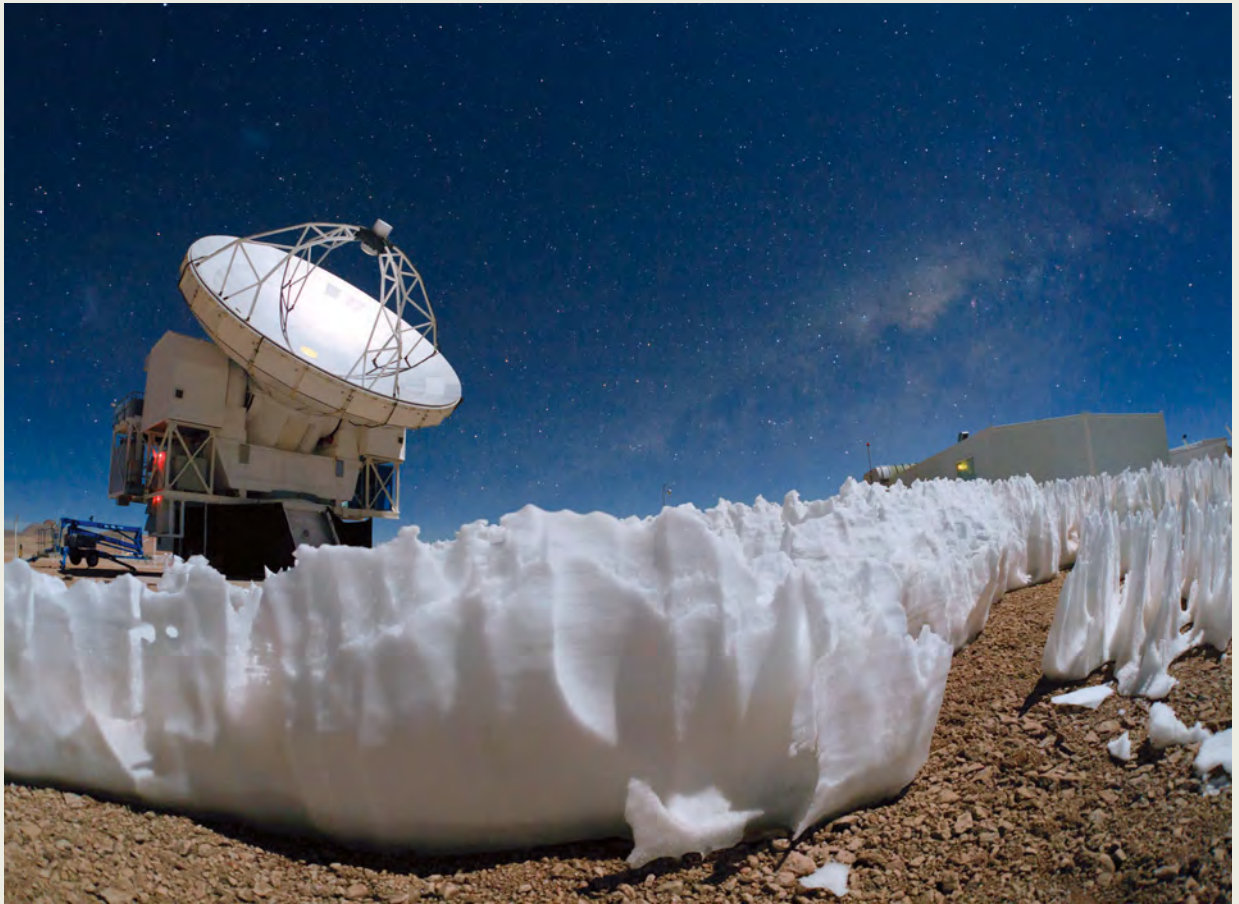


Photo: ESO/B. Tafreshi

## Cold Cosmos

At 5,100 meters above sea level, the air is thin and dry as a bone – properties that astronomers appreciate immensely. Up there, the dense aerial ocean of the Earth’s atmosphere and its otherwise substantial water content pose only a minor hindrance to observations, enabling researchers to get much closer to the vast wilderness of starry wasteland. That’s why they built an antenna on the Chajnantor plateau in the Chilean Andes: the *Atacama Pathfinder Experiment*, or APEX for short. The 12-meter dish detects millimeter and submillimeter radiation at the boundary between infrared light and radio waves.

Astronomers and technicians are currently upgrading the telescope. The centerpiece of this high-tech machine will be a camera with around 25,000 pixels, aimed at facilitating surveys of the heavens with unrivalled resolution. Of course 25,000 pixels isn’t much compared with, say, a smartphone camera, but the detectors have to operate at a temperature of minus 272.85 degrees Celsius, or just above absolute zero. The field of view of the camera is half the apparent size of the full moon.

Speaking of the moon: APEX’s application range extends far beyond our solar system. The telescope explores primarily cooler regions, especially molecular clouds in interstellar space. In these cosmic nurseries, new stars are born out of gas and dust; these stellar embryos are mostly invisible in optical light, but APEX is well suited to studying the physical and chemical properties of these clouds. Researchers also have their sights set on the most distant and therefore youngest galaxies, as the expansion of space has stretched their light and shifted it to the submillimeter or millimeter range of the spectrum.

The APEX partners are the Max Planck Institute for Radio Astronomy (MPIfR), the Swedish Onsala Space Observatory (OSO) and the European Southern Observatory (ESO), which operates the telescope on behalf of the consortium. The members recently agreed to extend the partnership until the end of 2022, so the dish on the Chilean high plateau will continue delivering deep insights into the cold cosmos in the coming years.



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Numerous refugees are seeking sanctuary or a new home in Germany. A project at the Max Planck Institute for the Study of Religious and Ethnic Diversity is taking a look at what needs and goals the refugees have and how firm a foothold they are gaining in their new life.

### 26 At the Margins

It's easy to overlook the marginalized. Research, too, has so far paid little attention to the phenomenon of social exclusion. Six Max Planck Institutes have now begun to address this issue and have joined forces to study the exclusion of migrants. Their aim is to uncover exclusion and develop fair rules to regulate migration.

### 34 A Model for Greater Togetherness

*La Convivencia* is viewed as a golden age of peaceful coexistence between Muslims, Jews and Christians in medieval Spain. Researchers at the Max Planck Institutes for Social Anthropology and for the History of Science are examining the myth of this period and its possible function as a model for today's world.

**ON THE COVER** It's just a passport with stamps on its pages – but it is what determines who may enter a given country. In the first instance, it is bureaucracy that regulates who may come and who should stay out. Migration, however, often follows different laws when people are fleeing or searching for a better life. Science is investigating the phenomenon, questioning the rules and exploring the conditions for peaceful coexistence of different cultures.

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# Additional Positions for Excellent Female Scientists

New initiative offers long-term prospects for female junior scientists with outstanding qualifications



With the Lise Meitner Excellence Program, the Max Planck Society is strengthening its commitment to supporting high-achieving women in their scientific careers. Starting in the spring of 2018, up to ten additional Max Planck Research Group positions will be made available each year for female scientists. The positions will be filled through a multi-stage selection process in close collaboration with interested Max Planck Institutes. The Group Leaders will receive a fixed-term, five-year W2-level contract. In addition, they will have the opportunity to participate in a tenure-track procedure that, following a comprehensive assessment, will secure them a permanent W2-level position with group facilities. “This new program offers unique opportunities,” emphasizes Max Planck President Martin Stratmann: “free scientific development, long-term job security and clear career prospects. I am convinced that this will help us attract future Directors.” The Max Planck Society is set to invest more than 30 million euros by 2022 to enhance career prospects for female scientists.

Opening the door for talent: The Max Planck Society aims to enhance its pool of high-calibre female researchers through the Lise Meitner Excellence Program.

## Innovation to Improve Machine Text Comprehension

Spin-off company of the Max Planck Institute for Informatics develops technology to automatically comprehend information

The ability to understand texts correctly remains a challenge for computers, as such content often contains ambiguous terms that are hard to interpret. For example, humans can decipher the meaning of the headline “Sterling tumbles once again” based on the context. An informed reader would recognize that, rather than reporting a drop in the currency market, the article relates to England soccer player Raheem Sterling, a midfielder with a reputation for fall-

ing too easily. For machines, such interpretations are barely possible – yet they are essential if we hope to make comprehensive use of digital content.

To solve this problem, researchers at the Max Planck Institute for Informatics in Saarbrücken created the knowledge base Yago. It’s a semantic database containing more than ten million entities (names, organizations, cities and similar items) and is something like a lexicon for machines. Am-

biverse, a spin-off company from the Max Planck Institute, used the database to develop an intelligent software solution for automatic and accurate recognition and interpretation of ambiguous words and phrases in texts. Ambiverse aims to tailor search and analysis tools to suit companies’ requirements, making them better able to electronically evaluate such data from news archives, company documents and product reviews.

# “Moral courage is needed everywhere”

Anna Baumert is investigating which personality traits enable fearless intervention in the face of injustice

Moral courage is a quality we hold in high regard. But why do we so often hesitate to stand up for justice? And how do morally courageous individuals differ from others? Together with her team, Anna Baumert, Leader of the Max Planck Research Group on Moral Courage at the Max Planck Institute for Research on Collective Goods in Bonn, is currently searching for answers to these questions. One thing is certain: wise and supportive intervention can be learned everywhere – even on a small scale.

*Dr. Baumert, moral courage is often sensationalized in the press. Where does your focus lie?*

**Anna Baumert:** We're concerned with basic research. We investigate situations in which someone commits an injustice, breaks rules or behaves immorally – and is observed by another person. The psychological processes and mechanisms that dictate whether a bystander intervenes against a perpetrator are presumably quite different than, for example, the processes that dictate whether a person helps a stranger.

*So, just how courageous are we humans?*

When an injustice occurs, far fewer people intervene than you might expect. I don't exclude myself from this. I would hope that, if I were to find myself in a sticky situation, I would be prepared to come up with an effective way to intervene. However, research confirms that my thinking that I would intervene doesn't necessarily match the reality. We described a scenario to participants and then placed them in the actual situation. It became clear that there are major discrepancies between intending to intervene and actually intervening. Many people overestimate their will or ability to act.

*But there are always people who intervene in difficult situations. What sets them apart?*

So far, we can only speculate about that. First of all, there is a certain moral dispo-

sition. How conscious is a person of moral issues? How important are their moral principles to them? How strongly do they tend to react with negative emotions when they experience injustice or witness immorality? It's also a question of impulsiveness: How strong is a person's impulse compelling them to intervene in certain situations? Their willingness to break internalized social rules also plays a role. Most of us have learned to conduct ourselves in a controlled manner, manage our emotions and leave others in peace.

*So are these societal norms the reason why few people intervene?*

That's our assumption, yes. In situations where there is a perpetrator who could be detained, a person must first defy numerous internalized conventions. It's not that easy.

*It's also often not clear whether intervention is actually justified or not.*

With actions driven by moral courage, there is certainly a risk of falsely accusing someone – and thus getting yourself into an embarrassing situation. Intervening can be just as much of a mistake as doing nothing. Ultimately, you must ask yourself what the consequences of each “mistake” might be.

*Should I feel bad if I don't intervene?*

From a psychological perspective, there are many hurdles that make not intervening understandable. However, everyone should realize that their behavior impacts the behavior of others. If you remain inactive and do nothing, the risk increases that others will follow suit and do the same. It's important to weigh up each situation. We recommend not always getting right in the middle of something – or you just might find yourself in great danger.

*What should we do if things become precarious?*

Essentially exactly what the police recommend: Engage other people and point the injustice out to them. Look to make



Anna Baumert

allies, get help and then stay on the scene as a witness.

*You're hoping to develop a characterology of courageous helpers through your study. What is your approach?*

We invite people who have shown moral courage in the past to take part in our study. These are people who have been recognized in Germany for their actions. We also issued a more general call for participants who experienced injustice as a bystander and intervened in some way. We send everyone to whom this applies a two-part questionnaire that can be completed online and then analyze their answers anonymously.

*There are training schools for moral courage – can anyone learn to act courageously?*

This is a very individual matter. Schools are positive and helpful, and I'm sure our research findings can also be relevant for such training courses. But it isn't only about major conflict situations; moral courage is needed everywhere – in schools, in neighborhoods and even in the workplace. There are plenty of minor situations in which people can intervene against injustice. Becoming more conscious of injustices is something you can learn anywhere.

Interview: Martin Roos

# Twofold Partnership with Harvard

Max Planck Society launches two new collaboration projects with leading US university

Max Planck scientists work closely with their colleagues at elite US universities in a number of fields. Now two new collaborative endeavors have been established at the institutional level. In October 2017, work commenced on a new center to research the ancient Mediterranean region. The primary focus of the Max Planck-Harvard Research Center for the Archaeoscience of the Ancient Mediterranean is mobility in the Mediterranean region between 1600 and 1000 BCE. The Center will enable scientists at Harvard University in Cambridge (Massachusetts) and the Max Planck Institute for the Science of Human History in Jena to combine established archaeological and historical approaches with state-of-the-art biotechnological methods.

The Max Planck Harvard Research Center for Quantum Optics took up its work in January. One hundred years after the quantum nature of light and matter was discovered, quantum physics is currently experiencing something of a revolution: new techniques are laying the foundations for major discoveries in particle physics and for innovative devices, such as the quantum computer. The joint Center combines the expertise and infrastructure of the Max Planck Institute of Quantum Optics in Garching and Harvard University, offering new ways to address the unsolved problems of quantum physics.



Opening handshake: Mark C. Elliott, Vice Provost for International Affairs at Harvard, with Max Planck President Martin Stratmann at the inaugural ceremony for the joint Research Center for the Archaeoscience of the Ancient Mediterranean.

## Fourfold Success

Four Max Planck Directors awarded this year's Leibniz Prize

The German Research Foundation (DFG) selected 11 successful candidates from among 136 nominations for this year's Leibniz Prize – and four Max Planck Directors were among the winners. Alessandra Buonanno of the Max Planck Institute for Gravitational Physics in Potsdam received the honor for her theoretical models that make it possible to identify and interpret gravitational waves. Erika L. Pearce from the Max Planck Institute of Immunobiology and Epigenetics in Freiburg was honored for her exceptional research

into metabolism and immune processes. The prize was also awarded to Jens Beckert of the Max Planck Institute for the Study of Societies in Cologne in recognition of his accomplishments in renewing an interdisciplinary perspective in social sciences, particularly at the interface of sociology and economics. The fourth member of the Max

Planck Society's prizewinning quartet is Bernhard Schölkopf of the Max Planck Institute for Intelligent Systems in Tübingen. The computer scientist has made key contributions to the theory and success of machine learning. The prizes, which carry an endowment of 2.5 million euros, were awarded at a ceremony in Berlin in March.



The triumphant four (from left): Alessandra Buonanno, Jens Beckert, Erika L. Pearce and Bernhard Schölkopf receive the Leibniz Prize 2018.

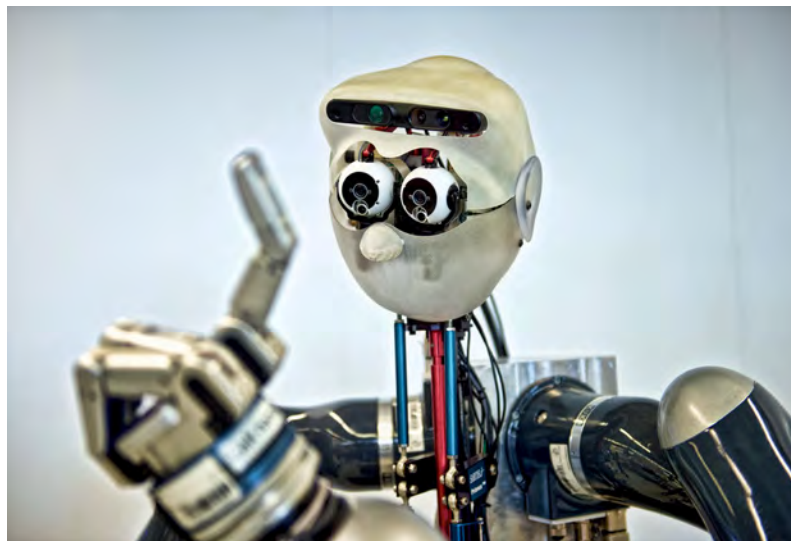


# Amazon Arrives in Cyber Valley

The technology company is supporting a project to develop artificial intelligence in the Stuttgart-Tübingen region

Cyber Valley has gained another industry partner: Amazon wants to take part in the research project initiated by the Max Planck Society in December 2016. The technology company plans to contribute 1.25 million euros to research groups in the Stuttgart-Tübingen region over the coming years. Furthermore, Amazon will establish a research center of its own near the Max Planck Institute for Intelligent Systems in Tübingen and intensify its collaborative work with the Max Planck Society. Max Planck President Martin Stratmann welcomed the decision, saying: "We are gaining yet another strong partner that will further enhance the international significance of the research in Cyber Valley."

For the collaborative project – one of Europe's largest initiatives in the field of artificial intelligence – the Max Planck Society has joined forces with the German federal state of Baden-Württemberg, the universities of Stuttgart and Tübingen, and such companies as BMW, Bosch, Daimler, Porsche and ZF Friedrichshafen. The aim is to promote research into intelligent systems and create a suitable environment for a series of successful spin-offs.



An example of Cyber Valley success: Apollo the robot is expected to learn to move autonomously at the Max Planck Institute for Intelligent Systems.

## On the Net



### How to Reach 100 – and Enjoy It

That's the motto of "A Life Journey," a demographic app produced by Population Europe in Berlin. In addition to texts, infographics and videos, the app for iPad and iPhone includes a series of interactive games to introduce users to the topic of demographic change, for example by letting users calculate their life expectancy. The app, which is available in ten languages, is aimed primarily at students and teachers seeking an enjoyable method to explore demographic topics. A tutorial explains how to use the app, and additional teaching resources and webinars round out the app's content.

[www.population-europe.eu/video/how-use-app-life-journey](http://www.population-europe.eu/video/how-use-app-life-journey)

### In the Heart of Wendelstein 7-X

The new 360-degree panorama on the Max Planck Institute for Plasma Physics (IPP) website leads straight into the plasma vessel of the Wendelstein 7-X fusion research facility in Greifswald, Germany. Visitors to the website can also explore the experiment hall and visit the facility that heats plasma to several million degrees Celsius. Using a PC, tablet or smartphone, they can gain insight from every angle and zoom in to see even the smallest detail. With the click of a mouse, visitors can start and stop short videos in which IPP scientists describe their workplace, while pop-up information panels explain key components. The panorama was captured by Munich-based photographer Volker Steger, who previously produced the panorama of the IPP ASDEX Upgrade fusion device in Garching, near Munich.

[www.ipp.mpg.de/panoramaw7xeng](http://www.ipp.mpg.de/panoramaw7xeng)

### Computer Vision

The International Max Planck Research School for Intelligent Systems (IMPRS) has launched an introduction video aimed at students who have obtained an outstanding master's degree and want to do extraordinary research in the field of intelligent systems. This interdisciplinary PhD program offered by the Max Planck Institute for Intelligent Systems, the University of Stuttgart, and the University of Tübingen has 29 PhD students and 21 faculty members working in different areas of intelligent systems, including computer vision, machine learning, robotics, haptics, control systems, perceptual inference, computer graphics and micro- and nanorobotics. The School is looking for young people with new ideas on how to shape the future.

[www.youtube.com/watch?v=MXrW\\_yXJUal](http://www.youtube.com/watch?v=MXrW_yXJUal)

# The Power of Humiliation

Rituals of degradation have been used throughout the ages as a means of exercising authority. Judges made a public show of people by having them placed in the pillory, teachers made unruly pupils the object of ridicule with dunce caps. Such practices have been consigned to the past, but modern society has developed new methods for publicly stigmatizing outsiders, as our author describes.

TEXT **UTE FREVERT**

**T**he mention of public humiliation often conjures up images of pillories, flogging and branding, but one might wonder what such practices of public degradation and ridicule have to do with modern society. After all, these kinds of punishment began disappearing from European criminal codes in the mid-19th century, albeit only after lengthy disputes and bitter confrontations.

But just because European states have moved away from such humiliating practices certainly doesn't mean that they no longer exist. People are

rarely suspended. And as if that weren't enough, she also imposed what Americans call a shame sanction: an act of public humiliation intended to publicly stigmatize Hardin as an idiot. Such sanctions are intended not only to punish and discipline people, but also to educate and improve them, very much in the style of the 18th and early 19th centuries.

The US was also the setting of the story of 13-year-old Izabel Laxamana. In May 2015, she jumped from a bridge in the state of Washington because she couldn't bear the public shaming inflicted upon her by her father. Incensed by a selfie showing his daughter in a sports bra and leggings that was circulating at Laxamana's school, he cut off her long hair and filmed her while doing so. When the video spread and became the subject of classroom gossip, Izabel took her own life.

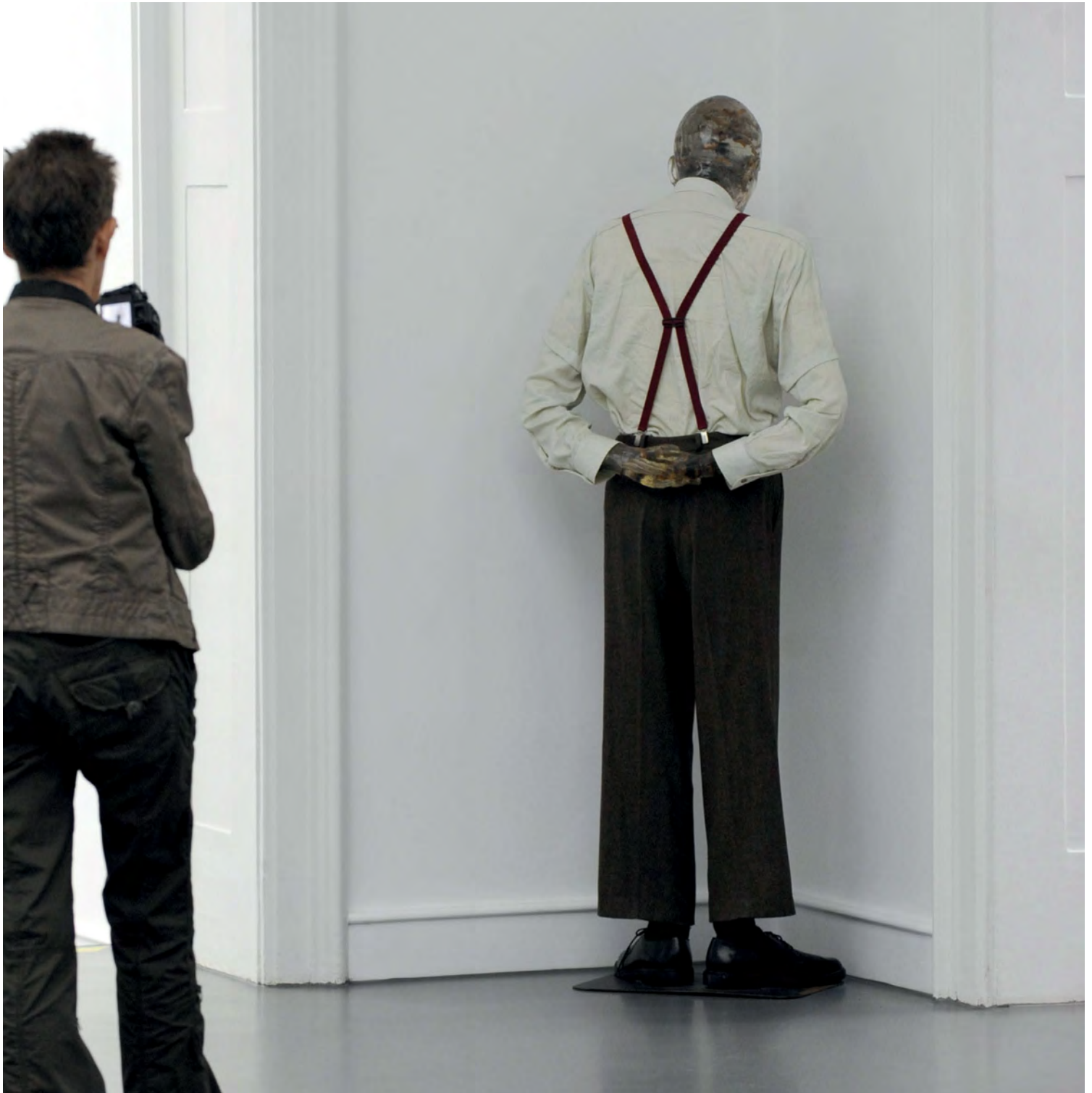
Yet here in Germany, too, such public humiliation and shaming is omnipresent – not solely, but overwhelmingly, online. Until recently, there was a platform where drivers could make their negative feelings known about other commuters while clearly identifying who they meant, to boot. In 2017, a foundation

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**Even here in Germany,  
such humiliation is omnipresent –  
especially online**

still publicly demeaned, ridiculed, treated with contempt and put in a virtual pillory. Take, for example, an incident from November 2012 in Cleveland, Ohio (USA), when Shena Hardin stood at a busy intersection holding a sign that read: "Only an idiot would drive on the sidewalk to avoid a school bus." Hardin had done just that on numerous occasions. The judge ordered her to pay a fine and had her license tempo-

Exposed for all to see: With his sculpture "Martin Into the Corner, You Should Be Ashamed," artist Martin Kippenberger addresses humiliating rituals that were commonplace during his school years in the 1960s. The approving gaze of others only intensifies the victim's shame and embarrassment.



close to one of the major political parties published an online lexicon of anti-feminist networks, organizations and individuals; widely seen as a form of denunciation, it was ultimately taken down by its publishers. New shaming platforms where people are mocked for supposedly being too fat, too thin, too promiscuous and so on appear each and every day.

But where does this need to showcase and publicly attack other people – even one’s own children – originate? What is such humiliation and shaming supposed to achieve, and what effects does it have? Why are such practices widespread even in societies that place great emphasis on dignity and respect? Are

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## An emotion of immense force and potency that has deadly potential

the “dark Middle Ages” in fact alive and well? Or is the bright, enlightened, sophisticated modern era exercising its own particular will to humiliate and inventing new methods of shaming to go with it?

Public humiliation is always a demonstration of power: By forcing others to their knees in front of onlookers, social protagonists reinforce their claim to an elevated position of power. “Power,” argued sociologist Max Weber, “is the probability that one actor within a social relationship will be in a position to carry out his own will despite resistance, regardless of the basis on which this probability rests.”

It was in this sense that Izabel Laxamana’s father exercised power over his daughter. He had forbidden her to post selfies on the internet, and when she defied him, he punished her with a humiliating act that he documented for public viewing. Those who operate their own online pillories aspire to hold power over people who they view as morally or socially inferior to themselves, a feeling that the act of shaming serves to reinforce.

Shame, as the philosophers of antiquity already knew, is a feeling of immense force and potency. It can be deadly, and it leaves an indelible mark on those who survive it. Anyone who has ever experienced deep, intense shame will struggle to free them-

selves of the memory. The presence of others when acts of shaming and humiliation occur is extremely important. Of course, it is possible to be ashamed of oneself for a thought or action that runs counter to social mores or one’s idealized self-image. For example, I might feel ashamed for envying a colleague’s well-deserved promotion. The same feeling would creep over me if I looked on gleefully as my boss gave a colleague a public dressing-down. Today, public humiliation is usually considered an intolerable abuse or even a violation of human dignity; accordingly, if I take pleasure in such actions, I should be ashamed of myself.

But what is it that makes humiliation so repugnant? It’s the painful knowledge of the power and violence of the public gaze – a gaze that can’t be cast off, that burrows under the skin and clings to the very body of the shamed individual. When other people witness individual mistakes or violations of social norms, it churns up feelings of shame, and the more a person values others’ estimation of them, the greater the shame they feel.

A child who steals a piece of bubble gum despite knowing that this is forbidden may secretly feel ashamed. If you were to catch the child in the act and inform their parents, they wouldn’t even need to scold the child: “You should be ashamed!” to evoke that emotion. Being exposed for all to see is enough to make the child blush and leave him or her wanting only one thing: to escape the humiliating gaze of those present.

This is why psychologists refer to shame as a social or interpersonal emotion. In most cases, shame is felt in the presence of others. In fact, in one survey, only a sixth of interviewees said they experienced shame as a private emotion. The very social embeddedness of shame makes it powerful and dangerous, and some people are willing to risk life and limb for fear of being shamed. In Erich Kästner’s classic children’s novel *The Flying Classroom*, for instance, young Uli jumps from a tall ladder to prove that he isn’t a coward. His schoolmates had frequently teased him for his lack of courage, making him turn “bright red.” While his leap did land him in the hospital with serious injuries, it also silenced his taunters and tormentors.

First published in 1933, Kästner’s book is set in a world where cowardice was one of the worst viola-



tions of norms for young males. Boys had to be courageous and ready to prove it. If they didn't, they were subjected to contempt, rejection and even exclusion from the group. Uli had accepted and internalized this, and doing something daring was the only thing he could think of to bring an end to the teasing. This wasn't the case for Izabel Laxamana: she was presumably not ashamed of having ignored her father's ban by posting pictures of herself scantily clad online. His perceptions of morals and decency weren't necessarily the same as hers. It was the punishment exacted by her father that shamed her, and in particular the public dissemination of the film he made of it.

These and many other examples clearly demonstrate the effects of public humiliation. Beyond illustrating the perpetrator's power to document and rebuke what they consider to be a violation of a norm or expectation, the examples also demonstrate the power of witnesses, whether real or imagined. The drama of power and impotence, shame and disgrace, perpetrators and victims, is always played out on a public stage. The audience can approve of the humiliation and exacerbate it – but they can also refuse to do so. Power relationships can be reversed, and the shamers can be shamed. Modern history provides plentiful examples of such instances: from gradual distancing to widespread criticism, from individual protest to collective revolt.

It is often said that the experiences of the Second World War did much to promote resistance to humiliation and shaming and that they inspired a culture of respect and mutual recognition. In fact, the preamble to the United Nations Charter of 1945 professes a belief in "the dignity and worth of the human person." In 1948, Article 1 of the Universal Declaration of Human Rights declared: "All human beings are born free and equal in dignity and rights." Germany's Basic Law, approved in 1949, proclaims human dignity as an inviolable, fundamental right and obligates the state to observe and protect it.

However, the notion of human dignity and the rights of individuals founded on it have been around for a long time. In the 18th century, human dignity was used as an argument by those who criticized degrading forms of punishment and demanded their removal from the legal system. From this perspective, the modern world appears as a place that confronts

the destructive power of social and political humiliations with equally strong instruments for protecting individual honor and dignity.

However, contemporary societies continue to use shame and humiliation as a means to exert social and political power – and some even view them as constructive methods. If, for instance, a person is lambasted in public for falling short of the normative expectations of their group, this does more than simply punish them. It also serves to reintegrate the individual into the group, provided, of course, that the individual regrets what he or she has done. Stigmatizing humiliation, on the other hand, serves to exclude an individual with no chance of return.

When German Wehrmacht soldiers cut off the beards of Jewish men in occupied Poland, or when Serbian soldiers and militiamen intentionally and systematically raped Muslim women in the Bosnian War of the 1990s, the point was neither punishment nor reintegration. Rather, the aim was to demonstrate the soldiers' power and denigrate members of another social group to such an extent as to permanently damage or even destroy their sense of dignity.

Both forms are planned and coordinated, and both take place in public. They are neither spontaneous nor random. Rather, they adhere to well-thought-out scripts and have a ritualistic structure. In this sense, one can speak of humiliation as a form of politics. It is a strategy that serves to reinforce power, that involves the participation of numerous actors, and that takes place in various settings and situations.

But targeted, deliberate acts of humiliation aren't the prerogative of institutions like the family, schools or the military, where they are primarily meted out from above. They also rear their ugly head among students or work colleagues. Such practices are even common in international politics, where the logic of power, honor and respect is played out even more unabashedly than in social relationships. If a country fails to give satisfaction and apologize after injuring the honor of another, war can be the end result, as happened between France and Prussia in 1870.

If the war ends in a peace agreement that humiliates the loser, as was the case with Germany, Austria and Hungary in 1919, renewed hostilities become more likely. In such instances, politicians and diplomats would be wise to tread lightly and avoid humiliating



their counterparts. On the other hand, they may choose to play with fire and inflict a dose of humiliation in order to secure an advantage in domestic or international power struggles.

An incident from 2010 illustrates this well. When a Turkish television channel aired a series that denounced Israeli soldiers as child murderers, Israel's Deputy Foreign Minister, Danny Ayalon, summoned the Turkish ambassador. Before the meeting, Ayalon told the reporters present that they would be witnesses to an act of symbolic humiliation: the ambassador would sit on a lower chair, the Turkish flag would fall,

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### A foreign diplomat is degraded by an ally in front of rolling cameras

and the Israelis wouldn't grant the diplomats so much as a smile. The deliberate staging wasn't lost on the Turkish government, which responded with a sharply worded protest and declared that the entire Turkish people had been humiliated. President Abdullah Gül demanded that Ayalon publicly apologize, which he refused to do. It was only following the intervention of Israeli President Shimon Peres – who feared for the then positive relationship with one of Israel's most important regional military allies – that Ayalon brought himself to declare that it was “not his way to insult foreign diplomats.”

Yet this wasn't enough for the Turkish government and, after another day of frantic diplomatic back and forth, Ankara's ambassador finally received a letter that read as follows: “I had no intention of humiliating you personally and apologize for the way the demarche was handled and perceived. Please convey this to the Turkish people, for whom we have great respect.”

Ayalon used diplomatic language, a lexicon that has been developing since the Early Modern Era. A relatively new addition to the repertoire, however, was the reference to “the (Turkish) people,” who were to be informed of the apology and for whom Ayalon expressed his respect. After the French Revolution, the affairs of the state became the affairs of

the entire nation, and the honor of the state – formerly held by its rulers – passed over to the nation. Consequently, violations of this honor affected each and every citizen.

This was why the Turkish government could declare that the humiliation of its representative had humiliated the nation itself, which in turn explains why the Israeli minister apologized to both the Turkish ambassador and the Turkish people. This isn't the only example of how modern international relationships often play out in front of a large, deeply interested public and are thus often highly dramatized. When diplomacy is conducted in front of cameras, humiliating gestures and words take on a force that was unthinkable in times when politics were shrouded in secrecy.

Processes of nationalization and democratization have been just as important for the international politics of humiliation as the media that disseminate and comment on it. Media outlets are increasingly becoming actors in their own right: they can identify violations of norms, sniff out and hype up alleged humiliations, and demand corresponding sanctions. They can also dish out humiliation themselves as they mock and caricature both foreign and domestic politicians, dragging them through the mud.

Current events continue to provide us with new examples of this. In 2016, for instance, German television personality Jan Böhmermann's poem of smears against Turkish president Recep Tayyip Erdoğan made waves internationally, causing Turkey's Deputy Prime Minister Numan Kurtulmuş to declare that the poem was a defamation of all 78 million Turkish citizens. Erdoğan not only brought a private libel suit against the satirist, but also wanted to see him prosecuted under Section 103 of the German Penal Code, which prohibits defaming organs and representatives of foreign states.

Unlike the laws on the books, which make a clear distinction between insult and slander (but contain no provisions on humiliation and shaming), our day-to-day language doesn't clearly differentiate between these practices of degradation and debasement. On the one hand, this is due to hybrid types of castigation that straddle the lines between the two, which are increasing in both form and frequency. When the forces that bind social groups are weakened and people are given more liberty to choose between dif-

ferent forms of belonging, classic methods of shaming lose their old power and sources of legitimacy. At the same time, new institutions and associations arise and create new practices of degradation, often under the auspices of rituals of initiation.

It isn't always possible to detect straight away whether such practices serve as normative, integrative sanctions or as acts of categorical exclusion. Homosexuals may be openly shamed if their sexual orientation is treated as an illness to be cured, as was once common practice and remains so in many countries even today. However, some societies also treat homosexuals in a humiliating, radically stigmatizing and exclusionary manner.

On the other hand, language changed considerably over the course of the 19th and 20th centuries. The issue of dignity came to the fore, while the concept of honor, once a guiding principle, lost its attraction. Accordingly, humiliation became a more common topic in public discourse while talk of shame was relegated to secondary importance. Despite this, it is often difficult to distinguish between the meanings of honor and dignity. When the German Federal Court of Justice ruled in 1957 that honor and decency were aspects of the "inalienable dignity of the human person, bestowed upon them at birth," it was repeating the prevailing view held by more people than just legal experts. However, in doing so, the court also recapitulated that view's lack of conceptual precision, which makes it nearly impossible to draw a clear dividing line between shaming and humiliation.

Yet this dividing line does exist in the perception of emotions that accompany such practices. A person who is shamed for violating the norms of their group or collective might feel a mixture of shame and regret, provided that they have emotional ties to these norms and to the group that adheres to them. But a person who is humiliated, stigmatized and excluded because they are different would feel embarrassed only if they considered their own otherness as something negative.

In this sense, an individual might feel ashamed of their social or ethnic heritage just as they might be of their sexual orientation or physical appearance. Yet this person won't feel regret for these things, as they have all come about without any action on their part and can't be controlled. ◀



## THE AUTHOR

**Ute Frevert**, born in 1954, is one of Germany's most prominent historians. She has taught modern history in Berlin, Konstanz and Bielefeld. She was a professor at Yale University from 2003 to 2007 and has headed the Center for the History of Emotions at the Max Planck Institute for Human Development in Berlin since 2008. She was awarded the German Research Foundation's Leibniz Prize in 1998, and received the Federal Cross of Merit, First Class in 2016.



# Braving the Forces of Nature

Max Planck scientists cooperate with partners in more than 110 countries worldwide. Here they relate their personal experiences and impressions. Marine biologist Greta Giljan is a doctoral student at the Max Planck Institute for Marine Microbiology in Bremen. She reports on a research expedition to the Irish Sea, on heavy storms, problems with equipment weighing several tons, and crew unity.

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When I look out at the clear Irish Sea from aboard the British research vessel *Cefas Endeavour*, it's difficult to believe that there are millions of microscopic creatures living in it. These guarantee that fundamental processes and cycles on our planet function properly, and that's why I find them so interesting.

With my deep-sea incubator, I collect and incubate them in their natural environment – the Irish Sea – at depths of up to 100 meters. But this requires painstaking dexterity: when we lower the device, which weighs just under a ton, it is connected to the research vessel only by a steel rope, a cable and a cable winch. There were powerful storms for the first eleven days after departure, so there was a substantial risk that these connections would snap and that we could lose the incubator, or that it would smash against the ship's hull.

All we could do was wait – and anyone who knows how valuable ship time is understands how frustrating this can be. Ultimately, I'm on my own, one of many marine researchers on board. And I'm glad I was able to come along, but irretrievable time was lost due to the storm. And even





**Greta Giljan**, 25, studied biotechnology in Darmstadt, Germany before coming to the Max Planck Institute for Marine Microbiology to complete her bachelor's thesis, which was followed by her master's thesis. Since September 2016, Giljan has been working on her doctoral thesis with Bernhard Fuchs in the Department of Molecular Ecology, where she researches the metabolic activity of a variety of marine populations with small genomes. It is thought that these populations can express only a few metabolic enzymes themselves and are therefore dependent on absorbing nutrients from the water column. In 2018, Greta Giljan is also serving as the Max Planck PhDnet treasurer.

an attempt to plot the route of the ship so that we would avoid the storm wasn't fruitful. Despite this setback and my dwindling motivation, I wasn't ready to give up yet. Heartened by the encouraging words of the crew, who initially doubted that deployment would be possible, I hadn't lost the hope of calm seas. At sea, you stick together.

And then the weather suddenly took a turn for the better. Now everything needs to run smoothly, every plan needs to work in order for the colossus to finally be lowered into the depths. But only now, in the hands-on situation, do we realize that, despite all our planning, communications with the device don't work! Fortunately, I'm in constant e-mail contact with our technicians at the Max Planck Institute, who can give me important tips thanks to their many years of experience. What on earth did researchers do in the past, without the internet?

I enjoy optimal conditions for my work as a marine researcher at the Institute in Bremen. I am fulfilling a childhood dream. As a child, I watched numerous documentaries about fish and the oceans, and I found the work on the research ships, in particular, so fascinating that I wanted to go along one day, too. All in all, it's even more diverse than I had imagined. After all, we environmental researchers aren't constantly outdoors in the wild, but spend a large part of our time at the computer. Data needs to be analyzed, visualized and evaluated – and this is where the real core of our work begins: delving deeper into the data and discovering what information it contains about our global material cycles.

Despite my fascination for marine research, it's difficult to make plans for the future. Of course it's all incredibly interesting, but the experience gained as a Max Planck doctoral student can also be put to good use in other professional fields. For example, the ability to organize oneself in everyday research, to convey newly gained insights, and sometimes to take a different perspective on things. At the moment, though, I'm focusing on analyzing my hard-won samples. Then I'll explore which waters I can lower my incubator into next – let's hope for a calm sea.



# Every Room Is Its Own Culture

Since 2015, around 1.4 million refugees have applied for asylum in Germany. They would like to find sanctuary or a new home here. How firm a foothold they gain in their new life depends on a number of factors. Researchers at the **Max Planck Institute for the Study of Religious and Ethnic Diversity** in Göttingen are taking a closer look at what needs and goals the refugees have – and whether these can be fulfilled.



TEXT **TIM SCHRÖDER**

**M**any people will remember 2015 for a long time to come. In the course of just a few months, Germany and many other European nations experienced a refugee influx unlike any seen since the Second World War. In Germany alone, the number of asylum applications that year approached 500,000 – from Syria, Iraq, Afghanistan and other countries. That's 500,000 cherished dreams of a better future; 500,000 men, women and children, each with their very own

personal life story, each with their very own dreams for the future.

The course of their future life in Germany began taking shape with the first shelter they were placed in. Many refugees lived in large halls in which sleeping quarters were separated from one another only by simple partitions. Sometimes more than ten people had to share living space. There was constant noise because the separate compartments weren't allowed to have ceilings. Other refugees were sheltered in apartments, providing greater privacy.

Difficult conditions: Refugees who are housed in factory buildings on the outskirts of the city are at a disadvantage in many ways. Not only is there a lack of quiet and privacy, but often also of shopping opportunities, medical services and volunteer helpers.

“Overall, Germany did a good job finding shelter for all these people within a short period of time – everyone had food to eat and a roof over their head,” says Shahd Wari at the Max Planck Institute for the Study of Religious and Ethnic Diversity in Göttingen. “The numerous initiatives of administrative

» The feeling of arbitrariness and powerlessness is one of the biggest problems for many asylum seekers.

bodies and of the many volunteers achieved a great deal.” However, the researcher and her colleagues at the Institute are interested in the details. Above all, they want to understand how the asylum seekers themselves perceived their situation.

In a study financed by the Volkswagen Foundation, the researchers investigated what needs and goals the refugees have – as well as what their initial conditions were upon arriving in Germany. Research was initially carried out in Göttingen – both the city and the surrounding district, which together have taken in around 1,500 refugees in

the past two years. The researchers accompanied asylum seekers in their day-to-day life and interviewed them. They spoke with the operators of refugee accommodations and with experts from government agencies and the administration, as well as with social workers and independent volunteers.

#### THE AUTHORITIES ACKNOWLEDGE ONLY FIVE CATEGORIES

“Our results are both simple and extremely complex: unlike what media reports suggest, it became clear that there isn’t just *one kind of* refugee,” says

Shahd Wari. “The personal backgrounds of the people differ greatly. This means that there can be no one-size-fits-all solution if we want to help asylum seekers establish a firm foothold in Germany.”

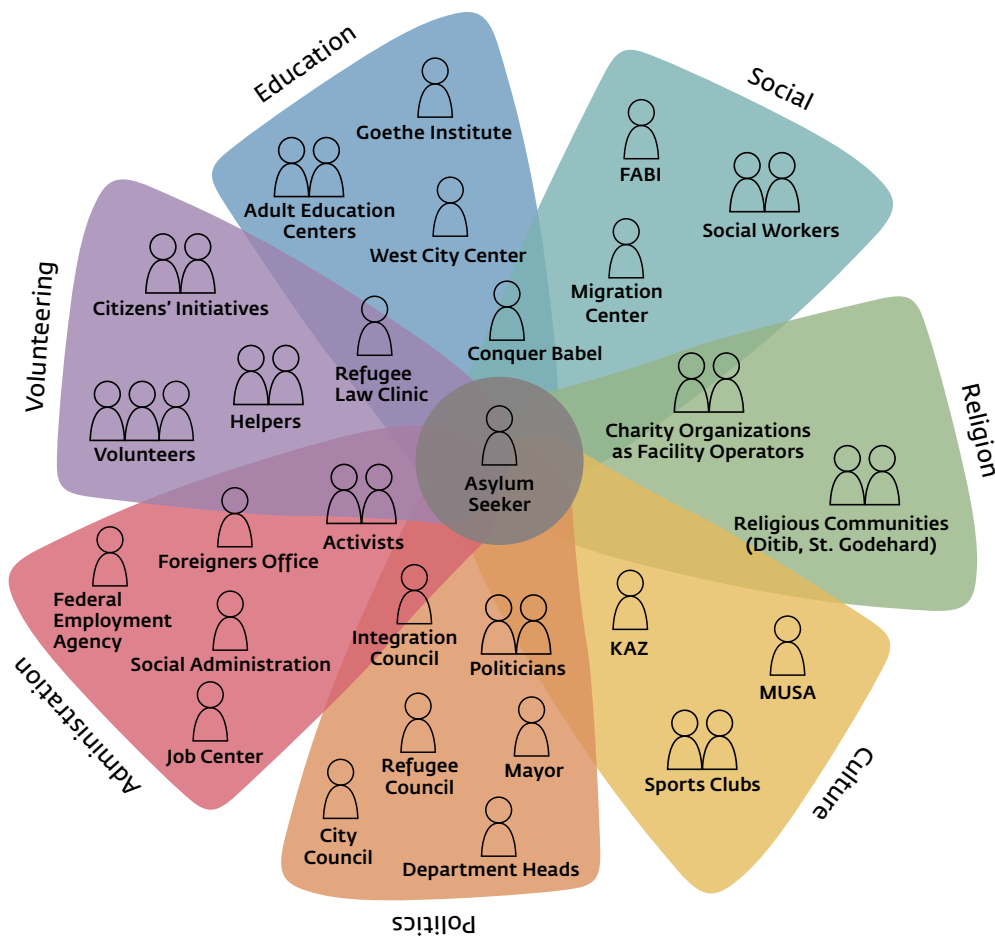
This insight seems almost trivial – after all, it is well known that people differ from one another. Yet the individuality of asylum seekers is often given little consideration in day-to-day life. It begins with authorities simplistically assigning asylum seekers to one of five categories based on nationality, gender, age, health and legal status. These categories are also often used when placing asylum seekers in refugee accommodations. Such a basis for classification is extremely crude and can give rise to conflict.

To give just one specific example from Göttingen: four women live together in a room in a collective accommodation. Two of them fall into the same five categories of the classification system, but their needs for privacy are very different. One of them would like to take off her headscarf when she is in her room, but she’s afraid of being seen through the window. The operator therefore placed a privacy film over the window so no one can see into the room. The other person, in contrast, perceives the privacy film, not as something that protects her privacy, but as something that limits her ability to look out the window, and therefore feels like she is in a prison.

“The goal of our study initially was to understand the needs and aspirations of asylum seekers. After all, we are conducting basic research,” explains Shahd Wari. “On the other hand, our in-depth insight has led to the development of some ideas as to how conditions could be improved.” For example,

Basic knowledge: Only those who learn German can gain a foothold here. However, asylum seekers aren’t eligible for a paid German course as long as their asylum procedure is still pending – which can take months.





Confusing complexity: Asylum seekers are confronted with numerous different contacts. The Göttingen-based research project clearly showed just how difficult it is for them to understand who is responsible for what.

it would make sense to look beyond the five main categories when providing accommodation.

In this regard, it would help if agency employees were to learn more about the various social and political backgrounds in the countries of origin – and not just with regard to differences between traditional and modern ways of life. It’s also important to consider various social strata and ethnicities that have conflicts in their country of origin, as can be the case with Kurds and Arabs in Iraq. This would reduce the potential for conflict in the accommodations.

In many cases it is a question of profoundly human characteristics – individual desires that are rarely taken into consideration in daily life, says Shahd Wari. For example, in some accommodations, many people must share one kitchen and one set of washing facilities – people with very different habits and needs when it comes to order and cleanliness. “It is precisely in collective

accommodations that more conflicts are reported, which is perfectly understandable in light of human nature,” says Shahd Wari. In one building, there were disputes relating to a television that had been donated. There was constant commotion in the hallway where the television had been installed. People came from other parts of the building at all hours of the day and night, so those who wanted to go to bed early could hardly get any rest.

### **BOTH SUBJECTIVE IMPRESSIONS AND FACTS ARE IMPORTANT**

What’s special about the study of the researchers in Göttingen is that it’s one of the first of its kind to use scientific interview methods to systematically investigate the situation of asylum seekers. “At the peak of the refugee crisis, many decisions were made on an ad hoc basis without undertaking a precise analysis of the situation of the asylum

seekers. And perhaps there was no other way to go about it,” says Wari. The study the researchers now present is a sort of well-paced status quo report.

In expert interviews with operators and representatives of government agencies, the researchers inquired about the financing and organization of the accommodations. Focus group discussions, in turn, provided the researchers with more information about the needs of the asylum seekers: in these groups, several asylum seekers met to discuss their family situation, their concern for those left behind, and other topics such as daily life in Germany. The interviewers refrained from asking too many questions and let the conversation take its course.

“We also spent a great deal of time with individual asylum seekers, went on excursions with them or accompanied them on visits to the doctor or appointments with the authorities,” says Shahd Wari. In the terminology of social scien-



tists, this is known as the hanging-out method – spending time together to learn more about the needs and viewpoints of others. “Now, when I walk through Göttingen, I often meet people who greet me and ask if I can help with this or that, for example translating a letter from the authorities.”

### A GOOD START DEPENDS ON CHANCE

The researchers spent an entire year on the study and also attended many public events on the topic of asylum seekers. During this time, they learned that the desires of many asylum seekers – a job, a place in a kindergarten, an apartment – are, of course, the same as those shared by many Germans.

In addition, asylum seekers have problems that few Germans have first-hand experience with – primarily as regards the enormous uncertainty involved, such as the long-term perspec-

tive. Asylum seekers have different chances of being recognized and allowed to stay in Germany depending on their country of origin. “The situation is also difficult because the refugees must sometimes wait several months for a hearing with the federal authorities,” says Shahd Wari. “During this time, they aren’t allowed to take German courses. It’s difficult to make one’s way in a foreign country without sufficient knowledge of the local language.”

Another point of concern for many asylum seekers is the feeling that they aren’t in control of their lives and are more or less governed by outside forces. “To a great extent, a good start in Germany depends on chance,” the researcher says.

There are a variety of reasons for this: for one, the regulations vary from one German state to the next, and sometimes even from one city to the next. In some federal states, for instance, official asylum seekers are obli-

gated to remain in the location to which they were originally assigned. Lower Saxony imposes no such residency requirement. Moreover, many new rules have been added since 2015, in part due to new statutes. As a result, asylum seekers can be treated differently depending on which set of rules is being applied. “It leads to frustration and uncertainty when one asylum seeker is placed in a worse position than another although they are both in the same situation or live in the same accommodation,” says Shahd Wari.

For example, in some cases, asylum seekers had different amounts of money allotted to them each month: “We know families for whom this makes it difficult to plan a monthly budget for food or clothing.” Those affected are bothered primarily by the fact that they can’t comprehend the reasons for it. The basis for calculation is often not clear. In other cases, detailed explanations are available only in German.

**Left** Human needs: The researchers in Göttingen categorize what each individual views as important. Some desires are rather personal, but many are fundamental and easy for everyone to understand.

**Right** Different perspectives: As an architect and urban planner, Shahd Wari (left) concentrates on spatial conditions and needs, while ethnologist Annett Fleischer (right) investigates living conditions.



There are also differences in accommodations. Some asylum seekers have the good fortune to quickly be allotted their own apartment – others live in a collective accommodation for more than a year. “This feeling of arbitrariness, of powerlessness is one of the greatest problems for many of the asylum seekers we spoke with,” says the Max Planck researcher.

Shahd Wari herself is from Palestine and speaks Arabic. “I was easily able to hold conversations with asylum seekers from Syria or Iraq. This helped enormously to establish trust.” Nevertheless, many asylum seekers are hesitant about opening up to others – because they experienced so many terrible things in the course of their flight, but also because so many institutions are involved. Government authorities, charitable institutions, translators from official offices and private individuals. Who can be trusted? Who has a say? Who is merely offering good

advice? Many were afraid of saying something wrong, of uttering something that would endanger their chances of receiving asylum, says Shahd Wari. “As a result, some don’t trust the official translators in the government offices. Under these circumstances, it would help if the asylum seekers could bring along a trusted person who could help with translation.”

#### THE RESEARCHERS WERE ABLE TO ESTABLISH TRUST

Shahd Wari came to the team as an architect and urban planner, so she is especially interested in the spatial needs of the asylum applicants and in architectural aspects of the accommodations. Sociologist Susanne Becker and ethnologist Annett Fleischer also worked with the team and generally devoted themselves to the living conditions of the asylum seekers. The study is currently entering its second phase.

Cultural anthropologist Simona Pagano is new to the team. “One insight we arrived at during the first study is that many asylum seekers who are housed in different types of refugee accommodations have differing degrees of success in gaining a foothold in daily life,” she says. “We want to understand more precisely just which factors are crucial here.” During the second phase, Pagano would especially like to investigate whether there are differences between different accommodations and locations – even when the operator is the same. She will work on this project not only in Göttingen, but also in Wolfsburg, to enable better comparisons.

There are already initial indications of why various accommodations do, in fact, offer differing starting conditions. Location can play a role. Housing on the outskirts of the city, for instance, has the disadvantage of poor accessibility. Buses run less often, it takes longer to reach the city, and likewise to travel

to appointments with authorities and doctors – or even to informational events at which asylum seekers can receive important tips on day-to-day life or exchange views with one another. “But that’s just one factor,” says Simona Pagano. “We want to gain a clearer understanding of why one refugee accommodation is more successful than another.” More successful in that asylum seekers there quickly adapt to daily life.

### MIGRANTS SHOULD BE ABLE TO PARTICIPATE IN DAILY LIFE

Simona Pagano doesn’t like to use the word “integration.” She prefers to speak of participation. “Social scientists and migration researchers regard the concept of integration as too nebulous, as it is very vague about what it takes for people to gain a foothold in a society.” Moreover, it is often conflated with the concept of assimilation – which describes how people adopt customs, traditions and rules of a society in order to blend in.

Participation is more accurate. What form this participation takes can vary from one person to the next, says Pagano. For one person, money and work are important, and for another, social contacts or privacy. “In principle, the key is to be able to participate as much as possible in all aspects of normal daily life.”

In interviews for radio stations and newspapers, the researchers in Göttingen have often been asked what constitutes “successful integration.” “If only it were that simple,” says Wari. “For me, the first step is to understand that there isn’t just one kind of refugee.” The circumstances are different for every refugee – in terms of their background as well as the living con-

ditions in the refugee accommodations or the city in which they live.

Steven Vertovec, Director at the Max Planck Institute in Göttingen, emphasizes that migrants have highly diverse social skills and backgrounds that, from the outset, make it easier or more difficult for them to find their way in Germany: “Some asylum seekers are able to develop cordial relationships with the local population even if they don’t have good language skills. Others learn German well, find a job, and still have hardly any social contacts.”

All of these differences accumulate in the accommodations. “One refugee summarized the situation quite eloquently to my colleague Susanne Becker,” says Shahd Wari: “In his opinion, every room is its own culture. That hits the nail on the head.” The researchers have also noticed this based on how incredibly difficult it sometimes is to find a suitable translator. “There are many who can help with Arabic, but for a refugee from a mountain region in Iran, from Balochistan, one could look for months and still not find a translator, making a hearing with the German Federal Office for Migration and Refugees impossible.” And even if a transla-

tor is available, it is often difficult to establish a good rapport with the refugee, because very private matters surface very quickly.

For many asylum seekers, the road to self-determination and a secure daily life in Germany is long. Above all, the initial steps are difficult. Simona Pagano, Shahd Wari and Susanne Becker now want to find further answers to the question of how this road can be made less rocky in the future. The researchers have since become friends with many asylum seekers. “We spend a lot of time together, even completely independently of our working hours,” says Wari.

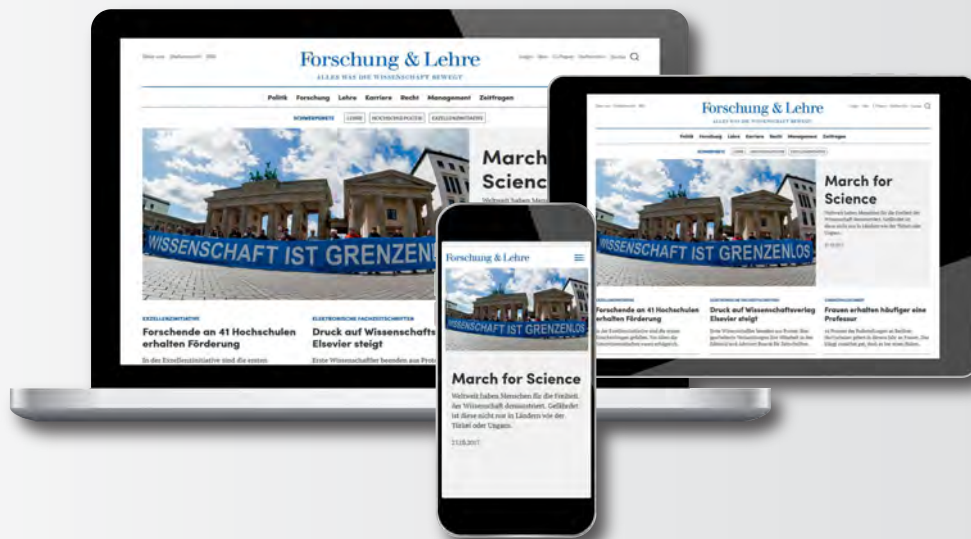
During the year of the study, she particularly enjoyed one meeting place – a cafe in Göttingen where locals and asylum seekers could easily meet and chat. What was special about it was that only one of two drinks ordered had to be paid for. The one for the asylum seeker was on the house or paid for by other guests. Any places where people can forge contacts are very important to Shahd Wari – group hobby courses, group breakfasts. “There are numerous options. What’s important, in the end, is that solidarity and cooperation are established between refugees and locals.” ◀

#### TO THE POINT

- Researchers conducted a detailed investigation into the situation of asylum seekers in refugee accommodations in Göttingen in order to learn their needs and goals, as well as their subjective perspective of the situation.
- This work made clear how diverse the group of refugees is.
- It is hoped that the results of the study will help make it easier for refugees to gain a foothold in Germany right from the start.
- For instance, they should be informed clearly and transparently from the outset of their rights and duties, and of the steps involved in the asylum procedure.
- In addition, those responsible for the refugees should make greater efforts to take their basic needs into account.



# Forschung & Lehre



**Ab dem 15. Februar entdecken:** Die neue Website von Forschung & Lehre, der auflagenstärksten hochschul- und wissenschaftspolitischen Zeitschrift Deutschlands. Im modernen und responsiven Design erwarten Sie aktuelle Nachrichten, Hintergrundberichte, Interviews und Essays zu hochschulpolitischen und -rechtlichen Fragen. Ergänzende Ratgeber informieren über Karriereperspektiven und Karrierepraxis in Hochschule und Wissenschaft. Das alles jederzeit, tagesaktuell und optimiert für jedes Endgerät.

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# At the Margins

It's easy to overlook the marginalized. Social exclusion can have very different causes and consequences – also in the context of migration. Six Max Planck Institutes have now joined forces for a cross-institute project focusing on the topic. The project examines, among other things, the question of why immigrants often lose their good health. It explores what prompts Somalis to move from Europe to Kenya, and what consequences the deal between the EU and Turkey might have for the rights of asylum seekers in Greece. Their common aim is to uncover exclusion and develop fair rules to regulate migration.

INTERVIEW AND TEXT **MECHTHILD ZIMMERMANN**



Two worlds: In the Hessian town of Marburg, it's not merely a fence that separates life in the tented accommodations from that in the surrounding houses. The asylum seekers housed there are excluded from much more: they aren't allowed to work or to leave the state of Hesse.



# “The Other Side of the Coin”

Marie-Claire Foblets from the Max Planck Institute for Social Anthropology on the objectives of the research initiative on exclusion

Against the backdrop of the refugee crisis in the spring of 2015, the Max Planck Society launched a research initiative to investigate the issue of migration. The concept: several institutes already active in the field pool their expertise in order to gain new insights into a subject that is of great significance to our society. Marie-Claire Foblets coordinates the project in collaboration with Ayelet Shachar and Steven Vertovec from the Max Planck Institute for the Study of Religious and Ethnic Diversity.

*Integration is the greatest challenge facing society today. Why aren't you and your colleagues conducting research in that field, Prof. Foblets?*

**Marie-Claire Foblets:** Integration is indeed a very important topic. It would be an obvious area to research. However, we made a conscious decision to start by surveying the landscape of ongoing scientific research in the broad field of migration and came across a considerable number of projects dealing with integration. One aspect that is often overlooked, however, is that the focus on integration also excludes or marginalizes people.

*What is it about exclusion that particularly interests you?*

Exclusion is never entirely preventable. Every human society defines who belongs to it and who doesn't. Nevertheless, integration and exclusion are two sides of the same coin – they don't preclude one another. For instance, immigrants from outside the EU have been af-

forded limited political rights here, but this doesn't mean that they can't be well connected here in Germany. Some of them are highly skilled but are still granted only a temporary residence permit. Time also plays a role. Our aim is to better understand the mechanisms and dynamics of exclusion.

*Is exclusion primarily the result of state regulations?*

The state is an important player. It determines what rights and obligations immigrants have, and the areas from which they are excluded. As a result, legal status is a key focus of our initiative. We are scrutinizing the criteria that guide decisions on exclusion and integration and to what extent these decisions are – or are not – implemented. What about respect for human rights? Are the criteria for this clearly defined, or is there room for discretion in individual cases? Is there a risk that decisions will be made on a whim?

Of course, an individual's socioeconomic status – their chances on the labor market, living arrangements, education, local connections and familiarity with German society – also plays a crucial role. Here in Europe, an individual's socioeconomic status is a decisive factor for the recognition they are afforded. Those who are ill or traumatized, and therefore most in need of protection, are at risk of being marginalized. Yet even recognized refugees who, from a legal perspective, are placed on nearly equal footing with domestic citizens can often feel excluded from society.

*Why is that?*

There are emotional communities in every society. These are groups that people feel associated with. One's sense of belonging is defined by a variety of informal criteria and unwritten rules, such as behavior, values, languages, religion and much more. Those who didn't grow up here and who have yet to internalize these aspects may find it difficult to find their place.

*Isn't it simply a question of time before someone who recently immigrated learns these rules?*

Time plays an important role. However, exclusion can persist for an astonishingly long time. A subproject of the MPI for Human Development looks at two examples from history. One concerns the integration of displaced Germans after 1945: it took more than a generation for them to feel accepted as part of the local population and develop a sense of belonging. The second example concerns refugees who were violently expelled from Pakistan following the partition of India in 1947. Here, too, it took decades for them to be integrated into their new home in India.

*Some migrant communities can sometimes give the impression that they don't want to integrate and would rather stay among themselves.*

That can happen, too. But that can be explained, in part, as a reaction to past instances of marginalization. People who are or feel excluded develop a demeanor that enables them to deal with this. A per-

son who fails to receive the requisite level of social recognition in society can either keep trying and getting involved until they succeed or give up and join a different emotional community. Someone who isn't legally recognized as an asylum seeker can resort to court action and can often cite valid reasons against their deportation – or they can go into hiding in hopes of protecting themselves.

*The latter option isn't exactly in line with the law ...*

...but it is a consequence that can't be ignored. This is another area that our research initiative will address. Legal provisions and regulations are there for people to make use of. If they offer no prospects, then for some people, the risk of being deported is so daunting that they will do everything they can to prevent it from happening. We should put ourselves in their position and consider how we would behave in such a situation.

*The treatment of refugees varies considerably in Germany and depends to a great extent on the regional authorities responsible for the case. Measures range from issuing work permits to deportation.*

Regulations and the application of laws actually differ greatly between the different German states. Putting refugees in a position that obliges them to live with major uncertainty for long periods can be particularly problematic. Living in limbo is a great burden. People don't know whether it's worth making new social contacts, learning the local language or



"One of the strengths of our joint project is that the individual teams can benefit from one another's data, knowledge and expertise," says Marie-Claire Foblets.

trying their utmost to find a job if everything they work so hard to build up might last for only a few weeks or months.

*The topic of migration was one of the main bones of contention in the negotiations to establish a new federal government here in Germany. Can't our politicians do more to support these newcomers, for instance by proposing a new Immigration Act?*

Our primary task is basic research, not political consultancy. This means that we gather insights – specifically concerning the mechanisms of exclusion and migration and how they interact. One of the

strengths of our joint project is that the individual teams can benefit from one another's data, knowledge and expertise. The expectation is that, by compiling these results, we will be able to create an overall picture and more clearly identify the deficits and contradictions in the current system. Academic freedom affords us the opportunity to work independently of political concepts and electoral considerations. On this basis, we certainly intend to develop alternatives to existing regulations that may prove relevant for policy making. But to do that, we need time to collect and then analyze the necessary data.

# A Return or a New Start?

Somali refugees aren't migrating solely from Africa to Europe – some are moving in the opposite direction. A project at the Max Planck Institute for Social Anthropology in Halle is investigating the motives behind this and exploring the implications.

Since the central government of Somalia collapsed in the early 1990s, hundreds of thousands of people have been forced to flee the military conflicts

waged between warlords, clans and an array of militias. The majority fled to neighboring countries such as Kenya. Those who could fled further to Europe, North America and the Arab countries.

For some time, however, there has been an opposite trend, as Tabea Scharrer from the Max Planck Institute for Social Anthropology in Halle has observed: some Somalis are relocating from Europe back to East Africa, including to Kenya. There are already a good number of Somalis living in Kenyan cities – some are Kenyan citizens, while others are Somali refugees, many of whom have lived in Kenya for decades now. In addition, Somali returnee families are also settling there, coming primarily from Western countries, but also from Arab states.

In the context of East Africa, these returnee families belong to the middle and upper classes – either hailing from well-off families or having established themselves economically outside of Africa. The majority of them have also gained citizenship in the countries where they have lived for many years. Many families are moving to East Africa because the parental generation – those who first migrated to Europe – fear that their children would be too heavily influenced by life in the West. But there are also young people who grew up and completed vocational training outside of Africa and who are now seeking to settle in Kenya.

It is this phenomenon that Tabea Scharrer aims to investigate more closely. One of the project's key questions is what compels people to "return" from Europe to East Africa. Exclusion could play an important role: Did they not feel at home in Europe? Did their children experience discrimination at school? Was it too difficult to find their place in society? And how are the returnees managing in East Africa? Do they find it easier to settle in there?

Back in Mombasa: Buildings like these house middle-class Somalis who moved from Europe to Kenya.



Another issue is the potential impact returnees could have on Somali society in Kenya. It is often observed among Somalis that ethnicity plays a major role for identification processes. The perceived difficulty in maintaining their own culture in Western countries is the primary motivation in some Somalis' decision to leave Europe. In

Kenya, they could further reinforce certain values of Somali society; this may also explain the striking tendency of Somalis to distance themselves from other segments of the Kenyan population.

For Tabea Scharrer, however, contrasting developments are also possible: the time spent away from Somali soci-

ety in East Africa could also engender a cosmopolitan lifestyle – primarily among the returnees' children, many of whom would have preferred to remain in Europe or North America. Their experiences with migration and life in other societies could also lead to Somali society in Kenya becoming more open and diverse. ◀

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## What Laws Apply in the Greek Migration Hotspots?

The EU has established refugee camps on numerous Greek islands, applying its own admission conditions and procedures. A research project at the Max Planck Institute for Comparative Public Law and International Law in Heidelberg is examining whether these regulations are in line with the legal principles and how they are implemented in practice.

**W**hen increasing numbers of people fled across the Mediterranean to Europe in 2015, the European Commission reacted by establishing “hotspots” in Italy and Greece. These camps, which were conceived as an emergency measure, were intended to allow refugees to find shelter, register with authorities and submit applications for asylum. Since then, however, these hotspots have become permanent institutions.

In March 2016, the EU made a deal with Turkey whereby migrants who travel illegally from Turkey to Greece were to be returned. The hotspots on the Greek islands of Lesbos, Chios, Samos, Leros and Kos are now de facto deportation camps. Catharina Ziebritzki of the

Max Planck Institute for Comparative Public Law and International Law and Robert Nestler of the Max Planck Institute for Social Anthropology are currently investigating the situation of refugees in these camps. The processes and acceptance conditions applied there contravene various Greek laws, EU standards and international conventions.

As a result, the living conditions in the camps fall below the minimum levels specified by the EU itself. The accommodations are overcrowded, and the vast majority aren't winter-proof. Medical provision is poor, as is the security situation. Contrary to the original intention, most refugees spend several months there, and some even more than a year.

In actual fact, an accelerated asylum process is in effect at the EU hotspots

in Greece. At the core of this process is an eligibility check that is intended to determine in advance whether an asylum application will even be accepted – or whether the asylum seekers were already granted (or could have been eligible for) asylum in Turkey, the country from which they arrived in the EU. The researchers are critical of the fact that, for this to happen, the conditions applied in Turkey must match the requirements of European guidelines – something neither the EU nor the Greek authorities can control.

European law scholars regard the fact that the accelerated procedure currently lacks any legal basis as a serious flaw. After the EU-Turkey deal was signed, a corresponding law entered into force following a considerable delay. The term of this legislation expired

in early 2017 – yet the procedure continues to be used. As a result, the period in which an asylum seeker can appeal against rejection of their application is reduced from 30 days to five. Given the fact that asylum seekers in the hotspots have hardly any access to legal information or advice, many lawyers consider this to be highly problematic.

Ziebritzki and Nestler also see the role of the European Asylum Support Office (EASO) as questionable. The agency is simply supposed to support the Greek administration; in practice, it exercises significant influence over asylum decisions. According to the re-

searchers’ work, in most cases it is exclusively EASO employees who are responsible for conducting eligibility checks. They hear an asylum seeker’s case, produce a protocol and issue a “recommendation” that, as a rule, the Greek asylum authorities follow.

The two researchers are also critical of the fact that the EASO occupies an influential position in other areas of the asylum procedure – without any judicial recourse against its decisions. This is because there is no court that ensures effective legal protection against the EASO’s activities – a shortcoming that, incidentally, also applies to Frontex, the

European border control agency, and Europol, the EU’s police authority. At present, the only method by which rights can be asserted against these institutions is submission of a complaint to the European ombudsperson.

This brings up a series of further research issues: The hypothesis is that the EU is increasingly impinging on asylum decisions – not only legally, but also administratively. The researchers therefore aim to investigate the function and methods of the EASO, as well as the responsibility of the EU for the violations against the law committed in Greek hotspots. ◀



Freezing cold in the hotspot: Even several years after refugee camps were established on the Greek islands, some of the accommodations are still not winter-proof.





A new home in Manhattan: More than one-third of New Yorkers were born outside the US. These migrants are generally healthier than the native residents.

## Does Exclusion Make Migrants Ill?

From US studies we know that migrants are usually healthier than average citizens of the same age. However, this effect lessens with time. Scientists from the Max Planck Institute for Demographic Research in Rostock are looking into whether this phenomenon also applies to Europe, as well as the possible causes that might help explain it.

A person who sets out to start a new life in a foreign country usually meets one main precondition: he or she is generally healthy. People with chronic illnesses or other physical ailments rarely emigrate. In science, this phenomenon is known as the healthy migrant effect. As a range of international studies have shown, migrants are thus, on average, healthier than their new fellow citizens. And they also differ in one further respect: there is usually a clear connection between an individual's socioeconomic status – education, profession and income – and the state of their health. Poor and socially disadvantaged persons tend to suffer from heart disease, diabetes and asthma much more often than the rest of the population. Yet this connection is far less evident among migrants.

However, any health advantages apply first and foremost to recent migrants. The longer migrants spend in their new home country, the smaller the differences compared with the rest

of the population become. Such insights are particularly well founded for classic immigration countries such as the US and Canada. However, research in Europe has so far produced contradictory results.

A team headed by Mikko Myrskylä of the Max Planck Institute for Demographic Research is now using large data sets from Italy, Finland and Sweden to systematically examine the healthy migrant effect in the European context. The researchers suspect that the effect will also be evident here and will ebb away in the same manner over time. The issue of what causes this phenomenon is at the very heart of the investigation: why does the state of migrants' health worsen with time?

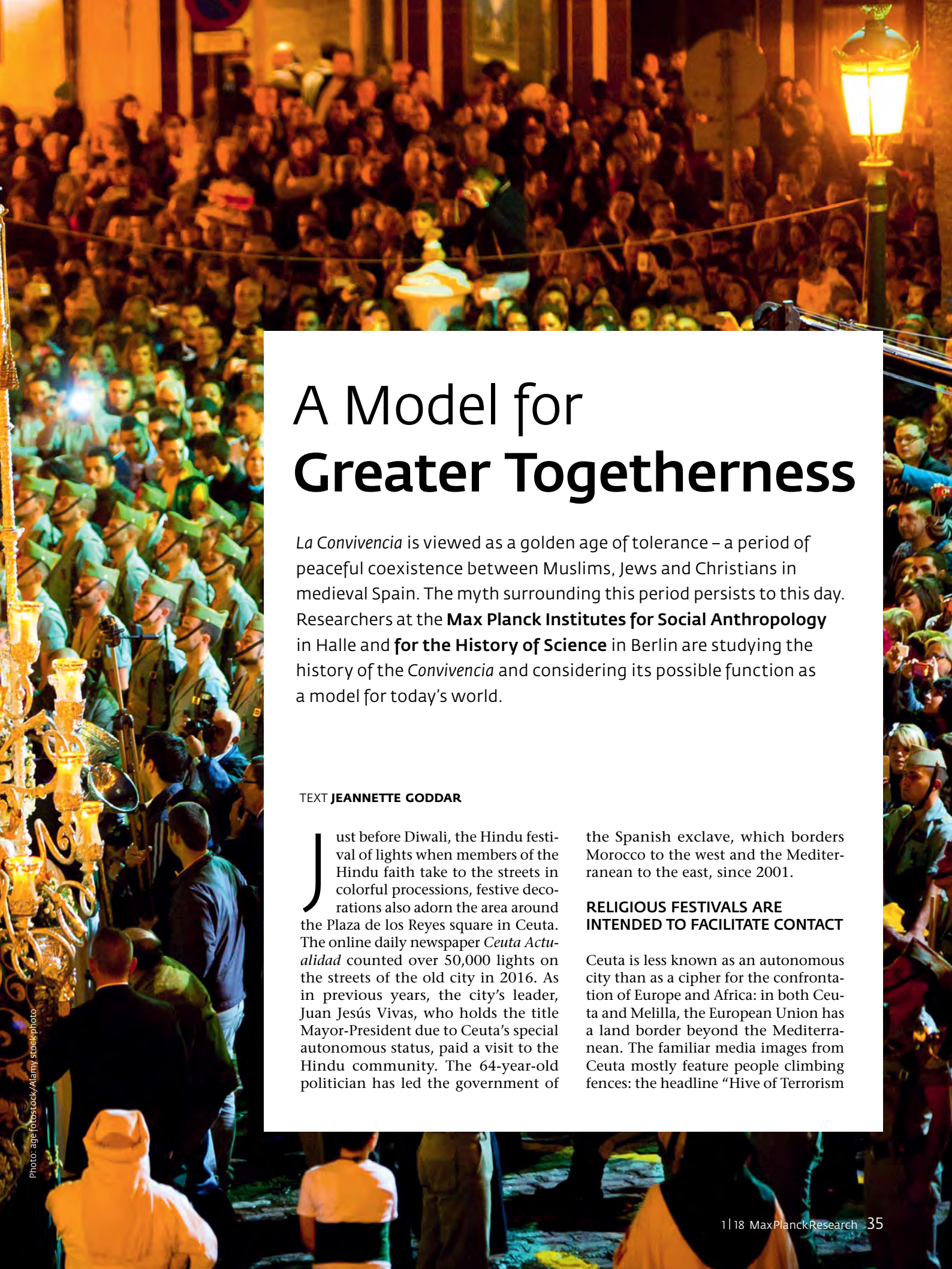
The researchers have proposed the theory that exclusion could be the primary factor, as migrants suffer from disadvantages in various areas: it's harder for them to make social contacts, as they often have a poor grasp of the language. Many of them find themselves in poorly paid jobs that are looked

down upon – partly due to linguistic barriers, and partly because their qualifications aren't recognized. In terms of the healthcare system, the language barrier also poses a hurdle. Furthermore, migrants are less likely to lead healthy lifestyles; one reason may be that campaigns promoting healthy living are less likely to reach them.

If the researchers can prove that socioeconomic disadvantages damage the health of migrants, it would be an important insight for society as a whole. Until now, it has been hard to identify the causal relationship that exists between social exclusion of migrant populations and health. Are immigrants ill because they are excluded? Or are they excluded because good academic qualifications and a well-paid job can only be attained with a robust constitution? Both connections certainly exist. As the migrants enjoyed better-than-average health when they first arrived, their example may serve to demonstrate the impact of social exclusion on health. ◀



Living faith: In Ceuta, a Spanish exclave in North Africa, the religious communities play a very prominent role in public life: Christians – here in a traditional procession for Holy Week – Muslims, Jews and Hindus alike.



# A Model for Greater Togetherness

*La Convivencia* is viewed as a golden age of tolerance – a period of peaceful coexistence between Muslims, Jews and Christians in medieval Spain. The myth surrounding this period persists to this day. Researchers at the **Max Planck Institutes for Social Anthropology** in Halle and **for the History of Science** in Berlin are studying the history of the *Convivencia* and considering its possible function as a model for today's world.

TEXT **JEANNETTE GODDAR**

**J**ust before Diwali, the Hindu festival of lights when members of the Hindu faith take to the streets in colorful processions, festive decorations also adorn the area around the Plaza de los Reyes square in Ceuta. The online daily newspaper *Ceuta Actualidad* counted over 50,000 lights on the streets of the old city in 2016. As in previous years, the city's leader, Juan Jesús Vivas, who holds the title Mayor-President due to Ceuta's special autonomous status, paid a visit to the Hindu community. The 64-year-old politician has led the government of

the Spanish exclave, which borders Morocco to the west and the Mediterranean to the east, since 2001.

## **RELIGIOUS FESTIVALS ARE INTENDED TO FACILITATE CONTACT**

Ceuta is less known as an autonomous city than as a cipher for the confrontation of Europe and Africa: in both Ceuta and Melilla, the European Union has a land border beyond the Mediterranean. The familiar media images from Ceuta mostly feature people climbing fences: the headline "Hive of Terrorism



**Top** Under one roof: This Hindu shrine in Ceuta contains not only images of the goddess Durga and other Hindu gods, but also Christian and Muslim symbols.

**Bottom** In the open: Muslims in Ceuta mark the end of Ramadan – the month of fasting – with the traditional celebration prayer.

on the Outer Borders” has already appeared in a reputable national newspaper based in Zurich.

Juan Jesús Vivas doesn’t attend Diwali because a particularly large number of Ceuta’s 82,000 inhabitants believe in Brahma, Shiva, Vishnu and the rest of the Hindu pantheon; over 95 percent of Ceuta’s inhabitants are Christians and Muslims. Vivas attends because he understands that the joint celebration of religious events – be it Diwali, Yom Kippur, Eid-al-Kabir or Easter – is a means of promoting social peace and stability. “When Vivas became Mayor in 2001, Ceuta was completely divided,” says anthropologist Brian Campbell from the Max Planck Institute in Halle.

Christians and Muslims kept to themselves. It was very clear who was in charge: the Christians considered themselves the city’s true citizens and divided power among themselves, and the Muslims had to make do with whatever remained. The certainty regarding who belonged and who didn’t ran so

deep that immigrants who had arrived from South America in the 1980s were naturalized before Muslims who had been living there for generations. Christians and Muslims have cohabited in Ceuta since it was conquered by Portugal in the 15th century. It was later ceded to Spain.

### CEUTA CAN’T BE REDUCED TO ITS BORDERS

Brian Campbell himself comes from a country located on the external border of Europe: Malta. Since 2011, he has spent time among the inhabitants of Ceuta over the course of many visits, some of which lasted several months. It all started because, at the beginning of his doctoral career, he was searching for a “textbook example of multiculturalism.” In Ceuta he found, along with many other things, a place where, although people coexist under extraordinary conditions, the actual situation bears no relation to the image presented in the European media. “Ceuta can’t

Photos: JORDI CAMI/Alamy stock photo (top), Reuters (bottom)

»» Every society carries within it the roots of violence – but also the potential for reconciliation.

be reduced to its borders,” explains Campbell, “People live there and they love it because it’s their town. And, like people everywhere, they try to make the best of what their lives have to offer.”

And they are supported in this by the mayor: In an environment in which ethnicity and religion are extremely interconnected, where Muslims are almost always of Moroccan descent and Christians almost always have Iberian roots, Juan Jesús Vivas deliberately involves the different religious communities as actors in the city’s policies. “Instead of suppressing ethnicity, culture and religion, he uses them to bring people into contact with each other. He gives them positive connotations rather than negative ones,” explains Brian Campbell.

Every religious community that celebrates festivals or other rituals receives financial support. There is one non-negotiable condition: the spaces and squares – and the buffet – must be open to all the city’s inhabitants, including those with a different religious affiliation or with no religion at all. As quickly becomes evident, this creates an opportunity for people to talk to and get to know one another, and thus also to establish trust. But as Campbell reports, it’s about more than that. It fosters a sense of belonging that firmly establishes that, irrespective of who or what they believe in, they are all Spaniards.

The mayor has given his model a name: *convivencia*. A quick check of the word in a Spanish-English dictionary yields both “coexistence” and “cohabitation.” When applied to societies comprising people of all persuasions, and even to families, these aren’t the same

thing: the former implies a space that is used jointly by several people or groups, while the latter implies that these people or groups make joint use of all the structures in which their shared lives, including the contact between them, are organized. “People who cohabit share more than just the space,” adds Campbell, “they live, not alongside each other, but with each other.”

### LA CONVIVENCIA WAS A GOLDEN AGE IN SPAIN

In the historiography, particularly the Spanish version, *convivencia* stands for much more than this: it denotes a period during which large parts of the Iberian Peninsula were under Muslim rule and became known as “al-Andalus.” The Berber-Muslim military commander Tariq Ibn Ziyad, who invaded the peninsula from the Mediterranean, gained control of the then Visigoth Kingdom in 711. This marked the beginning of a period in which the Iberian Peninsula was governed first as a caliphate and later by numerous – initially – Muslim kingdoms, which were subsequently converted to Christian rule under the *Reconquista*.

Apart from Christians and Muslims, the region was also inhabited by a minority of Jews. Christians didn’t regain power until 1492, with the *Reconquista*, and then they wanted the entire country for themselves: the last Muslims were reported to have been expelled from the region in 1614, despite the fact that many of them had long since converted to Christianity.

This also marked the end of an era in which Spain flourished intellectually,



Temporary Ceuta resident: Social anthropologist Brian Campbell spent weeks and sometimes even months in the Spanish exclave to get to know how the different religious and ethnic groups there live together.



**Left** Collegial exchange: Helge Wendt, Elena Serrano and Mònica Colominas (left to right) work on historical aspects of the *Convivencia* at the Max Planck Institute for the History of Science.

**Right** Dialogue across the ages: A 14th-century image shows Islamic philosopher Averroes (left) in a fictitious disputation with the ancient scholar Porphyry. Averroes, who lived in Spain in the 12th century, is renowned for his works on ancient Greek philosophy, especially the writings of Aristotle.

culturally and economically: Córdoba, the capital of the caliphate, was the third largest city in the world in the 10th century and famous for its art and crafts, poetry and philosophy. One of the most popular stories from “al-Andalus” concerns the fascination with Aristotle and ancient Greek philosophy on the part of Muslim philosophers, especially Ibn-Rushd, who is better known in Europe under the Latin name Averroes.

### PEACE WAS FRAGILE EVEN IN THE GOLDEN AGE

Whether people coexisted or cohabitated, and how or even whether they did so peacefully in the Christian-Jewish-Muslim collective, is still a matter of dispute. On the one hand, the idea of this period as a golden age of tolerance survives, and there is evidence that a sense of belonging prevailed among the different religious communities – also, incidentally, at joint festivities. On the other hand, it’s impossible to speak of the *Convivencia* as an era of equality: those who governed did

so with varying degrees of violence. Conflicts repeatedly arose, as did religiously motivated persecution – including the massacre of the Jewish population in Granada in 1066.

Günther Schlee, Director at the Max Planck Institute for Social Anthropology in Halle, refers to it as a period of “relative peace with highs and lows,” but also one that lacked anything even approaching equal rights: “The society of that period can’t be considered under the aspect of the modern principle of equality,” says Schlee. On the contrary, the Caliphs considered the non-Muslims as *dhimmis*, or protected persons: “They collected taxes from them, assigned them a clear role, for instance in relation to the professions they were allowed to practice, and guaranteed that they would be provided with a certain level of protection in exchange,” explains the scientist.

Günther Schlee and postdoctoral researcher Brian Campbell are just two of the approximately 15-member multidisciplinary research partnership working under the umbrella of the Max Planck Society. As part of their project

entitled “*Convivencia. Iberian to Global Dynamics 500–1750*,” they are carrying out research with scientists from the Max Planck Institute for the History of Science in Berlin, the Max Planck Institute for European Legal History in Frankfurt am Main and the Kunsthistorisches Institut in Florenz, which is also part of the Max Planck Society.

### THE RELIGIONS COMPETED IN DISPUTATIONS

American historian David Nirenberg is also involved in the project as an external scientist. As far back as 1996, he presented a groundbreaking exploration of cohabitation on the Iberian Peninsula in his book *Communities of Violence. Persecution of Minorities in the Middle Ages*. Roughly speaking, Nirenberg considers violent conflict to be a systemic feature of the *Convivencia* – part of a process that makes social stability and peaceful cohabitation possible again.

At the Max Planck Institute for the History of Science in Berlin, historians are investigating the paths by which knowledge is transferred. “We are inter-



ested in how ideas from one human community enter another, be it between societies, down through the ages, or even from academic or religious elites to the general population, and vice versa,” explains Elena Serrano, who, in addition to carrying out her own historical work, is responsible for the coordination of the project. An example of this approach is the research carried out by her colleague Helge Wendt, which focuses on the writings of indigenous groups in the 16th and 17th centuries in Mexico and Peru and examines how the latter held on to their convictions, which came under pressure through colonization, and passed them on.

Arab studies expert Mònica Colominas is carrying out research in Berlin on the so-called polemics. As used in this context, the term has little to do with the vernacular understanding of the word “polemical”. What is meant here, rather, are documents in which the different – and competing – religious communities recorded their arguments and with which they entered into contact with each other. Specifically, Colominas

is examining the traditions of the Muslims in the period starting in 1500, when the Iberian Peninsula was entirely under Christian rule again.

The exchange of positions between Christians, Jews and Muslims was entirely normal in the Middle Ages, explains Colominas: “From Bagdad to Barcelona, under both Muslim and Christian rule, the followers of different religions came together for public disputations.” All the participants prepared for such events – which sometimes took on the character of a spectacle – by compiling sophisticated texts: “After all, each participant wanted to emerge as victor, or at least perform as well as possible.”

### HISTORICAL PARALLELS ARE OF LIMITED VALIDITY

The polemics provide insights into the strategies adopted by the different religious communities to try to convince their counterparts of the greater validity of their positions. As Colominas’s colleague Helge Wendt explains, this had nothing to do with traditional reli-

gious conversion: “The rational age had begun. Even colonial efforts relied more often on the power of persuasion than on forced conversion.”

Within the religious communities themselves, the polemics fulfilled a number of purposes: “They strengthened the community’s self-esteem, fostered communication and helped with the further development of ideas,” says Colominas. They also helped channel disputes – and thus, similar to the role suggested by David Nirenberg’s theory, served as a sort of safety valve. Helge Wendt identified another purpose in his analysis of the indigenous writings: “They made it possible to express things that weren’t actually allowed to be said: when someone states something that is prohibited and another person – generally a superior – contradicts it, the censured idea is still conveyed, and thus preserved.”

A glance at the polemics studied by Mònica Colominas also reveals how Muslim communities of the late Middle Ages asserted themselves in a Christian environment: How did they comply with the five pillars of Islam, which



include the five-times-daily prayer and fasting during Ramadan? To what extent could Muslim minorities compromise or suspend these practices in order to better fit into society? Who had the authority to allow such compromises and speak on behalf of the Muslim community?

Certain parallels to the present day are obvious, even if Colominas – entirely in keeping with her role as a historian – points out that every era is different and stands for itself. As she attests, the questions that arise are similar: “Then, as now, people were asking what kind of strategies they should adopt to stand their ground in a setting that functions very differently.” This sums up quite accurately what the Convivencia project can and wants to achieve: the aim, says Günther Schlee, is to carry out a “general comparative study of forms of societal integration. One emphasizes description over explanation and gives rise to a stimulating exchange of information and ideas from the perspective of different academic disciplines.”

According to Brian Campbell, “People constantly seek explanations for things in the past – parallels help us sort out the world.” Science can’t ignore this. But what can the – in Campbell’s case – reverse perspective on today’s Ceuta contribute to the research on the conditions in medieval times? “Ceuta is a living model,” says Campbell. “In an area of 20 square kilometers, people there ask themselves every day: What does convivencia mean to us?” To put it very briefly and, as always, to ignore the exceptions, the answer is: convivencia should be more than coexistence – togetherness rather than just a parallel existence.

### THE EXCLAVE IS NO MULTICULTURAL IDYLL

What Campbell did not find in Ceuta, however, was a multicultural idyll. At its core, he describes the city as having massive disparities in terms of power and resources between the almost equally large Muslim and Christian populations, with an almost entirely

Christian middle and upper class, on the one hand, and high rates of unemployment, school dropouts and poverty among the Muslims, on the other.

In education, too – where opportunities and therefore the future distribution of resources are decided – the roles are also clearly divided: “In many schools, exclusively Christian teachers teach exclusively Muslim students,” says Campbell, “and only in Spanish: Arabic, the language spoken by many Muslims at home, is not spoken in either the schools or the administration.” The fact that many Muslims see themselves as being very much excluded from equal opportunities results in frustration – and criticism of the model: “A considerable number of people see the shared rituals simply as a move designed to distract from who still holds all the power,” says the social anthropologist.

As a result, tensions are the order of the day – at times in connection with the very festivities that are meant to bring people together. “Of course there are also religious groups in Ceuta that refuse to



**Left** State theatrics: Every few years, the people of Ceuta are invited to kiss the Spanish flag and declare their loyalty to the country – a dubious ritual for Muslims, as their affiliation with Spain is constantly questioned.

**Right** Skeptical observer: Günther Schlee, Director at the Max Planck Institute for Social Anthropology, challenges the myth of the *Convivencia*. According to his research, the members of the different religious groups were anything but equal.



eat with other groups,” says Brian Campbell. “As is the case everywhere else, *the* Muslims do not exist there any more than *the* Christians.” Nor are violent confrontations uncommon.

After six years of observing the system in Ceuta, Campbell also believes that *convivencia* is not a fixed state, but a process. “The question is not: peaceful or not peaceful, but that of conflict and solutions,” he says. This, too, follows Nirenberg’s approach that every society carries within it the roots of violence – but also the potential for reconciliation.

Seen in this way, *convivencia* becomes a social model that creates structures needed for dialogue – which is helpful in the event of conflict, as these structures can then be activated without having to first engage in the complicated process of creating them. Brian Campbell hopes it will be possible to transfer this model – not to other societies, but as a theoretical framework that scholars and other experts might use to study other places: “Does this framework fit? And if not, why not?” ◀

### TO THE POINT

- Ceuta, a Spanish exclave in North Africa, tries to foster peaceful cohabitation between different religions and ethnic groups by using religious festivals as an opportunity for the groups to get to know each other and to establish contact between them.
- The model for this system is provided by *la Convivencia*, the historical period that stands for the peaceful cohabitation of Christians, Muslims and Jews on the Iberian Peninsula in the Middle Ages.
- Even though violent conflicts repeatedly arise in Ceuta, there is evidence of a sense of belonging beyond religious boundaries and of the existence of an intellectual exchange and interaction between the different religious groups.
- Despite this, the historical *Convivencia* and its adaptation in Ceuta is insufficient as a social model due to the fundamental difference between living conditions in medieval Iberia and contemporary Germany.

### GLOSSARY

**al-Andalus:** Arabic name for the parts of the Iberian Peninsula under Muslim rule between 711 and 1492. The term is also sometimes used to refer to the period.

**Indigenous groups:** Population groups that lived in an area prior to colonization by other peoples.

**Comparative studies:** A scientific discipline that compares the literature of different cultures; in a broader sense also the scientific comparison of different cultural phenomena.

# Beautifully Sad

A new study shows why we enjoy negative emotions in film and art

We often perceive works of art that evoke negative emotions as more intense, more interesting and even more beautiful than a pure shower of positive emotions. Re-



Self-imposed pain: People who go to the movies also want to experience negative emotions, such as grief, fear and anger.

searchers working with Winfried Menninghaus, Director at the Max Planck Institute for Empirical Aesthetics, have developed a model that explains this apparent paradox. To this end, the scientists combined new findings in the psychology of emotion with basic principles of aesthetic perception. The model is based on two factors: First, people classify the perception of works of art in a different category of experience than that of day-to-day reality. This cognitive distancing creates a kind of safe space in which we can experience negative emotions. Second, art that involves us in the interplay of positive and negative feelings is more varied. The positively experienced narrative tension isn't possible without feelings of uncertainty or fear for the protagonists. In addition, the aesthetic power of the representation (the beauty of music, language or colors, for instance) renders the experience of negative emotions both more intense and more positive. And finally, searching for meaning can lead to discovering something positive even in negative feelings. ([www.mpg.de/11801437](http://www.mpg.de/11801437))

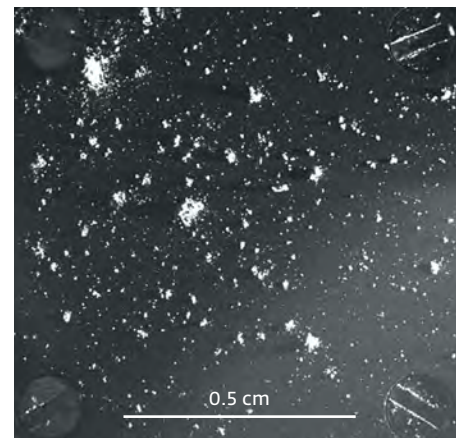
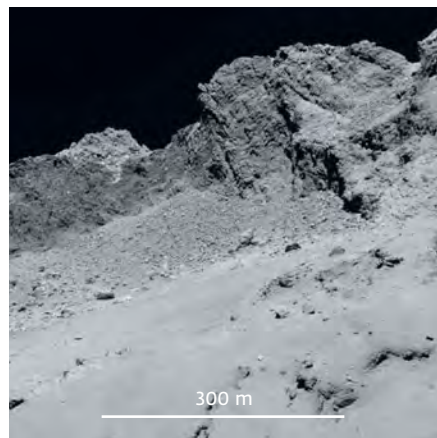
# Recipe for a Comet

Researchers analyze which chemical elements make up comet 67P/Churyumov-Gerasimenko

The dust that comet 67P/Churyumov-Gerasimenko spews into space consists of about 50 percent organic molecules. This material is also one of the most pristine and carbon-rich substances known in our solar system. These are the findings of a team that used an instrument on board the *Rosetta* space probe to investigate the comet. In their study, scientists from various institutes including the Max Planck Institute for Solar System Research are analyzing the chemical elements that make up comet dust more comprehensively than ever before. They collected and analyzed more than 35,000 dust particles of various sizes – from 0.01 to 1 millimeter in diameter – over a period of about two years. They bombarded these particles with a high-energy beam of indium ions, which released

secondary particles that they weighed and investigated in a mass spectrometer. The results showed that organic molecules account for about 45 per-

cent of the weight of the solid material; the rest is contributed by mineral substances, mainly silicates. ([www.mpg.de/11813538](http://www.mpg.de/11813538))



Glimpse of an alien world: As comet 67P/Churyumov-Gerasimenko approaches the Sun, frozen gases below the surface evaporate, dragging tiny particles of dust along with them (left). These dust grains can be captured and examined using the COSIMA instrument on board the *Rosetta* space probe. Targets such as this one, measuring only a few centimeters in size, act as dust collectors, retaining dust particles of up to 100 micrometers in size (right).

# Bacteria Replace Laboratory Animals

A new method to produce antibodies could reduce the need for animals in research

The antibodies of the immune system normally protect humans and other vertebrates against pathogens, but they are also indispensable tools for research, for example in microscopy. Researchers obtain them from the blood of such animals as donkeys, goats and rabbits by injecting these animals with a tiny amount of a substance the researchers want to investigate. The animals then form antibodies against the substance. As thousands of research laboratories around the world use these antibodies, the demand for animals is enormous. Researchers at the Max Planck Institute for Biophysical Chemistry in Göttingen have now developed an alternative that may soon drastically reduce the number of animals needed for antibody production. It relies on what are known as nanobodies: fragments of particularly simple miniature antibodies from the blood of camels and their relatives, the alpacas. The researchers in Göttingen can produce these nanobodies in any quantity using bacteria. This is not possible with conventional antibodies due to their complex structure. ([www.mpg.de/11868152](http://www.mpg.de/11868152))



Alpacas, which are native to the Andes, have special antibodies in their blood: they are much smaller and have a simpler structure than those of most other mammals, enabling them to be produced in large quantities using bacteria.

## Revenge Is Sweet

Living together in a community requires that members cooperate with each other. To achieve this, uncooperative behavior is often punished. Researchers at the Max Planck Institutes for Evolutionary Anthropology and for Human Cognitive and Brain Sciences in Leipzig have now discovered that even six-year-old children reprimand antisocial conduct. To investigate children's behavior, the researchers staged a puppet show: a friendly character gave the children their favorite toy, a mean one kept the toy for itself, and a third played the role of punisher. In the case of the friendly puppet, the children usually did not want to watch it suffer. If, in contrast, the mean one was punished, many six-year-olds even spent money to witness the punishment – but the four- and five-year-old spectators did not. The researchers observed similar behavior in chimpanzees in a zoo, but they don't know yet whether the children or the chimpanzees feel something like spite when watching the punishment. ([www.mpg.de/11866358](http://www.mpg.de/11866358))

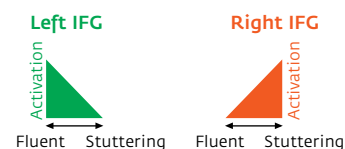
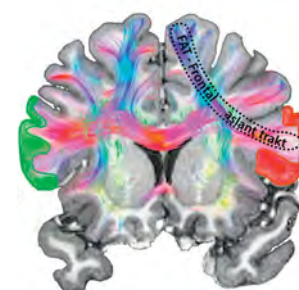
Photos: Irene Böttcher-Gajewski/MPI for Biophysical Chemistry (top), MPI for Human Cognitive and Brain Sciences (bottom)

## Stop Signals in the Brain

A hyperactive network in the right frontal lobe inhibits the flow of speech

Roughly one in every one hundred adults in Germany stutters. Based on previous studies, we know that an imbalance in activity in the left and right hemispheres inhibits the flow of language: a region in the left frontal lobe is underactive while the corresponding region in the right hemisphere is overactive. Using magnetic resonance imaging (MRI), scientists at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig have now found that overactivity in the right inferior frontal gyrus is actually what causes stuttering. In people with speech disorders, this region is linked to other areas of the brain via an unusually strong fiber tract. This part of the frontal lobe is particularly active in all people when we stop speech movements. Exces-

sive inhibition of the motor functions required for speaking could therefore be the real cause of stuttering. ([www.mpg.de/11856655](http://www.mpg.de/11856655))

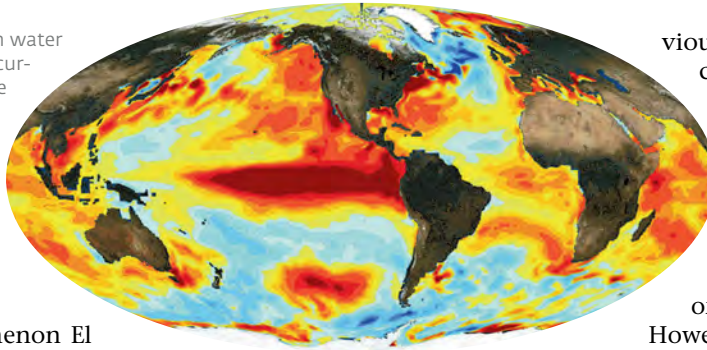


Normally, the right inferior frontal gyrus (IFG) in the frontal lobe stops the flow of speech, while the left one supports it. In people who stutter, these two areas are conversely activated: the right IFG is overactive and shows stronger connections with the frontal aslant tract. This inhibits activity in the left IFG and thus the flow of speech.

# El Niño Intensifies the Greenhouse Effect

The climate phenomenon causes a rise in atmospheric carbon dioxide

El Niño wreaks havoc with water temperatures and ocean currents in the Pacific near the equator every two to seven years. Most recently, this climate phenomenon significantly increased water temperatures in the eastern and central Pacific (red) in December 2015.



The climate phenomenon El Niño fuels the greenhouse effect more than previously assumed. According to an international team of researchers from the Max Planck Institutes for Chemistry in Mainz and Biogeochemistry in Jena, the concentration of carbon dioxide in the atmosphere rose by 8.8 billion tons as a result of the 2015-16 El Niño. That corresponds to about one quarter of the world's annual carbon dioxide emissions caused by human activities. Pre-

viously, geoscientists assumed that this climate event releases 1.2 billion tons of carbon dioxide, as droughts result in more peat, bush and forest fires in these years. The much larger amount that has now been determined from satellite data is apparently due primarily to plants absorbing significantly less carbon dioxide in regions influenced by El Niño. However, the researchers assume that, unlike man-made emissions and the increase in carbon dioxide caused by fire, this increase in greenhouse gases due to reduced biomass production will be reversed after El Niño years because plants absorb more carbon dioxide. But human activity is likely to exacerbate the problem: particularly peat fires that are deliberately set, for instance, tend to get out of control more easily in regions that have been dried up by El Niño.

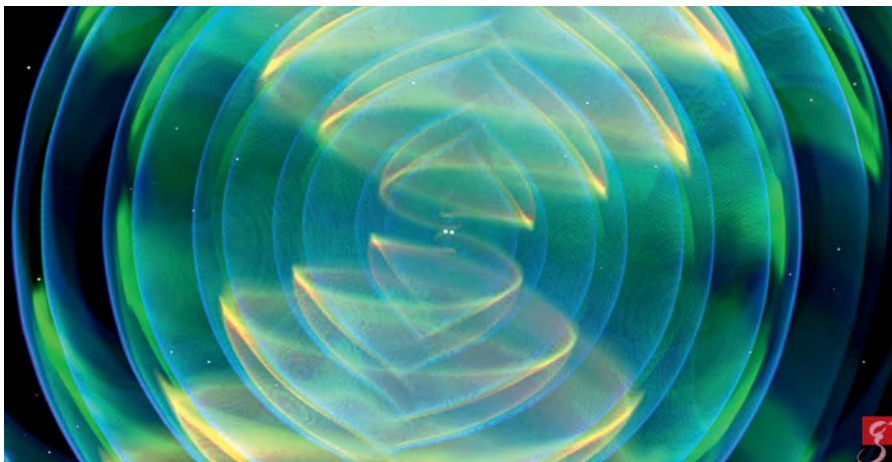
# Gravitational Waves from Neutron Stars

The cosmic event was also observed in visible light and provides an explanation for gamma-ray bursts

For the first time, researchers simultaneously measured the gravitational waves of two merging neutron stars and registered the light from this event in several areas of the electromagnetic spectrum. This discovery on August 17,

2017 confirms what theorists had long suspected: that the collision of neutron stars leads to a short gamma-ray burst. In addition, the explosion that follows, known as a kilonova, is the source of heavy elements such as gold, platinum

and lead. The two LIGO detectors in Hanford, Washington (USA) and Livingston, Louisiana (USA) observed the signal referred to as GW170817 for around 100 seconds, and the simultaneous measurements of the Virgo detector in Tuscany improved localization in the firmament considerably. Meanwhile, the Fermi and Integral satellites registered a gamma-ray burst from roughly the same direction as the gravitational wave signal. Finally, optical telescopes discovered a point of light located in the NGC 4993 lenticular galaxy system, approximately 130 million light-years away – apparently the origin of the cosmic collision. ([www.mpg.de/11646260](http://www.mpg.de/11646260))



Dance of the heavyweights: Two neutron stars orbit each other, spiraling ever closer together, radiating gravitational waves in the process.

# Light Makes Algae Sticky

The fine hairs of *Chlamydomonas*, a unicellular alga, adhere to surfaces only when illuminated



Sunlight enables green algae to do more than just carry out photosynthesis, with which they produce sugar. As physicists at the Max Planck Institute for Dynamics and Self-Organization in Göttingen have now observed for the first time, blue light also makes the flagella of these unicellular organisms sticky. The microorganisms use these fine hairs to swim in the dark through their aqueous habitat, but the light-controlled adhesion allows them to latch onto surfaces that are suitable for their nutrient production. These findings could help genetically paralyze the light switch in algae for the production of biofuels. This would prevent the microorganisms from forming on the glass of reactors and reducing their efficiency. ([www.mpg.de/11493896](http://www.mpg.de/11493896))

In blue light, the proteins in the flagella of green algae rearrange themselves, moving sticky protein molecules toward the outside and causing the fine hairs to adhere to surfaces.

## Flying South Pays Off

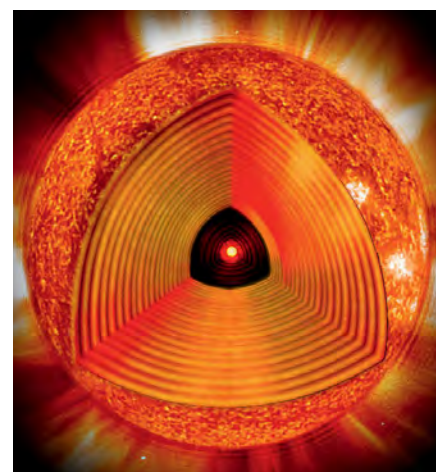
About half of the songbirds that live in Germany fly south in the fall – it's warmer there, and there's plenty of food. However, the journey is arduous and dangerous. So, is it really worthwhile for migratory birds? Blackbirds are ideal subjects for studying this question, as only some of the birds in central Europe fly south in the fall, while the rest of them brave the cold here. That's why, for several years, researchers at the Max Planck Institute for Ornithology in Radolfzell ringed almost 500 blackbirds at Lake Constance or fit them with small tracking devices, then looked for ringed returnees from the south in spring. Automatic recording devices installed in the study area also indicated whether birds wearing a radio transmitter were still alive. The researchers found that winter is the most critical phase in the life of a blackbird. Most of them die in this period, regardless of whether they migrate south or remain here. However, the migratory birds are considerably more likely to survive the winter than those that remain in central Europe. ([www.mpg.de/11778765](http://www.mpg.de/11778765))

# Looking Deep into the Heart of Stars

Researchers measure the structure of distant suns from their oscillations

Looking inside a star would seem to be an impossible task. Now, for the first time, a team led by Earl Bellinger and Saskia Hekker at the Max Planck Institute for Solar System Research has succeeded in doing just that. To this end, the researchers observed the oscillations of the stars, which propagate like sound waves inside them, based on fluctuations in the stars' brightness – a method used in the field of asteroseismology. By analyzing the oscillation frequencies, the scientists determined the structure of binary stars 16 Cygni A and B, located 70 light-years away from Earth. Bellinger and Hekker

adapted various stellar evolution models until one of them fit the observed frequency spectrum. Finally, the inverse method showed that the speed of sound in the central regions of the two stars is greater than that predicted by the models. In the case of 16 Cygni B, these differences can be explained by correcting the mass and size of the star. For 16 Cygni A, however, no model could be found that explains the observations: it seems that some physical phenomena have not yet been taken into account in the current theories of stellar evolution. ([www.mpg.de/11872053](http://www.mpg.de/11872053))



Into the heart: An artist's impression of the interior of the star, which can be studied through oscillations on its surface.

# On the Leash!

Max Planck researchers discover the oldest images to date of dogs on leashes

Dogs are considered to be man's oldest companions, but the role these animals played in early human history remains shrouded in mystery. While conducting research in Saudi Arabia, scientists from the Max Planck Institutes for the Science of Human History and for Evolutionary Anthropology discovered images that provide the first ever insight into life with dogs at that time. The rock carvings are estimated to be between 8,000 and 9,000 years old. They depict hunting scenes: men with bows and arrows shooting at gazelles and antelopes, dogs holding lions and leopards in check, and dogs killing smaller game by biting them. It is notable that individual dogs are kept on leashes. Images of leashes had previously been found only in ancient Egyptian art, which is much more recent. People may have wanted to prevent valuable dogs that were particularly adept at picking up the scent of prey from getting injured during the hunt. Or they may have wanted to keep the dogs close to them for their own protection. Another possibility is that they put leashes on young dogs that they wanted to train. ([www.mpg.de/11802436](http://www.mpg.de/11802436))

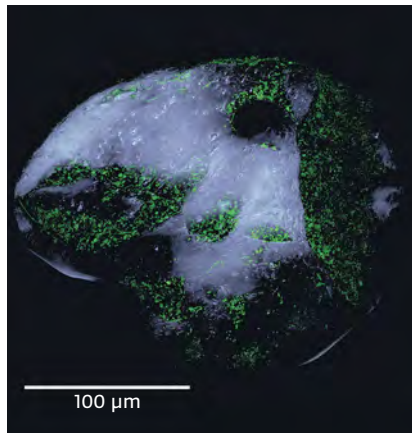


Large hunting scene: The lines connecting two of the dogs to the hunter on the right are clearly recognizable. The carvings were highlighted in white to make the images clearer.

## Sand Is a Paradise for Bacteria

A single grain of sand harbors as many as 100,000 microorganisms

Anyone who builds a sandcastle at the beach is also installing billions of bacteria: according to a study carried out by researchers at the Max Planck Institute for Marine Microbi-



A grain of sand under a fluorescence microscope: The green spots are stained bacteria that have colonized primarily the depressions on the surface.

ology in Bremen, between 10,000 and 100,000 microorganisms live on each individual grain. They bustle about almost exclusively in protected cracks and depressions in the grains, avoiding exposed areas. The diversity of bacteria is impressive, too, with species numbering several thousand. Together, the sand and its inhabitants act as a purifying filter that breaks down substances dissolved in seawater. The distribution of the bacterial species is important for this filter function: more than half of the species are found on all grains. Each grain thus has the same fundamental population. Thanks to the great diversity, sand cleans seawater even under diverse environmental conditions. ([www.mpg.de/11830658](http://www.mpg.de/11830658))

## Less Fertilizer Decreases Fine Particulate Matter

There are many sources of particulate matter – not just traffic, which is a frequent target of particular scrutiny for this. Calculations performed by researchers at the Max Planck Institute for Chemistry in Mainz show that the amount of harmful particulate matter could also decrease considerably if fertilization and livestock breeding were to be reduced, thus releasing less ammonia. Reducing ammonia emissions by 50 percent worldwide would lower the impact of particularly harmful particles with a diameter of less than 2.5 micrometers by 11 percent in Europe, 19 percent in the US and 34 percent in China. Since ammonia and the resulting particulate matter spread out over large areas, this would also have a major impact on the health of exceptionally polluted cities: according to calculations by the researchers in Mainz, a 50 percent reduction in agricultural emissions could decrease deaths attributable to air pollution by 8 percent globally – corresponding to 250,000 deaths each year. ([www.mpg.de/11667398](http://www.mpg.de/11667398))

# Less Stress, More Social Competence

Adults, too, can acquire skills such as empathy – and can personally benefit from them

The human brain can change and adapt to new conditions throughout life. Until recently, it was unclear to what extent this also applies to brain areas that control our social behavior. To find out, a research team led by Tania Singer, Director at the Max Planck Institute for Human Cognitive and Brain Sciences, developed special meditation techniques that train social skills. One method focused on socio-affective skills, such as compassion, gratitude and dealing with difficult emotions. This involved two people from a larger group sharing their emotions with each other. A second technique targeted socio-cognitive skills – in particular the ability to assume others' perspectives – through partner-based exercises and classical meditation. For comparison, there was a third module that used conventional mindfulness training. The researchers found that the brain regions trained in each case actually grow larger and the specific social skills or attention improve in all participants. In addition, the two so-

cially oriented methods strengthened the stress resistance of the participants measurably. The mindfulness training,

which is frequently used with burn-out patients, failed to achieve this effect. ([www.mpg.de/11533187](http://www.mpg.de/11533187))



Chilling out: One of the goals of meditation is to forget about life's adversities. The best way to reduce social stress is with special partner-based meditation exercises.

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## Fibers Spun from Slime

Under the influence of shear forces, nanoparticles from the secretion of velvet worms form stiff polymer threads that can be recycled in water



Nature is always a good teacher for materials scientists. Chemists, for instance, could develop reusable polymers using velvet worms as a model. These small, worm-like animals shoot a sticky secretion at prey and predators. As soon as the victim moves and tries to escape, the secretion hardens into firm threads. Scientists at several institutes including the Max Planck Institute of Colloids and Interfaces have now found that this slime con-

tains tiny globules that are each made up of balled-up protein filaments and fat molecules and measure 75 nanometers in diameter. Under the influence of force, the proteins unravel to form elongated fibers, which the fat molecules surround. The biomolecules retain this shape when they dry. In water, however, the fibers dissolve again and form the same nanoparticles contained in the original secretion. ([www.mpg.de/11550818](http://www.mpg.de/11550818))

Sophisticated hunting weapon: Velvet worms, which look like caterpillars with short legs, capture their prey with a secretion that forms polymer threads as soon as their victim moves.

# Crystals under Control

To alter properties of materials with light as if with the wave of a magic wand: that is **Andrea Cavalleri's** mission. The Director at the **Max Planck Institute for the Structure and Dynamics of Matter** in Hamburg uses lasers to change the behavior of crystals, fleetingly producing superconductors that conduct electricity without loss at room temperature.

TEXT **ROLAND WENGENMAYR**

Use light to freeze water," says Andrea Cavalleri, explaining – albeit light-heartedly – the nature of his research to his six-year-old daughter. She's familiar with Princess Elsa from the animated film "Frozen," who uses magic to turn water into ice, so this gives her an idea of what Daddy does as a scientist when he uses light to manipulate matter.

And anyway, the Director at the Max Planck Institute for the Structure and Dynamics of Matter in Hamburg talks about his work so animatedly that it's easy to imagine him explaining it to a rapt group of children. Somewhat older listeners might tend to think of Harry Potter, who can transform things with a wave of his magical wand. As in Harry Potter's magical world, the materials the physicists in Hamburg manipulate retain their new properties for only a limited time – and it is still extremely short.

Cavalleri's magic wand consists of specially prepared laser light. It can briefly shift atoms around in such a

way that it completely alters the physical properties of a material for a brief moment. But water isn't yet on the list of research objects – he's concerned with other substances. In 2014, Cavalleri's team, in cooperation with other groups, achieved a major scientific breakthrough: for several picoseconds, the researchers were able to produce superconductivity – conduction of electricity without resistance – at room temperature. A picosecond is a billionth of a second, so this exotic state lasted for only an ultra-brief period.

## THE GOAL: ROOM-TEMPERATURE SUPERCONDUCTIVITY

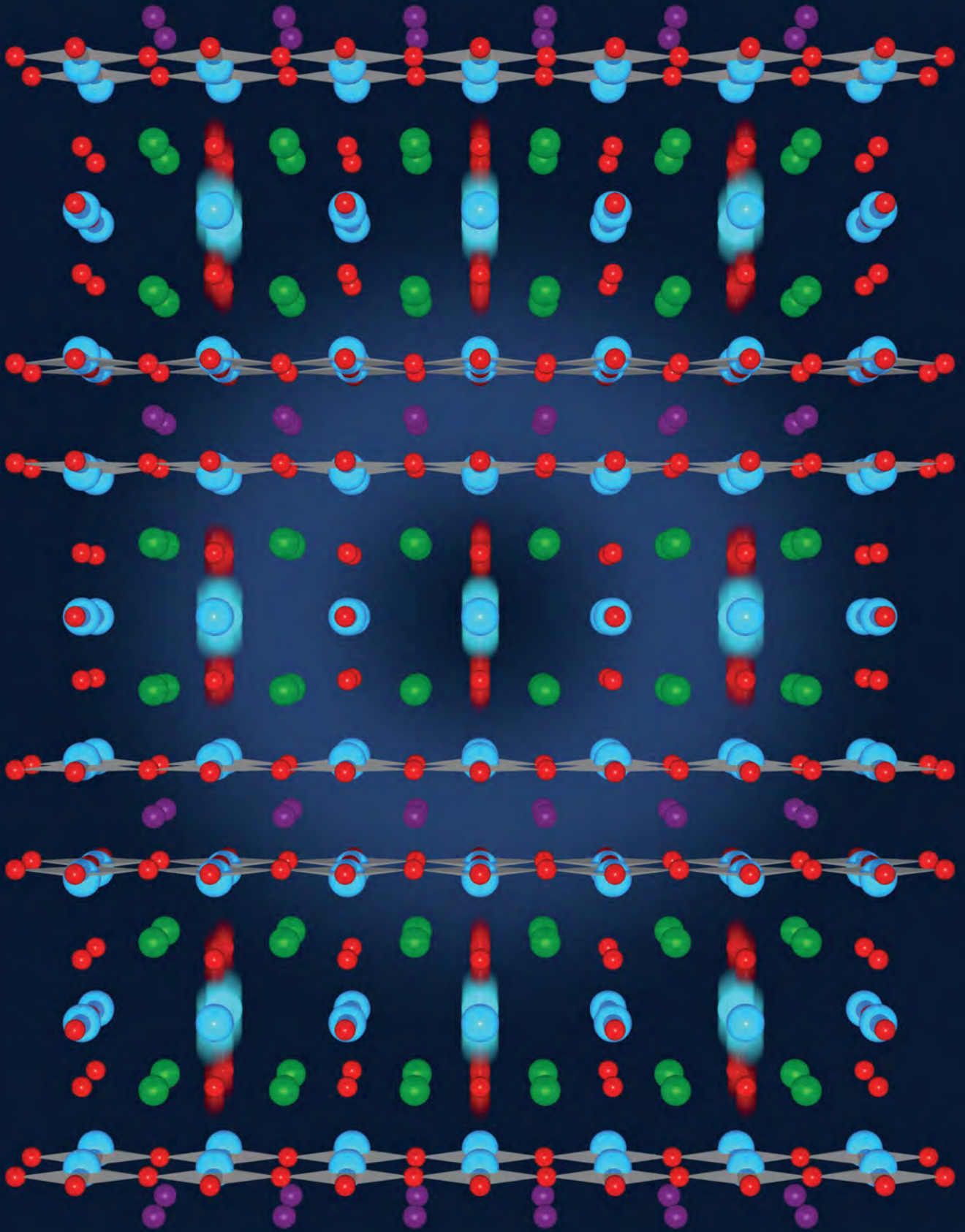
Nevertheless, the discovery caused a sensation. After all, superconductivity at room temperature is the holy grail of materials research. Superconductors that lose their electrical resistance at temperatures well below zero degrees Celsius are already being wound into coils that generate extremely powerful magnetic fields, for example in medi-

cal MRI scanners. Zero-resistance power lines that don't require cooling could one day enable electricity to be transported without loss, for example from large-scale wind farms out at sea to remote areas on the mainland. The discoveries and insights of Andrea Cavalleri's team may well lay the foundations for such practical applications.

Before we turn our attention to the Hamburg-based researchers' projects, the two of us delve into the young Institute's history in Cavalleri's small meeting room. The Institute was officially founded on January 1, 2014, but Cavalleri, a young physicist who was already known internationally at that time, had been building it up since early 2008. Before that, the Italian scientist had been conducting research in the US. In 2004 he relocated to England, to the University of Oxford, where he was offered a professorship with tenure in 2006. "I was happy and thought I would never leave Oxford," he says. But an offer from the Max Planck Society to set up a brand-new in-

Light switch for superconductors: In a cuprate of yttrium (purple), barium (green), copper (blue) and oxygen (red), Cooper pairs carry current without loss in closely packed double layers even at relatively high temperatures. When a laser causes the copper atoms to vibrate between the double layers, the layers move closer together, and Cooper pairs are then able to flow perpendicular to them.







A racetrack for electrons: In the XFEL free-electron laser, particles whiz through a 3.4-kilometer-long tunnel between the DESY research center in Hamburg-Bahrenfeld and Schenefeld (top), producing X-ray flashes in the process. Employees travel through the X-ray laser tunnel on bicycles (bottom).

stitute in Hamburg was just too tempting. “I was the first employee,” Cavalleri says. “I connected my phone myself at the time.”

The Max Planck Institute for the Structure and Dynamics of Matter has grown rapidly since then and has now moved to the premises of the Center for Free-Electron Laser Science (CFEL). The striking three-story flat cylindrical building stands on the grounds of the German Electron Synchrotron (DESY), a research center that was originally dedicated solely to particle physics.

But accelerator technology has also produced brilliant light sources for materials research, and right next door, a very special light source went

into operation in September 2017: the European XFEL is the strongest X-ray laser in the world and is set to play a significant role in Andrea Cavalleri’s research. X-ray light is required because its extremely short waves match the distances between atoms in materials. It is the only source that can precisely probe the structure of materials at the atomic level.

This is the perfect setting for the new Max Planck Institute, which currently consists of three departments in which 110 scientists conduct their research, with Cavalleri’s team contributing about 30 people. While we talk, muted construction noise can be heard outside. The Institute’s new building is current-

ly being built in the neighborhood and is due to be completed in summer 2019. “I had to deal with a lot of new questions, such as what, exactly, a Max Planck Institute is,” Cavalleri says about the founding period. “The Max Planck Society is a very good, highly flexible organization,” he says, then adds: “Here you’re limited only by your skills. If you fail, you have no one to blame but yourself.”

**CRYSTAL LATTICE AS A RACETRACK FOR ELECTRONS**

Our conversation then turns to Cavalleri’s favorite topic: his research. For a layperson, it’s important to realize

that much of the matter surrounding us consists of crystals. We usually associate crystals with table salt or precious diamonds, but many other materials – metals, for instance – are also made up of tiny crystals. In the atomic world, crystals are characterized by a regular spatial order. Table salt, for example, consists of a lattice of myriad tiny cubes with sodium and chlorine atoms alternating at their eight corners.

Electrons are responsible for the quantum connections between the atoms in all crystals. In the case of an electrically conductive metal, the crystal lattice formed by the atoms becomes a three-dimensional racetrack for electrons. Those electrons can flow virtually freely through the crystal, carrying electric current and heat energy. Individual electrons in the crystals of other materials can also act like tiny, rotatable magnetic needles. They are usually then bound to specific atoms in the lattice. When these collectively turn in one direction, the crystal acts as a magnet. Highly complex crystals also exist; they include a group of substances known as cuprates. These copper oxides are known to be high-temperature superconductors and number among Cavalleri's research objects.

The scientist studies the physical properties of crystals and how they can be manipulated with light. The crux of the matter here is that, in every crystal lattice, the properties of the material are determined by the exact arrangement of atoms. "Imagine the atoms in the crystal lattice as spheres that are connected by coil springs," he explains. "You can pull the spheres



A balancing act with atoms: The method by which the Max Planck researchers in Hamburg hope to stabilize a superconducting non-equilibrium state of crystals can be compared to an attempt to hold a ball on a saddle. Normally it would roll off. However, if the saddle is rotating very quickly, it acts like a bowl that traps the ball.

apart at one point, but as soon as you let go, they spring back to their original positions."

#### ATOMS IN A NON-EQUILIBRIUM STATE

When the spheres are in this equilibrium state, the spring forces all cancel each other out. In a true crystal, as well, the atoms strive to take up equilibrium positions – like marbles rolling into a trough. The equilibrium state therefore determines the crystal's permanent physical properties.

Cavalleri's team is working on methods that can artificially nudge selected atoms in crystals out of their comfortable state of equilibrium. "Our aim is to selectively tug on the springs between the spheres, distort the interatomic bonds and then see what happens," Cavalleri explains. "It's about maneuvering the atoms, at least momentarily, into positions in the crystal where they wouldn't normally remain of their own accord. It's a balancing

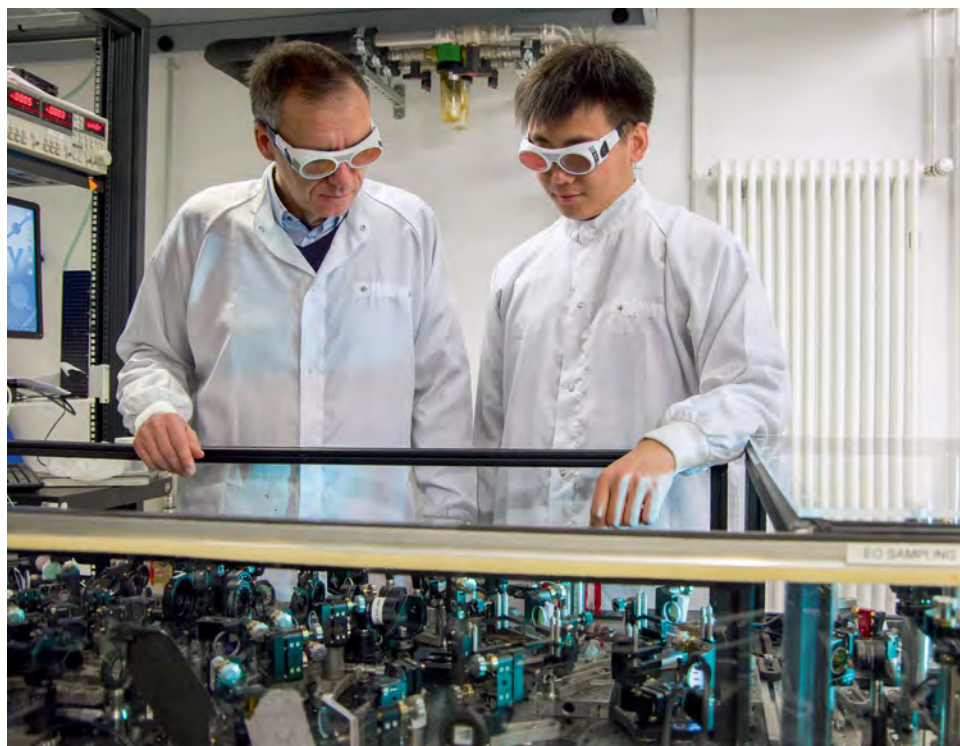
act." Cavalleri illustrates this on the computer with an animation of a ball on a saddle. When the saddle is at rest, the ball immediately rolls to the side. But if the saddle rotates fast enough, it forms a virtual trough in which the ball remains trapped.

This is precisely what the scientists hope to one day achieve with specially prepared laser light: like the rotating-saddle model, they want to hold atoms within a crystal in a non-equilibrium state, thus changing the crystal's properties. This is Cavalleri's dream, because it would make it possible to alter material properties as long as the material is exposed to laser light.

The trick is for suitable laser light to induce oscillations – physicists call them phonons – within crystal lattices. The method can be visualized by considering what happens when children jump up and down on a mattress. In this analogy, the metal springs in the mattress correspond to the crystal lattice. For example, jumping could result in the springs always squeaking at a

**This page** When Michael Först and doctoral student Biaolong Liu induce properties in crystals with light, they work at a bench on which an array of optical instruments has been set up. They first use a laser pulse to produce oscillations that alter the material's behavior. With a second pulse, they then probe the momentary state of the crystal.

**Right page** Using a pump-probe experiment, the Hamburg-based researchers produced superconductivity in a crystal consisting of soccer-ball-like fullerene molecules.



specific point during compression before rebounding. The squeak would then reveal the sought-after non-equilibrium state.

Continuing with this analogy, the researchers want to know precisely how the mattress springs are deformed in that state. This information can provide a snapshot of the mattress that captures it at just the right moment to yield a sharp spatial image of the squeak-inducing state.

That is, in principle, exactly what the researchers are doing with crystals. In scientific terminology, the jumping is known as “pumping,” while the squeaking corresponds to “probing.” Both pumping and probing of the momentary state are achieved using strong laser systems developed by Andrea Cavalleri and his team in the Institute’s laboratories. The researchers also carry out the probing measurements, which, like the squeak of a spring, tell them indirectly whether they are on the track of the sought-after non-equilibrium state. Once they’re

certain they are, it’s time for the intricate X-ray snapshots.

For this, the scientists in Hamburg need a free-electron laser that generates X-rays. In the past, they had to travel with their experimental setups to the Linac Coherent Light Source in Stanford, California up to three times a year. Until recently, the Linac facility was the world’s most powerful X-ray source. Now, the even more powerful European XFEL is located right on the Institute’s doorstep. Like a camera, it can capture extremely sharp images of atomic positions at just the right moment.

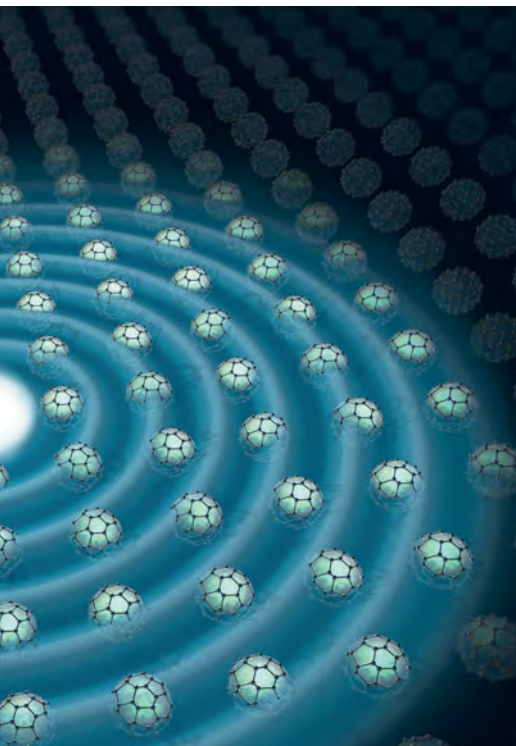
### A PUMP-PROBE EXPERIMENT

“We want to bring the search for new materials and new material properties to the optical bench,” Andrea Cavalleri stresses. However, it’s very difficult to generate laser pulses (light flashes) that can induce the desired oscillations (phonons) in a crystal.

This is demonstrated by senior scientist Michael Först in one of Ca-

valleri’s four laboratories on the ground floor. Before entering, we must don cleanroom clothing and laser goggles. “Dirt on the mirrors plus intensive laser beam equals broken mirrors,” the physicist jokes. Many of the mirrors and lenses scattered around the heavy optical benches, creating elaborate labyrinths for laser light, are expensive, custom-made instruments. The experimental setup before us covers the area of an average apartment. It is a complete pump-probe experiment. The laser flash used for probing the crystal state – physicists call it the probe pulse – must be very short to provide a snapshot of the lattice structure. Without X-ray laser light, however, it would be impossible to capture an image of the atoms’ positions. Moreover, the probe pulse must be a diverted copy of the pump pulse, because only if both pulses are synchronized can the probe pulse provide meaningful information about the excited crystal lattice.

A titanium sapphire laser generates strong laser flashes. Each laser pulse



lasts only a few femtoseconds, which is one-millionth of one-billionth of a second. A semi-transparent mirror splits the beam. The more powerful of the twin pulses is then used to excite the sample, corresponding to the children jumping on the mattress. The second, weaker pulse is sent via an optical delay circuit, so it arrives at the sample after the pump pulse and captures its momentary state. By varying the delay time, the researchers can find the precise moment at which the crystal takes on the state of interest – the point at which the mattress emits a squeak.

However, the setup in front of us is even more complex. Like the optical equivalent of a reduction gearbox, it must convert the infrared light of the femtosecond laser to a wavelength that is up to 25 times longer. This terahertz radiation, as it is known, lies between infrared light and microwaves on the electromagnetic spectrum and can induce the desired oscillations in the crystal lattice. The atoms in crys-

tals are electrically charged by the emission or absorption of electrons. The oscillating electric field of the terahertz waves thus pulls the atoms along, like buoys bobbing up and down on a passing water wave.

Recently, Cavalleri's group succeeded in using terahertz laser radiation to create a kind of artificial magnetism in a material called erbium iron oxide. In simple terms, the laser induced a precisely choreographed mix of oscillations in the crystal lattice. Collectively, the phonons generated a magnetic field in which the iron atoms in the crystal momentarily rotated in one direction like tiny magnetic needles. The result was laser-switchable magnetism. This effect could be of interest for future materials and electronic components.

### COOPER PAIRS FORM A QUANTUM FLUID

Having returned from the laser lab to Cavalleri's room, we talk about the discovery of short-term superconductivity at room temperature in cuprates, the best-known high-temperature superconductors. "They are actually copper rust," Cavalleri says of copper oxides. Superconductivity is based on the fact that certain quantum effects in crystal lattices marry two electrons to form Cooper pairs, which behave quite differently from individual electrons. They gather in a collective quantum state to form a sort of quantum liquid that can flow through the crystal lattice without any resistance whatsoever.

In the case of cuprates and other high-temperature superconductors, it is still unclear what mechanism binds

Cooper pairs together, but it works relatively well. It forms Cooper pairs even at room temperature, whereas in other types of superconductors they fly apart at temperatures well below minus 200 degrees Celsius due to tiny thermal movements. Even before he came to Hamburg, Cavalleri had found indirect experimental evidence of relatively temperature-resistant Cooper pairs.

But the cohesion of Cooper pairs in cuprates evidently still isn't sufficient for them to become superconducting at room temperature and thus conduct a current without resistance. The main obstacle is the sandwich-like layer structure of the complex cuprate crystals. At certain levels, which can be likened to the buttery layers of a sandwich, the Cooper pairs are able to slide around smoothly even at high temperatures. Above and below those, however, are layers of copper oxide that pose an insurmountable obstacle at room temperature. Those layers could be compared to layers of thick bread in a multi-layer sandwich. Only when this layer is compressed, so the buttery layer spreads out somewhat, do they approach each other close enough for Cooper pairs to slip through the layers vertically, as well. That is the precise moment when three-dimensional superconductivity occurs. Cavalleri's team has succeeded in inducing this state in a cuprate for ultra-short periods of time. At the X-ray laser in Stanford, the researchers also determined the exact positions of the atoms in a superconducting crystal.

The Max Planck researchers have now studied high-temperature superconductivity on a completely different



Magic with light: Andrea Cavalleri explores how material properties can be altered with laser pulses. His insights could find applications in sensors and optoelectronic devices.

material. “It’s actually a superconducting plastic,” Cavalleri explains, half-jokingly. This superconductor has no crystal lattice of atoms, but rather a cube-shaped lattice of molecular spheres. The soccer-ball-shaped molecules are buckminsterfullerenes consisting of 60 carbon atoms each.

It has long been known that the fulleride crystals become superconducting at temperatures below minus 253 degrees Celsius. However, Cavalleri’s team recently produced superconductivity with terahertz laser radiation at a comparatively warm minus 170 degrees Celsius. The discovery that superconductivity is possible in a wide variety of materials at relatively high temperatures could provide insights into the universal properties of this quantum phenomenon.

Andrea Cavalleri’s idea of altering the properties of materials with laser light could stimulate the invention of innovative sensors, for instance for electromagnetic radiation. It could also lead to the development of optoelectronic devices in which electrons are controlled by light or vice versa, or the development of tiny mechanical drives for nanotechnology. It is also conceivable to use light to rapidly turn window glass opaque, Cavalleri says – so his experiments in the microcosm could also find applications in our macroworld. ◀

### TO THE POINT

- **Andrea Cavalleri and his team at the Max Planck Institute for the Structure and Dynamics of Matter manipulate the properties of materials with laser light.**
- **Using special laser pulses, the researchers briefly induce the crystals of a cuprate high-temperature superconductor to conduct current without loss at room temperature. In the same way, they also produce superconductivity in crystals of spherical buckminsterfullerenes at relatively high temperatures.**
- **With the help of X-ray lasers such as the XFEL in Hamburg, the scientists are investigating what changes in the arrangement of the atoms are responsible for these effects.**
- **The findings could lead to the development of innovative sensors, for instance for electromagnetic radiation or optoelectronic components.**

### GLOSSARY

**Cooper pairs:** In superconductors, two electrons join together to form Cooper pairs, causing the electrical resistance of the material to drop to zero. The mechanism by which the electrons pair up is understood only for conventional superconductors (see below): lattice oscillations in a metal force conducting electrons together at low temperatures.

**Superconductivity:** Among the materials that conduct electricity without loss, physicists distinguish between conventional and unconventional superconductors. In conventional superconductors, superconductivity under normal pressure usually begins below minus 196 degrees Celsius, so that the materials must be cooled using very expensive liquid helium. Unconventional superconductors, in which the formation of Cooper pairs isn’t caused by lattice oscillations, include high-temperature superconductors. The most prominent examples are cuprate ceramics, which, in addition to copper oxide, contain other metals such as barium and yttrium. In these materials, superconductivity occurs above minus 196 degrees Celsius, and in extreme cases at minus 140 degrees Celsius or higher. They can therefore be cooled with relatively inexpensive liquid nitrogen.

**Terahertz radiation:** That portion of the electromagnetic spectrum with a wavelength of between 100 micrometers and 1 millimeter, placing it between infrared and microwave radiation. In addition to many research applications, it is used in body scanners for security screening, and may also be useful in medical diagnostics.

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# Mice Are Here to Stay

Wherever people live, there are mice. It would be difficult to find another animal that has adapted to the habitats created by humans as well as the house mouse has. It thus seemed obvious to **Diethard Tautz** at the **Max Planck Institute for Evolutionary Biology** in Plön that the species would make an ideal model system for investigating how evolution works.





TEXT CORNELIA STOLZE

**T**he mice at the Max Planck Institute in Plön live in their very own house: they have 16 rooms where they can form their family clans and territories as they see fit. The experiments Tautz and his colleagues carry out to study such facets as the rodents' communication, behavior and partnerships sometimes take months. During this time, the mice are largely left to their own devices. Humans enter their realm only to clean up and provide them with food and water.

The mouse house in Plön meets its inhabitant's requirements fully. After all, house mice also live in large family clans in the wild and maintain extensive physical contact and communication with each other. The squeaking familiar to humans is only a small excerpt of the rodents' vocal and sound repertoire. Most of their communication occurs in the ultrasound range, which is not perceptible to the human ear. And while the sounds can be heard by the

mice themselves only within a range of 30 to 50 centimeters, they convey highly complex messages.

Diethard Tautz and his colleagues have discovered that house mice behave naturally only when they live in a familiar environment and interact with other members of their species. When animals living in the wild are captured, they lose their familiar environment: everything smells and tastes different, and they are no longer able to move about freely. And most importantly, they lack contact with the family – a key element in the lives of these extremely social animals.

### A MODEL FOR EVOLUTION

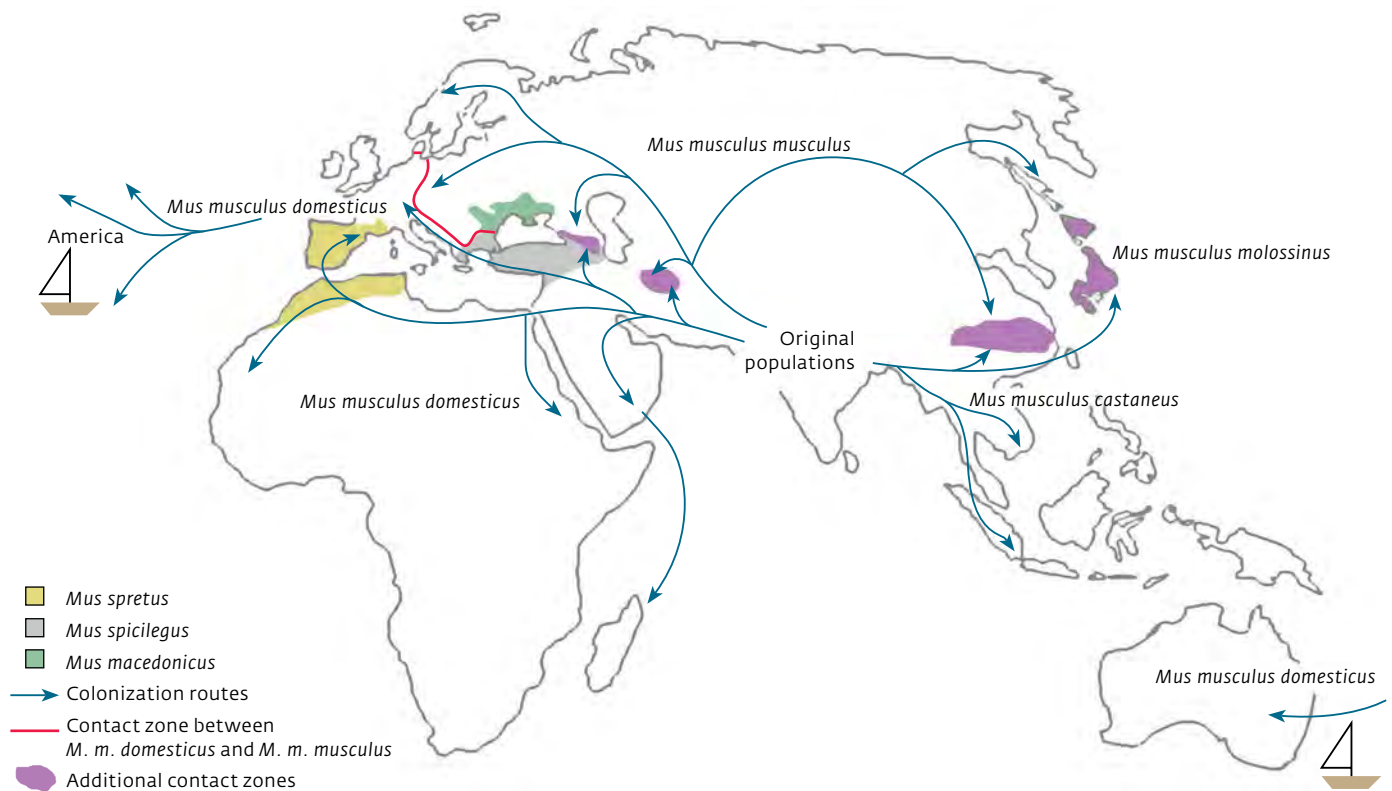
The mice in the mouse house, in contrast, can indulge in their entire repertoire of behaviors. This is the only way the latest evolutionary development of the rodents can be studied, as the results of research carried out in the past showed that differences in behavior

can be a key factor in the emergence of new species. For Tautz, the house mouse is a model for the processes of evolution: it would be difficult to find another animal species that lends itself so well to the study of the genetic mechanisms of evolution.

“Not only is this species extremely adaptable, as demonstrated by its dispersal all over the globe, but we also know its genome better than that of almost any other species,” says Tautz. After all, scientists have been breeding and studying mice in the laboratory for more than a hundred years, observing their behavior and decoding their genome. Today's laboratory mice are descendants of the house mouse, but they are far less genetically diverse than their wild relatives.

The house mouse's first ancestors lived around 500,000 years ago in the region that is now Iran, where they split into subspecies. When humans settled there around 14,000 years ago and started farming, a new age began

While the eyes of the house mouse (*Mus musculus*) tend to be underdeveloped, the rodent's nose and ears play a very important role in the social life of its species: their vocalizations are so complex that the animals can even develop “dialects.” Such regional differences influence the mice's choice of reproductive partner.



for the mice: they couldn't resist the corn fields and storerooms of the first farmers. It's hard to imagine a more reliable and convenient source of food.

From then on, the house mouse conquered the world in the wake of humans. As part of this process, it followed different dispersal routes: the eastern European house mouse (*Mus musculus musculus*) populated northern Asia and eastern Europe and adapted to the continental climate there. The western European house mouse (*Mus musculus domesticus*) reached western Europe, with its Atlantic climate, on Phoenician merchant ships crossing the Mediterranean. Then, with the first European seafarers, they made it as far as America, Australia, Taiwan and even remote archipelagoes such as the Faroe Islands.

With the first European whalers, the mouse also penetrated almost as far as Antarctica, populating regions where it quickly adapted to average tempera-

tures of just under 5 degrees Celsius. To research this diversity, there are mice from all over the world living at the Max Planck Institute in Plön: in addition to mice from Germany and France, there are conspecifics from the Faroe Islands, Spain, Austria, Kazakhstan, Iran and even Taiwan.

### FROM VEGETARIAN TO CARNIVORE

When necessary, the house mouse even adapted its originally vegetarian eating habits. The descendants of the former sea-faring mice, for instance, feed on insects, worms and larvae. On the island of Helgoland, they even became accustomed to eating dead sea birds. They are so flexible that, as long as they have a good food supply, mice don't even need direct access to water.

A few years ago, Diethard Tautz discovered a possible key to the evolutionary success of the house mouse: new,

functional genes can form from parts of the genome within a short period of time. These genome sections had previously baffled researchers, as they don't contain any information that can be translated into functional proteins. For this reason, up to 90 percent of the mouse genome was classified as junk DNA. However, the Max Planck working group discovered that these originally functionless DNA sequences could give rise to new genes. "They really are complete reinventions – something that previously would have been considered impossible," explains the evolutionary biologist.

By genetically analyzing several mouse species, Tautz and his colleagues discovered that only a small percentage of the DNA is translated into proteins. Nevertheless, almost every DNA section is transcribed into an RNA molecule and can thus be a candidate for a new gene. Sections of DNA that are read but not translated into proteins

**Left page** Origin and range of the house mouse: Two million years ago, their closest relatives *M. spretus* (yellow), *M. spicilegus* (gray) and *M. macedonicus* (green) separated; today their ranges overlap in different regions of Europe. Half a million years ago, subspecies of the house mouse then emerged in the area that is now India and Iran. The rodents gradually spread across the globe in the wake of the first farmers: the eastern European house mouse (*M. m. musculus*) migrated to northern Asia and eastern Europe, the southeastern Asian house mouse (*M. m. castaneus*) to eastern Asia, and the western European house mouse (*M. m. domesticus*) to western Europe. From there, the western European house mouse spread to all the other continents by ship. The different subspecies encountered each other in different regions of the world and cross-bred with each other (purple). One example of this is a narrow hybrid zone in central Europe (red line). A new hybrid subspecies, *M. m. molossinus*, emerged in Japan as a result of the contact between the eastern and Asian house mice.

**Right** Diethard Tautz at the demonstration enclosure in the visitors room at the Max Planck Institute for Evolutionary Biology. The mice live here in a highly diverse environment under nearly natural conditions. The actual experiment rooms are fitted with the same structural elements.

are thus called precursor genes or proto-genes. Whether they become genes or not depends on the environment: if an RNA molecule assumes an important function, the coding section of the DNA remains active and is retained. If the RNA molecule fails to find a useful task, the section becomes non-coding DNA again.

But new genes also arise through a second mechanism: when a gene for a protein arises from an originally non-coding section due to a change in the DNA reading frame. A reading frame comprises three consecutive letters of the genetic alphabet. Each of these triplets stands for an amino acid into which the genetic code is translated. If this reading frame shifts, new triplets arise and the sequence of letters can be translated into amino acids. The scientists in Plön identified several genes that were overwritten due to such a change in the reading frame. One example is the *Hoxa9* gene





Diethard Tautz and his colleague Christine Pfeifle have completed all the preparations. The inhabitants will now be left undisturbed for months; their behavior is recorded by cameras. The rooms are equipped with wood shavings for burrowing and digging, and with feeding dishes and water bottles; the red "huts" with access tubes and removable lids serve as nests. The mice live in differently equipped environments depending on the nature of the experiment: in this relatively unstructured experiment room, the researchers are studying the social behavior and the territory formation of *Mus spicilegus*, a particularly social species. Working together, the animals built themselves a nest in a corner under a pile of bedding (back) and assembled all the food supplies in the middle of the room.

– a gene that controls embryonic development. In rodents and primates, this gene uses an additional, alternative reading frame of this kind.

The researchers suspect that genes frequently form anew. According to their findings, only around 60 percent of the mouse genes originate from the early phase of evolution. Over time, apparently every section of the DNA is, at some point, read and tested to see whether it is suitable as a gene. "The non-coding sections of the genome are therefore a reservoir for new genes that can thus help the animals rapidly adapt to new habitats. This harbors enormous potential for evolution, and we previously knew nothing about it," says Tautz.

The studies carried out at the Max Planck Institute in Plön also showed that the emergence of new genes can increase significantly under certain circumstances. A lot of new genes arise after major ecological changes: for instance, a particularly high number of new genes emerged during the transition to the Cenozoic era, when the di-

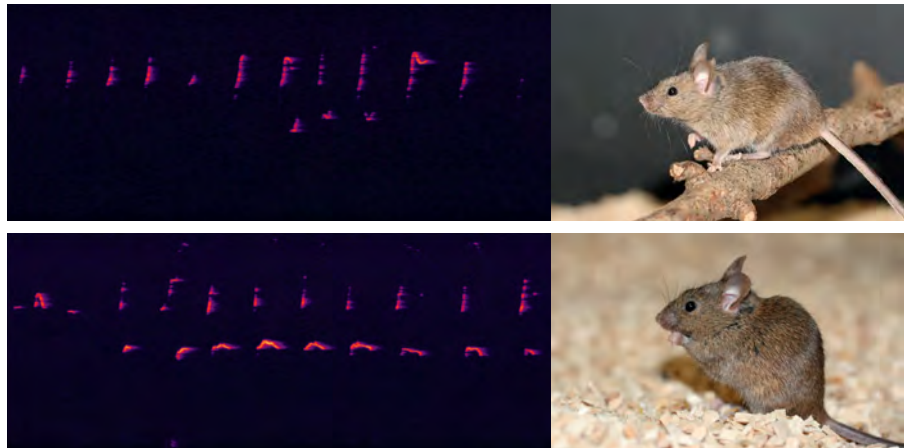
nosaurus became extinct, and in the most recent lineage leading to mice.

In addition, whenever the house mouse encountered a new habitat over the course of evolution, new populations formed with different characteristics and occupied different ecological niches – a phenomenon known as adaptive radiation. "It was long believed that this kind of adaptation to new living conditions was a very slow process," explains Tautz. "Recent studies have shown, however, that animals sometimes adapt after just a few dozen generations – so, for mice, within just a few years."

### ISLAND MICE GO THEIR OWN WAY

Tautz and his colleagues are able to study the consequences of adaptive radiation and the very rapid adaptation of animals to new conditions using the house mouse in different locations in Germany, including the island of Helgoland. Located 50 kilometers from the mainland, house mice arrived on this

Comparison of some ultrasounds of animals from the same subspecies, *M. m. domesticus*, from France (top) and Germany (bottom). The animals communicate using complex syllables that can differ from one region to the next. The females communicate a lot with each other – especially when they are alone together. The females make fewer and different sounds when in contact with males.



North Sea island on board ships only a few hundred years ago. “This is a mere blink of an eye in terms of evolution. Nevertheless, the animals on the island already differ considerably from their conspecifics living on the mainland,” says the Max Planck researcher.

Evolutionary biologists attribute this to, among other things, differences in the food supply: while house mice on the mainland have a mostly plant-based diet, their relatives on Helgoland were forced to become accustomed to eating meat, as there is no farming on the island. They now presumably eat dead sea birds instead of plants, and their chewing apparatus has developed toward that of a predominantly meat-eating species.

The Helgoland mice hardly mix with their relatives that are constantly arriving from the mainland, so it’s only a matter of time before the Helgoland animals become a separate species: when two populations no longer exchange genes, different mutations arise in the two groups and they develop in different directions. This kind of geo-

graphical isolation, combined with new adaptations, is considered to be one of the mechanisms for the emergence of new species.

This species formation, which is known as allopatric speciation, is already further advanced in the eastern and western subspecies *M. m. musculus* and *M. m. domesticus*. The two still belong to one species. However, they are clearly distinguishable both genetically and in terms of their external appearance, and the two groups’ ability to reproduce with each other is now limited. This can be observed particularly well in the range boundary of the two subspecies along the climate divide between the Atlantic and continental climates: their ranges overlap in a 40-kilometer-wide strip – known as a hybrid zone – along this divide. The animals come into contact with each other here and reproduce regularly.

Consequently, the genome of the resulting hybrids consists of those of the western and eastern subspecies. However, the two species’ genomes are evidently now compatible only to a

limited extent, as the hybrid offspring suffer from a weak immune system and are more vulnerable to parasite infestations. This also has an impact on the rodents’ intestinal flora. John Baines, a visiting professor at the Max Planck Institute in Plön, carried out a genetic analysis of the biodiversity of these intestinal bacteria. He found that the hybrids’ intestinal flora includes fewer bacterial species, and that the different species also occur with different levels of frequency. For example, a hybrid mouse has considerably more helicobacter bacteria than its purebred parents. In humans, these microbes can cause intestinal ulcers.

### IMMUNE SYSTEM ALTERS INTESTINAL FLORA

The scientists explain this as follows: Different variants of genes for the immune system result in the formation of different immune cells. The hybrid mice thus have different T cells. These immune cells also occur in intestinal tissue and evidently have an adverse ef-



fect on the bacteria there. This doesn't appear to benefit the mice, as the hybrids are more prone to intestinal tissue infections than their parents.

In addition, sperm maturation is severely impaired in the hybrids, causing them to produce fewer offspring. Leslie Turner and Bettina Harr, two former colleagues of Tautz, discovered a complex network of interactions between different gene regions that can prevent reproduction between the hybrids over the course of evolution. In this way, the differences between the forms of mouse constantly reinforce each other until the two subspecies eventually give rise to completely separate species. Crossbreeds of the two subspecies can't survive in nature in the long term. "If the offspring of a hybrid are less fit than their parents, the populations inevitably drift apart," concludes Diethard Tautz.

But a species split isn't triggered solely by physical differences; differences in behavior are often the starting point for separation. In this way, a highly diverse group in which all males and females can theoretically produce offspring together can lead to

populations that cease to operate harmoniously – be it because the animals no longer find each other attractive, because one group builds different nests, or because the females are fertile at a different time. Such changes in behavior are the main reason for the incipient isolation of one or more groups within a population. Researchers call this sympatric speciation.

### GENES FOR PARTNER SELECTION

Tautz and his team recently encountered a complex in the mouse genome that is made up of several genes and that crucially influences the animals' partner selection. This PWS region, as it is known, controls several behaviors and ensures that different "personalities" form between individual populations. The researchers discovered, for example, that western house mice from western Germany and the south of France differ in their mating behavior.

"If we put animals from the area around Cologne, far west of the hybrid zone, together with members of the same species from the French Massif Central in our mouse house,

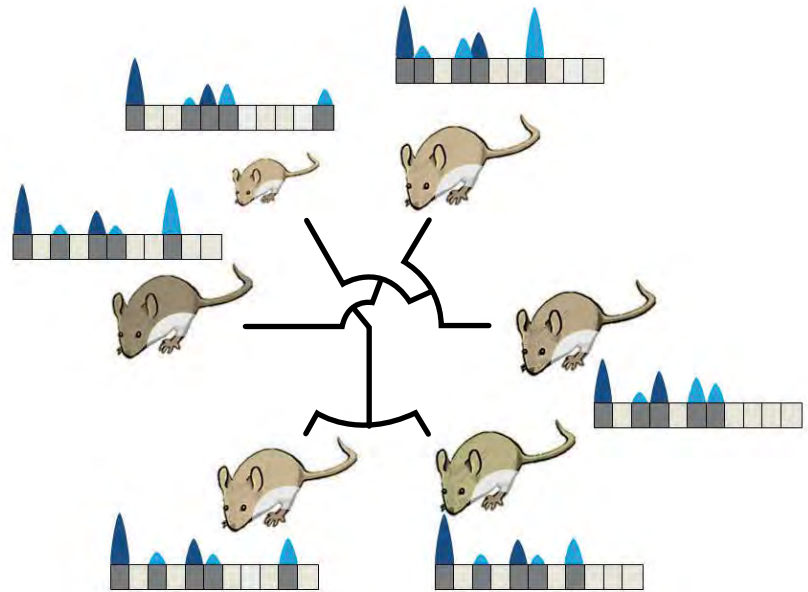
they all mate with each other initially," says Tautz. "However, something surprising happens with their offspring: the mice with one German and one French parent later show a preference for partners of the same origin as their father."

It is still unclear precisely what causes such preferences. What is known is that, in mice, a partner's attractiveness is conveyed through odorants and sounds in the ultrasound range of 50 to 70 kilohertz. "We originally suspected that the males, in particular, convey mating signals through the sounds they make, just like the chirping of songbirds. But then we observed that females communicate far more with each other, particularly when they are alone together," says Tautz.

French and German mice differ in the sounds they make, and thus speak, as it were, different languages – despite belonging to the same subspecies. This contributes to the separation of the populations, but the search for the cause of the paternal preference continues. The German and French mouse populations clearly were physically separated from each other long enough

**Left page** Diethard Tautz (standing), Johana Fajardo, Derek Caetano-Anolles, Chen Xie, Kristian Ullrich and Wenyu Zhang (clockwise) discuss their projects.

**Right** DNA sections with varying degrees of activity in the genomes of different mouse species (black lines indicate the relationships between them): dark gray boxes represent regions that are translated into RNA molecules and the height of the triangles above the boxes indicates the volume of RNA produced. While 10 percent of the DNA in all the animals is used identically (box on the left), non-coding sections are read at varying levels of intensity. The resulting RNA molecules are retained only if they offer an evolutionary advantage. New genes can then form from these sections.



for the initial indications of separate development to emerge within the subspecies.

In addition, another aspect of sexual behavior accelerates speciation: although mice have many different sexual partners, the researchers also regularly observed cases of fidelity and inbreeding. Large families in which fathers produce offspring with daughters and mothers with sons often arise in the behavioral rooms. This promotes the formation of genetically uniform groups and thus strengthens the speciation process. This natural inbreeding is also the reason why mice are such a good genetic and biomedical model system: the requisite genetically uniform inbred strains are particularly easy to establish with mice.

The research by Diethard Tautz and his colleagues shows that mice are much more than pests and carriers of disease. On the contrary, their proliferation across the globe is an object lesson in how organisms can adapt to new habitats. The different house mouse populations on earth constitute evolutionary experiments from which new species could one day emerge. ◀

### TO THE POINT

- The modification of existing genes isn't the only thing that gives rise to new characteristics in evolution: completely new genes can also be created from previously non-coding sections of DNA. This happens especially when major ecological changes occur or when species populate new habitats.
- As hemerophiles – animal and plant species that thrive in habitats altered by humans – house mouse populations and subspecies have spread throughout the world and repeatedly adapted to new environmental conditions. Accordingly, they constitute a natural experiment on the part of evolution – one that enables scientists to study the emergence of new species.
- Differences in behavior, for example in partner selection, and in the formation of social systems are the first steps in one species splitting into two separate species.

### GLOSSARY

**Allopatric speciation:** Individuals of one species are separated by external factors such as mountains or estuaries. Over the long term, this spatial isolation results in the accumulation of different mutations in the subpopulations and, consequently, the formation of genetic differences. The animals can no longer reproduce successfully with each other, and two new species form. When species split in the absence of spatial separation, it is referred to as sympatric speciation.

**Radiation:** Diversification of a group of organisms or a species into a larger number of new species, which adapt to new ecological niches and thus form new characteristics. This can cause an abrupt increase in the number of new species, for example when a new habitat is populated. In contrast, the fragmentation of an originally contiguous habitat can also trigger the emergence of new species, but this is a continuous process that unfolds over a long period of time. New species can also take over the vacated ecological niches when competitors disappear, as was the case with mammals when the dinosaurs went extinct, for example. A successful evolutionary innovation can also result in the emergence of many new species.

# Biomolecules in Action

Techniques that provide insights into the nanoworld continue to garner Nobel Prizes. However, none of those methods has made it possible to observe exactly how enzymes and other biomolecules function. **Frank Vollmer**, Leader of a Research Group at the **Max Planck Institute for the Science of Light** in Erlangen, has now changed all that – with a plasmonic nanosensor.

TEXT **CHRISTIAN MEIER**

**F**rank Vollmer spared no effort. Sure, scientists often put a lot of time into developing new methods, especially when they're looking for something fundamentally new. But Vollmer, a biochemist by training, spent around 20 years working as a physicist to devise the tool he needed to realize his project. Ever since his days as a biochemistry student in Hanover in the 1990s, he's always wanted to watch the machinery of life at work.

That desire still drives him today in his role as a Research Group Leader at the Max Planck Institute for the Science of Light in Erlangen and a professor at the University of Exeter. He wants to understand why the tiny machines that keep life processes running sometimes go awry, causing us to become ill. To realize his plan, Vollmer had to become

an inventor. He needed a kind of camera that can record individual enzymes and the movements of their parts, but the laws of physics appeared to prohibit such a device. Nevertheless, the scientist recently caught a glimpse of one of the most delicate mechanisms of life.

## BIOLOGICAL TOOLS WORK LIKE TECHNOLOGICAL ONES

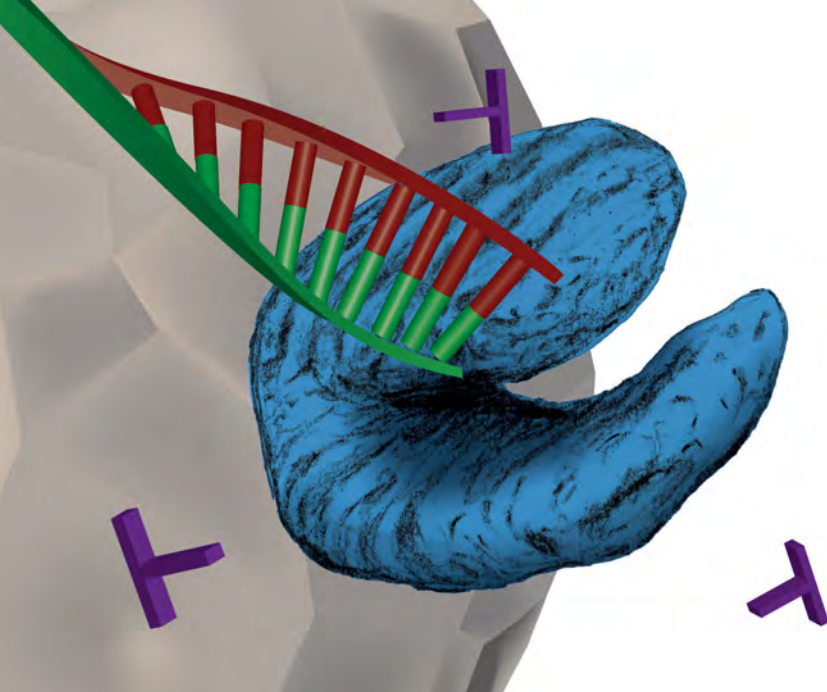
“We all consist of nanotechnology,” says Vollmer. That's true. For one thing, proteins, enzymes and other biomolecules are just a few nanometers in size. One nanometer, a millionth of a millimeter, is as tiny as a soccer ball is in relation to planet Earth. For another thing, like man-made machines, these tiny workhorses in the body each serve a specific purpose – one protein transports oxygen, another breaks down sugar mole-

cules, a third reads genetic information – and often have moving parts.

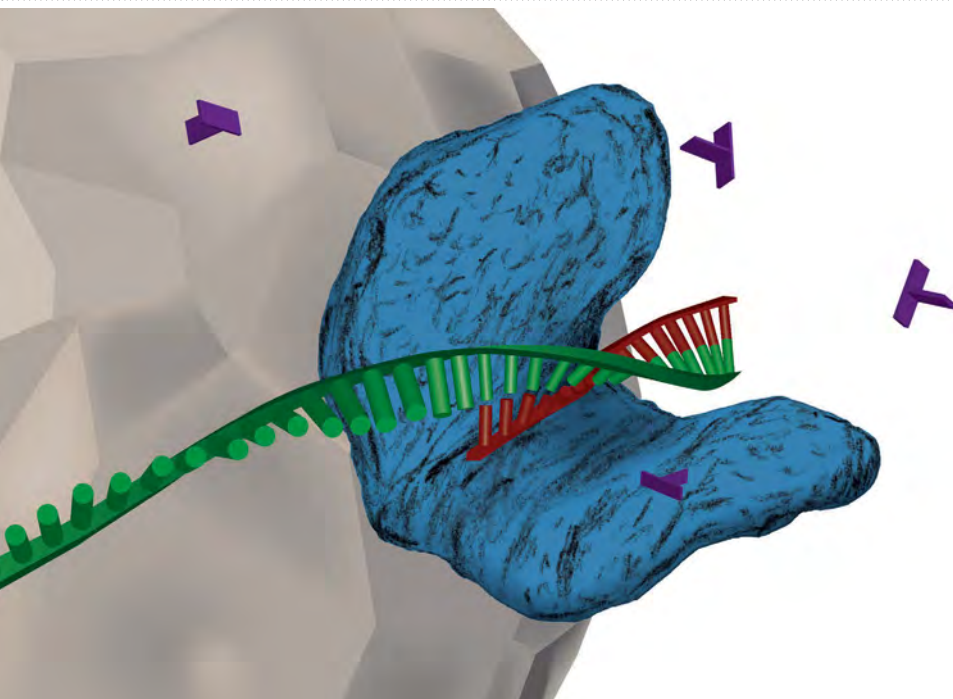
An enzyme that carries out a fundamental life process reveals just how similarly biological and technological tools function: DNA polymerase duplicates the DNA molecule, thus enabling cells to divide. This process underlies every form of reproduction. The enzyme is reminiscent of a hand with a thumb and fingers that literally grasps the DNA strand being copied.

Observing enzymes such as DNA polymerase in action is especially important when the biological machines develop a hitch. Catching a glimpse of these nanomachines at work could then reveal where the problem lies. When DNA is copied during cell division, errors can occur, much like typographical errors in a book. In some circumstances, such mutations can lead to





An enzyme gets a grip: Like a hand opening and closing, DNA polymerase grasps the building blocks of our genome. When the biomolecule is bound to a gold nanowire that focuses light tightly, the overlap with the light spot changes. In this way, the movement of the enzyme can be observed.

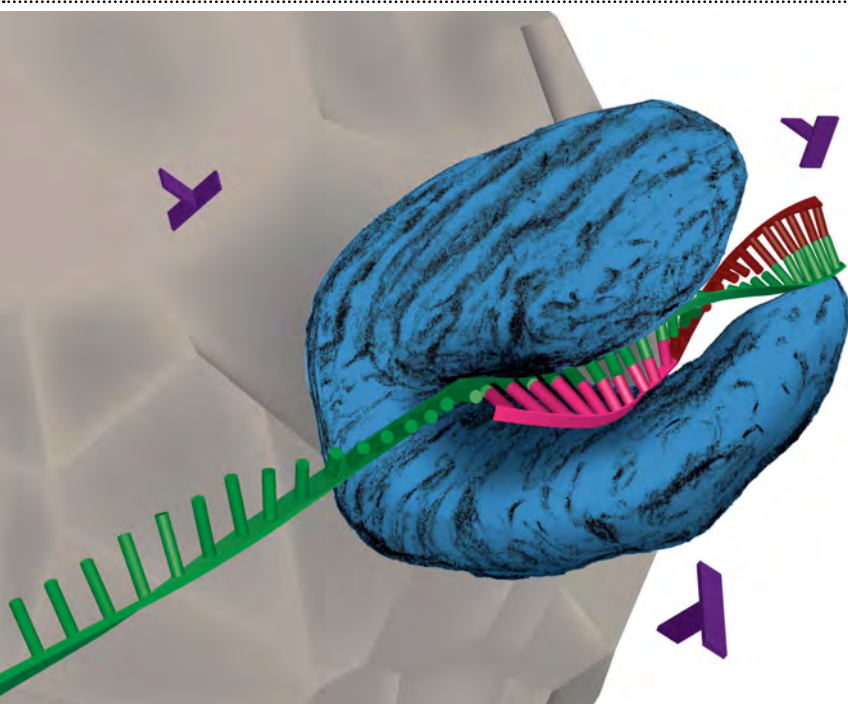


diseases, such as cancer. In other illnesses, such as Alzheimer's, proteins change shape, causing biomolecules to lose their ability to function.

Frank Vollmer regrets that science has so far been largely blind to the movements of biomolecules. "We can't see the very thing that's so crucial for our understanding of disease," he laments. "The fact that the hand opens and closes very rapidly doesn't help matters either."

Despite the tiny size and extremely rapid nature of life processes, Frank Vollmer found a way to watch nature's nanotechnology at work. To do this, he uses visible light – just like our eyes, cameras and video cameras do. Light waves are a harmless part of the electromagnetic spectrum. They are much gentler than, say, X-rays, whose high energy can virtually pulverize molecules. In addition, they cause very little heating of a sample. In short, visible light is a practically neutral observer.

Unfortunately, a normal light microscope is unable to resolve nanostructures because visible light can't be focused to a small enough point of light. A focal point measuring half the light's wavelength is about the limit, or around 200 nanometers. Although some methods, such as STED microscopy, use physical tricks to get around this resolution limit, they can only observe cell components that are labeled with fluorescent molecules, or markers. The





Frank Vollmer wanted to understand how RNA is read. To answer this question, he first had to develop a suitable method.

points of fluorescent light then show how the biomolecules move about, much as car headlights at night reveal where a car is heading. But a great deal remains in the dark, such as whether the points of light belong to a car or a truck, or whether a door is opened on a stationary car. In the same way, the fluorescent molecules don't show in detail whether or how a protein changes shape. Moreover, scientists can never be sure that the labels don't interfere with the function of the biomolecule they are investigating.

### LIKE A WHISPERING GALLERY

Frank Vollmer reached the limits of optical observation at the latest during his doctoral work at Rockefeller University in New York, where he was researching how the second carrier of genetic information, RNA, is read. "At that point, I realized that a suitable method had yet to be invented." The biochemist decided to devise one himself and became a physicist to do it. He had, after all, always been interested in this discipline.

Before long, Vollmer came across a technique that pointed in the right direction. It is the optical analogue of a whispering gallery. In a rotunda, a word whispered toward the wall can easily be heard on the opposite side of the chamber because sound waves travel along

the curvature instead of spreading out in all directions. Similarly, a light wave runs along the inside of a glass bead measuring just a few micrometers (thousandths of a millimeter), whizzing around inside it tens of thousands of times. As it circulates, the wave keeps encountering itself. At a well-defined wavelength that depends on the size of the glass bead, the wave crests traveling around the glass bead overlap precisely with the crests of previous laps. Physicists refer to this phenomenon as resonance. This is analogous to the resonant body of a musical instrument that, because of its dimensions, amplifies only certain sounds.

The optical whispering-gallery effect makes the glass bead a very sensitive sensor. The light wave extends somewhat beyond the surface of the bead. If a virus or protein, for example, adheres to the surface of the microbead, the particle interacts with the light wave, slowing it down a little. The effect is the equivalent of increasing the circumference of the bead's wall. Consequently, the virus or protein alters the resonant wavelength of the microbead. Although the change is minimal, it can be detected thanks to the sharpness of the resonance.

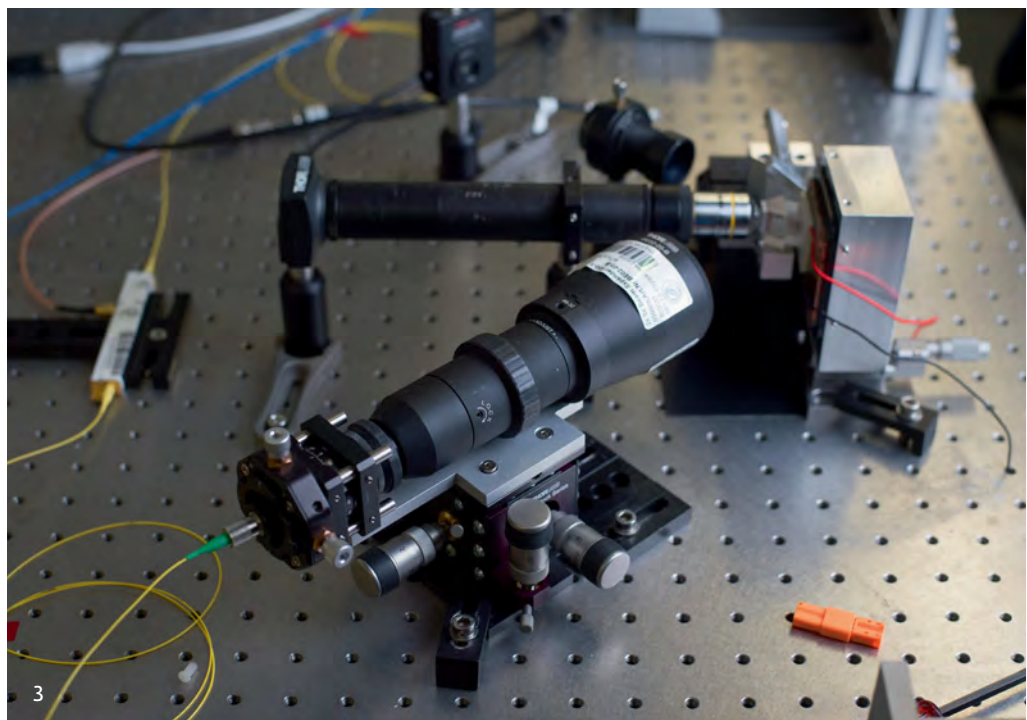
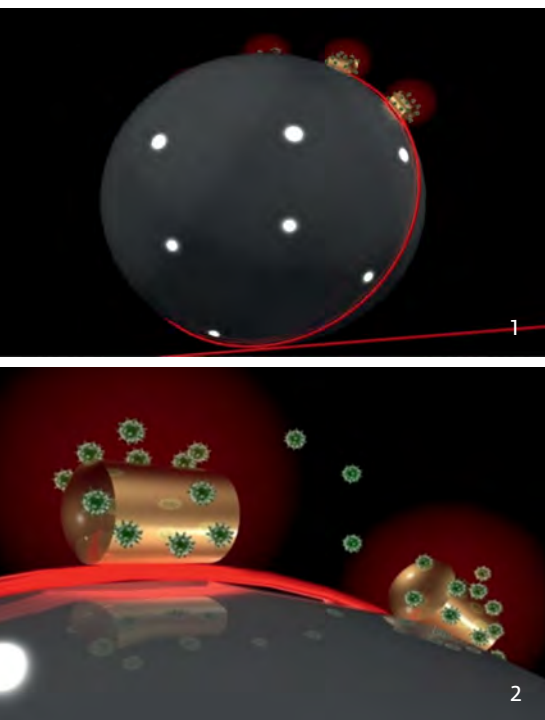
Vollmer succeeded in using the optical whispering gallery as a biosensor for the first time while still working in

New York. He shone laser light into a glass bead and used it to detect proteins. At the time, though, he was able to detect only *multiple* proteins bound to the bead, as only then did the wavelength of the circulating light change appreciably. However, to understand how the nanomachines of life work, it is necessary to observe *single* biomolecules. An ensemble of proteins produces only an average value from which it is impossible to determine the behavior of individual molecules.

### THE TRICK: A COMBINATION OF OPTICS AND PLASMONICS

While head of a research group at Harvard University, Vollmer thus worked on refining the method. He ultimately succeeded in using the glass bead to detect *single* viruses. It was a remarkable triumph, but he had not yet achieved the actual goal of observing single biomolecules. After all, a virus is still ten times larger than a protein.

"We soon realized that it would be far more difficult to detect individual biomolecules," Vollmer says. The light path changes in relation to the volume of a detected nanoparticle. The change caused by a single molecule is therefore only about one-thousandth the magnitude of that caused by a virus, putting it well below the detection limit. Fellow



physicists advised Vollmer to try other methods. “But such methods would have required much more complicated experimental setups,” Vollmer explains. He wanted a tool that biologists can use relatively easily.

In 2010 he came up with an idea that would lead to a breakthrough. The trick was to combine optics with a very different branch of physics: plasmonics. Plasmonics exploits the fact that electrons in a metal form a sort of collective, similar to a liquid, that moves freely past the firmly fixed atomic cores in the crystal lattice. Because the negatively charged electrons are attracted to the positively charged atomic cores as though they were attached to them by coil springs, the collective oscillates back and forth. The oscillations of the electric charge are called plasmons.

Plasmons produce an electrical wave that extends beyond the metal surface, just like light waves extend beyond the surface of the optical whispering gallery. The fact that such plasmons

can interact with light was also crucial for Vollmer’s plans. The researchers reasoned that if they attached a nanowire about the size of a single biomolecule to an optical whispering gallery, the light waves that extend beyond the surface would excite plasmons in the metal. That, in turn, would generate light waves on the surface of the wire.

### A HOTSPOT AMPLIFIES THE INTERACTION

Thus, a nanowire would effectively draw the light wave out of the glass bead and focus it on a spot about the size of a protein. This hotspot focusing, as Vollmer calls it, would amplify the interaction between light and the object under investigation. In this way, even a single biomolecule could lengthen the path of the light to the extent that the change would be measurable.

Vollmer set about implementing the idea at the Max Planck Institute for the Science of Light in Erlangen. DNA

An optical whispering gallery as a nanosensor: When laser light of a suitable color (here red light) is guided through a glass fiber into a glass microbead, it circulates within the bead like sound in a rotunda (1). Gold nanowires attached to the bead concentrate the light by means of a plasmonic effect. Proteins and other molecules that bind to the nanowires (2) change the wavelength of the light coupled to the bead, thus allowing the molecules and their movements to be detected. Such nanosensors for proteins and their movements were successfully tested for the first time in an experimental setup at the Max Planck Institute for the Science of Light (3).

»» A nanowire draws the light wave out of the glass bead and concentrates it on a spot the size of a protein.

polymerase served as a good test enzyme because its opening and closing motions resembling those of a “hand” should result in a periodic increase and decrease of the overlap between the enzyme and the light at the hotspot, much like the shadow of a hand changes as it opens and closes in front of a light source.

First, Isabel Schuldes, a master’s degree student in Frank Vollmer’s group, attached gold nanowires with a diameter of just 10 nanometers and a length of 40 nanometers to a glass bead with a diameter of 80 microns. Normally, electrostatic forces would bind the gold to the glass. In Erlangen, however, this mechanism conflicted with the chemical conditions required by the polymerase. Its preferred pH tended to break the electrostatic bond. After an elaborate search, Schuldes found a linker molecule that binds the nanowire to the glass bead: “That gave me a great sense of achievement,” she says.

Now the scientists were able to focus their nanospotlight on biological machines. They attached DNA strands to the fine wires and dipped their nanosensor into a polymerase solution. The enzyme then copied the attached DNA.

In another experiment, the researchers attached the polymerase to the nanowire and mixed DNA into the solution. Schuldes had previously confirmed that attaching the enzyme to the gold doesn’t affect its activity. In both cases, during the copying process, the polymerase was inside the light spot focused by the nanowire and, it was hoped, would change the measurement signal as the enzyme hand opened and closed.

#### THE RESEARCHERS EVEN OBSERVED SINGLE IONS

And the researchers did indeed observe their signal waxing and waning in cycles of about 20 to 50 thousandths of a second. “For the first time, we were able to observe protein dynamics without using markers,” says Vollmer. And they were able to do so live, in such conditions as occur in nature. Vollmer even thinks it is possible to record the sequence of the DNA letters as the polymerase is reading them. Copying errors could be detected this way, too. “It would also be a very simple and inexpensive method for studying DNA,” Vollmer says.

After this success, the researchers wondered about the limits of their new method. To their own astonishment, they were even able to observe *single* ions – that is, electrically charged atoms. The zinc and mercury ions they used are one hundred times smaller in diameter than a protein. It helped the researchers that the gold nanowires tapered to a single gold atom at the tip. The plasmonic light spot therefore focuses on an extremely small spot at the very tip, causing the electrons to gain more energy than they would normally have in gold. Because of their energy gain, the charge carriers activate a reaction between the gold atoms and the mercury ions. The researchers in Erlangen were able to observe this reaction.

“It’s not about detecting single mercury ions,” Vollmer stresses. The sensitivity for single ions can be used, for example, to investigate the function of ion channels, he says. These channels are embedded in the membranes of neural cells, for instance, and help conduct electrical stimuli through nerves.

Thanks to its ability to track reactions such as that between gold atoms and mercury ions, the nanosensor is also suitable as a chemical tool, the bio-

**Top** Isabel Schuldes, Ying-Jen Chen and Frank Vollmer (left to right) have made the plasmonic nanosensor so sensitive that it can even detect substances that form during cell death. It takes a fine touch to couple the laser light to the sensor.

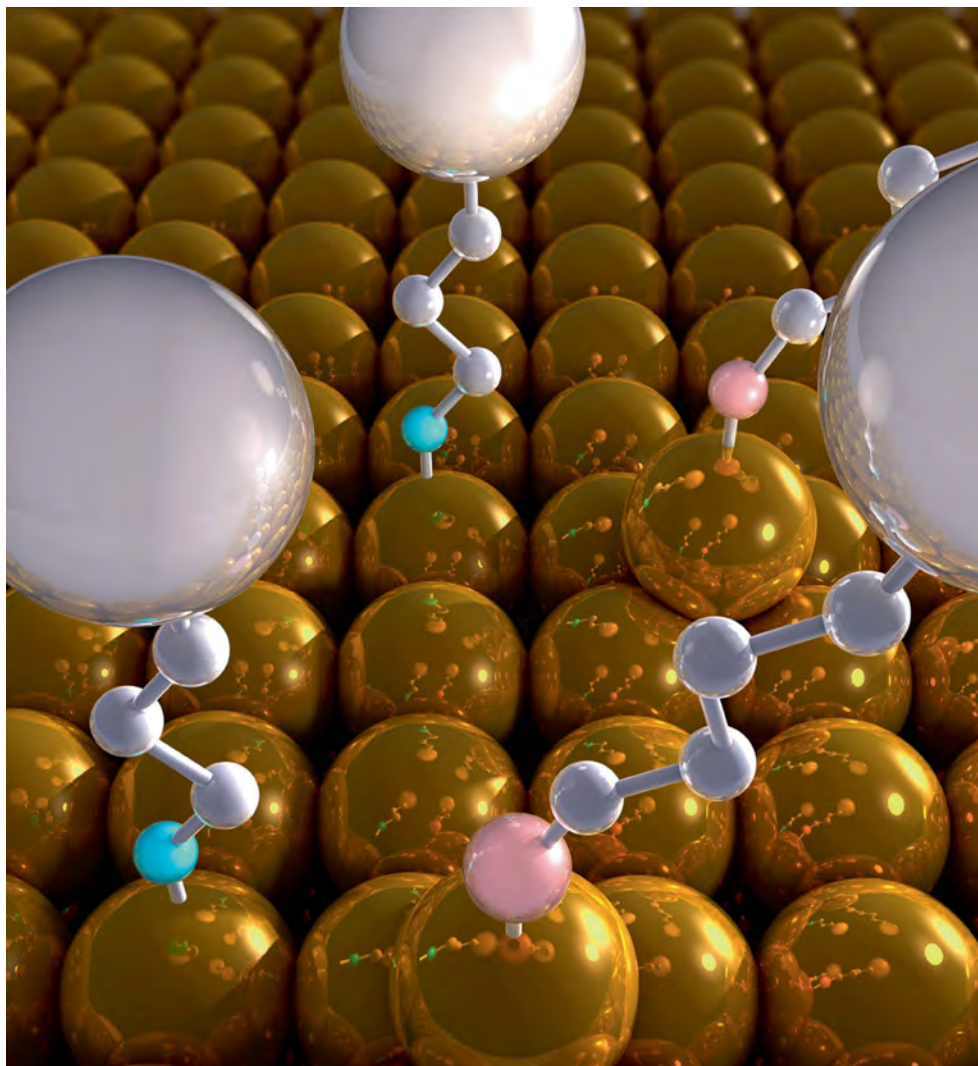
**Bottom** The nanosensor is also suitable for analyzing chemical reactions. The Max Planck researchers used it, for example, to show that molecules with amino groups (pink) adhere to gold atoms protruding from the surface of the nanowire. Molecules with thiol groups (blue), in contrast, bind to gold atoms embedded in the surface.



physicist explains. It can be used to test and optimize conditions to *control* reactions to a certain extent. The team in Erlangen even showed how to do this. By increasing the light intensity in the focused light spot, they caused the electrons in the gold tip to reach a very high energy level. This allows a particularly strong type of chemical bond, known as a covalent bond, to form. In this way, the researchers created an amalgam between gold and mercury as if by turning a light dimmer switch.

In an experiment with two types of molecules, the researchers demonstrated the precision with which the mechanisms of chemical reactions can be observed using the Erlangen method. One type of molecule bonded with the gold via an amine group, the other via a thiol group. "It turned out that the two groups react with the gold surface through two different mechanisms," Vollmer explains. Whereas the amines combine only with gold atoms that protrude above the surface, the thiols bind only to atoms that are fully embedded in the surface.

The extreme sensitivity of the nanosensor that Vollmer's team developed isn't its only distinguishing feature. As





A sensor with many senses: At the Living Systems Institute of the University of Exeter, Hsin-Yu Wu, Serge Vincent, Jolly Xavier, Frank Vollmer, Tom Constant and Sivaraman Subramanian (left to right) built an experimental setup that combines various approaches: the effect of an optical whispering gallery in a glass bead, the plasmonic concentration of the light that circulates inside the bead, and microscopic and spectroscopic methods. The researchers' aim is to analyze the movements of biomolecules in as much detail as possible.

an added benefit, even non-physicists can use it without the need for costly special equipment, Vollmer points out. It also works in aqueous milieus, giving biologists and physicians an eye, as it were, that they can place right at the center of microbiological life.

Vollmer's doctoral student Ying-Jen Chen, for example, uses the sensor to observe the death struggle of cells. Although this process, called apoptosis, is an intracellular process, Chen managed to observe it from outside the cell without influencing the process itself. Using the microbead method, Chen detected a chemical marker of cell death: the

protein cytochrome c. To do this, Chen coated the sensor with an antibody that binds exclusively to cytochrome c.

#### CHIPS FOR RAPID CANCER DRUG SCREENING

Chen is also trying to shrink the microbead method down to chip size. Individual cells are held in tiny channels in plastic tiles barely larger than a fingernail. A toxin flows through the channels, causing the cells to initiate apoptosis. The released cytochrome c is then flushed out and sent to the sensor setup, which still occupies most of the

# Gravitational waves detected!

Gravitational waves – those ripples in the fabric of space-time predicted by Albert Einstein – are real.

The Foundation supported Karsten Danzmann at the Max Planck Institute for Gravitational Physics – he played a key role in developing the highly sensitive detectors crucial to this groundbreaking discovery.



surface of a lab bench. The goal, however, is to shrink the measuring apparatus so that it, too, fits on a chip.

“The chips could be used, for example, to screen cancer drugs much faster than is normally possible today,” Chen says. Many of those drugs trigger apoptosis in cancer cells to kill them. “Our method is suitable for use as an organ-on-a-chip,” Vollmer adds, referring to chips that simulate entire organs by connecting cell cultures via complex microchannels or mechanisms.

Vollmer has since reached a point in his research career where he is able to return to biology after his excursion into the world of physics. He now wants to use the plasmonic nanosensor in a biological and medical setting, namely at the Living Systems In-

stitute at the University of Exeter. “This is the ideal place for it,” he says. There, he plans to investigate pathologically deformed proteins. It is possible to visualize such defective proteins by using light to stimulate the biomolecules to vibrate.

But Frank Vollmer also wants to further develop the nanosensor – into a laser scanner for single molecules. Using multiple focused light spots, it should be possible to scan molecules atom by atom and reconstruct an accurate 3-D atomic image from the data at several million frames per second. “This could finally reveal the secrets of the nanotechnology of life,” Vollmer says. He may soon be recording entire movies of biomolecular machines – lights ... camera ... action! ◀

## TO THE POINT

- **Max Planck researchers working with Frank Vollmer have developed a plasmonic nanosensor that makes it possible for the first time to observe enzymes and other biological molecules in action and even to record the movements of their parts.**
- **The nanosensor consists of a glass microbead with a gold nanowire attached to it. It exploits the effect of an optical whispering gallery, with light of a defined wavelength circulating inside the bead tens of thousands of times. At the same time, it uses plasmons to focus the light on a point just a few nanometers wide. Whenever a biological molecule binds to the gold wire or a bound nanoparticle moves, the wavelength of the light coupled to the glass bead changes.**
- **The researchers have used the sensor to track the movements of DNA polymerase, the process of cell death, and reactions of mercury ions and organic molecules with gold atoms in the nanowire.**

## GLOSSARY

**DNA polymerase:** An enzyme that makes a copy of DNA during cell division.

**Plasmon:** Oscillations of the electrons in a metal can produce electrical waves. These are known as plasmons, and they can be excited with light.

**STED microscopy:** In fluorescence microscopy, fluorescent markers on a nano-object are excited with a focused laser. According to the diffraction limit, the light spot can be focused no more tightly than half the wavelength of the light, so to an area measuring around 200 nanometers across. A STED (stimulated emission depletion) microscope circumvents this limitation by extinguishing part of the emission in a controlled manner.

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A man in a blue t-shirt and red shorts stands in a dense forest, looking upwards and holding a clipboard. The scene is filled with green foliage and tree trunks, with sunlight filtering through the leaves.

Before Henrik Hartmann began researching trees, he lived in a Canadian forest for a while.



# Rooted in the Forest

Sometimes it takes a while for a person to find their vocation. **Henrik Hartmann**, for example, didn't attend university until he was at an age when others have already earned a doctorate. Today, the forestry scientist heads a research group at the **Max Planck Institute for Biogeochemistry** in Jena. And the things he experienced prior to studying were no less exciting.

TEXT **PETER HERGERSBERG**

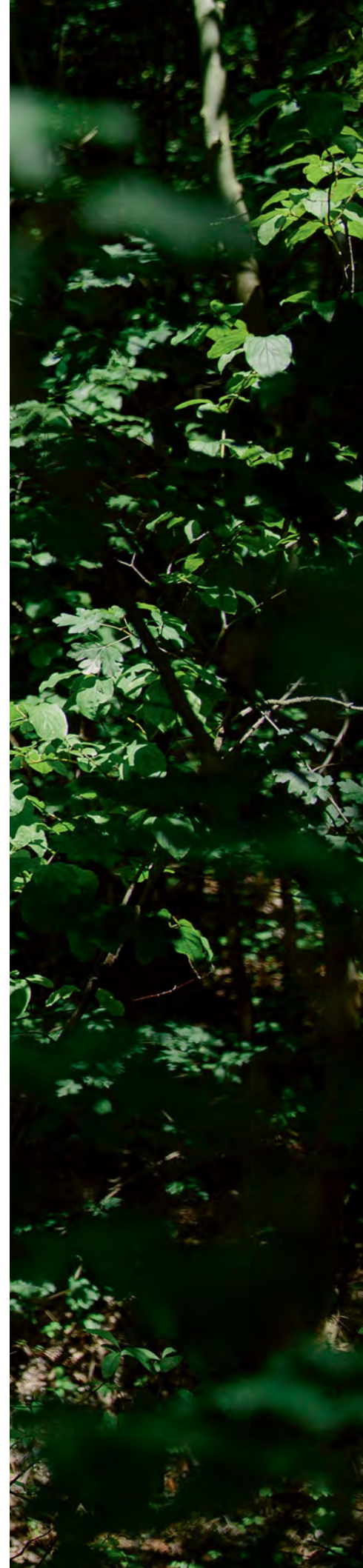
**H**enrik Hartmann's scientific inquisitiveness barely had a choice. As it gradually asserted itself and sought a purpose, Hartmann lived in a remote house in a Canadian forest, owned 45 hectares of it himself, made his own wood and worked in forestry. "Life there was dominated by the forest," he says. "And I trekked through it often enough." That led him to wonder why, in a hollow in his forest, he encountered only conifers, but a little further on, only birch, and then suddenly beech trees.

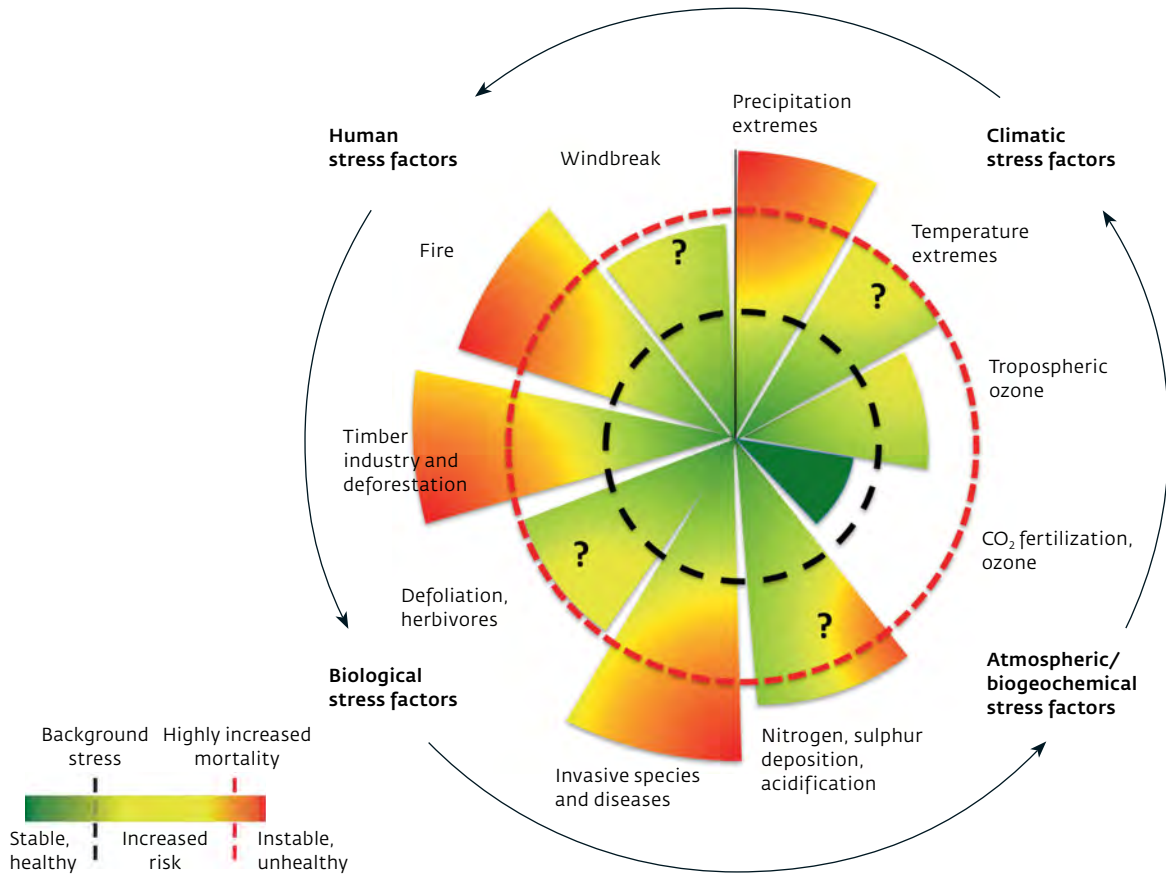
Hartmann, with his athletic build, sparse hair cut short, a thin goatee and an earring in his left ear, has an energetic step and a firm handshake – a guy who you immediately believe dragged two-meter-long tree trunks from the forest to his house using a homemade harness. Today, he is a Research Group Leader at the Max Planck Institute for Biogeochemistry and lives in Jena with

his Canadian wife, who also works at the Institute, and his three children. He researches why trees die if they don't get sufficient water or nutrients, and how they use scarce resources.

The water balance of trees is also the topic of a multi-day seminar in a branch of the Technical University of Munich in Freising – a mixture of internship and camping. Here, biology students learn how to measure physiological processes in trees, such as water transport. "Why is it important to study such processes on individual trees?" Hartmann asks the group. "One could also analyze the mass transfer of the whole ecosystem from a tall measuring tower. Wouldn't that be more important from a global perspective?"

The students piece the answer together with some effort: surveying individual trees reveals how different species manage resources and why some cope with changing environmental conditions better than others. As differ-





ent species assume different functions in the ecosystem, these findings shed light on how an ecosystem responds to droughts, for example, which are likely to be compounded by climate change. That's why Hartmann adopted the ecophysiology of trees as his topic.

### WILL THERE STILL BE FORESTS IN 100 YEARS?

However, he also knows that the ecophysiological perspective is insufficient for making reliable statements about climate-induced global changes in forests. He therefore took the initiative and twice assembled his fellow researchers in workshops with representatives of other disciplines who deal with tree mortality, but who previously looked at it only with their own limited focus: researchers who analyze the state of the forest using satellites; those who inventory trees in the forest and assess their condition; and modelers who translate their colleagues' findings into computer programs to predict the

fate of forests in a warming world. "We also want to be able to tell politicians whether the forests we depend on will still exist in 100 years," the tree and forest researcher explains.

That Henrik Hartmann would one day initiate collaborative endeavors that give new impetus to his discipline wasn't apparent at as early a stage in his life as with other scientists. That's because his path to research was anything but straightforward.

He did at least announce to his mother at an early age that he wanted to become a scientist and study "how life works." He was just three years old at the time. But he didn't seriously tackle this goal until an age when others have already earned a doctorate. "I've always been close to nature; I walked in the forest a lot as a child," he says. "But I wasn't a forest freak who could already name 200 tree species at the age of six."

In Canada, Hartmann became, perhaps not a freak, but certainly a forest expert. His family still owns the house

and the forest in Auclair, a small village in eastern Québec. From there, he has to drive 25 kilometers to the nearest larger settlement with shops for everyday needs.

On a short hike to a lookout point overlooking the Max Planck campus in Jena, Hartmann talks about the time before he got into science. The SaaleHorizontale trail, a circular route that describes a wide loop around Jena along the slopes of the Saale valley, runs close by. Every year, a 100-kilometer march is hosted there – Henrik Hartmann has already participated three times with institute colleagues. They also did it for a good cause: for each kilometer they completed, the Max Planck staff collected money to fund, for instance, the education of a talented child from an underprivileged family.

Today, there isn't enough time for the SaaleHorizontale trail, but at least there is for Hartmann's story. He grew up near Dillenburg, in Hesse, Germany, between the Westerwald and Rothaar Mountains: "A beautiful scenic

**Left page** Numerous factors subject trees to stress. Inside the dotted black line, trees can cope well with this. However, if their influence crosses the dotted red line, they substantially increase tree mortality. The effects of some stress factors aren't yet known.

**Right** During his doctoral thesis, Henrik Hartmann collected samples with a chain saw. Today, he likes to use it to cut wood in his forest in Québec. He lived in the hut (image on the right) for two years with no running water or electricity.



area, but very rural." He gushes about what a wonderful woman his mother is. "She just should have been firmer with my father, perhaps – he was a very difficult person." Still marked by the National Socialist era, the war and the final total collapse, a house and car were his ideals, but they didn't bring him happiness.

### HIGH SCHOOL DIPLOMA, THEN TWO YEARS OF MILITARY SERVICE

"I had no models," says Hartmann, when he explains why he didn't resolutely pursue the path to science from the outset. His teachers, for example, weren't passionate educators who could get their students excited about a topic. Some were more enthusiastic about their hobbies than they were about teaching, while others were still so strongly affected by the Second World War that they repeatedly shared their memories with their students. "Many seemed to have given up and to be rather out of place," says Hartmann.

After finishing high school, he initially enlisted for two years of military service. "I've never enjoyed doing what everybody else is doing," he says. The same applied to his decision about whether to do military service or alternative community service. "All my friends actually refused to do military service," he says. "And I thought: no, that's not right."

It was 1987, the world was divided into East and West and the Cold War wasn't over yet. "We were still looking down the barrels of millions of loaded weapons. If there was an equilibrium back then, it was only because the others were just as scared of us as we were of them." Nevertheless, he was happy when the two years had passed: "Toward the end, in particular, I often yearned for Friday on a Monday morning – there was too much, and often nonsensical, routine."

Then followed his first attempt at a university: he enrolled to study biology in Göttingen. Right in the introduction, the instructor announced that

only three of the 125 freshman students would actually get a job. Not exactly encouraging. Hartmann was soon drawn to Berlin. There began what he today regards as a period of breaking away from rigid social norms. And he makes no secret of it: "It's part of my biography, and it's better to have such a phase of discovery in your early 20s than in your late 40s, when it could potentially destroy a whole family."

In Berlin he lived to some extent as a *Heinzelmannchen*, as the local job placement office for students was called. "You could get really good jobs there." He worked this way for a few weeks here and there until he had amassed enough money to travel or go to concerts – his musical tastes ranged from punk rock to crossover and even reggae.

"I did this for a while until I'd had my fill and thought: there must be more," Hartmann says. In the early 1990s, an opportunity arose to travel to Canada with friends from Göttingen. This connection quickly crumbled, though, and Hartmann then first trav-



**Left** Hartmann's team studies where trees store sugar and other substances. To this end, the researchers use liquid nitrogen to freeze twigs, for instance, in an insulated vessel in order to grind them and analyze how much of the substances in question they contain.

**Right page** In the laboratory, Henrik Hartmann and his doctoral student David Herrera can precisely regulate how well they supply their test trees with carbon dioxide, for example. In addition, they measure the trees' gas exchange. They repeatedly cut off shoots to analyze different substances.

eled through the US. On an intermediate stop in New York, he realized he didn't want to return to Germany. In order for him to stay, his then girlfriend – a Canadian he had met in Germany – offered to marry him. "It was very fast and uncomplicated there," says Hartmann. Canadian immigration, on the other hand, took two years, during which time he lived from savings and janitorial jobs. "During that time, it became clear to me that I want to live in a forest somewhere."

So he and his then wife bought a reasonably priced plot of land with a wooden house and a hut that had been built in the 1930s and had hardly been altered since. The social dropout lived in the hut for more than two years, with no electricity, running water or sewer system. Hartmann collected water from a well near the house at the opposite end of the property. Sled dogs helped him in winter, but it was still quite laborious. He baked his own bread, starting with milling the grain. In winter, he had to shovel enormous

amounts of snow. There was also the young daughter the couple had since had. "You don't stop to question the sense of it all, things just have to be done, period," says Hartmann. But there was also little time for anything else – except maybe for meeting other dropouts in the area.

### A SWOLLEN KNEE IS A FORTUNATE COINCIDENCE

"This intuitive life with very simple means is good – for a while," he says. It became clear to him that, "no, that can't be it. I have a background that includes education." At some point he felt like he had no identity: "And if I end up being a lumberjack, then I'm a lumberjack. But then I'll know what I am!"

So he started working, not as a lumberjack, but as a supplier of maple syrup harvesting equipment. This wasn't particularly good for his relationship with his wife, and they began to drift apart. "I told myself: I am now committed to my job." They separated and

he moved out of the hut and into the wooden house, where at least there was electricity.

There was also a setback with his job, which later turned out to be a fortunate coincidence. One morning, Hartmann's knee was swollen to the size of a handball; he couldn't work for a while. His boss terminated his employment, but supported him in enrolling for training as a forest warden. There, Henrik Hartmann asked more questions than the trainers had answers for. They often told him: "If you want to know that, you'll have to attend university, they'll explain it to you there."

"I found that amusing," says Hartmann with a slightly bitter laugh that accompanies many of his ironic remarks. "One would expect them to sit down and find out for themselves. But that's not how they were." He found this unsatisfactory and followed the advice that was probably not even meant seriously. After finishing his training, he studied forestry at the Université de Moncton in New Brunswick.



Although he was now getting on track professionally, today he describes this phase as the worst time of his life. The dispute over the custody of his daughter turned very nasty. Henrik Hartmann still seems very upset when he talks about it. A judge finally ended the dispute by saying that he didn't have time to examine the case in detail. Normally, children are better off with the mother, so the mother gets custody. The fact that he had since met his present wife and together they had been exercising custody of his daughter for more than a year did nothing to help the matter. "The court didn't really care that I had purposefully pursued my education and that my daughter would much rather have stayed with us. Because despite the burden of studying, the time spent with us was valuable to her, too." Hartmann felt and feels this to be deeply unjust.

Despite the exhausting dispute and the disappointment over the loss of custody, he completed his studies and – now at the Université du Québec – be-

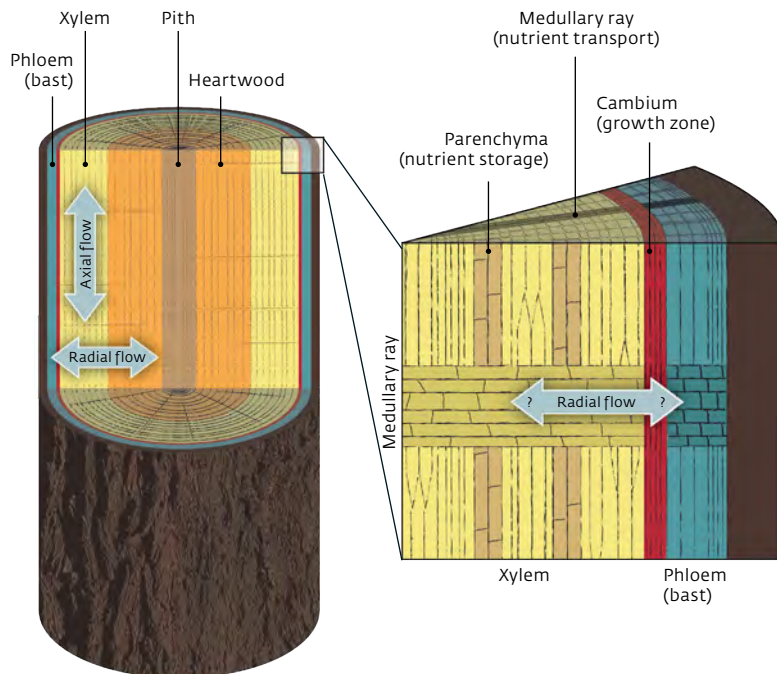
gan a master's degree, to which he immediately appended his doctorate. The topic of his dissertation: stress factors and mortality in selection silviculture forests. In selection silviculture forests, individual trees are removed in such a way that the stock always includes trunks of different thicknesses.

### THE LACKEY MOTH AFFECTS TREE VITALITY

Right at the beginning of his doctoral thesis, on June 9, 2005, Hartmann experienced his second birthday, as he calls it: together with a bachelor student, he was inspecting the areas for his field experiment. In a pickup, they drove along one of the forest roads used by numerous freight trucks, which were often quite fast. In a curve, a semi-trailer came toward them on their side of the road. Hartmann was just able to avoid a head-on collision, but his vehicle slammed under the side of the trailer and was thrown back about 30 meters by its rear axle. Afterwards, the

vehicle looked like nobody could have gotten out of it alive. His passenger, however, suffered no more than a few bruises, and he himself only broke a metacarpal in his hand and suffered a few cuts. "I still really can't believe it," says Hartmann.

The rest of his dissertation passed without further incident. Using dendrochronological methods, he studied whether the entire tree stock suffers when individual trees are felled. He therefore compared the growth rates, determined from the tree rings, of dead and surviving trees, and in this way documented when dips in vitality occurred. He compared these events with foresters' archival data on natural disturbances, such as large-scale defoliation by insects. "We couldn't identify any negative effect of selective felling on tree vitality, but the results clearly showed the influence of epidemics by lackey moth caterpillars." These pests can completely defoliate a tree and it then no longer forms the sugar that it needs to live. >



**Left** How trees manage metabolic products and where they store these for emergencies is still largely unknown. What is clear is that, in summer, sugar flows axially through the phloem, the bark's bast fiber, from the leaves to the roots, and in the opposite direction in springtime. However, the researchers aim to discover to what extent substances are also transported radially and stored and retrieved from living cells in the otherwise dead sapwood, and how this is controlled.

**Right page** To understand the metabolism and thus the carbon balance of trees, Henrik Hartmann and Susan E. Trumbore, Director at the Max Planck Institute for Biogeochemistry, capture the gases that a tree releases through its bark.

The doctoral thesis raised questions that continued to spur Henrik Hartmann on. Hunger need not mean the death of the tree; if it has access to reserves, it may survive lean times. He was now interested in how trees manage their resources, particularly when they are scarce. And which deficiencies lead, in the worst-case scenario, to their death. This led him, in 2009, to the Max Planck Institute for Biogeochemistry, where in 2006 he had met Christian Wirth during an internship. Wirth was a Research Group Leader at the Institute and offered Henrik Hartmann a postdoc position. The forestry scientist aimed to use isotope-labeled carbon dioxide to study the sugar balance of plants during periods of drought.

"When I returned to Germany after 15 years, I was surprised at how much the country had changed," says Hartmann. He attributed this primarily to the 2006 FIFA World Cup. "There was suddenly a much more cosmopolitan atmosphere. It was apparent that people of different cultures were welcome here." That's one of the reasons why he was happy to stay in Germany

and immediately brought his wife and his now three children with him.

Initially, however, his research didn't progress as he had hoped. For weeks, he was unable to carry out his investigations. He passed the time by writing a review in which he summarized the state of research on the question of whether trees are more likely to suffer from thirst or hunger during droughts, which are likely to increase with climate change. Colleagues in the field still ask him about the article today. At the time, they were surprised they weren't familiar with the author.

### TO FIND OUT HOW TREES DIE, YOU HAVE TO KILL THEM

The article begins by praising trees, which tells us how fascinated Hartmann is by these organisms. Nevertheless, he repeatedly kills trees – "I belonged to the tree-killer community," he says. "Because if you want to find out how trees die, you also have to kill them."

In his first experiments at the Max Planck Institute in Jena, for example, he allowed spruce to die of thirst and thus discovered that they perish be-

cause the roots starve to death; without water, the supply of carbohydrates from the needles fails. To understand how trees manage their resources in times of crisis, it helps to know how they handle them when there is no shortage. For this reason, Henrik Hartmann today investigates what trees normally do with vital substances – not just sugar, but also substances that defend against pests, for example.

As a scientist, he has clearly found his identity – but it's not all smooth sailing: "In terms of job description, being a researcher is my dream job. But the conditions for scientific work are sometimes difficult." Hartmann currently attends numerous conferences to make himself and his research known. "In my situation, I sometimes simply can't afford to say no," he explains. "I don't want to have to tell myself in three years: if only you had gone there back then and made that contact, you may have gotten a job."

What bothers him about the numerous trips isn't only that his work at the Institute goes undone: "The papers waiting for me to work on them are beginning to pile up." He is also con-



Photo: Sven Doering

scious of what he's putting his family through with the many trips: "I sometimes feel guilty when I leave my dear wife alone again with all the work at home." That's also a matter of fairness.

And then there's climate change, to which he is contributing with the flights – recently from Frankfurt to San Francisco, for instance. As an example, scientists from the Max Planck Institute for Meteorology calculated how much Arctic sea ice disappears for precisely this flight. "The paper was published a week before I boarded the flight," he explains. "I thought: oh great!"

Even though he pursues primarily basic research, he hopes his work will help make forestry and agriculture more sustainable and mitigate the effects of climate change. "I think that, as scientists, we have a duty to give something back to society – in the end, this is certainly more important than a NATURE paper." That is why he plans, together with Susan Trumbore, Director of his department, and Jonathan Gershenson, Director at the neighboring Max Planck Institute for Chemical Ecology, to bring together scientists, politicians and plantation owners at a round table in Brazil. "That's where the soy we feed our pigs is grown," he says. "You can't take that away from the people, they depend on it. But we can try to make it as sustainable as possible."

At the moment, however, he is mainly concerned with how to proceed when his position as Research Group Leader expires. After all, Hartmann published his postdoctoral thesis in 2017. In it, he summarizes his findings on which substances plants preferentially produce when resources are scarce. His conclusion is simultaneously the title of the paper: *You can't always get what you want*. In the meantime, he's already been invited to job interviews. "Prospects are looking very good right now," says Henrik Hartmann. "It would be quite something if I were to become a professor now after all." ◀

# Splitting Atoms in a Beer Cellar

The **Kaiser Wilhelm Institute for Physics** in Berlin opened its doors a century ago. One of its future directors was Werner Heisenberg, the father of quantum mechanics. In February 1945, he and his colleagues gathered in Haigerloch in the Württemberg region of Germany. There, in a secret cellar in a cave, the researchers embarked on a daring experiment.

TEXT **ELKE MAIER**

Berlin, February 23, 1945: A truck convoy sets out in the bombed-out capital. It is carrying one and a half tons each of uranium cubes and heavy water, and ten tons of graphite blocks. Its destination is the small town of Haigerloch in Württemberg. Far away from the devastation of the Berlin bombing raids, scientists there are hoping to trigger a nuclear chain reaction. The project is headed by Werner Heisenberg, who was appointed Director of the Kaiser Wilhelm Institute (KWI) for Physics two and a half years prior.

The KWI for Physics in Berlin was opened during the First World War, on October 1, 1917. Originally, it was supposed to be dedicated to the young, burgeoning field of quantum physics. At the time, the field of quantum research consisted of little more than a jumble of data and theories relating to Planck's energy quantum, the details of which, however, were still rather hazy. In order to move forward, it was decided to create a think tank and bring together the best minds in the field. No one seemed better suited to serve as its director than Albert Einstein.

The concept of the new research facility was revolutionary in that, unlike at other such establishments, no actual experiments were planned. Instead, a six-member board proposed projects that were then reviewed by a board of trustees and, with funding from the Kaiser Wilhelm Society, were delegated to external institutes. As no laboratories were required, the institute was able to do without a dedicated building, and instead opened its first premises at Haberlandstrasse 5 in Schöneberg – Einstein's home address.

The idea worked at first, and several projects were successfully completed. However, Einstein's enthusiasm concerning his new role was muted. He hated the bureaucracy his position entailed, and he had no knack for bringing researchers together and kick-starting projects. Einstein was and remained a brilliant lone wolf.

In July 1922, he therefore decided to provisionally relinquish directorship of the Institute to fellow physicist Max von Laue.



A scientist with a flash of inspiration: 23-year-old Werner Heisenberg created the foundations of quantum mechanics while at a health resort in Heligoland.

He himself planned to travel for an indefinite period. When he returned to Berlin the following year as a Nobel laureate, he passed the scepter to Laue for good. Officially, however, Einstein remained on the books as director until 1932.

Max von Laue set out to reorganize the Institute from the ground up and secure its future competitiveness, and it was set to finally get a dedicated building. The money was provided by the American Rockefeller Foundation. Then the Nazis came to power in early 1933 and brought things to a sudden standstill. Leading scientists, including Albert Einstein, emigrated. Under these circumstances, Laue presumably lost the desire to run the Institute. In the end, the director's post was transferred to Dutchman Peter Debye, who had previously been working in Leipzig.

The official inauguration of the new Institute building in Berlin-Dahlem took place on May 30, 1938. Above the entrance stood the words "Max Planck Institute." The scientists in Berlin chose this name to commemorate the outgoing president of the Kaiser Wilhelm Society. The authorities were not pleased; Planck, after all, was a Nazi opponent. Nevertheless, the name remained. What would the Rockefeller Foundation have thought if the name had been changed? The KWI for Physics was thus the very first Max Planck Institute, pre-dating the foundation of the Max Planck Society by a decade.

The Second World War broke out on September 1, 1939 and the Institute was placed under the command of the German Army Ordnance Department the following year. A project that was unofficially known as the "Uranium Club" was launched to explore the possibilities of nuclear fission, which Otto Hahn and Fritz Strassmann had discovered at the KWI for Chemistry in December 1938. Barred from leading a war project as a foreigner, Director Debye was asked to take on German citizenship. He refused and was banned from the Institute, making Werner Heisenberg the lead scientist of the Uranium Club.

Heisenberg, who was born in 1901, had a brilliant career behind him. Based on his outstanding performance in secondary



school, he was granted a scholarship by the Maximilianeum Foundation for gifted students and completed his studies in just three years. He wrote his doctoral dissertation at the age of 22 and became the youngest professor in Germany at the age of 26 – despite nearly failing his doctoral examination. He was flummoxed by, among other things, a question about the resolution of the microscope.

In the spring of 1925, however, he came up with an idea that more than made up for this slip-up. At the age of 23, he was plagued by hay fever and travelled to Heligoland for treatment. One night he had a sudden flash of inspiration that led to the development of quantum mechanics and that would earn him the 1932 Nobel Prize in Physics.

So Heisenberg and his colleagues were working on nuclear fission during the Second World War. The group also included such famous physicists as Walther Bothe, Hans Geiger, Otto Hahn and Carl Friedrich von Weizsäcker. By then it was known that, under certain conditions, uranium nuclei can be split by neutron bombardment to release, not just energy, but also other neutrons, which in turn could split more uranium nuclei. The physicists envisioned a self-sustaining chain reaction that could be harnessed to create a “uranium burner” to obtain energy – or a bomb.

In the course of their work, however, they realized that an atomic bomb couldn't be built that quickly. Some historians assume that Heisenberg delayed the project to prevent the Nazis from getting their hands on a nuclear weapon. Others believe that he and his colleagues simply failed in their endeavor. In any

**TAGESSPIEGEL on April 14, 1985**



Europe's most advanced power plant – a top-secret nuclear reactor consisting of uranium cubes, heavy water and graphite cladding – was built in the Prussian town of Haigerloch in an environment that was a mixture of Freischütz, Faust and James Bond.

case, the German Army Ordnance Department eventually lost interest and returned the KWI for Physics to the Kaiser Wilhelm Society in 1942. The uranium experiments were continued, but now with a view to realizing a “uranium machine.”

The biggest experiment to date, known as B8, was planned for January 1945. Everything had been prepared in the bunker in Berlin: heavy water had arrived from Norway and uranium ore from Bohemia. But the Russian troops were closing in, and in the end, the scientists deemed it too risky. In the face of constant air raids, parts of the Institute had already been relocated to Hechingen in Württemberg. Now the uranium experiment was to be relocated as well.

Some 15 kilometers from Hechingen lies the idyllic town of Haigerloch. The center is dominated by a massive cliff on which



Where it all took place: The beer cellar of the former Schwanenwirt pub in Haigerloch is now home to a replica of the legendary B8 experiment.

the castle church stands. At the foot of the cliff, directly below the church, is a cellar where the innkeeper of the Schwanenwirt pub stored his beer – the perfect location for the nuclear researchers.

A lease was soon signed with the innkeeper for 100 reichsmarks per month. The supplies were removed, a hole blasted into the ground and the facility constructed. Finally, at the end of February, everything was ready: the material had arrived from Berlin and the experiment could begin.

In greatly simplified terms, the reactor consisted of 664 uranium cubes that measured five centimeters on each edge and that were attached to chains in the lid. The cubes were immersed in a graphite-clad magnesium tank set in a concrete pit and filled with heavy water. The neutron source could be introduced via a tube in the lid. The researchers recorded the neutron proliferation at periodic intervals. A large increase would indicate that the reactor had reached a critical state and that the goal of a self-sustaining chain reaction had been achieved, in which case the experiment would be stopped.

But it never got that far. The neutrons multiplied, but without reaching the critical point. Werner Heisenberg calculated that they would need around 50 percent more uranium and heavy water. Due to the war, however, there was no prospect of receiving the necessary supplies.

Instead, a special US unit arrived in Haigerloch on April 23, 1945 and discovered the cellar. All traces of the experiment had been provisionally removed and the uranium cubes buried in a field near the castle. The scientists were arrested. The Allies captured Heisenberg, who had fled by bicycle, at his family home at Lake Walchen in Upper Bavaria. He and his colleagues spent the following months interned at Farm Hall in England.

The Americans were ordered to blow up the cave cellar, but the courageous town pastor forbade it. He showed the commanding officer the almost 350-year-old church above them with all its art treasures. The Americans then settled for a smaller, pro forma detonation. The church remained intact. Today, a museum in the Haigerloch cave cellar commemorates the former hub of German nuclear research.

After the war, the KWI for Physics was rebuilt in Göttingen. In 1948, it officially became a Max Planck Institute. Ten years later, the facility relocated to Munich. Werner Heisenberg remained Director for almost 30 years. He died in Munich in 1976.

# An Alternative View of Art

Explaining climate research with the help of Kirchner and Calder

The Max Planck Society and the Städel Museum in Frankfurt am Main have joined forces for the first time as part of the “Guest Commentary” event series. The series was kicked off by Hamburg-based climate researcher Dirk Notz, Research Group Leader at the MPI for Meteorology.

Frankfurt’s Städel Museum has run the event format for several years now. For the 2018 series, however, exclusively Max Planck scientists have been invited to speak and give a thematic tour based on their field of expertise, taking in the works of the Städel Museum’s collection. In preparation for his guest commentary, Dirk Notz already visited the Städel Museum last year in order to gain an overview of the works he might use for his guest tour. The museum’s digital collection also helped him find relevant paintings and sculptures.

At four stations, Dirk Notz spoke about natural and man-made climate change, as well as the “set screws” that influence climatic developments in general. Beginning with “The Rain Shower,” a painting by 19th-century French artist Antoine Chintreuil, visitors were familiarized with the role of solar radiation, clouds and the composition of the atmosphere.

The second stop was a classic for all climate researchers: a winter landscape by Flemish painter Lucas van Valckenborch dating back to the 16th century. This painting pro-


vides valuable insight into the so-called Little Ice Age, which lasted from the 15th to the 19th century and is an example of natural climate change, a recurrent process in the Earth’s history.

That process is quite different from man-made climate change, which is caused by human lifestyle and is a considerably more rapid process. To illustrate his talk and inspire his audience, Dirk Notz also selected Ernst Ludwig Kirchner’s “Western Port in Frankfurt am Main,” a painting that depicts industrialization with smoking chimneys, locomotives and the new image of humanity in which man has dominion over nature. Finally, two sculptures – a mobile by Alexander Calder and “Composition” by Otto Freundlich – illustrated the fragile balance while simultaneously conveying the interdependencies between individual climatic factors.

The 30 audience members weren’t the only ones who considered the format a success – Notz did, too. “I enjoyed giving the tour and preparing for it, as it afforded me the opportunity to examine my research from a completely new perspective,” the climate researcher concluded.

Three further Max Planck scientists will appear as part of the 2018 guest commentary series: May 6: Thomas Duve, MPI for European Legal History; October 21: Ute Frevert, MPI for Human Development; November 18: Martin Stratmann, President of the MPG and Director of the MPI für Eisenforschung. Those interested can register their attendance directly with the Städel Museum. Participation in the guest commentary is free of charge, but attendees must purchase an admission ticket for the museum.

**For more information, visit:**

 [www.staedelmuseum.de](http://www.staedelmuseum.de)

The correlation between industrialization and climate change: Dirk Notz in front of Kirchner’s 1916 work “Western Port in Frankfurt am Main” (below) and Otto Freundlich’s sculpture “Composition”.



# To Kuwait and Back

Max Planck Institute for Chemistry collects data on the chemical composition of the atmosphere on the shipping route between Europe and the Persian Gulf

Starting in the Mediterranean Sea, the “Kommandor Iona” research ship sailed along the Suez Canal and around the southern tip of the Arabian Peninsula to reach Kuwait – and then returned to the south of France. The aim of the scientific voyage, part of the AQABA (“Air quality and climate change in the Arabian Basin”) project, was to investigate the impact of air pollution on public health, the climate and the environment.

On their voyage, the researchers encountered a unique spectrum of diverse environmental conditions: They sailed through clean, undisturbed air across the Arabian Sea, while the air over the Red Sea was polluted and dusty, having blown over from Africa. In the Middle East, dry air currents from urban settlements dominated, along with ship exhaust gases.

Max Planck Director and expedition leader Jos Lelieveld described the initial measurement results: “Air pollutants alter the chemistry of naturally occurring dust in the atmosphere. This in turn impacts the water cycle, as the dust particles act as condensation nuclei for cloud droplets, which can alter rainfall and the climate as a whole.”

Lelieveld, who is also a professor at the Cyprus Institute, went on to describe how such changes can also affect flora and fauna. In addition to the Cyprus Institute, the AQABA project also includes researchers from the Kuwait Institute for Scientific Research and other institutions from Saudi Arabia, France and the US. The measurements were initially taken using drones launched from the ship, while scientific instruments were housed in five temperature-controlled laboratory containers on deck. The data sets will be used in studies on the interactions of gases and aerosols.



MPI staff in front of the “Kommandor Iona”.

## Research Summit in Mexico

More than 15 Directors and Group Leaders from 14 Max Planck Institutes spoke at the first Frontiers in Science symposium in Mexico City. The conference, attended by high-ranking participants, was held at the auditorium of the National Museum of Anthropology.

The aim of the three-day event was to intensify scientific exchange and personal contact between leading Mexican scientists and to enable closer and more sustainable cooperation on research topics of mutual interest. Almost 40 scientists from Mexico and Germany gave presentations including social scientists, such as Axel Börsch-Supan (Max Planck

Institute for Social Law and Social Policy) and Ute Frevert (Max Planck Institute for Human Development), neuroscientists, like Jason Kerr (Center of Advanced European Studies and Research (Caesar)), and materials researchers, such as Beatriz Roldán (Fritz Haber Institute of the MPG). Other research fields that were covered at the first Frontiers in Science symposium in Mexico included astrophysics, biomedicine, archaeogenetics and chemical ecology. The symposium was organized by the Max Planck Society's liaison office for Latin America in collaboration with the Mexican Research Council CONACYT.

# The History of the Theory of Everything

New cross-sectional research group investigates efforts to achieve a unifying framework for physics



Alexander Blum at the MPI for the History of Science in Berlin. His Max Planck Research Group officially started work in February.

By way of example, Blum names renowned physicist Werner Heisenberg, who was a Director at both the Kaiser Wilhelm and the Max Planck Institute for Physics. On April 25, 1958, he gave a speech on the 100th birthday of Max Planck in which he introduced his “theory of everything.” Using a single equation, this theory was supposed to explain all observed microscopic particles and their interactions, plus – at least in principle – the entire macroscopic universe. “However, Heisenberg’s formula provided no precise solutions, so the implications of his theory of reality were contested,” explains Blum. “Worse yet, not even the math was considered consistent.”

Despite all his efforts, Heisenberg never managed to persuade the doubters – but he also never retracted his ideas. On the contrary, he continued to pursue them with a handful of colleagues. The Research Group now aims to investigate, for instance, how one of the 20th century’s foremost scientists could be misled by his belief in a theory, basing its research on more than simply biographical interpretations such as hubris or naivety.

This is where the Group’s cross-sectionality comes into play. Initially, three Max Planck Research Groups are set to be established – two have issued calls for applications to start work in 2019, and Blum is now leading the way with the first. For Blum, whose MPI belongs to the Human Science Section (HSS), the connection with the MPI for Gravitational Physics, part of the Chemistry, Physics and Technology Section (CPTS), is very important as it facilitates collaboration with their colleagues there. “It may sound trivial, but it’s essential that we talk to people who deal with formal aspects of mathematics in their daily work,” the researcher explains. Dialogue with physicists who themselves work on quantum gravity is a valuable source for the historical perspective. “The attraction of this particular piece of history lies in the fact the topic is still being researched to this day.”

A joint Research Group between the Max Planck Institutes for the History of Science and for Gravitational Physics is currently addressing one of the major problems in physics: the century-long search for a “theory of everything.” The Group, led by Alexander Blum, is the first in the MPG to bring together disciplines from two Sections.

The modern view of the universe rests on two pillars: quantum theory and the general theory of relativity. The former describes the universe on a very small scale, the latter on a very large one. However, this intellectual edifice has one significant flaw – the two theories aren’t compatible. In fact, they diverge as far back as the very beginning of time, in their description of the Big Bang. Back in 1916, Albert Einstein speculated that his theory of general relativity would have to be merged with quantum theory, which in those days was still in its infancy. To this day, however, scientists are still struggling with this so-called quantum gravity.

It is this work that Alexander Blum’s Group on the “Historical Epistemology

of the Final Theory Program” is examining: “We want to reflect on and evaluate the search for the theory of everything using methods of historical epistemology,” says the 36-year-old, who studied physics at the University of Heidelberg and has worked at the MPI for the History of Science in Berlin since 2010. After considering the two main theories of physics in the 20th century more or less in isolation, it seemed appropriate to direct his attention to the long history of reconciling the theories, as Einstein had called for.

“In doing so, we came across an unusual situation – a research issue that existed 90 years ago and is still current today,” said Blum. “We’re interested, for example, in how knowledge has progressed to date. How has the relationship between theory and experimentation developed?” The Research Group comprises half a dozen members – including two postdocs and a doctoral student – and addresses the obstacles to the concept of such an all-encompassing theory.

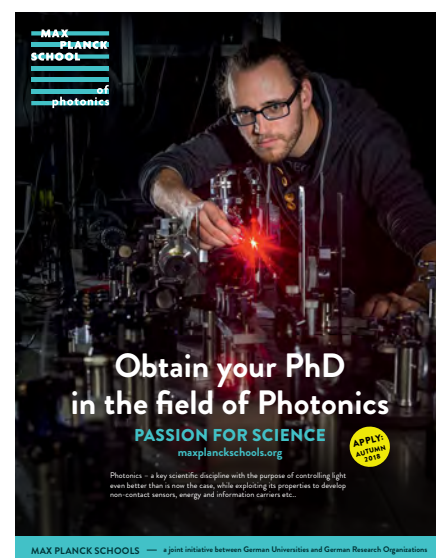
# Max Planck Schools Develop International Presence

Uniform brand appearance created for the new doctoral training format

Preparations for the opening of the first three Max Planck Schools, innovative national networks for exceptional graduate education, are in full swing. At a meeting with the selection committee held late last year, the speakers introduced their now finely detailed concepts for the schools' implementation. These concepts currently form the basis for developing financial plans and curricula and for negotiating contracts with partners. In the fall of 2018, the Max Planck Schools will issue calls for appli-

cations in the new, uniform format. This date is planned to coincide with the application cycles of leading international universities, with which the schools aim to compete for the best doctoral candidates. The first students will begin their programs in 2019, and this offer is also open to bachelor's degree graduates in a fast-track procedure (two years for a master's degree, three years for a PhD). The joint website will go online at [www.maxplanckschools.org](http://www.maxplanckschools.org) in April this year.

Of the eight draft proposals, the committee led by Max Planck President Martin Stratmann and Horst Hippler, President of the German Rectors' Conference, selected three schools for a pilot phase: the Max Planck School of Cognition, the Max Planck School of Photonics and the Max Planck School Matter to Life. These schools bring together members from 21 universities and 31 institutes of non-university research organizations, underscoring the initiative's inter-institutional nature.




The three Schools and their logos: The design was selected to ensure that each Max Planck School is visible as an individual entity while still accentuating the common idea.

## Call for Meitner Group Applications

Starting in 2018, up to ten additional research groups will be advertised each year in order to recruit exceptional female scientists as part of the Lise Meitner Excellence Program. The MPG hopes that the program will offer women transparent and clear career prospects. The program and the procedure were developed by a structural commission headed by Vice President Angela Friederici, with the participation of all three Section Chairs, and discussed within the Sections. Lise Meitner Groups will receive at least the same support as Max Planck Research Groups

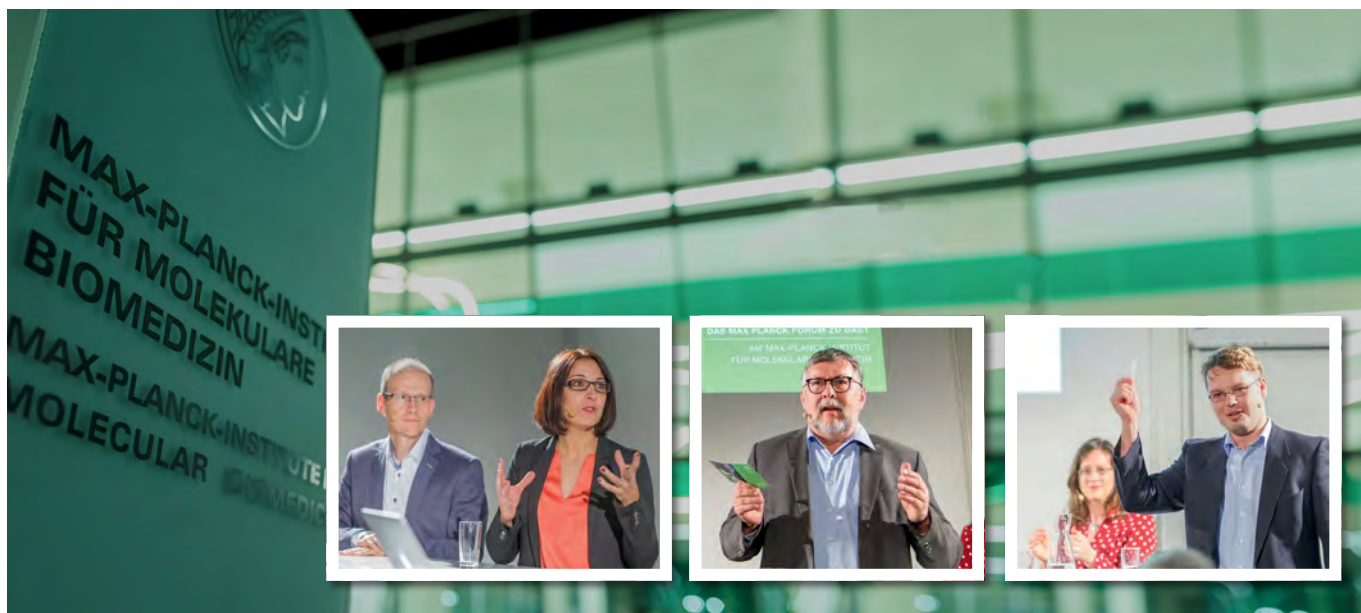
and will be centrally financed for a period of five years with the prospect of further extensions. The Lise Meitner Group Leaders will also be offered the opportunity to take part in the W2 tenure track procedure. The call for applications opened on March 1 and ends on April 18, 2018. Directors can also directly encourage candidates to apply.

**The call for applications:**

 <https://www.mpg.de/lise-meitner-excellence-program>

# Successful Communication Event

Max Planck Forum on animal research wins over researchers and the audience



Ralf Adams and Kerstin Bartscherer (left) as well as Wiebke Herzog and Jan Bruder (right) outlined their research work in short presentations. Hans Schöler (center) took part in the panel discussion.

Animal research is a controversial topic, which is why few researchers – too few in fact – discuss it in the public domain. By withdrawing from the arena, scientists leave the field open for opponents of animal research. If you enter the term “*Tierversuche*” (animal research) into Google, on the very first page of search results you’ll find five hits with information on organizations campaigning against animal research. The link to the *tierversuche-verstehen.de* alliance website and the MPG’s main website on the issue ([www.mpg.de/themenportal/tierversuche](http://www.mpg.de/themenportal/tierversuche)) don’t appear until the second page.

Animal welfare groups aren’t just present online, they also take their campaign to the streets with information stands in pedestrian areas and the “mouse mobile,” which tours throughout Germany. Their messages constantly seep into public perception without contradiction.

Such messages include, for example, the notion that basic research is done solely to satisfy the scientists’ curiosity and is of no benefit to humans. Those

who see human benefits only in drug development fail to recognize that basic research is primarily about understanding the body’s fundamental processes. A Max Planck Forum that attracted 100 attendees to the MPI for Molecular Biomedicine in Münster in late November was therefore given the title “The development and healing of tissue – what we learn from animal research.”

Kerstin Bartscherer, Wiebke Herzog, Ralf Adams and Jan Bruder first outlined their research work in easily understandable, 10-minute presentations. What could be achieved with a particular animal or cell culture model? And can the findings also be transferred to humans?

The range of topics included flatworms, with their incredible regeneration capacity, zebra fish, mice and human organoids. The researchers explained that key genes can be found in the development of the lymph vessels, not just in zebra fish and mice, but also in humans, and that mutations to such genes can cause serious diseases. As Jan Bruder explained, human organoids are

a valuable addition to biomedical research. Tiny organs can be grown from human cells in petri dishes, enabling particular aspects of disease and active substances to be examined.

During the subsequent panel discussion with Berlin-based science journalist Volkart Wildermuth, in which Hans Schöler also took part, criticisms of animal research were once again discussed, the limits of research on mini-organs were explored, and other key aspects were considered, such as the time-consuming authorization procedure in Germany.

The audience was full of praise for the four speakers, who won them over with “both the substance of their arguments and their personal charisma.” One audience member hoped that “at least some of those in the crowd who were skeptical of or opposed to animal research would now reconsider their views.” Overall it was an extremely successful event, a view that was also shared by the speakers themselves, including Hans Schöler. More of the same is now in order.

# 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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