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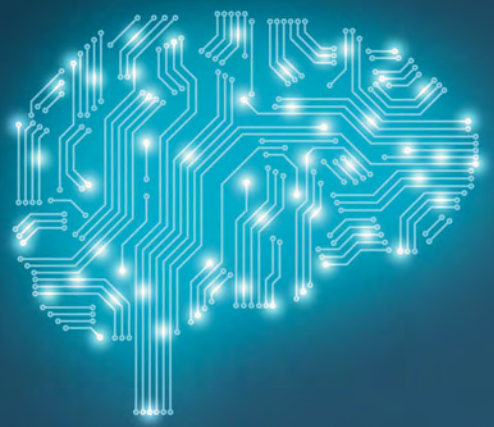
Max Planck RESEARCH

The Science Magazine of the Max Planck Society 4.2019



Learning

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Democracy needs science

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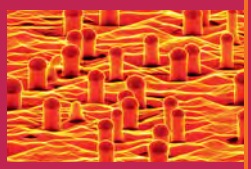
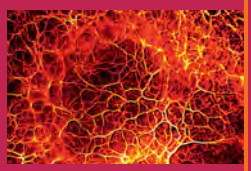
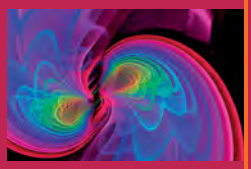
Patterns of terror

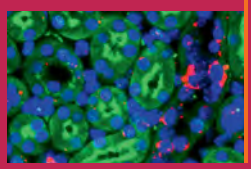
Max-Planck-**Innovation**

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 inter-disciplinary 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

www.max-planck-innovation.de

Take-off for the stars

Just reaching the space port is an odyssey. It will take you about 24 hours to get from Munich to Baikonur – in the middle of nowhere, some 200 kilometers east of the North Aral Sea. Close to the city, with a population of 60 000, a handful of decent hotels and some good restaurants, the Cosmodrome has been launching rockets since 1957 – first Soviet, now Russian. Over the years, many a dream has literally gone up in smoke here, but many have also come true. July 13, 2019, is a case in point. At 2.31 p.m. Central European Summer Time, a three-stage Proton-M rocket thundered into the flawless blue sky above the 43 °C hot Kazakh steppe. Watching from the ground: scientists from the Max Planck Institute for Extraterrestrial Physics. Stowed in the rocket's nose: *eRosita*.

This X-ray telescope, developed and constructed by a consortium of German research facilities headed by the Institute in Garching, Germany, flew piggyback with the Russian space observatory *Spektr-RG* to its observation location at a distance of one-and-a-half million kilometers from Earth. Out there, way beyond and behind the Moon, the probe from Earth will scan the entire firmament over the next four years to produce the first complete map in the mid X-ray range.

It was a nail-biting wait for the watching scientists; due to technical issues with the rocket, the launch had to be postponed three times. In the end, the launch on July 13 was exemplary. *eRosita* survived the lift-off unscathed and then set course for its destination as planned. There was a slight delay in commissioning the observatory, but since October 13, all seven modules of the X-ray telescope have been observing the sky simultaneously, its custom-made CCD cameras operating flawlessly. The first composite images show the neighbor of our Milky Way, the Large Magellanic Cloud, as well as two interacting clusters of galaxies at a distance of about 800 million light years away. The astronomers are jubilant – their long journey to the steppe at the end of the world was worth its while.

Photo: Roscosmos

18 LEARNING

18 Speaking out

For us, it appears natural that children should start to speak at some point. Yet learning language is a major feat, which is still not fully understood even today. At the Max Planck Institutes for Psycholinguistics and Human Cognitive and Brain Sciences, scientists are studying how children learn this complex system of communication, apparently without effort.

26 Singing lessons for finches

No zebra finch emerges from the egg as an accomplished singer: each young bird first has to take singing lessons. Songbirds are, therefore, excellent model organisms for the study of learning processes in vertebrates. A team at the Max Planck Institute for Ornithology in Seewiesen is conducting research into how various songbird species learn their songs and what happens in their brains during the process.

32 Eye to eye with computers

Our eyes are our window on the world, but they also reveal a lot about us. Researchers at the Max Planck Institute for Informatics in Saarbruecken and at the University of Stuttgart exploit this by teaching computers to interpret our gaze. Ultimately, their aim is to enable robots or avatars to communicate with us eye to eye.

ON THE COVER Learning, or the acquisition of skills, follows complex rules and basic principles that apply to humans, animals and computers alike. In all cases, learning in living organisms demands a high level of intellectual ability, whether by infants acquiring language skills or birds learning to sing. When it comes to machines, learning requires highly sophisticated algorithms and large quantities of data, so that a computer can interpret human eye movements, for example.

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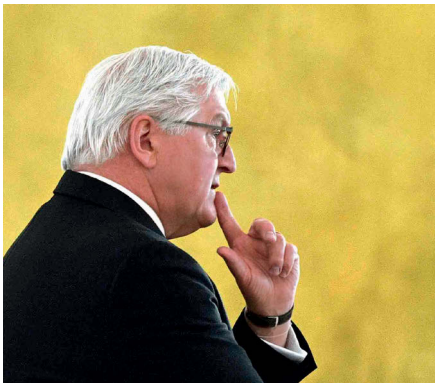

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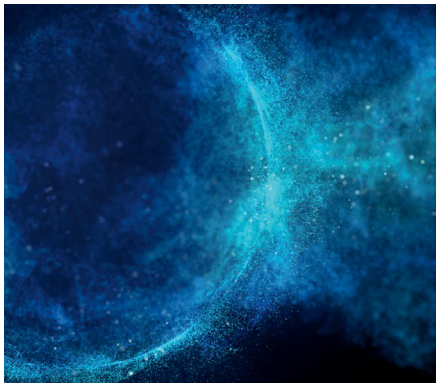

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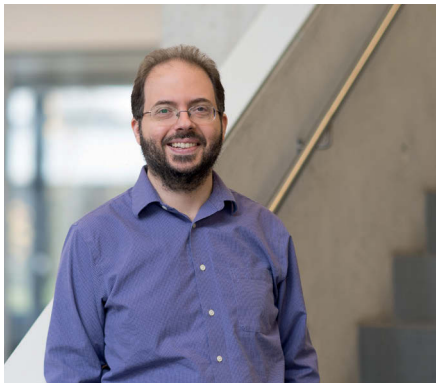

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SPECTRUM

PHYSICS & ASTRONOMY

MATERIALS & TECHNOLOGY

ENVIRONMENT & CLIMATE

CULTURE & SOCIETY

REGULAR FEATURES

Photos: Daniel Dominguez/CERN, Wolfram Scheible, Paulo Brando

Prestigious award for two U.S. social scientists

Max Planck-Humboldt Research Award and Max Planck-Humboldt Medal presented in Berlin

Ufuk Akcigit from the University of Chicago is the winner of this year's Max Planck-Humboldt Research Award. The social scientist received the honor for his outstanding contributions in the field of macroeconomics. Among other things, he has demonstrated clear relationships between innovation and long-term economic growth, as well as between innovation and social mobility. The award is linked to a research residency in Germany, which Akcigit will spend at the Halle Institute for Economic Research (IWH). There, he wants to study the causes of economic disparities between East and West Germany. Elliot Tucker-Drob from the University of Texas in Austin received the Max Planck-Humboldt Medal for his services to the field of personality and developmental psychology. He studies how social and biological processes shape the psychological development of individuals over their entire lifespan. The awards were presented by Michael Meister, Parliamentary State Secretary at the Federal Ministry of Education and Research, Max Planck President Martin Stratmann and Hans-Christian Pape, President of the Alexander von Humboldt Foundation, as part of the Berlin Science Week in November 2019.

Newly honored: Ufuk Akcigit and Elliot Tucker-Drob (from left) at the awards ceremony in Berlin.

"Oscars of Science" for Max Planck researchers

Two of the lucrative Breakthrough Prizes have been awarded to Franz-Ulrich Hartl and the Event Horizon Collaboration

Franz-Ulrich Hartl, Director at the Max Planck Institute of Biochemistry in Martinsried and his American colleague Arthur L. Horwich are two of the winners of the Breakthrough Prize in Life Sciences 2020. The researchers were honored for discovering functions of molecular chaperones in mediating protein folding and preventing protein aggregation. In the 1980s, they demonstrated that – contrary to the general dogma – most proteins need assistance from so-called molecular chaperones in order to fold into the correct shape. Misfolded proteins clump together and are one of the main causes of severe neurodegenerative disorders such as Alzheimer's or Parkinson's disease. The Breakthrough Prize in Fundamental Physics was awarded to the Event Horizon Collaboration. With eight sensitive radiotelescopes strategically positioned around the world, this international consortium of 60 institutions has captured an image of a black hole for the first time. The Max Planck Institute for Radio Astronomy in Bonn and the Institute for Radio Astronomy in the Millimeter Range (IRAM) played a preeminent role in these efforts. The Breakthrough Prize is awarded annually in three categories, each of which has a prize money of 3 million U.S. dollars and is therefore worth more than any other scientific award.

Artistic trophy: the winners of the Breakthrough Prize are awarded a sculpture from the Danish artist Ólafur Elíasson.

Photos: David Ausserhofer (top); Breakthrough Prize Foundation

"There is no reason for germline therapy"

Stefan Mundlos, from the Max Planck Institute for Molecular Genetics, explains why there will be no "designer babies" in the near future

It was only when the first genetically modified children were born in China in 2018 that many people realized how far-reaching the capabilities of genome editing actually are. This method allows researchers to sever DNA at a precise location and therefore to switch genes off or insert new fragments. But the genome editing of cells from the human germline raises a plethora of scientific and ethical issues. In 2019, the Ethics Council of the Max Planck Society prepared a detailed discussion paper on genome editing, in which Stefan Mundlos of the Max Planck Institute for Molecular Genetics in Berlin discusses the risks and opportunities of this method for the world of medicine. The researcher, who also uses the CRISPR/Cas9 technique in his own work, believes that concerns over uncontrolled manipulation of the human genome are unfounded.

Professor Mundlos, is the modification of human cells ethically justifiable?
Stefan Mundlos: It depends whether we are talking about normal body cells – the somatic cells as they are known – or about germline cells: sperm and egg cells. Somatic cells do not pass on their genetic material. If the genome of these cells is modified, the mutation disappears with the death of the patient. Such an intervention for the treatment of hereditary conditions or cancer is comparable to other cell-based therapies and is therefore ethically unproblematic.

What about germline genome editing?
That's completely different. The task of sperm and egg cells is to provide offspring, and so they pass on their genetic material to the next generation. Manipulating the germline will therefore affect people who are not yet born at the time of modification and cannot give their consent. That's ethically unacceptable. As genome editing is also not yet precise enough to avoid causing unintended mutations, the Max Planck Society took a clear stand against interventions in the germline in its discussion paper on genome editing.

How safe is the technique then?
CRISPR/Cas9 does work very precisely and almost always cuts the DNA at a defined point. But despite that, mistakes can happen. Researchers are currently working on even more exact and less error-prone variations of the technique. In any case, we will always have to check whether modified cells do indeed only carry the desired mutations.

What significance will genome editing in humans have in the future?
The modification of normal body cells definitely has great medical potential. Conditions that are caused by one – or a few – mutations, such as some forms of leukemia, could be treated this way. I'm sure that we'll be able to treat the first patients using this method in just a few years. On the other hand, I don't see any need for germline gene therapy, since there are equivalent and ethically less problematic alternatives. Using in vitro fertilization and pre-implantation diagnostics, embryos free of adverse mutations can be selected for implantation.

Many people fear that genome editing will be used not just for treating illnesses, but also to optimize human characteristics. In the future, will we have particularly intelligent or tall "designer babies" thanks to this new technique?
I don't see any danger of this happening in the foreseeable future. Characteristics such as intelligence, height or other characteristics we might wish to optimize are influenced by many different genes. We are far from even understanding these gene networks, let alone being able to manipulate them. It's quite possible that doing so will be completely impossible without triggering undesired effects elsewhere.

Stefan Mundlos

Some scientists are demanding a moratorium, a voluntary commitment to refrain from carrying out any modification of the human germline. What you think about that?
I don't believe such a moratorium would be effective. The circle of scientists who can implement the technology is too wide for that. There will always be someone, somewhere in the world, who doesn't feel bound by the moratorium. And in any case, who would be responsible for policing it?

Is there no stopping the manipulation of the human genome then?
I'm convinced that the lack of benefit will be much more effective than bans or voluntary commitments regarding germline gene therapy. There would be no reason and therefore no "market" for it.

Interview: Harald Rösch

Photo: Edgar Zippel/MPG

Quantum tricks at the push of a button

Max Planck – New York City Center for Non-equilibrium Quantum Phenomena inaugurated in New York City

At the official opening: Max Planck Vice President Ferdi Schüth (center) with Graham Michael Purdy from Columbia University, James Simons from the Simons Foundation, and Maya Tolstoy and Mary C. Boyce, both from Columbia University (from left).

The new Max Planck Center will see the Max Planck Institute for the Structure and Dynamics of Matter and for Polymer Research join forces with Columbia University and the Flatiron Institute to understand, control and manipulate the uniquely useful properties of quantum materials. The New York City Center for Non-Equilibrium Quantum Phenomena aims to harness these materials for a wide range of applications, including quantum computing and innovative measurement and cryptography technologies. Together, the scientists will study quantum materials that are not settled into a stable state. Scientists can perturb these materials using methods such as electric currents, heat pulses and barrages of photons or by embedding them in quantum cavities. In non-equilibrium states such as these, a material may exhibit new properties such as magnetism, ferroelectricity or superconductivity. If researchers succeed in carefully controlling these processes, they could develop materials for wide-ranging and potentially revolutionary applications. The new research center at Columbia University was inaugurated by all four partner institutions in November 2019.

On the net

Neighborly assistance
African grey parrots voluntarily help others to obtain food without expecting anything in return – showing they understand when they have to "lend a wing" to a peer! The parrots exhibit a high level of social intelligence and willingness to cooperate. They readily help others, even when there is no immediate opportunity for return. Moreover, they return received favors and do not appear to be jealous if their fellow grey parrots obtain a better reward than themselves. Our YouTube video demonstrates this fascinating neighborly assistance.
https://youtu.be/HEvO5SBiv6k

Marshmallow experiment 2.0
An adapted version of the famous Stanford "marshmallow experiment" from the late 1960s, which explored the importance of young children's ability to delay gratification to future life success, shows how sweet it is to cooperate. The study, conducted by Rebecca Koomen, Sebastian Grueneisen, and Esther Herrmann of the Max Planck Institute for Evolutionary Anthropology, suggests that kids are more willing to delay gratification for cooperative reasons than for individual goals.
https://sciencedaily.com/releases/2020/01/200114104024.htm

Farewell, UK!
On January 31, 2020, the United Kingdom left the European Union after 47 years of membership. But what impact will Brexit have on universities, joint research programs and scientific exchange? The European University Association (EUA) has prepared an overview of the consequences. Read EUA's briefing with a focus on areas of relevance to universities.
https://eua.eu/resources/publications/906:brexit

Photo: Asiya Khaki

License for new drugs to treat Parkinson's disease

The company Modag is developing a substance discovered by researchers in Goettingen and Munich

In most cases, Parkinson's disease first appears between the ages of 50 and 60. It is characterized by the loss of dopamine-producing nerve cells in the substantia nigra, a structure in the midbrain. Under the microscope, abnormal deposits of clumped alpha-synuclein proteins are visible in the brain, which appear to be extremely toxic to nerve cells. Until know, there were no drugs that tackled the root causes of Parkinson's disease. This is where the work of research teams led by Armin Giese of LMU Munich and Christian Griesinger of the Max Planck Institute for Biophysical Chemistry in Goettingen comes in. A few years back, the two researchers discovered an active substance that significantly reduces the rate of growth of the protein deposits and delays nerve cell degeneration in mice. However, applications in humans remain a long way off. The company Modag has taken over the preclinical development of the substance and, with a patent for new chemically modified drug candidates, agreed another exclusive license with the Max Planck Society in September 2019. On this basis, Modag can now push forward with the development of new drugs for Parkinson's disease.

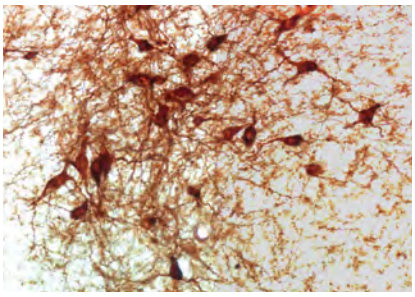


Photo: Max Planck Institute of Neurobiology / Aron & Klein

Disrupted system: dopamine-producing nerve cells in the brain of a diseased mouse.

Democracy needs science

In times when different groups in society are increasingly isolating themselves from each other, science is also threatening to become just another opinion bubble. Yet in order to resolve global problems – particularly climate change – we need scientific expertise. At an event held by the Alliance of Science Organisations in Germany on September 26, 2019 in Berlin, the Federal President therefore demanded that scientists engage in dialog with politicians and society. You can read a transcript of his speech below.

SPEECH BY THE FEDERAL PRESIDENT FRANK-WALTER STEINMEIER

It is a pleasure to be here with you today, at the closing event of this important and broad campaign for academic freedom – which you have hosted to mark the 70th anniversary of our Basic Law. (…) It is good to see that your community can speak out, loud and clear and with one voice, on such an important issue – namely the constitution that underpins our society. For that, I extend my special thanks to both the Alliance of Science Organisations in Germany and to all of you. (…)

You say clearly and unmistakeably – on the occasion of the anniversary of our constitution – that, during seven decades with our Basic Law, we have accomplished something we can be proud of: we have reached a broad consensus on academic freedom in our country. I would add that this was a fortunate development – there was much opposition, and it extends far beyond the scientific community.

This consensus can be summed up in two sentences that we have probably heard many times before – Namely: first, academic freedom is a valued asset in our democracy and a fundamental right set out in our Basic Law – a freedom that we all are called on to nurture, protect and, if need be, defend. Second, in a liberal democracy, academic freedom brings with it the expectation that science bears responsibility for the world it explores, for the society in which it conducts research, as well as for humanity and nature in general.

> We are witnessing attacks on the freedom of science – very real attacks, across the globe

I think that each and every one of you will agree with me when I say that the academic freedom we are bound to protect and the responsibility that arises from this freedom are inseparably linked. So, ladies

Photo: John Macdougall/AFP via Getty Images

"Enlighten our democracy": Federal President Steinmeier encourages scientists to play a constructive role in political discussions.

and gentlemen – will that be all? (…) We've paid tribute to academic freedom, so we're that much closer to the buffet reception.

Frankly, no – because the agreement that exists in this room hardly mirrors the outside world. We are witnessing attacks on the freedom of science – very real attacks, across the globe. For this, we need not even look to distant lands, to strong or rising autocracies, where freedom is not worth much – countries in which science must serve authority and ideology.

We also need not look across the Atlantic, where scientific discoveries based on decades of research are brushed aside with an abrupt tweet – where, in the worst case, one can no longer distinguish between the two. No, we need look no further than Europe, where an entire university is driven out of a country, where some opinion leaders express their desire for a world without what they consider to be troublesome experts, a world without critical thinkers and where science places itself entirely at the service of politics.

I would like universities to be places where people can experience and learn about what democracy means

All this should worry us. And, what is more, we must speak out when scientists come under pressure. We must help where we can – this includes, for example, when academics from these countries seek refuge here. The influx of academics under threat shows that Germany, which has a truly difficult history, has today become a harbor of reason, a partner for all those who demand freedom of thought and speech worldwide. Let us be ambitious in realising that potential.

Yes, academic freedom is valued in this country. But that is no reason for us to rest on our laurels! Particularly given the situation around the world, particularly because we can see every day how academic freedom is being challenged, we should ask ourselves in what ways we can secure a future for this precious basic right.

I want to address three areas here. Firstly, there is always also a material aspect to academic freedom. As our country's scientists and academics, you are entitled to a solid financial foundation. Top-notch, world-class research, the kind that we all want to have, as well as freedom of thought and creativity – all this requires sufficient funding.

Our country does fare well by international comparison, particularly in view of increased investment over the last decade and a half. That said, in the next few years, it will at least not become any easier to maintain this ambitious level. This effort requires universities and research institutes to remain fully aware of the conditions that guarantee their independence, and to be circumspect in defending these conditions. This applies as much to the political sphere as it does to third-party funding – for example, from business and industry. To me, however, one thing is clear: primary responsibility for ensuring that the basic material needs of science and academia are met lies with the state. It is therefore not a bad idea for you to periodically remind everyone of this fact.

Secondly, academic freedom must apply not only at the very top, but also for junior scientists and researchers. I would like universities to be places where people can experience and learn about what democracy means. For the university to be a place of democracy, it must first be a place of freedom. Some complain that, these days, courses of study give individuals too little opportunity for finding their calling in life and their place in society. I think that's somewhat exaggerated. Apart from the many new structures and increased demands imposed by Bologna – with Bachelor's and Master's courses, modules and grading – there is one key priority: students' freedom, which begins with their course choices and extends to intellectual growth beyond the boundaries of their chosen subject and their country; this freedom should be, and should remain, at the core of every academic education.

Photo: John Macdougall/AFP via Getty Images

Later, among doctoral researchers and research assistants, there is of course also the freedom to develop one's research topics, unfettered by dependency on, or excessive influence of, one's predecessors. Because the academic freedom to which we are paying tribute today begins not at the upper end of the academic salary scale, but rather must extend to all research assistants, doctoral and postdoctoral students, as well.

Thirdly, and most importantly, we must firmly anchor the freedom of research in society. I believe this will only succeed if we build trust in scientific methods, renewing it where necessary. After all, the often-invoked post-factual age is dawning not only in other parts of the world. In Germany, too, 43 percent of those questioned already believe that facts are a matter of opinion. This number can and should worry us. We must, of course, understand what lies behind it – but more importantly, we must learn how to deal with it.

I believe that where there is a lack of trust in scientific discoveries, there is an all the greater need for trust in the process by which these discoveries are made. The process must be credible – that is, not subservient to predominant interests. By advancing logical arguments, verifiable facts and transparent methods. And by making an honest distinction between proven findings, on the one hand, and hypotheses that are still disputed in the scientific community, on the other hand.

Faced with public pressure, science must not become yet another bubble of opinion. That is why I want to direct the following words of encouragement at all scientists and academics: remain engaged in the scientific process, with the ambition and high aim that you are engaged in "the production of truth". Because, for there to be social progress, it must be based on your findings. The big issues of tomorrow call for not only emotional, but also well-informed, debate.

Yes, it is politicians who must express their commitment to, and garner support for, trust in science, but science itself must also time and again create this trust. Because without trust in research, society will lose its ability to detect future opportunities, and science will fall easy prey to the enemies of freedom.

A few months ago, I was in Iceland, a small country at the outermost edge of Europe – and one that is feeling the existential impact of man-made climate change. You can imagine what it means for a country that even has "ice" in its name when the first glaciers cease to exist – even today. As is often the case for such trips, I invited guests from Germany to come along and represent our country. These frequently include scientists – some of them are here in this room – and I am happy to see all of you.

> Misunderstanding must not come to characterize the relationship between science and politics

As we sat down during this trip to Iceland for a discussion with scientists about climate change, one thing was clear: no one questioned whether the facts were real. The data and their interpretation were not the issue.

Rather, the discussion centered on why "politics" is not taking action, why "politics" is not living up to its responsibility and why "politics" – which should finally begin listening to what scientists are saying – is so slow to implement the necessary measures. This brings me to something that has been very important to me recently – something we must talk about when it comes to academic freedom and responsibility – namely, the relationship between "science" and "politics" in general.

Particularly regarding the major issue of our times, climate protection, I see and hear much incomprehension, disappointment and dissatisfaction when scientists talk about "politics". I see and hear how people citing scientific facts are accusing "politics" of delay and failure – not only during my travels as Federal President, but also in town squares all across our country. But let me quite clearly say that,

as Federal President, it is not my role to take up the cause of one of these sides. As Federal President, it is my role to help reconcile differences.

Of course, people have reason to be impatient. And criticism is justified. Naturally, it is politics that is first and foremost called upon to act. It is also right that Germany, as a country that once led the way on

> We should regard democracy as being a space in which we can jointly untie knots

mitigating climate change and the development of renewable energy, runs the risk of losing not only this position, but also its ambition. A number of years ago, we set ourselves lofty goals. What counts now is mustering the political will to actually reach these goals! That is the true benchmark of climate policy, and to get there politics must act courageously and with decision.

That is all true. No one can deny anymore that action is urgently needed. But that alone is not enough. Carl Friedrich von Weizsäcker once said, "it must be the scientist's top priority to recognize how discoveries and changing the world are interlinked". Yes, discoveries and changing the world are closely interlinked – but they are not one and the same thing! You may be thinking "that's a shame, isn't it?" – and Plato, for one, would probably agree. We're in need of philosopher kings – and instead we have subcommittees, summits and climate cabinet meetings.

As Federal President, I am not here to justify politics – and I'm certainly not here to defend specific decisions the coalition has taken on the climate protection dossier. Yet I would like to remind everyone that democracy does not work like science. Democracy does not function exclusively thanks to a keen sense of reason, or on the basis of merit, peer review and the impact factor. Politics in a democratic system has its own rules. For that alone, it should not be derided – also not by science – as being intrinsically indecisive, or even bothersome.

Science is essentially focused on discovery – and politics is essentially focused on action. This means that democracy needs science – and very much so – yet democracy needs many more things, as well. It must weigh different views and priorities, balance interests, seek majorities, struggle to find compromises, and look after those whom progress leaves behind. Politics – and climate policy in particular – becomes even more effective when more people are given the opportunity to participate and assume responsibility.

The discussion during my Iceland trip also gave me the impression that we were actually speaking different languages and talking at cross purposes. We increasingly fell into the trap of viewing "science" and "politics" as two orbiting planets that send out brief radio transmissions to one another and then get upset when the other side does not immediately reply "roger" in confirmation. I want to make one thing perfectly clear today, namely, that misunderstanding and walls of silence must not come to characterize the relationship between science and politics.

To avoid this requires effort on both sides. Politics, for its part, must not take the easy way out – the path of least resistance, by choosing the smallest common denominator. Politics should be a motor – and not at the mercy of events, as appears to be the case all too often regarding climate change. Politics must have the courage to also take daring steps. Politics can take advantage of the opportunities that are being created by civil society. Especially for such a highly complex topic as climate change, it holds true that politics needs expertise and evidence. Politics should get back in the habit of visiting lecture halls and laboratories. Politics must time and again go and seek advice from experts; it must place its trust in scientific expertise – and it must defend this expertise against the notorious individuals who oversimplify the world, stir up opinion and beat the populist drum.

Photo: John Macdougall/AFP via Getty Images

However, my appeal is directed both ways. Science, too, especially because it enjoys certain freedoms and privileges, bears a special responsibility for the success of democracy. First and foremost, it must remain honest and transparent to both itself and the general public – in line with the fact/value distinction that was drawn by Weber. This also means that when science makes normative judgments, and when it sees the need for change, science must be willing and able to step up to politicians and society – explaining, advertising and acting as an intermediary. It must be willing to become part of the democratic debate. It shouldn't put its own findings on a tall pedestal – thereby making democracy, with its many voices and complexity, appear to be not the way to a solution, but rather an obstacle. In short, we must avoid pitting science against politics.

Regarding climate change, we are most certainly faced with the proverbial Gordian knot. As we all know, it can certainly not be cut by a single actor – or act of legislation. However, if in frustration over this situation we each begin tugging at the knot, then it will only become more snug. Therefore, it is my wish that we stand shoulder to shoulder and continue to demand that democracy deliver no more, but also no less, than what it truly is: a space in which we can jointly untie knots!

Anything else is the apocalypse. I don't know if you agree, but I think that the spectre of the apocalypse paralyzes. It does not invigorate. It creates fear where we need the courage that can bring change. It makes doubts appear larger than they are, and it drains every effort of vigour.

That is what I ask of science: be persistent! Explain that which needs explaining – and if need be, more than once. Point to what the future holds. Encourage others. Enlighten our democracy! Thank you very much. ◀

This speech was given by Federal President Steinmeier on September 26, 2019 in the Futurium Berlin. It was made at the closing event of the "Freedom is Our System" campaign, which was initiated in 2019 by the Alliance of Science Organisations in Germany.

Frank-Walter Steinmeier (born in 1956) has been President of the Federal Republic of Germany since 2017. The doctor of law began his political career in 1991 in the state chancellery of Lower Saxony. In 1998, he was appointed Under-Secretary of State in the German Chancellery under Chancellor Gerhard Schröder. One year later, he became Chief of Staff of the Chancellery. In 2005, he was appointed Minister of Foreign Affairs in Angela Merkel's cabinet, becoming Vice-Chancellor in 2007. During the period of the CDU-FDP coalition in Berlin, Steinmeier served as an SPD delegate in the Bundestag. Four years later, he again became Minister of Foreign Affairs until January 2017.

Photo: Bundesregierung/Steffen Kugler

Experiencing history in a canoe

Max Planck researchers cooperate with partners in around 120 countries all over the world. Here, they write about their personal experiences and impressions. Thomas Turnbull from the Max Planck Institute for the History of Science in Berlin is involved in the project "Mississippi. An Anthropocene River". As part of this venture, Turnbull paddled down a stretch of the Mississippi. He talks about a river that epitomizes the changes that humans have made to natural systems.

As a historian, I'm more at home in the archives than in a canoe. A research expedition that offered the opportunity to experience a river up close therefore seemed like quite an adventure. The Mississippi project investigated whether this river could be used to illustrate the Anthropocene, a proposed geological epoch dominated by humanity.

The three-month journey along the river from Minnesota to the Gulf of Mexico was a fundamental part of this project. I joined the expedition for a week, traveling from Cairo, Illinois, to New Madrid, Missouri, in the company of other researchers, artists and students from Augsburg University in Minneapolis who were spending the fall semester on and near the river.

The impressions I gained on the canoe trip provide an important part of my research, in which I am investigating the history of technical change in the Mississippi Valley. During this trip, I experienced at first hand the positive and negative consequences of past technical intervention in the river's course – the dam and levee system.

The dam systems and levees were largely built in the 1930s to make the Mississippi easily navigable and help keep it in its channel. This system kept floods at bay and made it possible to use the river as a non-stop transport route for bulk cargo. Nowadays, however, we know that this construction critically undermined the dynamics of the river system and gave rise to new flood risks.

Graphic: iStockphoto

Photo: Claire Pentecost

Dr. Thomas Turnbull, 33, studied history at King's College London. He worked for organizations including an environmental think tank and a project for the preservation of endangered languages. Afterwards, he studied at the School of Geography and Environment, University of Oxford. In 2017, Turnbull was awarded a doctorate for his thesis on "Energy Resource Conservation in Britain and America, 1865 – 1981". From 2018 to 2020, he will be working as a guest scientist at the Max Planck Institute for the History of Science. The Mississippi project and other planned activities are all in keeping with his research interests, which lie between the history of science and historical geography.

My starting point was Cairo, a small town on which the deindustrialization of previous decades has clearly left its mark. Nevertheless, the river still strongly resembles an industrial waterway. Tugboats transport cargo day and night, ranging from maize and soybeans to spare parts for oil refineries. Despite their leisurely pace, the tugboats create huge waves and their rattling drowns out the rustling of the nearby trees. Behind the wall of hickory trees and cypresses on the bank, agricultural machinery harvests vast quantities of soybeans, the hop-like scent of which occasionally wafted in our direction. Yet there were hardly ever any people to be seen. It was almost surreal.

Day after day, we paddled down the steadily flowing Mississippi – a never-ending conveyor belt of water and sediment. It was much quieter and wilder than I had expected. We camped on sandbanks and tiny islands in the river. The nights were pitch black, illuminated only by the stars, our campfire and the lights shining from tugboats. The crews were no doubt puzzled by the fact that we spent the night on these narrow sandbanks – and sometimes even sang accompanied by a guitar.

During the expedition, one of our guides found a tree trunk covered in oyster mushrooms. We watched Asian carp leap out of the brownish water and listened to the birds twittering in the trees. Often, the only signs of human habitation were the garbage of civilization that had washed up onto the banks. We even found a large plastic Star Wars spaceship, half embedded in the mud.

Thanks to my experiences on the canoe expedition, I can now think in much more concrete terms about the environmental history of the Mississippi valley and its role in the Anthropocene era – for example about how flood control, industrial agriculture, the transport of fertilizers and power generation are linked by this body of water.

Look who's talking: most children can say their first words at just one year old, while three-year-olds are already able to conduct conversations. That makes them far more advanced than any animal, or even artificial intelligence.

Speaking out

For us, it appears natural that children should start to speak at some point. Yet learning language is a major feat, which is still not fully understood even today. The Departments led by **Caroline Rowland** at the **Max Planck Institute for Psycholinguistics** in Nijmegen and **Angela Friederici** at the **Max Planck Institute for Human Cognitive and Brain Sciences** in Leipzig are using a wide range of methods to investigate how children learn this complex system of communication with seemingly no effort.

TEXT **TIM SCHRÖDER**

The path to the laboratories where Caroline Rowland works leads through a small park. When you walk along it, you immediately notice that something is different. A baby blue porcelain elf sits in the grass on the edge of the path, and a few steps later you see a pink fairy, about the size of a Barbie doll, then another, then another... until you reach a side entrance.

Once you're inside, this part of the Max Planck Institute for Psycholinguistics also looks different from the rest of the building with its offices and laboratories. In the hallway you see brightly colored stools shaped like mushrooms, which are just the right size for children to sit on comfortably. "And here's our waiting room," says Caroline Rowland as she opens a door onto a small play area with small chairs, cuddly toys, picture books, boxes full of board games and games that test children's skills. Caroline Rowland and her colleagues have arranged everything to make sure that children feel comfortable straight away, since it's they who are the real stars of her research.

She is Professor of Psychology and Director at the Max Planck Institute for Psycholinguistics in Nijmegen in the Netherlands. She wants to find out how children learn their native language – even before they start to become proficient in many other skills. "During their first years of life, most children have no difficulty learning the most complex communication system in the known universe. I want to find out how they manage to do this and why this is the case." To this end, she regularly invites parents and their children to take part in playful experiments. She finds her work with babies and young infants who are just starting to learn their native language fascinating.

Next to the colorful waiting room is one of the laboratory rooms where Caroline Rowland and her team conduct their studies with the children. The contrast couldn't be greater: the room has an austere atmosphere and the walls are bare. Nothing must be allowed to distract the children. In the middle of the room, there is a large monitor with a table and two chairs in front of it. This is where the parents sit with their children. The researchers then show scenes or images on the monitor: a dog chasing a cat or objects such as balls or rubber ducks – things that children are familiar with from their everyday lives. Together with team members Julia Egger, Christina Bergmann and Andrew Jessop, Rowland observes which items attract the children's attention. For this, she uses eyetrackers, which contain infra-red cameras that follow the movements of the pupils and iris and are able to register the direction, and movements, of the children's eyes.

Using this technique, Caroline Rowland, together with her team and colleagues from Liverpool University in

Photo: Michele Constantini/plainpicture

the UK, are able to measure the speed at which a child processes language. This approach is known as the "looking-while-listening" paradigm. A child sits in front of a screen and sees pairs of images, only one of which is mentioned. If, for example, an apple and a car are shown on the screen, they are directed to "look at the apple" by a clear, child-friendly voice.

Using the eyetracker, the scientists can measure how quickly children direct their gaze to the apple. The speed with which children identify the correct picture indicates how quickly they process the language that they hear.

NO PAUSES BETWEEN WORDS

The study aims to solve the biggest puzzle surrounding language development: how is it that some children speak their first words at just eight months, while others only begin to talk when they are two or three years old? And on a very practical level, how is it possible to detect at an early stage whether children are simply rather late developers, or whether they have a language acquisition disorder that requires speech and language therapy early on? The study showed that the speed at which 18-month-old infants process language is indeed a key factor in language development.

Fast language processors have a clear advantage: they are able to learn more from every sentence that they hear, and their vocabulary and even their knowledge of sentence structure grow more rapidly than those of slower processors. What's more, the larger their vocabulary, the faster they can process what they have heard. The project team intends to investigate this phenomenon in greater detail as part of their future research – also with the aim of finding opportunities to help children who struggle with language to learn language more quickly.

For Caroline Rowland, the ability to quickly and accurately process the language that has been heard is crucially important in learning to speak. What newborn babies and young infants first perceive is an unceasing flow of individual sounds and syllables. Adults will recognize this from learning a foreign language: often, the flow of words is almost incomprehensible, and it is only occasionally possible to extract individual, familiar terms and make an attempt to work out the meaning of what is being said. "Usually, when we say a sentence, we leave no pauses between individual words," the scientist explains. "For small children who have to learn the language from scratch, the challenge is therefore to recognize words in this flow of syllables." And not only that: they also need to do this simultaneously with other difficult tasks such as differentiating between different types of words and learning to understand the grammar.

One key question is therefore how children process the linguistic input. In this area, research needs to take into account the fact that in spoken language, the words aren't enunciated evenly. When we speak, we use different accen-

Photo: MPI for Psycholinguistics

Left Playful research: the scientists in Nijmegen perform child-friendly experiments to study which language abilities children have already obtained.

Below Caroline Rowland is the Director of the Language Development Department at the Max Planck Institute for Psycholinguistics.

Photo: MPI for Psycholinguistics

tuations, make pauses, and talk with a certain inflection of speech. We emphasize what we have said with gestures and looks, and we naturally refer to objects and people around us. According to Caroline Rowland, these factors have not yet been taken sufficiently into account by research. In her opinion, this constitutes a complex challenge.

CHILDREN MAKE CLEVER MISTAKES WHEN THEY SPEAK

She herself tackles this challenge using various different methods. In other words, she uses a whole range of approaches: neuroscientific methods, computer models, behavioral experiments and detailed studies of everyday conversations.

To analyze these conversations, Caroline Rowland and her team use large online databases such as CHILDES, in which dialogs by and with children are transcribed into written form from audio or video files. "You can draw a very large number of conclusions from the conversations that children hold," Caroline Rowland explains. Errors typically made by children, for example, provide useful information since they indicate which underlying grammatical patterns the children have already identified in the language. Younger children often make mistakes when forming plural nouns, such as "sheeps" instead of "sheep". For example, a child who says "sheeps" is using the fact that you can add '-s' to words in English to make them plural (as in "dogs"). It just happens that "sheep" is an exception to this pattern.

Among older children, the mistakes change as their language ability grows. A girl's response to being tickled by the father could be to say "Don't giggle me!" This example clearly illustrates the key issue: this isn't an error that involves the girl using words or parts of words in the wrong way. Quite the opposite: the girl is using a pattern that she has frequently heard, and which she can now use in a creative way to express something new, which in

A colorful team: in the Language Development Department, researchers in the fields of developmental and cognition psychology, the neurosciences, linguistics and speech therapy work in close cooperation with experts in computer analysis and simulation.

this case is not quite right according to the rules of the language. Rowland talks of "clever mistakes".

EVEN YOUNG INFANTS FIND PATTERNS IN LANGUAGE

Incidentally, language development researchers advise against correcting children's mistakes when this happens. Children don't consciously learn which language principles they are using. Instead of trying to teach them rules, adults would do better to repeat what the child has just said, but in the correct form ("I won't make you giggle"). In time, the children also learn not to make the "clever mistakes".

One explanation as to why even very young children are able to learn language patterns is what is known as "statistical learning". This describes the ability of the brain to identify general principles in a complex environment, to observe them and to learn from them. This is clearly illustrated by sentences such as: "Look at the baby, darling!" Usually, in everyday language the syllable sequence "ba" and "by" occurs more frequently than the combination of the syllable "the" and the syllable "by". Therefore, a child quickly learns that there is a connection of meaning between "ba" and "by" – the "baby".

This is demonstrated by experiments in which children hear an artificial language. The researchers integrate certain regular elements into this language. In the imaginary sentence, "dalobitaganodalobilimidenatidalobi", for example, which is spoken fluently, the syllables of the sequence "dalobi" occur together in this order multiple times. It has been shown that children learn these regularities very quickly, so much so that they can then easily recognize the term "dalobi" later on when it is spoken on its own. "We have several cameras in the room, which film the faces of the children in order to discover what they have learned by looking at how they react to familiar and unknown sounds,"

Photo: MPI for Psycholinguistics

Caroline Rowland explains. "When the children hear a term such as 'dalobi', with which they are familiar, their level of attention increases significantly and they look up, for example."

COMPUTERS HELP ANALYZE LANGUAGE

Rowland stresses that while this may sound banal, it is actually quite amazing. "Even at just a few months, the brains of human infants are already able to understand complex statistical relationships of this kind – and they are much better at doing so than any animal. Babies can extract complex statistical patterns from spoken sentences within the space of a few minutes. We can train apes to do the same, but it takes hundreds of attempts before they succeed." According to Rowland, if we want to understand why people are capable of developing such a complex communication system as language, it is essential to research how and why infants are so adept at statistical learning.

In her Department, Rebecca Frost, Katja Stärk and Evan Kidd are researching how infants use repetitive patterns in language in order to develop a better understanding of words and grammar. In their research, they don't just analyze conversations but also use behavioral and neurophysiological experimental techniques, such as eye tracking and electroencephalography, or EEG. For this purpose, hoods studded with electrodes are placed onto the babies' and infants' heads to record the weak electrical activity of the brain. In this way, the researchers are discovering how well infants use statistical language learning, and how good they are at it.

Such studies demonstrate that an awareness of language is developed at a very early stage, long before the children start to speak. Evan Kidd, for example, recently published a study according to which infants who later went onto have fast or slow language development reacted differently to language in infancy. Children who start gathering and using their knowledge of words earlier than others, instead of focusing on individual sounds, have an advantage later on when it comes to learning new words.

Another way of studying statistical learning is to analyze everyday conversations from databases. From these, it is possible to determine the language patterns that children are exposed to when they learn the language. Studies have shown, for example, which rules apply when differentiating between types of words. For example, in English, some words occur very frequently in little frames (e.g. the ... is). These frames predict, with a high degree of accuracy, the category of the intervening word (e.g. the intervening word between the and is is likely to be a noun; the cake is..., the apple is..., the universe is...). For example, one study shows that in English, nouns consist of more syllables than verbs do, and that they are more

Take a closer look: in Nijmegen, experiments on the screen are being used to study how rapidly children are able to classify terms. The faster they process words, the easier it will be for them to learn the language later on.

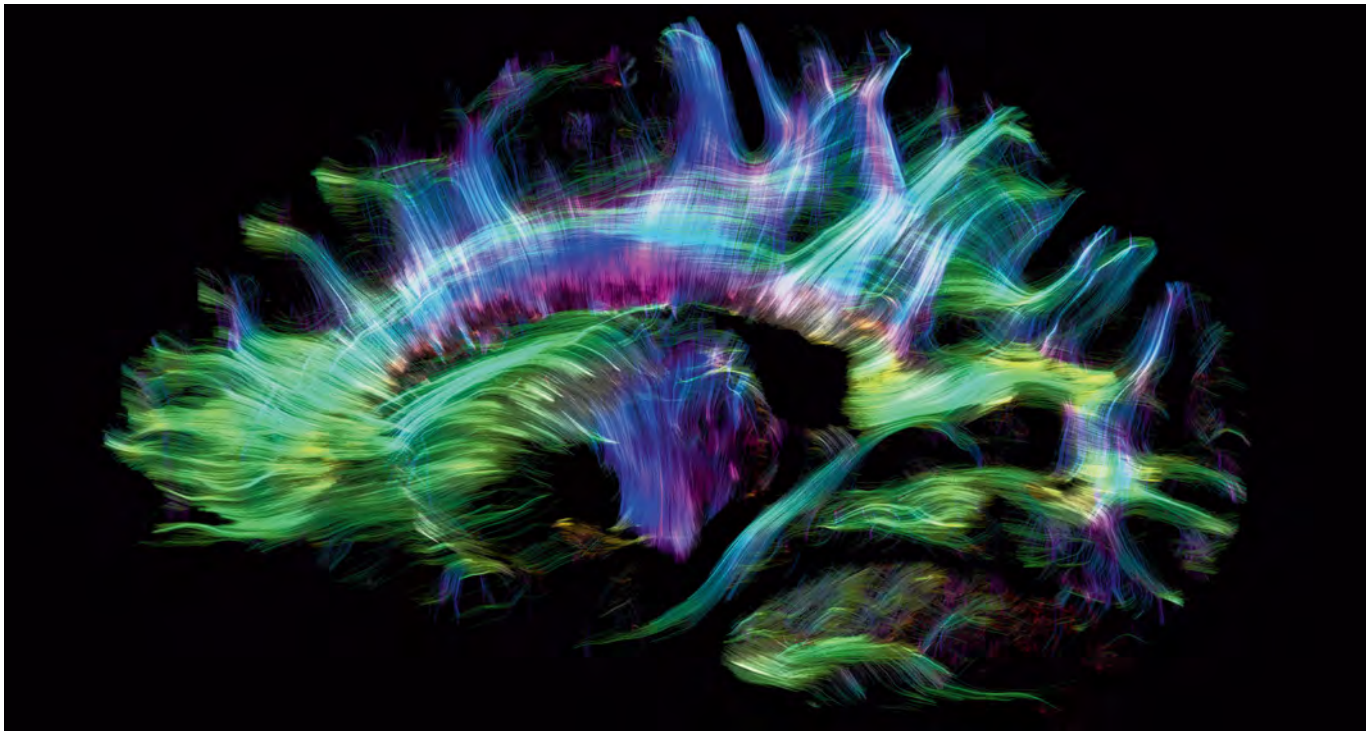
Photo: MPI for Psycholinguistics

commonly stressed on the first syllable than other types of words. Thanks to modern computer technology, researchers in this area have made significant progress in recent years. Automated systems are capable of analyzing thousands of verbal exchanges and statements in a short space of time. In this way, scientists are gaining an increasingly thorough understanding of the complex language input to which language learners are exposed.

ONLY HUMANS CAN CLEVERLY COMBINE WORDS

Computers can also be used to simulate learning mechanisms and in so doing, to examine existing theories of how children learn language. Caroline Rowland together with her project team – Evan Kidd, Raquel Garrido Alhama, Andrew Jessop and a colleague at Nottingham Trent Univesity in the UK – are building computer simulations that test different theories of how children learn language. The idea is to test whether the the computer model learns the language in the same way as children. However, according to Caroline Rowland, artificial intelligence is way behind children in terms of what it can do, for example when it comes to differentiating between various types of words. "Even three-year-olds know that you can't eat adjectives ("I ate the happy"), but models are unable to recognize this fact."

In Rowland's view, the problem is not the fundamental language development models. To a far greater extent, the computer's difficulty arises from the fact that in real conversations, language has added noise, as it were. People restart a sentence, make improvements, and fail to finish what they are saying. For computer models, it is hard to know how to handle this noise. Then there are the dual meanings in natural language, which even extend beyond different word types. Verbs can be the same as nouns ("I like fish.", "John can fish", or adjectives ("That dress doesn't fit you.", "He looks lean and fit.").



The connection makes the difference: the different parts of the brain communicate with each other via a network of fibers. The way in which language understanding develops is also closely linked with a nerve connection of this type.

Photo: Alfred Anwander/ MPI for Human Cognitive and Brain Sciences

"We still have a long way to go," says Caroline Rowland. She hopes that in the coming years, it will be possible to find the solution to many unanswered questions using her portfolio of different methods. During the process, she also takes careful note of the work being conducted by other colleagues, such as Angela Friederici, who is approaching language development from a different angle. The neurophysiologist is a Director at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig. Her work focuses mainly on the development of the brain, which plays a decisive role in language learning.

"In principle, Caroline Rowland and I are approaching the same topic from two different perspectives – language development is our common denominator," says Angela Friederici. "I am also asking what makes us human. Humans are the only living creatures who can logically combine language elements and phrases. No animal is capable of doing that." Dogs, for example, can learn individual words such as "stick" or "sit". However, they can't combine them in the same way as a young infant can.

A CHILDREN'S FESTIVAL AS A RECRUITMENT MEASURE

One of Friederici's most important research tools is functional Magnetic Resonance Imagery (fMRI), which can be used to observe certain processes in the brain from the outside, such as nerve connections and the activity of certain areas of the brain. Using this approach, she has made interesting discoveries, particularly by comparing children and adults. It has been known for a long time that two areas of the brain are particularly linked to language: the Broca area and the Wernicke area. The French surgeon Paul Broca discovered that people whose Broca area is damaged lose the ability to express themselves using correct grammar. In turn, the neurologist Carl Wernicke found that the area later named after him is important for understanding sentences.

Using fMRI, Angela Friederici discovered, among other things, that during the brain maturation process, a nerve connection is formed between two areas that is closely linked to the increasing ability among children to understand language. "Interestingly, animals don't have this connection. That means it probably plays a key role in language development," she explains. This research was only possible because Angela Friederici cooperates with clinics who provided her with image data from medical studies of newborn babies and young infants – naturally with the consent of their parents.

Caroline Rowland is also dependent on parents who are willing to travel to the Institute with their children for the language experiments. After all, these visits last about an hour. However, even the youngest children are able to stay the course, she says. Because everything is done in a playful way, the children are curious about what is happening. Once a year, Caroline Rowland and her colleagues from Radboud University next door organize a big children's festival, called "Kletskoppen", or "chatterboxes". It's a colorful, fun event, with which the researchers aim to fill others with enthusiasm for their work – particularly parents who want to get involved in their studies.

The event is attended by Dutch TV hosts, storytellers and children's authors, the researchers give informal presentations, and the children can play dozens of language games. "We want to make contact with people from different social backgrounds, not just with educated families who are more likely to be interested in research," says Caroline Rowland. The "Kletskoppen" is a door opener, she explains. "If we want to know how language development works, we also have to find out whether there are differences between children from all types of cultural, language and social backgrounds." This is crucial; if we want to understand language acquisition, and eventually develop better programs to help all children learn to talk, we need to discover how everyone learns language. ◀

Angela Friederici, Director at the Max Planck Institute for Human Cognitive and Brain Sciences, is investigating the connection between brain and language development.

www.mpg.de/podcasts/lernen (in German)

SUMMARY

- **Even very young children are capable of unconsciously recognizing language patterns and rules such as word relationships, types of words or sentence structure.**
- **For babies, one particular challenge is to be able to pick out individual words from the flow of sounds. However, tests have shown that they are able to identify repeated syllable combinations as words within a very short space of time.**
- **Children who start gathering and using their knowledge of words at an earlier stage than others are at an advantage when it comes to developing language later on.**
- **The development of the brain plays an important role when learning language. A nerve connection between two important areas of the brain, which is not formed until after birth, is closely linked to language understanding among children.**

Photo: fotografa_Berlin/ MPI for Human Cognitive and Brain Sciences

Photo: Axel Griesch

Singing lessons for finches

No zebra finch emerges from the egg as an accomplished singer: each young bird first has to take singing lessons. Songbirds are therefore excellent model organisms for the study of learning processes in vertebrates. **Manfred Gahr** and his team at the **Max Planck Institute for Ornithology** in Seewiesen are conducting research into how various songbird species learn their songs and what happens in their brains during the process.

TEXT **TOBIAS HERRMANN**

It doesn't take much imagination to see where the Zebra Finch got its name.

The Max Planck Institute for Ornithology is situated on an almost 30-hectare site between Starnberg and Ammersee on the outskirts of Munich, which even has its own natural lake. 170 people work there alongside some 2800 zebra finches, 500 canaries, chickens and fish.

Manfred Gahr's office, a large room flooded with natural light, containing two desks and an open fireplace, is on the first floor of one of the buildings dotted across the site. "It used to be a living room," as Gahr explains, at a time, when Erich von Holst and the later Nobel Prize winner Konrad Lorenz moved into the former Max Planck Institute for Behavioural Physiology in 1958, it was common practice for scientists to live permanently at the research site. "Unfortunately," he says, "I'm no longer allowed to light the fire, since last time, it enveloped the entire building in thick smoke."

Gahr had the choice between two research projects during his studies at the University of Kaiserslautern, one of which involved the female reproductive organs of cave-loving dwarf spiders, known among specialists as "epigynous troglobionic microphantids". The other option was to study birdsong. "Somehow," says Gahr with a laugh "the second option captured my imagination more." And so today, surrounded by beautiful nature, he is using modern technology to investigate what happens in a bird's brain when it learns to sing. >

Above Eavesdropping: the electrophysiologist Lisa Trost holds an antenna towards her birds, which carry small microphone transmitters on their backs. These pick up the vocalizations and transmit them to the antenna.

Right Trost analyzes this data on the computer and compares them with the birds' brain waves. Trost can record up to eight birds simultaneously.

In our native songbirds, it is mostly the males that sing, but there are exceptions, such as robins and starlings, where the females also sing. Warning calls, for example, are innate, but song has to be learned.

In the case of zebra finches, which originate from Australia, it is only the males that sing. They are so-called closed-ended learners with a limited learning phase. Finches have about three months in which to practice their song. Then they leave school and sing whatever they have learned up to that point for the rest of their lives. The saying "you never stop learning" is therefore not true of zebra finches.

Other species follow different strategies: the canary, for example, is what is known as an open-ended, or seasonal, learner. The young birds do their first singing exercises during their first summer of life after which they spend the whole winter working intensively on their songs, which they then sing the following spring and summer. The males then begin to add new syllables and refine their singing during the following fall. The birds therefore sing throughout most of the year, only taking a break during molt, the post-breeding plumage change phase.

PRACTICE MAKES PERFECT

However, ornithologists still disagree as to whether canaries learn their entire repertoire in the first months of life and gradually incorporate the different variants into their song, or whether they can acquire new syllables each year.

The actual learning process proceeds along very similar lines in most

Photo: Axel Griesch

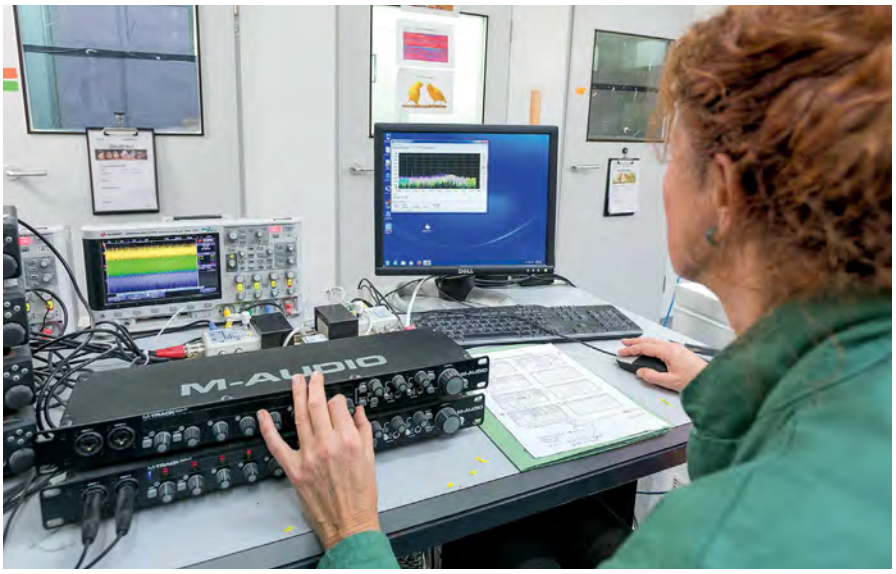


Photo: Axel Griesch

songbirds: the young birds first listen and then try to imitate what they hear. They store the sequence of vocal syllables that they have heard in their acoustic memory, which then serves as a template against which to compare their own song.

Usually, the father serves as teacher and lead singer, but there are exceptions: some young birds are known to learn their songs from their siblings, other bird species, and even from non-animal sources. Jürgen Nicolai for example, an ornithologist who arrived at the Max Planck Institute in Seewiesen in 1957, whistled the folk song "Ein Jäger aus Kurpfalz" to a group of bullfinches every day for six months. Not only did the bullfinches learn to whistle the song, they could also continue it without hesitation if the researcher interrupted it at any point.

Ornithologists in Seewiesen are studying how birds learn to sing, focusing primarily on zebra finches. As Gahr explains: "only a few genera learn their vocalizations. In addition to songbirds and humans, these include elephants, seals and whales." Among the many songbird species that learn their songs, zebra finches are particularly well suited as a model organism, because they are comparatively easy to keep in captivity: they are pure granivores, which makes feeding them in the aviaries easier compared to insectivores. Moreover, finches are sociable and can be kept in larger groups without problems.

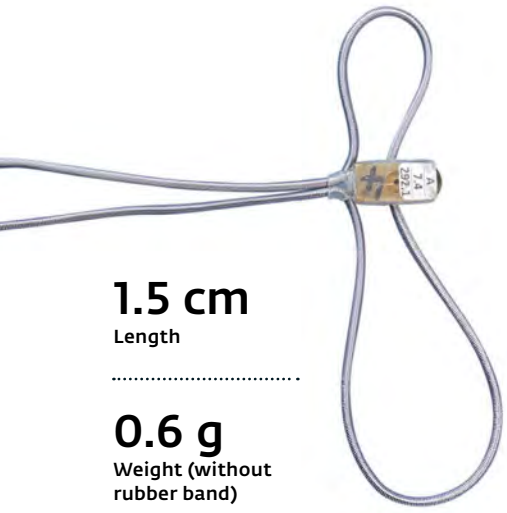
Another advantage is that it is easy to breed zebra finches in captivity: all that is needed is a nesting box and some nest building material. The young birds reach sexual maturity after just three months. "Zebra finches," says Gahr, "are opportunists. In their native and arid environment, they immediately start breeding soon after rainfall, evidently in the knowledge that the rain will produce a rich buffet of seeds and grains when their young hatch."

EACH FINCH'S SONG IS RECORDED INDIVIDUALLY

The song learning process in bird brains is similar to language acquisition in humans. The songbird's "vocal control system" comprises several interlinked brain areas. In terms of its function, for example, the "caudomedial nidopallium" resembles the Wernicke's area of the human brain, which is responsible for linguistic memory. Likewise, a bird's HVC (higher vocal center), which is activated during the learning process, corresponds to the Broca's area of the human brain. Based on these analogies, the research being conducted by the Seewiesen-based scientists is contributing to a better understanding of language learning processes in the human brain.

To study the song learning process, researchers need to know which bird is singing which syllables, when and for whom, which is why some of the zebra finches in Lisa Trost's aviary have been fitted with a kind of backpack containing a microphone transmitter recording individual vocalizations. The signals picked up by the microphone are transmitted to a computer via antennae. This enables Trost and her colleagues from Gahr's Department to record the songs of each bird simultaneously, while allowing the zebra finches to live in their social groups.

Other birds have an additional miniature transmitter on their heads. It transmits neuronal signals from



1.5 cm
Length

0.6 g
Weight (without rubber band)

A bug for the back: at the heart of the studies on song learning are the miniature transmitters weighing only 0.6 grams, which are strapped onto the zebra finches like a rucksack using rubber bands.

electrodes implanted in their brains. Vocal and neuronal signals are recorded synchronously.

The electrodes are implanted in such a way that they interface with certain areas of the vocal control system in the bird's brain. During the procedure, the birds are anesthetized and receive painkillers. The birds already interact with the rest of their group in a completely natural manner at the end of the day, as they recover extremely quickly from this procedure.

Neuroscientists usually connect this kind of electrode to a computer via a cable. To prevent the birds from getting tangled up in the wires, they would have to be isolated in cages without perches. Together with engineers, the researchers from Seewiesen have therefore developed wireless radio microphone transmitters as well as small transmitters that transmit brain waves, songs or even the heartbeat. This allows the birds to move completely freely and to communicate among themselves.

FIELD TEST IN THE SAVANNAH WITH RADIO TRANSMITTERS

In the meantime, the relevant technology has been developed to such an extent that it can also be used in the wild. Gahr and his team, for example, have been studying the singing habits of white-browed sparrow weavers in the South African Kalahari savannah, a bird species that lives in groups in which the dominant pair sings in duets with incredible precision. The precise tuning of their vocal syllables aroused the interest of the scientists. They were able to use their miniature transmitters to simultaneously record and analyze the song and the signals of nerve cells in the birds' natural habitat.

The result: when one duet partner starts singing, the nerve cell activity in the brain of the other bird, involved in the duet, changed. This causes a slow down of the song the rhythm so that the partners can take turns at singing. "The individuals' rhythmic duet singing is therefore achieved by means of an acoustic signal from the duet partner," Gahr explains. In this way, both brains synchronize to form a kind of network, acting as a single shared circuit, so to speak. The researchers assume that similar mechanisms may also be responsible for social interactions between humans, thus regulating the coordination of movement in couples dancing.

Gahr and his colleagues have also looked into what happens in the brains of young zebra finches during the learning phase when they imitate their role model. They discovered that a nerve growth factor, the so-called BDNF (brain-derived neurotrophic factor), is formed in the HVC area. Among other things, BDNF influences the formation of the contact points, the so-called synapses, between nerve cells. Therefore, the growth factor in the HVC could influence the differentiation of local circuits.

However, brain activity is not only influenced by hormone-dependent growth factors during learning phases. "The vocal system doesn't develop at all without sex hormones," Gahr explains. For a long time, researchers had been exclusively interested in the male sex hormone testosterone. This was still the prevailing dogma even when Gahr was a doctoral researcher, but he was not willing to accept it. "Testosterone can be converted to estrogen in the brain, which is classically seen as a female sex hormone. That's why I looked into what this estrogen actually does."

Photo: Axel Griesch

Could they get any smaller? In Seewiesen, scientists (Manfred Gahr, left) are working closely with engineers such as Johann Sagunsky to build even smaller and more powerful transmitters.

Photo: Axel Griesch

During the 1980s, cancer researchers began using antibodies to study the influence of estrogen on tumor formation. Using the same method, Gahr was able to prove the presence of estrogen receptors in the vocal areas of the avian brain for the first time. Both testosterone and estrogen therefore play an important role in the development of birdsong. "So finally, we found that sex hormones regulate the growth factor BDNF in the young zebra finches and facilitate the learning of songs."

This is why the females of many species can also be encouraged to sing by giving them testosterone. Recent studies on naturally singing female canaries show that this is probably also due to increased testosterone production in the female brain.

It is still unclear why birdsongs are not innate and why the animals have to learn them. Song learning could benefit speciation formation or provide information about the origin of the singer. Since in many species, song is involved in partner selection and territorial defense, females can select males whose songs differ from what they heard in their youth. Also the owners of neighboring territories can recognize an intruder by the fact that he sings in a different dialect. Vocal learning also aids communication within a bird family and facilitates the development of complex vocal structures, such as duets or group singing. ◂

www.mpg.de/podcasts/lernen (in German)

SUMMARY

- **As with most songbird species of Central Europe, only zebra finch males sing. However, they first have to learn their song.**
- **This learning process is controlled by the vocal control system in the finch's brain. The sex hormones testosterone and estrogen play a decisive role in this process.**

Eye to eye with computers

Our eyes are our window on the world, but they also reveal a lot about us. **Andreas Bulling** and his team at the **Max Planck Institute for Informatics** in Saarbruecken and at the University of Stuttgart exploit this by teaching computers to interpret our gaze. Ultimately, their aim is to enable robots or avatars to communicate with us eye to eye.

TEXT **PETER HERGERSBERG**

Pay more attention to your eye movements," says Andreas Bulling with a laugh as he leaves. That's good advice. My discussion with him has made one thing clear: viewing the world, we also allow the world to view us. Our eye movements can reveal our character or the social dynamics in a group, to name just two aspects of Bulling's research. A computer scientist who heads a research group at the Max Planck Institute for Informatics in Saarbruecken, he has now been made a professor at the University of Stuttgart.

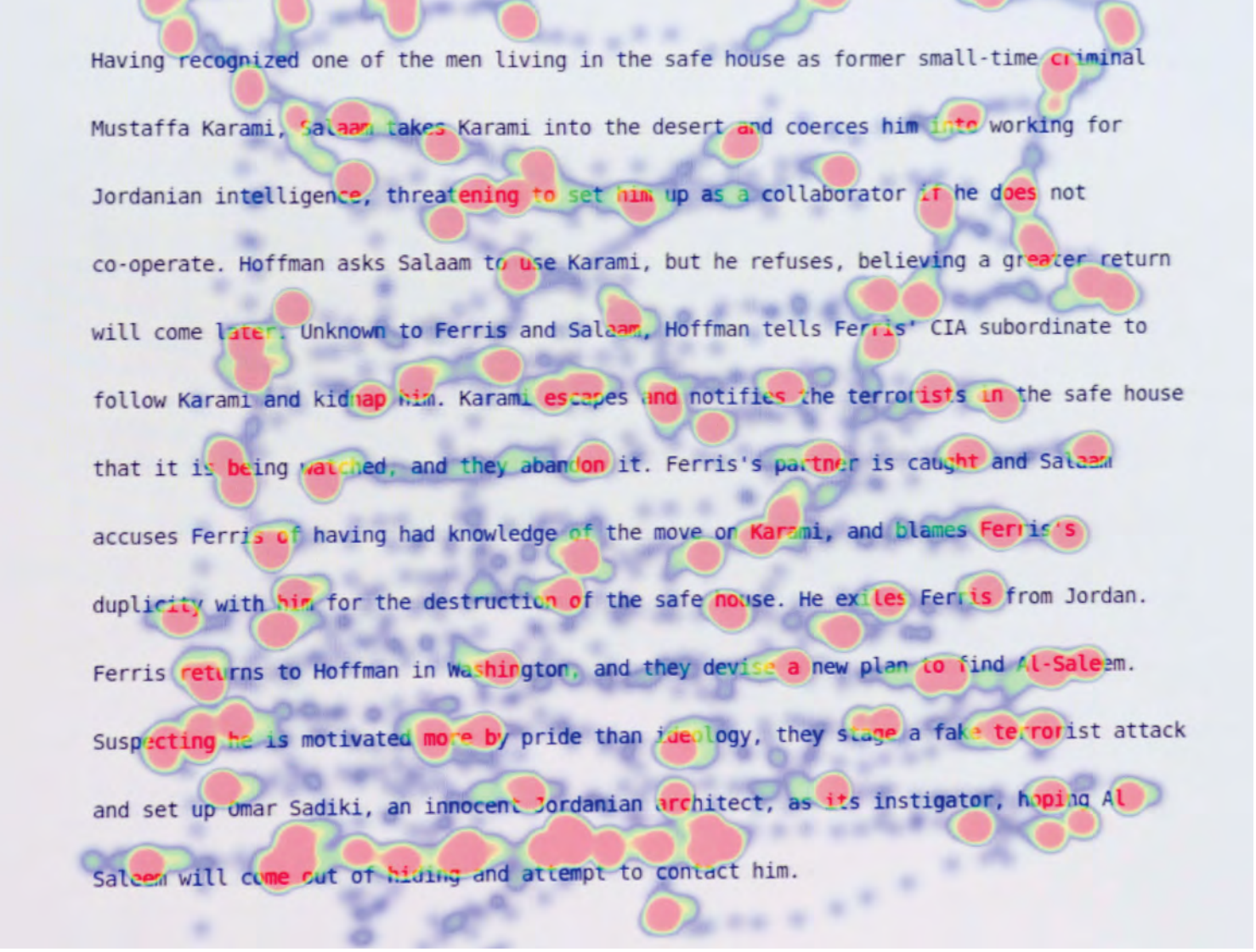
"We humans direct and analyze such signals subconsciously," says Andreas Bulling. "It's something some of us, such as people with autism, can't do." At times, they'll stare right through you in an unconnected way, while conversely, they often have trouble reading other peoples gazes. "It can be very disconcerting," says Bulling.

His research could help. As a computer scientist, he teaches computers to understand human eye movements. The software he has been developing could also help people with autism to interpret the gaze of others and to control their own eye movements, for example by relaying helpful instructions via a pair of eyeglasses.

Andreas Bulling and his team are also aiming to enable machines to communicate eye to eye with us humans. In the long term, humanoid robots, for example, would be able to interpret our gazes even in a crowd, and control the movement of their camera eyes in such a way that we experience their own gaze as natural. Our eye movements

Eye contact: Max Planck researchers have developed a computer program that can detect whether a person is looking into the eyes of another person.

Photo: shutterstock



Reading prediction: researchers have been studying eye movements in reading since the 19th century. Andreas Bulling's team is now developing a model that, on the basis of the text alone, is able to predict which words readers will fixate on.

could also provide important information for driver assistance systems.

Bulling and his team are using computer-aided analysis of eye movements to achieve this – helped by a decisive technique. "We were the first to apply machine learning in the field." Artificial intelligence has opened up completely new ways for the research team to read our eyes.

Researchers first started investigating gaze behavior back at the end of the 19th century. The French ophthalmologist Louis Émile Javal was a pioneer, investigating how people read. He discovered that our eyes don't continuously wander along lines of text, but instead skip from word to word, mainly, as it turned out later, fixating on key words.

From the 20th century onwards, companies have also discovered the significance of eye movements. Newspaper and magazine publishers, for example, examine what we are looking at in an article, while marketers analyze where they should position adverts or print information on packaging to attract the attention of customers. And some web designers design Internet pages on the basis of eye movements to ensure that the gaze of readers linger where they want it to.

EYE MOVEMENTS AS A CHANNEL OF COMMUNICATION

Customer decision-making is just one of the mental processes that cognitive scientists study using gaze analysis. "We use eye movements as a kind of window on cognitive processes," says Peter König, a professor at the University of Osnabrueck. "They provide us with a paradigm for how the brain functions."

Computer scientists like Bulling now research eye movements both as a data source and as a communication channel. Bulling's group isn't just focused on cognitive processes, but also on our behavior, for example how we interact with our digital devices. Their first task is to teach computers to correctly recognize where we are looking, and not just from a perfectly illuminated face and in a constant laboratory environment, as was previously the case in computer-assisted gaze analysis.

Scientists have long relied on machine learning to do this. But, up until now, the data they relied on to train computers wasn't very relevant to everyday life. To rectify this, Bulling and his team installed software on the notebooks of 15 volunteers. Over a number of days while they worked on their computers, the volunteers were repeatedly prompted by the software to fixate on a chosen point on the monitor, and a photo was taken of them.

This provided the team with images in varying environments and often in poor light conditions. As they also knew where the volunteers were look-

Photo: Wolfram Scheible

ing, the researchers were able to create a comprehensive dataset, which they used to train a program to determine gaze directions, even in difficult conditions. "Our data set is much larger and more natural, making it more revealing than previous ones," says Bulling. "But it's still not optimal." During the training, the volunteers were only sitting in front of computers, which they looked at more or less frontally. The program still recognizes eye position extremely poorly if someone moves or targets a point out of the corner of their eye. "We're still trying to figure out how to generate even more realistic data sets."

Mobile eye trackers are one possibility. They are fairly accurate, but up to now have been rather obtrusive: various cameras recording an individual's eye movement and field of view are attached to a device similar to a pair of eyeglasses, along with infrared LEDs whose reflections are captured by the cameras. The equipment makes subjects look like a cyborg – not exactly unobtrusive for onlookers.

Bulling's team has, therefore, developed a prototype eye tracker for everyday use with a handful of commercially available cameras that are only marginally larger than pin heads. Even though these cameras have a limited resolution, the researchers can compensate for this with the right training. Using data in which camera images have been linked with eye position, they train a computer to correctly interpret the poor-quality camera images. The Berlin start-up Pupil Labs, in which Andreas Bulling has a stake, is now marketing an eye tracker based on the concept of the Saarbruecken researchers that is almost comparable in accuracy to significantly more conspicuous eyeglass devices.

"We aren't yet using inconspicuous eye trackers in everyday communication, but we've already started employing them in market research and in virtual reality computer games," says Bulling. Primarily, however, they are of interest for research. "In studies involving social interaction, they allow participants to interact more naturally." In the future, they should also lend weight to the findings of Bulling's team on group dynamics.

WARNINGS FOR DISPLAY JUNKIES

The computer scientists have, nevertheless, already started to reveal some surprising insights using computer-assisted gaze analysis with conventional eye trackers. For instance, the researchers equipped 20 volunteers with the devices, and tracked their eye movements while using smart phones. They also identified the app that the participants were currently using and analyzed what was going on in their external environment.

As unlikely as it sounds, the hope was that such data could be used to predict whether, in the seconds that followed, the attention of smart phone users can be shifted to their surroundings and stay there. And, at least to some extent, that's just what the computer learned from the data.

Using such models, smart phone apps are potentially able to predict whether someone staring at their phone is about to walk into an obstacle, and give the display-fixated reader a timely warning. Attention analyses, a field which Andreas Bulling is now able to pursue with an ERC grant, could also provide clues as to how a person's focus can be held, for example, on a text. "We think we might be able to reverse the trend that people are becoming ever more prone to getting distracted from tasks," says the researcher.

Eye trackers can also help analyze the mood in group discussions as well as who is in charge. The crucial method involved was developed by Philipp Müller, a doctoral researcher at the Max Planck Institute for Informatics. From

Focused: Andreas Bulling (right), together with Sander Staal from the ETH in Zurich and others, are developing models of how our attention is controlled, for example to develop new ways of alerting computer users to incoming e-mails without interrupting their concentration.

Photo: Wolfram Scheible

An eye catcher for everyday life: based on work by Max Planck researchers in Saarbruecken, the Berlin-based company Pupil Labs has developed a mobile eye tracker that resembles normal eyeglasses.

regular camera shots of groups of people in discussions, his technique recognizes who is looking at whom and who is consistently looking beyond someone or everyone else. It can also read the mood of people from their faces. Combined with voice analysis, among other things, these characteristics can successfully reveal whether or not a discussion is progressing constructively, and who is emerging as the leader.

It's easy to understand how our gaze can tell us a lot about the dynamics of a group. The leader of a group tends to attract the gaze of everyone else, while if the mood of the group is poor, people tend to stare at the ground rather than seek eye contact. In future, computers should also be able to interpret such non-verbal signals.

Statistical analysis of gazes using machine learning isn't just limited to just concrete gaze patterns, however. If we want to analyze personality traits, for example, we need to be able to recognize highly subtle eye movement patterns. Using a combination of eye tracking and machine learning, Bulling and his team of researchers, together with colleagues from the University of South Australia, were able to make some reliable statements placing subjects into four character trait groups.

To achieve this, they asked 42 subjects at Saarbruecken University to complete a task, on average twelve minutes long, while simultaneously recording their eye movements. Some of the subjects also completed a standard psychological questionnaire, and this data was fed into a model. Trained in this way, the computer was able to read from the eyes of the other subjects how neurotic they were, how well they got along with others, whether their attitude to life was extroverted, and how conscientiously they completed tasks.

However, the model failed to provide a useful assessment of three other character traits that psychologists use to characterize personality. "And the predictions are not yet accurate enough to be useful in practice," says Bulling. But the system is certain to become more reliable in the future. Such a complex task will require training sets of more than just a few dozen subjects. More data on eye movements will enable more accurate character analysis.

THE IMPORTANCE OF DATA PROTECTION

Such advances bode well for how we will be interacting with robots and avatars in the future. After all, computer systems should, in the long term, be able to interpret all of our verbal and non-verbal modes of communication. However, the fact that computers will be able to analyze our personality solely on the basis of our subconsciously controlled gaze behavior is cause for trepidation.

Bulling is aware that the software may make it possible to subject people to a computer-based personality test – a possibility that could be abused by companies or autocratic regimes, which, even today, have already started digitally analyzing people's behavior. However, the computer scientist stresses that the technology is a long way from being able to reliably determine an unwilling subject's personality. This is not least due to the eye trackers that people still need to wear right in front of their eyes.

And even if one day it does, indeed, become possible to identify someone's character remotely and with little effort using their eye movements, as with all inventions, such technology can be employed both for good and for bad. "Analyzing people's personalities, attitudes and intentions, for instance at a job interview, isn't new – as performed by person," says Bulling. "However, we're mostly not aware it's happening or take it for granted, because it's being done by a human."

Science can't prevent misuse of its advances in many fields, but it can contribute to preventing it. Data protection for eye-tracking is, therefore, one of Bulling's main concerns. "I think it's crucial. As with other digital platforms, in particular social media, we need to be mindful of privacy in eye-tracking," he

Photo: Pupil Labs

Promising prospects: Andreas Bulling is convinced that analysis of eye movements for non-verbal human-machine communication will easily provide enough material for his future research life.

says. "We're at the forefront of research in the field, and over the coming years we'll continue to drive it forward."

Informational self-determination, in other words, control over what happens with our data, is generally only considered a cause for concern when data is used for a specific purpose. However, non-existent data can't be misused. Bulling and his team have therefore investigated how data in the images taken of people's field of view by eye trackers can be kept confidential. The images can reveal not only where a person is looking, but also what they are seeing.

The images may accidentally include passwords or secret codes, and, naturally, other people, who are unlikely to want to be recorded without their consent. Gaze analysis and machine learning once again have a role to play in the solution. The scene camera can readily be used to determine whether we are accessing our bank account on the computer, entering a PIN at an ATM, or are facing a stranger. The researchers developed a highly analog solution to the problem: the software merely slides a cover over the lens of the camera. "As the scene can't subsequently be analyzed, we have to infer from eye movements if and when the subject has moved on from the sensitive situation," says Bulling.

The ability of the software to learn is helping us solve the problem of data protection. Sometimes, however, this ability itself becomes a problem. A well-trained program is able to read much more from eye movement patterns than we humans can, such as whether the eye tracker is being worn by a woman or a man. "However, only a portion of the eye tracker data can be used to determine gender," explains Bulling. "As this is not required for the other analyses we're interested in, we just fade it out." We can treat other information obtained from our eye movements in a similar way. "Which data to preserve and which to fade out will be left to the user to decide in the future."

As Bulling has shown, non-verbal communication with humans or machines, life-like virtual reality, utilizing digital devices, and data protection in gaze analysis can all benefit from analysis of eye movements using artificial intelligence. And he's sure it will stay that way: "It's a gold mine," Bulling says. "There is easily enough material here for me for a lifetime of research." ◀

https://www.mpg.de/podcasts/lernen/maschinelleslernen (in German)

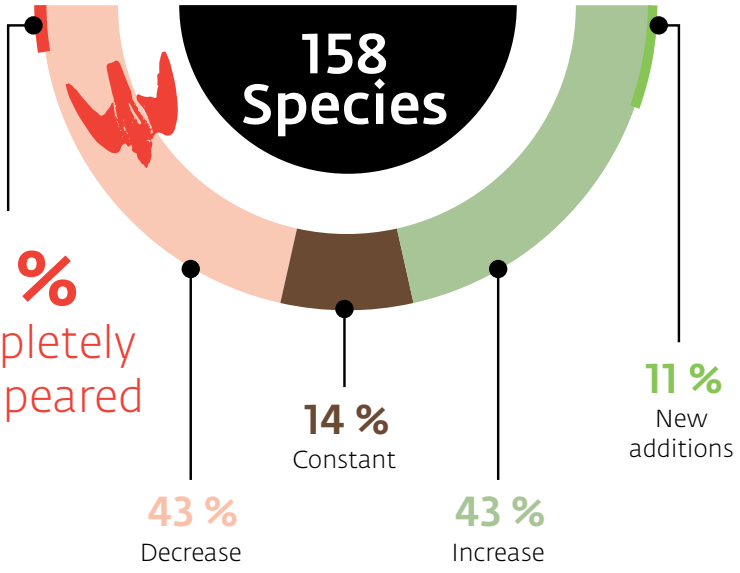
SUMMARY

- Eye movements play a significant role in non-verbal communication. Researchers are hoping that such modes of communication will be utilized by computer systems such as robots or driver assistance systems in the future.
- Andreas Bulling's team is refining computer-aided techniques that gauge the direction of a person's gaze. They are also developing models with the help of machine learning that can identify the personality traits of individuals or the mood of a group from eye movements. This should also help computers, for instance, to learn how to control the movement of a robot's eyes to appear natural.
- The researchers are working on various technical solutions to ensure that data gathered when analyzing eye movements is protected.

Photo: Wolfram Scheible

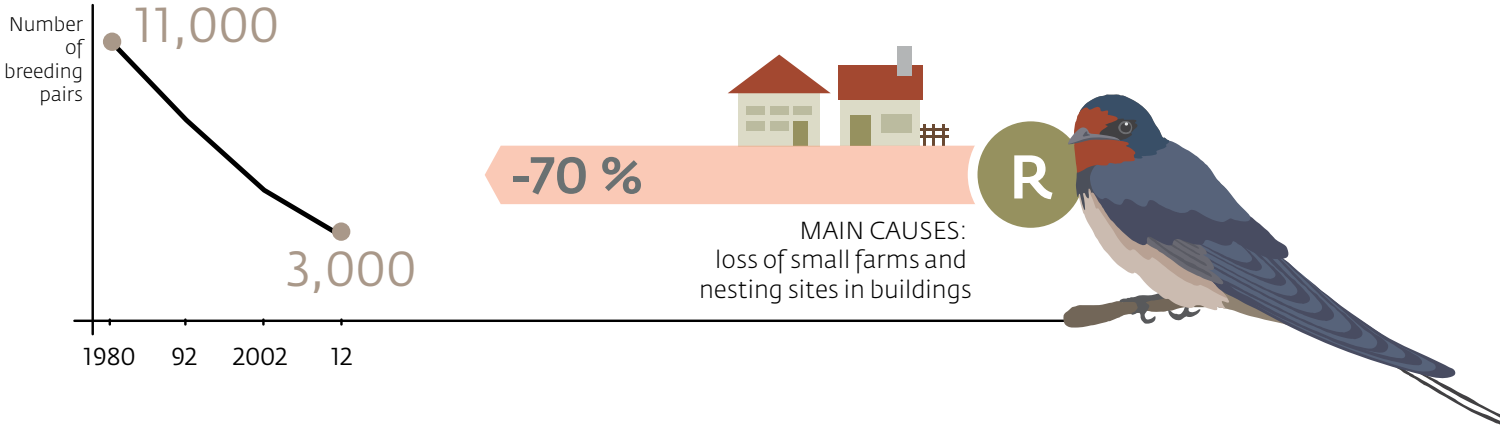
Ups and downs in the bird world

The abundancy of many bird species has decreased dramatically in Germany over the last decades. Now, a new study by the Ornithological Working Group on Lake Constance in cooperation with the Max Planck Institute of Animal Behavior in Constance demonstrates that there are losers and winners among the birds around Lake Constance: between 1980 and 2012, most of the species living in meadows, elds, and in residential areas strongly declined. Some have even disappeared completely. In forests and wetlands, on the other hand, the majority of them still thrive.

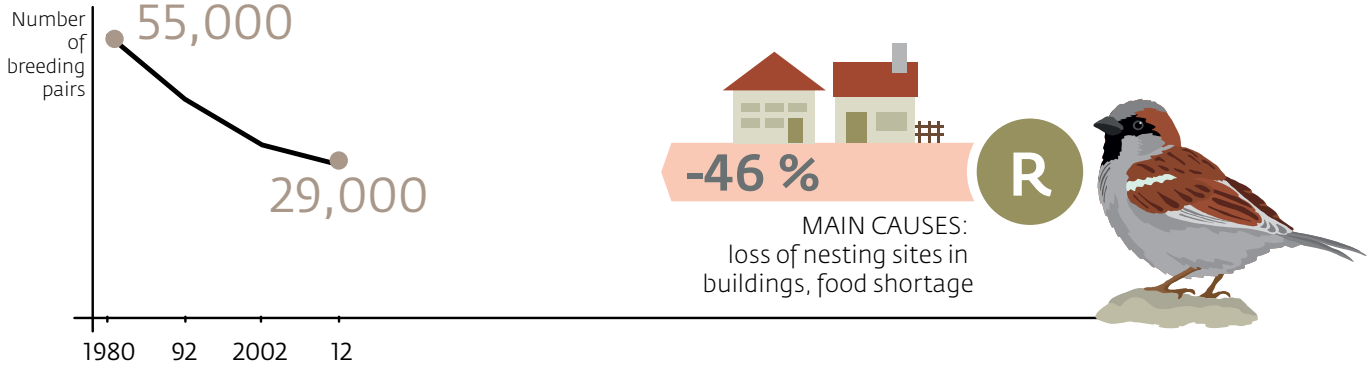


R RESIDENTIAL AREAS Fo FORESTS M MEADOWS Fi FIELDS

BARN SWALLOW

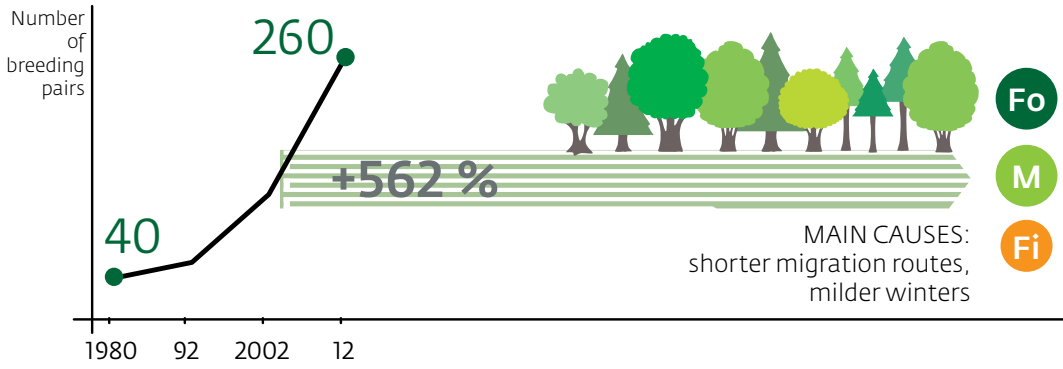


HOUSE SPARROW

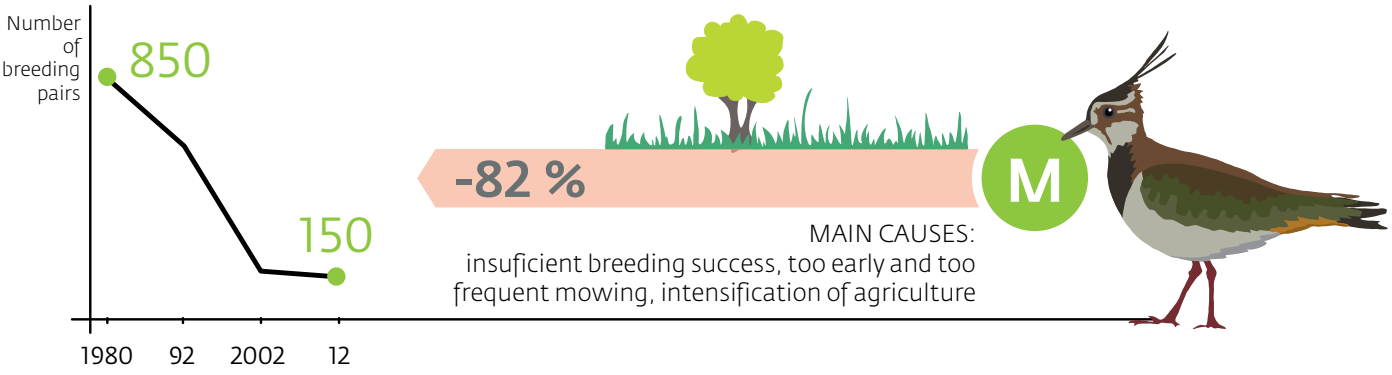


Graphics: dpa

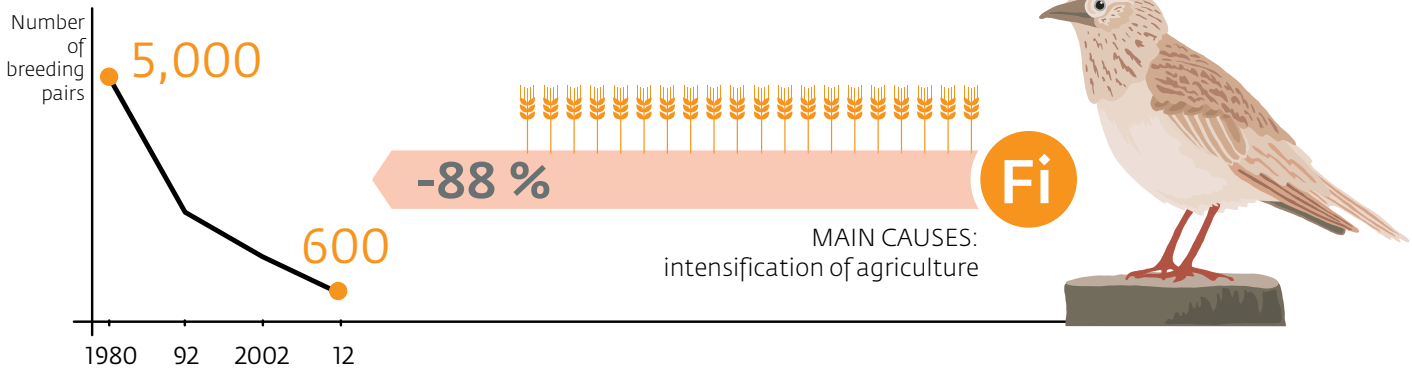
RED KITE



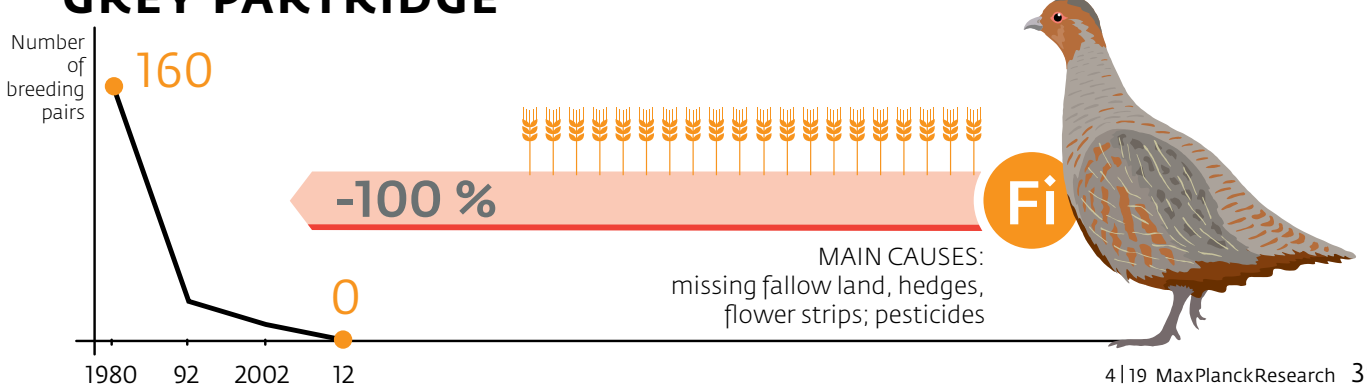
NORTHERN LAPWING



EURASIAN SKYLARK



GREY PARTRIDGE



The alchemy of neutron stars

Researchers have discovered that collisions between these cosmic objects actually produce heavy elements

On August 17, 2017, when astronomers observed gravitational waves from two merging neutron stars together with a kilonova in the optical range at the same location, it was nothing short of a sensation. At that time, it was assumed that such a cosmic collision and the succeeding explosion would produce heavier elements such as iron. Researchers, including scientists from the Max Planck Institute for Astronomy in Heidelberg, have now actually identified such an element in the spectra that appeared at that time: strontium, which was evidently produced during the so-called r-process. This rapid neutron capture appears to be of key importance for the production of heavy elements. The kilonova generated a bubble that expanded at 20 to 30 percent of speed of light. The quantity of newly-formed strontium in the expanding shell amounts to around five Earth masses. With this discovery, the scientists have now demonstrated beyond all doubt that the fusion of two neutron stars creates the conditions for the r-process in which new elements are formed. (www.mpg.de/14032050)

Collision in space: this artist's impression shows the fusion of two extremely dense neutron stars. Events of this type are followed shortly afterwards by a kilonova.

Dual-class society in the Bronze Age

Grave finds provide evidence of stable hierarchies on South German farms

A research team whose members include scientists from the Max Planck Institute for the Science of Human History uncovered early signs of social inequality while investigating Bronze Age cemeteries in the Lech Valley near Augsburg. These showed that there was a significant divide between rich and poor as far back as 4,000 years ago – both within households and between generations. The families of wealthy landowners were buried with weapons and elaborate jewelry. However, the grave sites also contained the bodies of poor people who came from the region and were part of the household but were not related to the family. It is not clear whether these were servants and maids, or perhaps even slaves of some kind. The findings suggest the existence of a social structure of the type known to have existed in ancient Greece and Rome. However, the families studied in the Lech Valley lived more than 1500 years earlier. Another interesting fact is that the women of these families were not local but came from some 400 to 600 kilometers away. The study was also the first to reconstruct family trees spanning several generations. (www.mpg.de/13979712)

Valuable indicator: the ornamental dagger found in a Bronze Age grave south of Augsburg shows that the person buried there enjoyed a high social status.

Graphic: University of Warwick/Mark Garlick/ESO (top); photo: K. Massy (bottom)

In good company

Large brains are not a requirement for the formation of multilevel social groups

The social structure of some fowl populations is more complex than originally thought. Researchers at the Max Planck Institute of Animal Behavior have discovered that vulturine guineafowl form stable social units. These African birds, which are the size of turkeys, must therefore be able to keep track of individuals in their own and in other groups – even though they have relatively small brains. This is the first time that such a social structure has been described among birds. The researchers spent one year tracking the social relationships of more than 400 birds, using GPS transmitters to record their positions round the clock. During this period, they discovered that each bird lives with 13 to 65 others of its species. Although the guineafowl regularly came into contact with other groups during the day, they did not change group. (www.mpg.de/14071193)

Vulturine guineafowl live in close-knit groups. This allows for mutual coordination on their journeys through the countryside.

Staying healthy in old age is a lifelong task

Changing the diet of elderly mice can no longer improve their health

How can we stay fit and healthy for as long as possible as we grow older? Researchers into aging have a simple answer: eat small amounts and eat healthily. But when do we have to start doing this if we wish to reap the benefits? And is it sufficient if we only manage to keep it up for a short time? Researchers led by Linda Partridge, Director at the Max Planck Institute for Biology of Ageing, conducted animal experiments that involved putting young and old mice on diets – with varying degrees of success. Mice live longer and enjoy a healthier old age if they are given 40 percent less to eat from the time they reach adulthood. These mice are given food enriched with vitamins and minerals in order to prevent malnutrition. However, waiting until they reach old age before reducing their food intake has hardly any effect on their life expectancy at all. Moreover, short periods of fasting do not provide lasting protection: if the mice eat the same quantities afterwards as they did before, their life expectancy once again declines. The reason for this appears to be that the fatty tissue can remember the diet consumed over the preceding years. This tissue is no longer able to adapt the activity of its genes to the change in diet. The researchers assume that the results can also be applied to humans. (www.mpg.de/14021239)

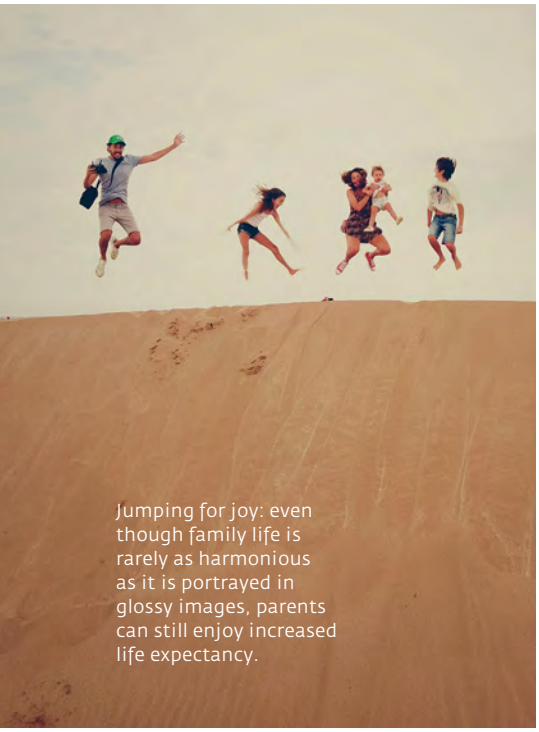
Heavyweight at the heart of Abell 85

In space, black holes appear in various sizes and masses. The record is now held by a specimen in the Abell 85 cluster of galaxies, where a black hole 40 billion times the mass of our Sun sits in the middle of the central galaxy Holm 15A, which is located 700 million light years away. Researchers at the Max Planck Institute for Extraterrestrial Physics and the University Observatory in Munich discovered it by evaluating photometric data and spectral observations. The astronomers had already suspected that Holm 15A must be something special: the heart of this gigantic galaxy – one of the largest in existence – appears extremely faint and diffuse through the telescope. The dimmer the center of the galaxy, the denser the black hole. It is highly likely that the massive black hole in Holm 15A originated when two galaxies collided and the black holes at their hearts merged. (www.mpg.de/14210061)

Record in a galaxy cluster: Abell 85, taken at the Ludwig Maximilian University of Munich's observatory on the Wendelstein. The bright central galaxy Holm 15A has an extended, diffuse core. This conceals a black hole with 40 billion times the mass of our Sun.

Photos: James Klarevas (top); Matthias Kluge/USM/MPE (bottom)

Children increase life expectancy



Jumping for joy: even though family life is rarely as harmonious as it is portrayed in glossy images, parents can still enjoy increased life expectancy.

There appears to be a link between people's life expectancy and the number of children they have: those who have one or two biological or adopted children usually live longer than those who have none. A study carried out by Kieron Barclay from the Max Planck Institute for Demographic Research and a Swedish colleague investigated the reasons for this. Their analysis revealed that parents are better off right from the start than people who have no children. In simple terms: healthy, well-educated and prosperous men and women are more likely to find a partner and have the resources to start a family than those in poorer circumstances. Moreover, the data suggests that most people change their lifestyle when they have children: mothers and fathers adopt healthier behaviors and are less accident-prone than childless people, and they are also less likely to suffer from cardiovascular disease. (www.mpg.de/14064449)

Imagined movements can alter the brain

Computer interfaces have a structural impact on brain substance

Brain-computer interfaces work on the principle that just thinking about performing a task triggers measurable changes in brain activity. These signals can be read and automatically converted into control signals, which can then be used to operate a prosthesis, for example. Researchers from the Max Planck Institute for Human Cognitive and Brain Sciences and their colleagues have now discovered that these thoughts can leave traces in the brain. During this study, the test subjects were set the task of imagining specific movements of their arms and feet. The participants used the brain-computer interface to fine-tune these imaginary movements. Their brains were examined before and after the training using magnetic resonance tomography (MRT). The researchers actually found measurable changes in the part of the brain responsible for motor tasks after just one hour of training. This method could be suitable for rehabilitating patients who have suffered a stroke or brain tumor. (www.mpg.de/14090102)

Less is more

Whales and dolphins developed from land-dwelling ancestors approximately 50 million years ago. Nowadays, these air-breathing mammals spend their whole lives in the sea. Researchers at the Max Planck Institute of Molecular Cell Biology and Genetics and the Max Planck Institute for the Physics of Complex Systems have now identified 85 genes that the aquatic mammals lost as they evolved. Some of them simply became superfluous. Whales and dolphins lack a gene involved in the secretion of saliva, for example – they do not require saliva to swallow food underwater. The loss of other genes is actually an advantage: the lack of one specific gene means that they are now better able to repair DNA damage caused by the considerable oxygen deficiency that occurs when they are diving. Since losing other genes, the animals are presumably protected from blood clots and lung problems under water. They have also lost all the genes required for the production of the sleep-regulating hormone melatonin. This might be the reason why these animals can sleep with just one hemisphere of the brain, while the other hemisphere coordinates their movement and breathing. Sometimes the loss of genes can drive evolution forward. (www.mpg.de/13915292)

Whales and dolphins evolved from land-dwelling ancestors. Some of their genes were not required for aquatic life.

Photo: Juan Cruz Mountford/unsplash; graphic: Carl Buell, John Gatesy

Every mouse is different

Scientists measure the personalities of rodents

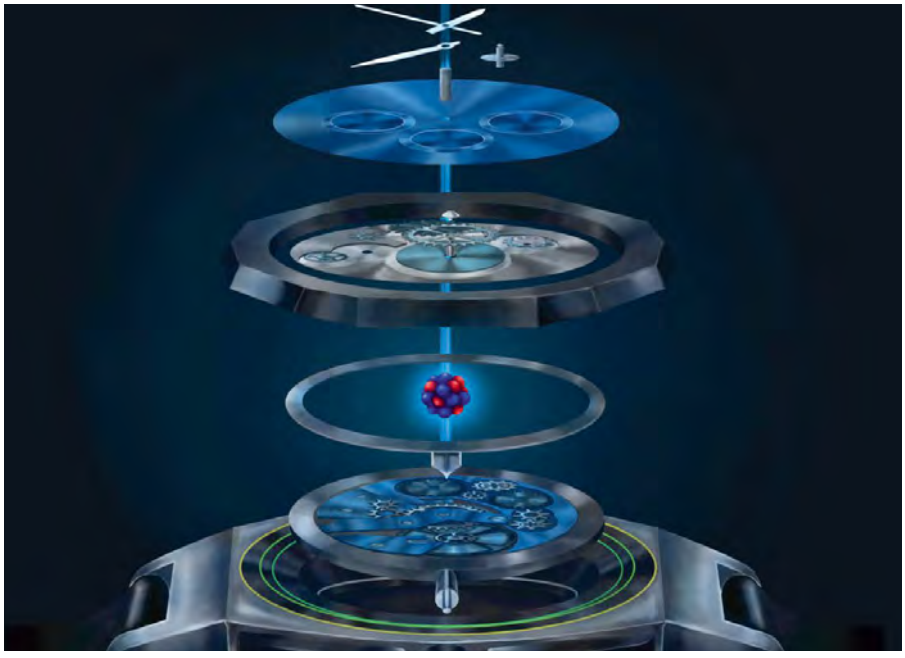
Some mice are curious and explore any new hiding place. Others are more fearful and prefer to stay in their nest.

Animals have personalities, too: some are brave, others fearful; some are loners, while others love company. Human character can be analyzed directly using multiple-choice tests; in animals, this is considerably more difficult. Scientists at the Max Planck Institute of Psychiatry in Munich have now developed a method of calculation with which they can measure the personalities of mice. The researchers analyzed 60 different behaviors in videos and used an algorithm to search for stable personality traits. While human character is commonly described on the basis of five categories, scientists found four categories in mice. These character traits remain stable over time, even when the animals live in different social groups. Furthermore, genetic analysis showed that various characteristics are associated with different types of gene activity in the brain. The results form the basis of a more precise, personalized form of psychiatry, as researchers are now able to investigate how character is influenced by genes, medication and age. (https://www.mpg.de/14109680)

Nuclear clocks get to the core

Excitation of thorium-229 facilitates greater precision in timekeeping

If global satellite navigation systems such as GPS or Galileo are to measure distances to within a few centimeters rather than to the nearest meter, they need more precise nuclear clocks. A team led by the Ludwig Maximilian University in Munich, whose members include researchers from the Max Planck Institute for Nuclear Physics, has now taken a step towards realizing these enhanced timekeepers. The physicists have succeeded in exciting oscillations in thorium-229 nuclei. These nuclei achieve significantly higher frequencies than the electrons that have served as the timekeepers in nuclear clocks until now. At the same time, nuclear excitation in this thorium isotope requires much less energy than in other elements and can be achieved using compact lasers. It should therefore be possible to integrate the necessary technology in nuclear clocks. (https://www.mpi-hd.mpg.de/mpi/en/public-relations/news/news-item/on-the-way-to-a-nuclear-clock)



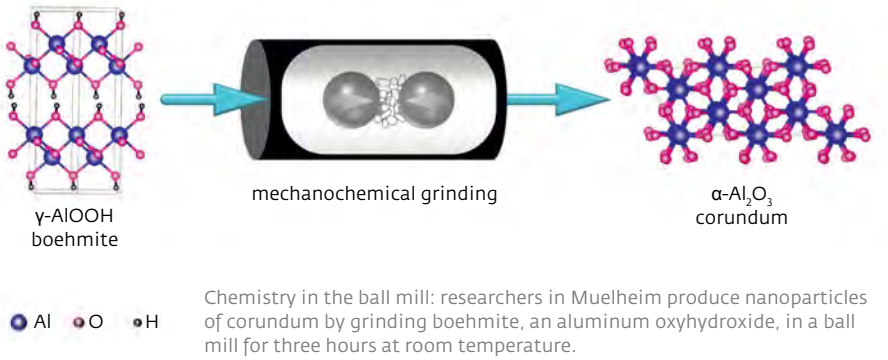
Assembly instructions for a nuclear clock: by exciting thorium-229 nuclei, scientists have created the conditions required to manufacture more accurate nuclear clocks that could also make satellite navigation more precise.

Photo: MPI for Molecular Genetics; graphic: Daria Bilous

Nanoceramics from the ball mill

Tiny corundum particles for automotive catalysts and stable ceramics can now be easily produced

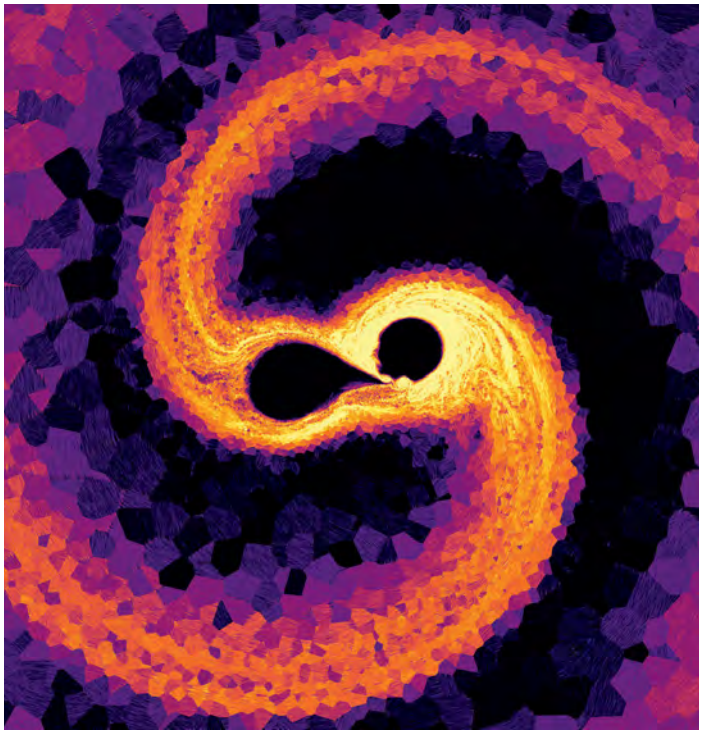
Automotive catalysts and materials for cutting tools and dental implants could become more robust and easier to manufacture than ever before. This is because chemists at the Max-Planck-Institut für Kohlenforschung have found a way to produce nanoparticles of corundum, a particularly stable variant of aluminum oxide, simply by grinding boehmite, an aluminum oxyhydroxide, in a ball mill for three hours. Until now, corundum could only be produced at temperatures of 1000 degrees or under high pressure in a week-long procedure which resulted in particles that were larger in size. The particles produced by the chemists in Muelheim using mechanochemical processes could be used as a resistant carrier material in automotive catalysts, for example, or as a starting material for particularly hard ceramics. The first industrial company is already working on the large-scale production of nanocorundum using the method developed in Muelheim. (www.mpg.de/14078015)



Chemistry in the ball mill: researchers in Muelheim produce nanoparticles of corundum by grinding boehmite, an aluminum oxyhydroxide, in a ball mill for three hours at room temperature.

Magnetars – simply irresistible

Computer simulations show how a strong magnetic field is generated when two stars merge



Magnetic mountains are the stuff of fairy tales, but magnetic stars really do exist. These magnetars, compact remnants of supernovae, are the most powerful magnets in space. Yet how do they acquire their remarkably powerful magnetic force – 100 million times stronger than the strongest magnetic field ever created by humankind? A team of astrophysicists from Germany and Britain has now solved this 70-year-old conundrum. The researchers merged two stars with normal magnetic fields in a computer simulation. These magnetic fields are nothing special; our sun also has one that produces convective currents in its gas envelope. Collisions between stars are also relatively common in nature. This is precisely the process that the astrophysicists reproduced. The end-product of the simulation was a single star with an exceptionally powerful magnetic field similar to Tau Scorpii, which can actually be observed in the sky. Should it one day explode as a supernova, a magnetar will be born from the debris. (www.mpg.de/13960571)

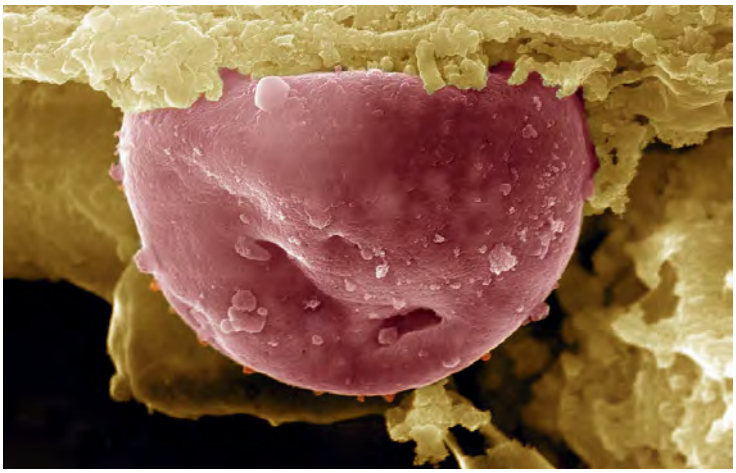
Fusion in the computer: the simulation shows the birth of a magnetic star such as Tau Scorpii. The illustration shows a cross-section through the orbital plane. The color reflects the strength of the magnetic force, while the hatching shows the field lines.

Graphics: Amol Amrute/MPI for Coal Research (top); Fabian Schneider, Sebastian Ohlmann (bottom)

Deadly networks

Immune cells cause malaria organ damage

15 years ago, researchers at the Max Planck Institute for Infection Biology in Berlin discovered a previously unknown defense mechanism utilized by the immune system. Special white blood cells dissolve their cell and nuclear membrane to release network-like DNA structures when they come into contact with a pathogen. The pathogens adhere to these DNA traps, known as NETs, and are killed. However, the NETs may only be activated locally for short periods, otherwise they attack the body's own tissue and trigger autoimmune diseases. According to the latest results obtained by the scientists in Berlin, NETs cause cases of malaria to progress with particular severity. High concentrations of NETs in the blood cause red cells to adhere to capillary walls in the organs, thus blocking them. Insufficient oxygen supply and bleeding from burst capillaries can then cause liver and kidney failure, pulmonary edema or cerebral swelling. (www.mpg.de/14014501)



A red blood cell adheres to the wall of a small blood vessel in the liver. This can damage the organ.

A fortress for sensitive data

New technology allows software components to be isolated from each other with little computational effort

Safeguarding passwords, credit card numbers or cryptographic keys in computer programs will require less computational effort in the future. Researchers at the Max Planck Institute for Software Systems have developed a technology known as ERIM with which software components can be isolated from each other. The system functions like a fortress, with various defenses that can be protected separately. This could protect sensitive data in the event of cyber attacks, which frequently target a single weak point, for example in an online service. The new method developed by the Max Planck scientists requires three to five times less computational work than the second best isolation technology. This makes the technology more feasible for use by online services such as Google or Facebook. (https://www.mpg.de/13848156)

Graphic: MPIIB/Volker Brinkmann

Particle hunters on the trail

The detection of the Higgs boson represented a huge success for the particle accelerator known as the Large Hadron Collider. But other expected or unexpected discoveries, which physicists hoped would explain the appearance of the world we live in, have failed to materialize. Now, **Hermann Nicolai,** Director at the **Max Planck Institute for Gravitational Physics** in Potsdam, and **Siegfried Bethke**, Director at the **Max Planck Institute for Physics** in Munich, are on a quest for new prospects in particle physics.

Inconceivable: this artist's impression from CERN attempts to give an idea of what the Higgs boson is all about. As significant as the particle's discovery was, it is also hard to visualize an elementary particle of this kind.

TEXT **ROLAND WENGENMAYR**

In 2012, the European Organization for Nuclear Research (CERN) announced a sensational discovery: the Higgs boson had been detected at the world's most powerful particle accelerator, the Large Hadron Collider (LHC). This discovery had been a long time coming and served as proof of the mechanism that gives elementary particles their mass, as had already been described in the 1960s by Peter Higgs, François Englert and Robert Brout among other researchers. Without this mechanism, neither we nor the universe we know would exist. Higgs and Englert received the 2013 Nobel Prize in Physics for their theoretical description – Brout had died two years previously. The Higgs boson also provided the final missing building block in what is known as the Standard Model of particle physics.

Since then, however, there have been no more reports from Geneva, at least when it comes to other major discoveries at the LHC. Predictions from the world of theoretical physics had raised high hopes for particle collisions in this accelerator ring, which measures just under 27 kilometers in length. These predictions related to a world of physics beyond the Standard Model and therefore touched upon literally existential relationships.

One such issue is the problem of antimatter, which should actually have been created in the same quantity as matter following the Big Bang – and the two should immediately have annihilated one another. Fortunately that wasn't the case, for a perfectly symmetrical world of that kind would have produced a universe without galaxies, stars and planets, filled only by the light echo left over from this total annihilation.

As astronomers have so far failed to find any antimatter in the universe, it is likely that a tiny, unknown structural flaw in the symmetry between antimatter and matter meant that a – not all that small – quantity of matter was left over, and it is this matter that we have to thank for our own existence. At present, the worlds of nuclear and particle physics, including at the LHC, are engaged in an intensive search for a flaw of this kind in the reflected image of antimatter.

No less mysterious – and just as significant for the universe that we call home – are the concepts of dark matter and dark energy, both of which should be illuminated by the LHC. Dark matter interacts neither with light nor with known matter but makes itself felt by its gravity. It is the only way to explain the high speeds of stars at the edges of galaxies – which indicate that there must be five times as much dark matter as there is visible matter. The gravity of visible matter alone does not generate sufficient accelerating forces. Just as hard to comprehend is the concept of dark energy, which – according to the current understanding – accelerates the expansion of the universe and makes up around three quarters of the energy within it. What this energy might be, however, remains a complete mystery.

The LHC has made almost no progress in the search for explanations for the asymmetry between matter and antimatter the nature of dark matter and dark energy. However, talk of a crisis in particle physics stems primarily from the fact that, so far, the experiments at CERN have failed to help solve another problem in physics. For many decades, clever minds have been attempting to unify the two theoretical pillars of physics, quantum mechanics and the general theory of relativity, into one overarching theory. In the process, physicists also hope to reduce the four fundamental forces that govern physical processes in our world to one common one, such as must have existed during the Big Bang according to their current theories. >

Photo: Daniel Dominguez/CERN

The Standard Model of particle physics and the quantum mechanics on which it is based only describe the microscopic world of elementary particles and the three forces that govern it: the strong and weak nuclear force and the electromagnetic force. Gravity, on the other hand, as the fourth force that falls within the regime of the general theory of relativity, is a huge 40 orders of magnitude weaker; this massive discrepancy is called the hierarchy problem. Gravity only takes effect over large distances and therefore dominates all of the processes taking place in the cosmos but plays no part in the microscopic world.

Both theories are extremely well supported by experimental observations in their own right. Efforts to unify them take various approaches, some of which have predicted discoveries at the LHC that have so far failed to materialize, such as micro black holes, rolled-up extra dimensions and supersymmetries.

DO PHYSICAL THEORIES HAVE TO BE NATURAL?

The existence of these phenomena was predicted by several schools of string theory – one of the areas of research seeking to establish a working description of quantum gravity. String theory states that, on the smallest scale, the world is made up of threadlike strings in which other dimensions of space-time are rolled up. According to some predictions, the extra dimensions rolled up in these space-time wraps should have been large enough to reveal themselves at the LHC. Likewise, the experiments should also have seen the emergence of supersymmetric (SUSY) particles, which belong to a supersymmetric mirror-image world and are related to the superstrings version of string theory. As these predictions turned out to be wrong, some specialists believe that the problem lies not in the experiments at the LHC, but in the theories that predicted certain measurement results.

When developing new theories, scientists are guided by criteria such as symmetry, naturalness, and the elegance of mathematical constructions. Among those questioning whether this approach has led researchers

A search engine for new particles: the CMS detector weighs 14,000 tonnes and has 75 million individual measurement channels in order to detect particles. Together with the Atlas detector, it detected the Higgs boson. It is also designed to discover SUSY particles, but none has been detected so far.

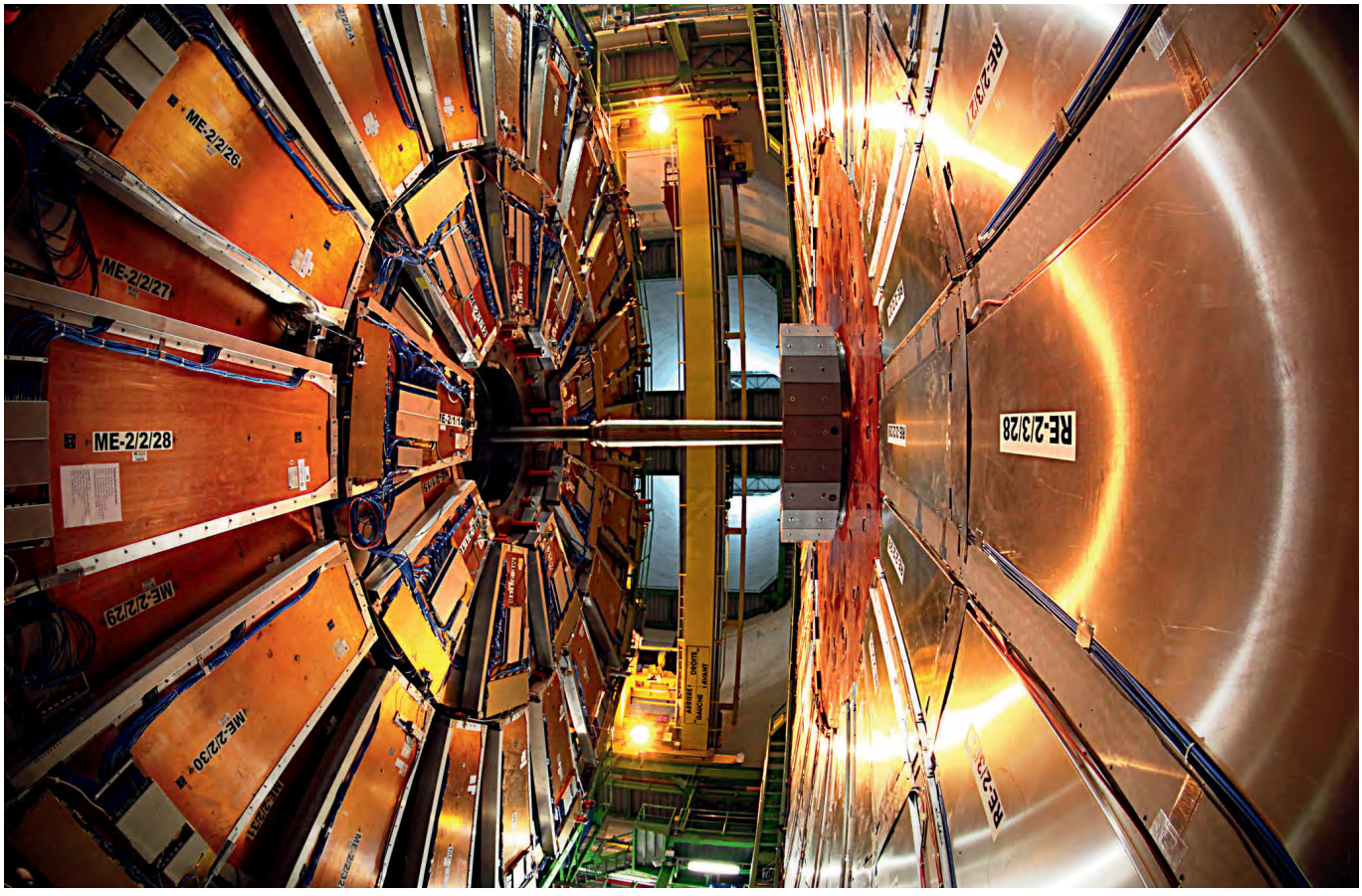


Photo: Michael Hoch/CERN

astray is Sabine Hossenfelder in her book *Das hässliche Universum* ("Lost in Math"). The scientist is currently conducting research into quantum gravity at the Frankfurt Institute for Advanced Studies.

To explain her skepticism around the concept of naturalness, for example, she begins by asking why theorists predicted the appearance of supersymmetric particles or rolled-up extra dimensions at the LHC. "People thought that the Standard Model could not be complete," says Sabine Hossenfelder. "And the reason is that the Standard Model can't be 'natural' in the sense in which the word is used by high-energy physicists."

Since the early 1990s, the idea that theories must satisfy this abstract criterion of naturalness has, in Hossenfelder's analysis, become firmly established without undergoing a proper process of reflection. In very simple terms, the condition stipulates that the masses – as well as other properties of particles – that are relevant to quantum gravity must not differ too much from one another.

A LACK OF EXPERIENCE AT THE MARGINS OF PHYSICS

For example, the physicist says, we would "consider a sunflower with a height of a million kilometers to be unnatural." However, a sunflower with a height in the order of about one meter is natural; we know this from our own experience. "In the Standard Model, all numbers are 'natural' in this sense," explains Hossenfelder, "except the mass of the Higgs boson." In the mathematical representation used by theoretical physics, it is 15 powers of ten too small and therefore unnatural for many theorists.

According to Sabine Hossenfelder, the problem with this concept of naturalness is the lack of experience when breaking new ground in physics. When we look at a field of sunflowers for the first time, experience tells us that extremely large flowers cannot exist. But at the margins of modern physics, we lack this kind of experience. According to Hossenfelder and a number of other theorists, naturalness therefore fails as an aesthetic criterion – especially as mathematics, the primary tool of theory, offers no logical justification for an aesthetic criterion of this kind.

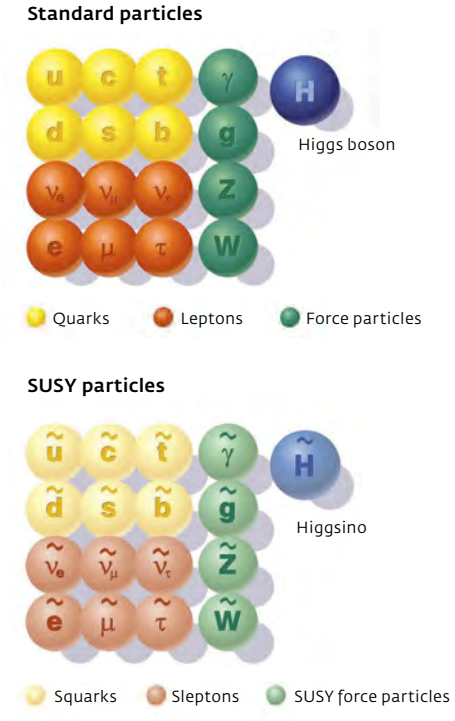
Another guiding star for researchers working on new theories is the principle of symmetry, and this approach has so far proved highly successful. In the world that is perceptible to humans, symmetries occur time and time and again, as do small deviations. For proof of this, we need look no further than the two halves of our own faces. While symmetries are thus occasionally of use also in everyday life, they play an essential role in the laws of fundamental physics. For example, symmetry considerations led the British theorist Paul Dirac to predict the existence of antimatter.

Symmetry is another criterion where Sabine Hossenfelder believes there is a risk that a concept of beauty that has become established based on positive experiences could also be misleading in fundamental physics. "Perhaps the universe is not as beautiful as particle physicists would like it to be," she says.

Hossenfelder's criticism receives mixed responses from the world of particle physics. Some find it destructive, while others react positively. Speculation about a crisis in particle physics is similarly controversial.

"In my view, there's no crisis at all – that assessment relates only to very specific theoretical approaches," says Hermann Nicolai, Director at the Max Planck Institute for Gravitational Physics in Potsdam. "On the one hand, the CERN experiment is a complete success because it once again offers excellent proof of the Standard Model. On the other, the precise point of these experiments is to eliminate incorrect models from the proliferation of theoretical ideas, and that is something that the LHC has also achieved."

Nicolai has never believed in SUSY particles himself, although he is very familiar with the history of supersymmetry's development. He obtained his doctorate under Julius Wess, one of the pioneers in this field of research.



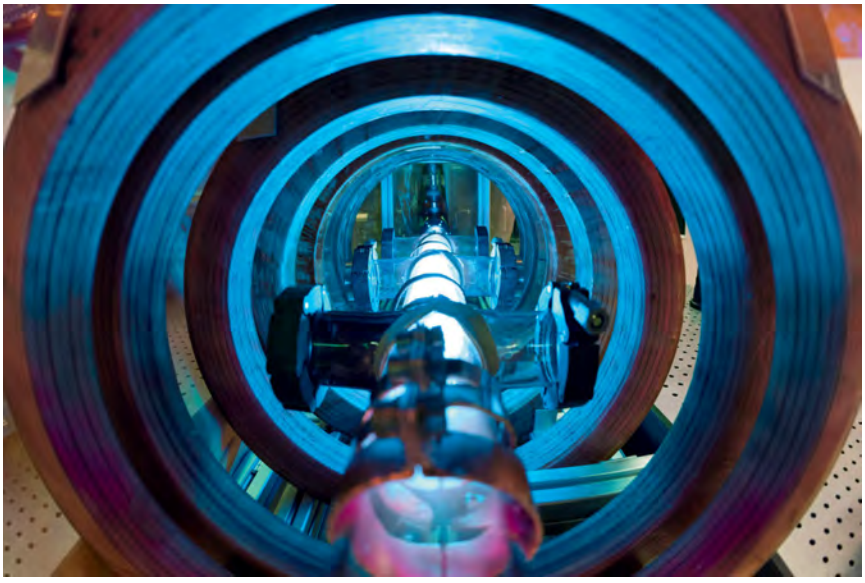
Illusory symmetry: according to some theories, SUSY particles were expected to join the collection of standard elementary particles. As they have not yet been detected in experiments, an increasing number of physicists believe they are an illusion.

Hermann Nicolai explains that the main motivation for supersymmetry was originally that it would combine internal symmetries of particle physics with symmetries of space-time. This was seen as a step towards unifying the general theory of relativity with quantum mechanics in order to derive a description of quantum gravity.

"However, these newer supersymmetric models that predicted the discovery of SUSY particles at the LHC do not realize the original goal of merging space-time and internal symmetries," says Nicolai. It quickly became clear, he explains, that a naive application of supersymmetry would conflict with observations.

"It was not until the start of the 1980s that people came up with the idea that supersymmetry could solve the hierarchy problem," says Nicolai. In other words, this theoretical construct was expected to close the explanatory gap arising from, among other things, the huge difference between the strengths of gravity and the other three fundamental forces. "But the price was high,"

Graphic: DESY



Scenario for future collision experiments: accelerators in which particles ride on a plasma wave, as seen here at CERN, could achieve far higher energies than conventional devices of the same size. This will likely pave the way for new insights into physics.

he says, because this most simple version of supersymmetry requires every elementary particle in the Standard Model to have a supersymmetric partner with almost identical properties.

"If this idea had been correct, then signs of it should already have been visible at the LEP accelerator," says the Max Planck researcher. The Large Electron-Positron Collider (LEP) was the forerunner to the LHC in the ring-shaped tunnel in Geneva. "The plain and simple truth is probably that there isn't much more to it than the Standard Model."

However, Nicolai emphasizes that supersymmetry and the approaches that go beyond it are by no means at an end, even if there may not be any SUSY particles. In general, Hermann Nicolai remains convinced that the principles of symmetry will be a key factor when it comes to developing a theory of quantum gravity and unifying it with the Standard Model, but that the current situation goes to show that "nature is far more subtle than many prominent colleagues imagined." And the researcher emphasizes: "I therefore see the LHC results above all as a great challenge for the world of theory: namely, to derive the Standard Model – just as it is – from a more fundamental approach."

Whether or not the theory of particle physics is in crisis is clearly a question of perspective. Some schools of thought have indeed seen decades of work reduced to rubble, while others are unaffected. But what do experimental physicists, who are responsible for testing the predictions derived from theory, make of the situation? One such experimenter is Siegfried Bethke, Director at the Max Planck Institute for Physics in Munich.

HOPING FOR A POINTER IN THE DIRECTION OF DARK MATTER

From the Max Planck side, Bethke and his group substantially contributed to design and build the Atlas detector, one of the two major experiments that detected the Higgs boson at the LHC. As the German scientific delegate on the CERN Council, he currently participates in the Update of the European Strategy for Particle Physics.

"Particle physics is not in crisis – although it's not easy to plan for the future right now," Siegfried Bethke says, adding that despite the lack of projects coming from the world of theory, there is still plenty for experimental physicists to do. Above all, many properties of the Higgs boson are still unknown – and as it is a key particle in the Standard Model, particle physicists want to take precise measurements of it. Moreover, they hope that the analysis of the Higgs boson will point them in the right direction in terms of where and how to continue their search for dark matter. After all, dark matter currently only makes itself felt by its gravity, which is connected with the Higgs boson.

However, the LHC is not all that well suited to precise analyses of the Higgs boson, for it generates it too rarely. The LHC was merely the search engine, so to speak, for finding the particle in the first place. The world of particle physics is therefore discussing smaller, more-specialized accelerators that produce the Higgs boson at higher rates so that it can be analyzed efficiently. The International Linear Collider (ILC), which has been planned in Japan for a number of years, is intended to be one such "Higgs factory," but it remains to be seen whether the project will actually be put into practice.

The ILC would also be a conventional accelerator from a technical perspective. Siegfried Bethke is advocating an unconventional alternative, known as CLIC (Compact LInear Collider), that is currently being developed at CERN. Although CLIC would require the construction of a new, straight tunnel in Geneva, it could achieve a higher energy than the ILC and would therefore also allow researchers to study the top quark. This was discovered in 1995, based on the latest successful prediction of a new particle originally made in 1977. The top quark is as heavy as an atom of gold, existed only briefly after the Big Bang, and can now be created in a particle accelerator.

Apparently, CLIC would therefore offer profound insights into the physics of the hot and compact baby universe. And, in the more distant future, it may be possible for the CLIC tunnel to incorporate revolutionary accelerator technology, known as AWAKE, that is currently being researched at CERN. This could achieve significantly higher energies and therefore cast light on even smaller structures in the world of elementary particles.

Whether or not these accelerators will open the door to a new world of physics is impossible to predict – as is so often the case in basic research. But it is rarely possible to plan major discoveries in physics. It's a bit like Christopher Columbus, who went looking for a sea passage to India, was almost defeated by a mutiny on the way, and ultimately discovered America. ◀

Photo: Julien Marius Ordan/CERN

SUMMARY

- **The experiments at the Large Hadron Collider led to the detection of the Higgs boson, but other predicted discoveries, such as supersymmetric particles, have failed to materialize.**
- **As some of the predictions of theoretical particle physics were not borne out, a number of theorists are calling on researchers to abandon their insistence on the existing guidelines for developing theories. They cast doubt on criteria such as naturalness, the elegance of mathematical constructions, and symmetry.**
- **However, many theorists – including the Max Planck researcher Hermann Nicolai – see symmetry in particular as being an important guideline for the development of new theories. Above all, this includes the search for a theory that merges the general theory of relativity and quantum mechanics to produce a description of quantum gravity.**
- **Despite this theoretical reorientation, experimental particle physicists see an opportunity to answer numerous research questions with the help of particle accelerators. For example, they want to take precise measurements of the properties of the Higgs boson, which they hope will provide clues about dark matter.**

GLOSSARY

Hierarchy problem is the term used by physicists for the extremely large difference in the strength of the strong and weak nuclear force and the electromagnetic force, on the one hand, and gravity, which is much weaker, on the other. This also applies to the step down from the elementary particles to the extremely small "Planck scale," which constitutes a fundamental frame of reference in physics. On this scale, it may be possible to unify the four fundamental forces.

Naturalness has, until now, served as a guideline for theoretical particle physics during the development of new theories. Critics consider this to be a flawed approach.

Standard Model of particle physics: This describes processes in the microscopic world and includes the elementary particles that make up matter and the forces acting between those particles, as well as the Higgs mechanism and the corresponding Higgs boson. This Standard Model follows the laws of quantum mechanics.

Symmetry plays a considerable role in physics. One example are the properties of antimatter, which are a mirror image of those of normal matter. This is how the British theorist Paul Dirac predicted their existence. Theoretical physics, however, also uses a multitude of abstract, mathematical symmetries.

The digital **language artist**

He describes himself as a bit unconventional. **Derek Dreyer** does, indeed, work with languages. Not, however, with everyday languages, but with programming languages, since they're more logical. The U.S.-born researcher works at the **Max Planck Institute for Software Systems** in Saarbruecken. Even though science is an important part of his life, he still makes room for passions like music. And then there's the thing about whisky – unconventional indeed.

TEXT **KLAUS JACOB**

Some offices are as impersonal as furniture store showrooms. Others can be read like a book. They reveal a lot about the people who work in them. That's the kind of office Derek Dreyer has. One of the end walls is dominated by a white board covered in cryptic equations that are only decipherable by insiders. Next to this are two colorful drawings by Derek's daughter. She's four years old. "No, four and a half," Dreyer corrects himself. With small children, every month counts.

The other end wall is completely covered by a shelf. Instead of books, the shelf contains row after row of whiskies, although not bottles, just their cardboard boxes. Dreyer is a big whisky enthusiast and knows almost every kind, but focuses on Scotch, not Bourbon.

The office feels open and comfortable, bright and spacious. Right in the middle there's a comfortable sofa, perfect for lounging on. The two long sides of the office are entirely paned with glass. One of these window facades provides a view of the wooded hillsides of Saarbruecken; the other, a complete view of the corridor. Dreyer, therefore, has an office all to himself, but the transparent walls (common to all the offices in this modern building), make the individual rooms feel almost like an open-plan office.

LOGIC AND MATH – DREYER'S STRONG SUIT

And that suits Dreyer. He's as open and friendly as the building, is willing to answer all my questions, and likes to laugh and engage with people. On his website, he writes that he can now be referred to as "*Herr Professor Doktor Derek Dreyer*" as he has been appointed an honorary professor at Saarland University. But he prefers just "DD", which is what his daughter Alma calls him.

Derek Dreyer is a computer scientist at the Max Planck Institute for Software Systems, where he researches programming languages. He is a member of the Institute management team and head of the independent group "Foundations of Programming", which comprises two postdocs and six doctoral researchers.

Logic and mathematics are Dreyer's strong suit. Spoken languages, on the other hand, are not. An American by birth, he's lived in Germany for eleven years, but you can't avoid speaking to him in English. This is primarily due to the fact that the working language at the Institute is English; most of the

An abstemious collection: Derek Dreyer collects unique whiskies, but in his office he only displays the empty boxes.

Photo: Wolfram Scheible

It's logical: Dreyer proves that some components of programming languages like Rust don't require stringent safety mechanisms.

researchers come from abroad. And his wife is also a U.S. citizen, although her German is much better. "*Es ist sehr peinlich*," [it's very embarrassing] says Dreyer in German with a thick accent, smiling. If there's a job that requires German to be spoken at home, his wife steps in.

Learning German is just too difficult, according to the researcher. There's a little playfulness in his modesty; he has a far better command of the language than he admits. At a minimum, he acknowledges that he knows the correct vocabulary for all food ingredients; good food means a lot to him, whether Japanese, Thai, French or Italian.

On business trips, he likes scouting for a good restaurant and invites a few friends and acquaintances to join him. "Give me any kind of food, and I'll tell you the German word for it," he says. He does, however, understand spoken German better than he speaks it. If he says something to his daughter in German, she laughs at him. For her, learning the new language in kindergarten is ... child's play.

Math on the other hand is a completely different matter. Dreyer mostly learned it effortlessly. He's an overachiever. With the help of his parents, he skipped several school grades because he was getting bored. He started university at the age of 13 instead of the usual 18. At 17 he moved to Carnegie Mellon University, one of the top universities for computer science in the U.S. Here too, he was five years ahead of his fellow students.

DREYER WASN'T PREDESTINED TO BE A COMPUTER SCIENTIST

His educational progress did hit a snag during his PhD studies, however. "I struggled at first," he says. Indeed, he almost had to drop out of graduate school in 2000, struggling to find his footing. He persevered, however, and was soon publishing his first scientific papers, finally earning his doctorate in 2005.

Derek Dreyer was born in 1980 in New York City, but soon moved with his parents into the suburbs of the metropolis, to Great Neck on Long Island. It's the area of New York made world-famous by the author F. Scott Fitzgerald with his novel *The Great Gatsby*, as Dreyer is fond of relating. Of his three siblings, he was the baby of the family, much younger than his two brothers and one sister.

His father is a pediatrician at the NYU Langone Medical Center, and has made a career for himself in numerous management positions in pediatrics. He became the President of the American Academy of Pediatrics, the largest pediatric association in the U.S. "He's very successful," Dreyer says about him, "and a great inspiration to me." His

Photo: Wolfram Scheible

» His expertise is in basic research. His proofs are universal and are helping to shape the programming languages of the future.

mother stayed at home and took care of the children and the household. Dreyer wasn't, therefore, predestined to be a computer scientist.

He did, however, love math at school and was intent on going on to study the subject. But his pragmatic parents encouraged him to enroll in computer science as well, as it would make finding a job easier. So, initially, Dreyer studied both mathematics and computer science, but then moved over fully to computer science. He's now glad he followed his parents' advice. In mathematics, he would miss real-world applicability. He likes the combination of theory and practice that computer science offers him.

Derek Dreyer hasn't just excelled in disciplines involving pure logic. He has also developed an active interest in the arts. Above all, he enjoys singing. As a pre-teen, he was singing in the chorus of the New York City Opera, even taking on some solo roles. Having developed into a tenor, he sang in the university church choir while he was living in Chicago. And music still has a strong hold on him, especially classical music and jazz. "My favorite composers are Bach, Britten and Shostakovich," he says. "I feel proud that this year I made the effort to explore Benjamin Britten's third cello suite. It's not easy music. I had to hear it about 20 times, but now I find it amazingly beautiful."

Dreyer never learned to play an instrument, however. "It's like the German language," he says with a smile, "you have to practice too many boring pieces before you can master an instrument." Maybe it's his perfectionism that makes him shy away from tackling things that he can't accomplish right away. He hasn't done much singing in recent years, but he likes to tap dance, even if not in public performances. To demonstrate, he jumps up and performs a few steps. It looks pretty professional ...

A GREAT OPPORTUNITY IN GERMANY

After studying and completing his doctorate at Carnegie Mellon University, Dreyer initially accepted a three-year independent research position at the Toyota Technological Institute at Chicago. The institution has nothing to do with cars – it's a basic-research institution funded by an endowment from Toyota. "It's like a mini Max Planck Institute," Dreyer says.

After three years, when his contract expired, he applied for positions internationally. The field of programming languages had now become his main focus, and there was little demand for it in the U.S. Although the community working in the field has grown considerably in recent years, it is still relatively small. The offer from Germany came at just the right time.

He didn't have to spend much time thinking about accepting the tenure-track position at the Max Planck Institute for Software Systems; if he achieved his scientific objectives, it offered him long-term prospects. He knew that experience at a Max Planck Institute is highly regarded in the U.S.

Dreyer reaches for his smartphone and shows me a worldwide ranking of all institutes involved in computer science and computer languages. The Max Planck Institute is near the top of the list. "It was a great opportunity," he says, especially because he had the chance to become involved in the initial development of the Institute. In 2008, he took up the post, initially on a short-term basis. Then, five years later, following an international evaluation, he was offered a permanent position with full scientific autonomy.

When asked whether the move from New York and Chicago to Saarbruecken was a culture shock, he provides a diplomatic answer: Max Planck is "great", and he works a lot, so the neighborhood isn't a major factor. "What's important for me is that I have fantastic students and colleagues, and Saarbruecken is a quiet place – a good place to work." For variety, he travels, and his job also takes him to many different places, even to major capitals such as Paris and London. So will Germany remain his second home? He has no plans to leave Germany in the near future, he says.

After that, he has no idea. He has considered other possibilities, but nothing comes close to his position at the Max Planck Institute. He can research whatever he wants here, and has

a great team and excellent resources. He also finds the combination of research and teaching ideal. "Besides," he says, "my wife Rose Hoberman has a great job at the Institute, teaching our doctoral researchers to write readable papers and give compelling lectures. And her office is two doors away from mine – beat that!"

One disadvantage of living in Saarbruecken is a universal fact of life for academics: the friendships he and his wife make are usually temporary. Most of their friends are students or postdocs from the Institute who leave after a few years. A career in science takes people all over the world.

Dreyer's work is as incomprehensible to the layperson as the formulae on his blackboard. It's ironic that his field is languages, as he has claimed not to be a keen linguist. But programming languages are a whole different ball game to German or Japanese; they are structured in an absolutely logical way.

RUST IS DESIGNED TO BE UNIVERSAL AND SAFE

Dreyer's current focus is principally on the relatively young language known as Rust, which can be used to write complex programs. In 2016, he was awarded a European Research Council (ERC) Consolidator Grant of two million euros for his five-year project called RustBelt.

The programming language Rust was designed by Graydon Hoare, an employee of the software company Mozilla, best known for the web browser Firefox. Initially, he created the language alone and as a personal project. Mozilla has been supporting the development of Rust since 2009, and version 1.0 was released in 2015, along with the associated compiler, which translates the commands into machine code.

Rust is now widely used by Google, Microsoft, Facebook and Dropbox, among many other companies. It is designed to overcome the weaknesses of conventional languages. Up to now, languages have either been safe (they automatically check the work of the programmer for important classes of errors), or they have been flexible but unsafe (they offer programmers extensive freedom – including the freedom to commit errors).

But an error in a complex program that is only revealed during initial test runs is extremely troublesome. Trying to locate it can drive programmers to despair. Rust is designed to manage the balancing act of being both universally applicable and safe. Understanding how this can be achieved requires a little background knowledge.

Ultimately, all programming languages have a control mechanism. However, these can vary in their degree of rigor. The stricter the controls, the more they restrict the freedom of programmers. They're like digital bouncers who sometimes interpret something as an error that is definitely useful, calling a foul on the programmer. Java is a language with strict controls. In contrast, C and C++ are, to a certain extent, the opposite.

Programming languages employ control mechanisms that go way beyond a document spell-checker. A particular example illustrates how they work. Most languages use pointers that refer to specific data in memory. Sounds pretty simple. Complex programs, however, require many pointers and many memory locations. It's easy for a programmer to lose track of them, resulting in a pointer that could be used to call up memory that contains nonsense.

Rust has a number of mechanisms designed to prevent this. Each pointer, for instance, has only a limited lifetime, i.e. it is only active in a specific section of code and is automatically switched off afterwards when the associated data has become obsolete. Also, no two pointers can ever simultaneously perform modifications to the same memory location. Such duplication is a common source of errors, because the data in memory can be modified with every operation, potentially leading to bugs if accessed simultaneously.

SAFETY WITHOUT DIGITAL BOUNCERS

However, such built-in safety features come with a disadvantage: some operations cannot be carried out. For instance, the creation of complex data structures requires memory locations that can be simultaneously accessed by more than one operation. To ensure that Rust remains universally applicable, it thus incorporates the possibility of the "unsafe mechanism". The programmer can specify that certain program components do not have to pass through the strict security gate. Using this mechanism, of course, runs the risk of errors creeping in – as with C or C++.

And that's where the work of Dreyer and his team begins. He provides formal proof that typical "unsafe components" are, in fact, safe, so that they can be used with confidence, even without a digital bouncer. To achieve this, he

Music and dance: as well as mathematics, Dreyer is keen on music, especially classical music. He even used to sing at the New York City Opera. His tap dancing is just a private pursuit, however.

utilizes interactive proof assistants; in other words, his proofs are automatically verified by the computer. Ultimately, as a scientist, his work focuses on his favorite combination of mathematics and computer science.

However, it would be a mistake to suggest that Dreyer is only working on the fledgling programming language Rust. His expertise is in basic research. His proofs are universal and are helping to shape the programming languages of the future. His interest in Rust is merely as a practical application, although his involvement in the language primarily concerns the most complicated "unsafe components".

The ERC Consolidator Grant he received for the project is one award that he is particularly proud of. Another is the Robin Milner Young Researcher Award conferred by ACM SIGPLAN, the Association for Computing Machinery's Special Interest Group on Programming Languages; it is the most prestigious international prize for young scientists in the field of programming languages.

He dismisses other awards that he has received for outstanding publications with a wave of his hand. Like knick-knacks, they're stored on the shelf along with the whisky boxes. They're neither given pride of place, nor presented in a showy way. In any event, the line of boxes of exceptional whiskies is much more eye-catching. In addition to enjoying these spirits, exceptional food and, above all, music, he also loves fine wines and has even joined a wine club. "It's my way of getting acquainted with Germans," he says with a smile.

THE PROMISED LAND FOR LOVERS OF SCOTCH

The members of the club are acknowledged wine connoisseurs. About a dozen men and women meet every three to four weeks, all of whom, except Dreyer, are German. They invite each other to their homes and serve wine from their own cellars. The wine tastings are in no way drinking binges; the experts spit samples out after tasting them. "Part of the deal," proffers Dreyer.

As a Scotch connoisseur, he has a sensitive enough palate to distinguish fine notes: "Every vintage is completely different," he says. Nevertheless, he has a handicap: wine connoisseurs employ a broad vocabulary to describe the flavors of the different terroirs and vintages. As an American, he just can't keep up: "I'm always wanting to say something interesting, but what comes out is consistently boring due to my limited vocabulary." It means he mostly just listens. On one occasion, however, he did indeed take the floor. He guided the members through a tasting of four lesser-known whiskies: Clynelish, Ben Nevis, Springbank and Ledaig, which are "unconventional, a bit like me."

For a lover of Scotch like Dreyer, Germany is the Promised Land. In the U.S., Scotch whisky is not only much more expensive, but in many cases not even available. The shelves are full of them here. But occasionally, Dreyer travels to Scotland to buy directly from the distilleries. Does he have a favorite brand? He ponders for a while, then settles on a Black & White Blend from the 1960s. "Outstanding quality and, at 100 euros, very cheap" – a bargain. He bought a bottle yesterday, and he considers it his current favorite. Tomorrow, it may be another. ◀

Photos: Wolfram Scheible

Burn damage
in the rainforest

This summer, there were more forest fires in Brazil than virtually any on record. **Susan Trumbore**, Director at the **Max Planck Institute for Biogeochemistry** in Jena, is looking at the consequences that the immense loss of rainforest has on the local, as well as global climate. She also examines the likelihood of a forest recovering from a fire. If only it is given the chance.

TEXT **TIM SCHRÖDER**

The rainforest in Brazil has been burning for decades, over and over again. In many places, farmers are setting the forest on fire, while elsewhere, clearing is taking place on behalf of beef barons. The goal is to obtain new farmland to grow soy, mainly for fattening animals in Brazil and other countries. Plenty of cleared land is also home to grazing cattle. Many farmers also burn their stubble fields after the harvest, not taking into account that sparks can cause wildfires.

Reports about crop fires are nothing new. However, particularly terrifying pictures appeared this summer, as the fires reached catastrophic proportions in August. Analyzing satellite images, the Brazilian National Institute for Space Research, the INPE, found fires to have increased by about two-thirds in the region, compared to the same time period in previous years, with more than 45,000 fires in total.

The fact that most of these fires were not caused by particularly severe drought is cause for concern. The past few summers had been even drier. This increase can be attributed to economic interests: most fires broke out on privately owned land and close to rural settlements. Brazilian experts assume that there has been an increase of fire-based forest clearing in these areas. The most alarming aspect is that there has been a massive increase in the number of fires even in public state forests and conservation areas.

Deforestation in the Amazon rainforest has dramatic consequences. Countless plants and animals are losing their habitat, and it is quite likely that hitherto unknown plant and animal

Fire detectors in space: the fires in the south of the Amazon Basin are particularly striking in satellite images from the Nasa Earth Observatory, but those in other parts of South America are also clearly visible.

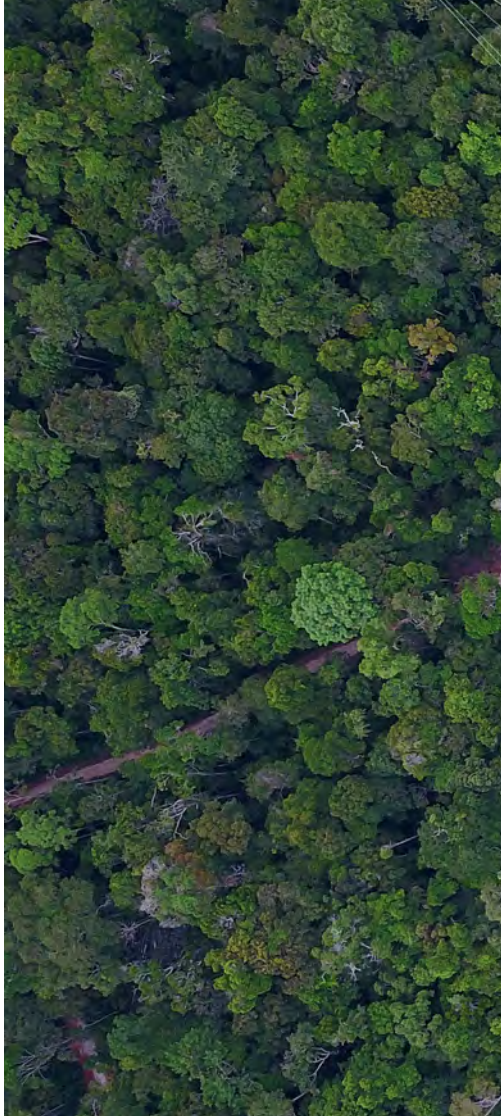
Photo: NASA/EOSDIS

species are being wiped out. The loss of forest is also expected to have an impact on the climate across large parts of South America, and possibly even on a global scale. The Earth system researcher Susan Trumbore, Director at the Max Planck Institute for Biogeochemistry in Jena, wants to gain a comprehensive understanding of the consequences this overexploitation has on nature.

She examines not only the impact on biodiversity after forests have slowly begun to recover years after a fire. She also addresses the question as to what extent the remaining forest has become more vulnerable to further disturbances, such as drought or windthrow, as farmland advances. She is collaborating with Brazilian researchers to explore how deforestation impacts regional and global climate, as well as the ways in which the forest reacts to such climate change. "We do not have sufficient data at this point to accurately illustrate the impact of the Amazon region in climate models," Susan Trumbore explains. "We would like to contribute to improving climate models in this respect."

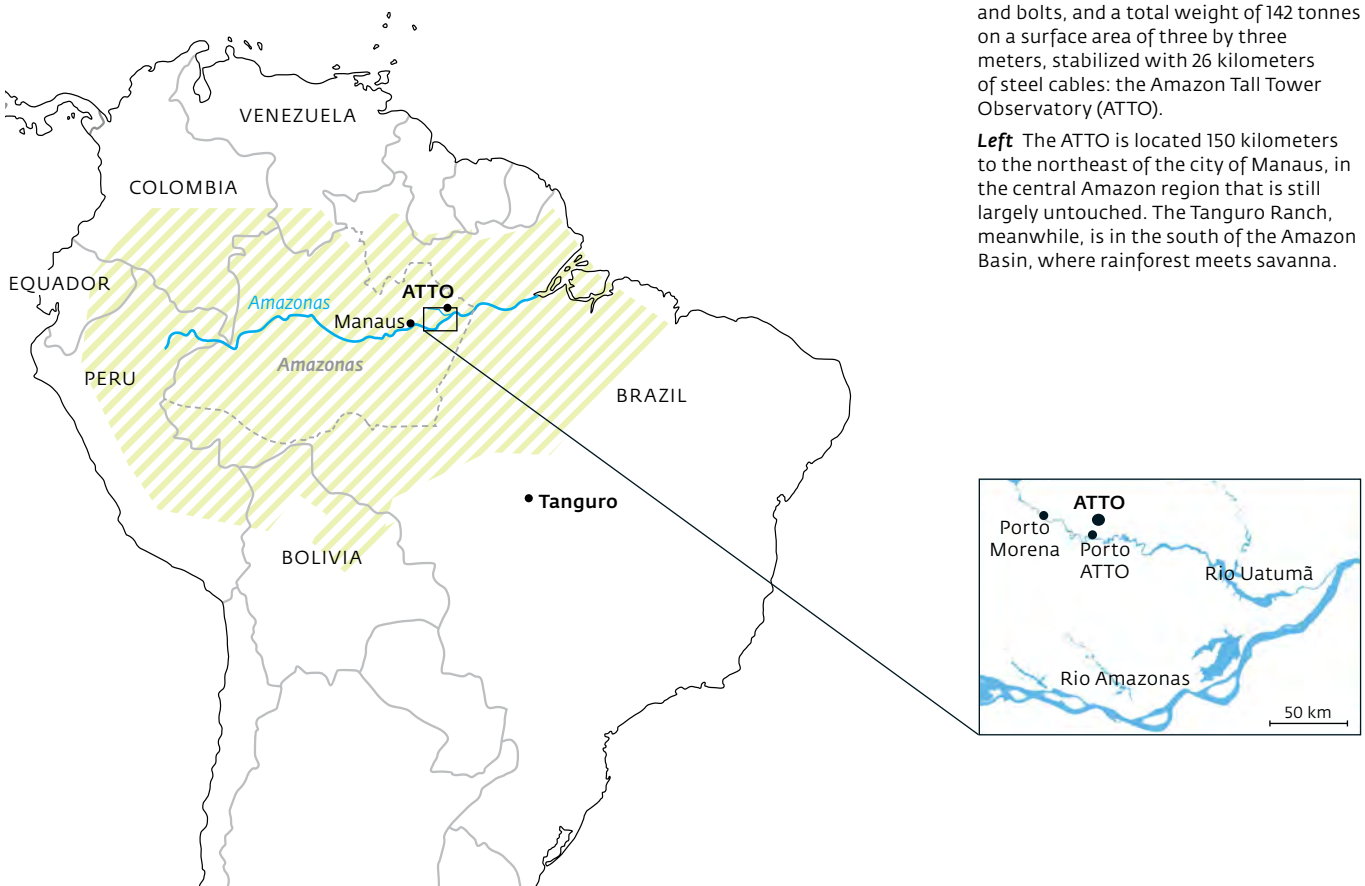
THE FOREST STILL ABSORBS THE FIRES' CARBON DIOXIDE

With regard to the local and regional climate, it is of particular importance that enormous amounts of water evaporate in the forest of the Amazon Basin. This has a cooling effect on the forest



Top 15,000 components, 24,000 screws and bolts, and a total weight of 142 tonnes on a surface area of three by three meters, stabilized with 26 kilometers of steel cables: the Amazon Tall Tower Observatory (ATTO).

Left The ATTO is located 150 kilometers to the northeast of the city of Manaus, in the central Amazon region that is still largely untouched. The Tanguro Ranch, meanwhile, is in the south of the Amazon Basin, where rainforest meets savanna.



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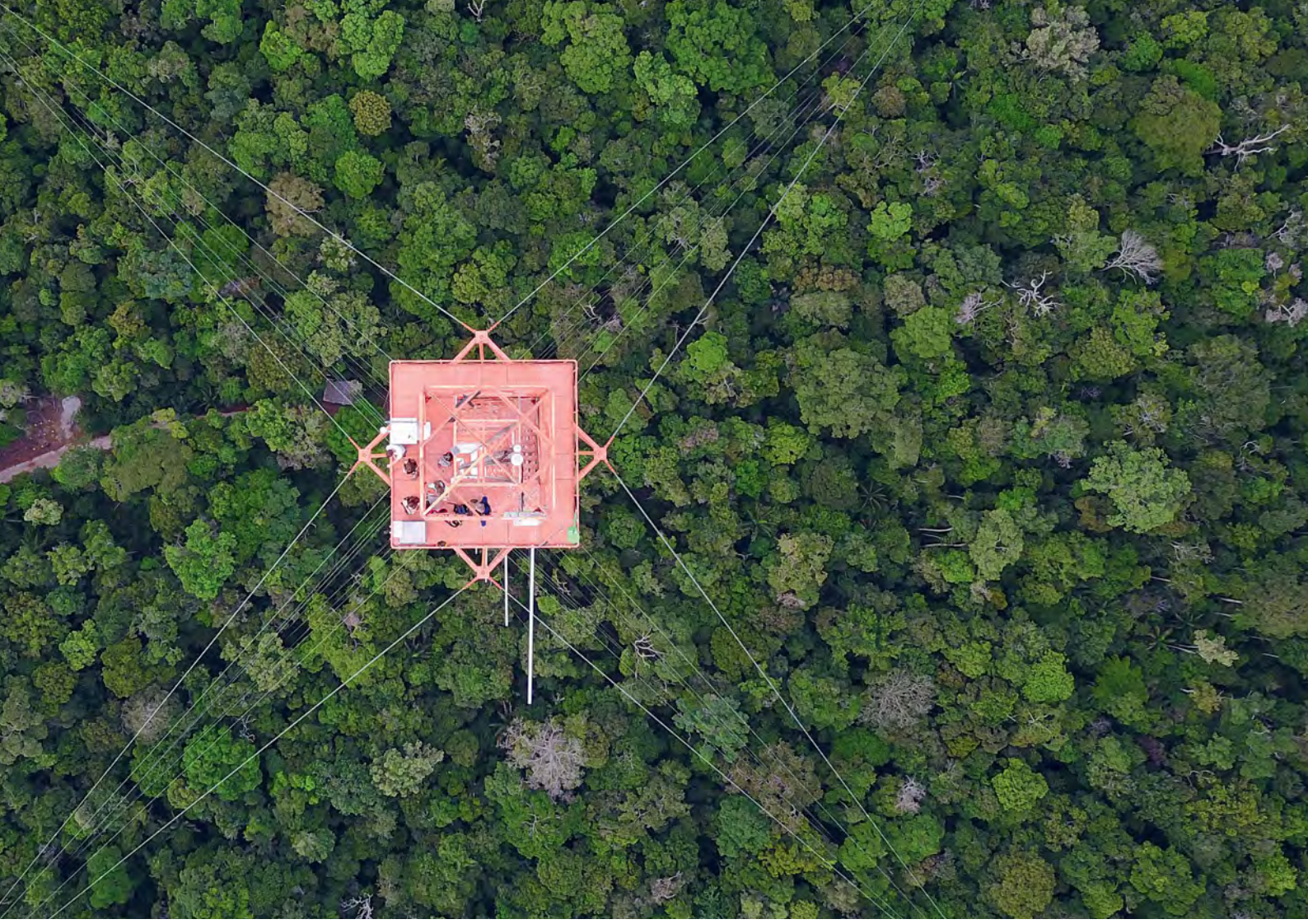


Photo: Achim Edtbauer / MPI for Chemistry

and its environment, and half of this water is returned to the area as rain. A part of the clouds that form move on, however, providing rainfall for large parts of South America.

Scientists agree that owing to its sheer size, the Amazon region has a significant influence on global climate. The Amazon Basin that feeds the Amazon River covers an area of around seven million square kilometers – about twenty times the size of Germany. Currently, 80 percent is still covered by forest. About one-third of the amount of carbon contained in the Earth's atmosphere at the start of the industrial revolution is still stored in this area today.

Today, the forest is still able to absorb the carbon dioxide that is released through fire clearance in Brazil. However, it can no longer filter greenhouse gases from the atmosphere that are generated elsewhere as a result of the use of fossil fuels. If the deforestation that had initially slowed down after 2003, but increased again in 2019, accelerates further, it could even happen that, on balance, greenhouse gases are released in the Amazon region.

Conversely, it is also likely that global warming will change the forest and its ability to absorb greenhouse gases. Scientists question whether the rainforest will survive a global rise in temperature by more than two degrees Celsius, since there is currently no rainforest anywhere in the world where temperatures are that high. This means that the Amazonian forest might disappear due to climate change. "It is impossible at this point to predict what a warming of the Earth by two degrees Celsius or more would mean," says Susan Trumbore. "How are habitats, the chemical and physical processes between the forest and the atmosphere and gas exchange going to change? And how are these changes going to affect our global climate?"

To be able to assess the feedback effect between climate change and the shrinking rainforest, scientists first need to understand the role that an intact forest plays with regard to the global climate. This is why, for the past few years, Susan Trumbore and her team have been involved in an extraordinary large-scale research project: ATTO, the Amazon Tall Tower Observatory, an ensemble of three slim steel framework towers, the largest of which, at 325 meters, is taller than the Eiffel Tower.

THE EFFECTS OF DAMAGE TO THE TREE POPULATION

The observatory is located deep in the rainforest, about 150 kilometers to the northeast of the city of Manaus. The journey takes several hours, and part of the distance is covered in boats on a river. "The area is unique," says Susan Trumbore. It is far from any cities or villages. It has the purest air anywhere on the planet. Here, it is possible to take very accurate measurements of the exchange of substances between the untouched forest and the atmosphere. >

"This is pretty much the last place on Earth where we can examine the original impact of a large intact forest," explains Trumbore.

Provided, that is, that there are no fires on the southern edge of the Amazon combined with unfavorable wind conditions. This causes soot particle aerosols to travel northwards, for example. As water vapor is prone to condensing on such aerosols, causing droplets to form, it is feasible that fires in the south can have an impact on cloud formation and rainfall across the entire Amazon Basin. However, experts are not yet able to tell whether this will lead to more rain or to any changes in the rainfall areas.

The measurement towers were constructed step by step by Brazilian and German research institutions, including the Max Planck Society with funds from the Federal Ministry of Education and Research. They are full of devices for measuring carbon dioxide, methane and other substances, as well as the amount of aerosols contained in the atmosphere. The researchers use sophisticated methods to measure and calculate which amounts of which substances are exchanged between the forest and the air. Other equipment is used to measure wind direction and speed, as well as solar irradiation above the forest.

The researchers working with Susan Trumbore at ATTO not only monitor substance and energy exchange between the forest and the atmosphere. They also examine the effects that damage has on the tree population. A few years ago, entire clusters of trees near the observatory were knocked over by thunderstorms. This created clearings in the otherwise dense forest that provide ideal research sites, the biggest of which is 28 hectares in total – about the size of 40 soccer fields.

RESEARCH AREA IN A BRAZILIAN HOTSPOT

Susan Trumbore and her team are able to conduct research on a wide range of aspects here, such as the rate at which trees decompose and to what extent they release their stored carbon as they do so. Severe storms may occur more frequently due to climate change; storms that are strong enough to uproot trees by the dozen. The wood decomposes and the forest's biomass is reduced as time goes by.

Susan Trumbore and her team members are also examining the speed at which the affected forests regenerate. They have found that evaporation and photosynthesis recover within just a few years, as these functions are taken over by rapidly growing shrubs and trees. It takes decades, however, for the same amount of biomass that

Left Susan Trumbore explores the interdependencies of the Amazonian rainforest and the climate.

Top Advancing agriculture: large forest areas have to make room for farmland at the edge of the Amazon Basin. This has caused a hotter and drier local climate, despite the fact that the remaining forest still has a cooling effect and provides the conditions for rain.

Photo: Paulo Brando

Photo: Paulo Brando

was contained in the old tree population to reform. It takes even longer for the forest to become nearly as biodiverse as it was before.

Susan Trumbore compares the results from the ATTO area with measurements taken in a second region in Brazil, where she has been conducting research for a number of years now. This research site, the Tanguro Ranch, is located in a Brazilian hotspot, where the forest meets cleared savannas and farmland, about 2,500 kilometers to the south of Manaus in the state of Mato Grosso, the driest part of the Amazon Basin. The transition zone between dense Amazonian forests and savannas is typical of the region. The land on the Tanguro Ranch is intensively farmed. In recent years, there have been more clearances in this area than anywhere else.

Researchers analyze how the local climate is changed by this loss of trees, but they also take a look at global climate effects caused by deforestation. There is already evidence that the intense deforestation is causing the climate to become even hotter and drier in this region, which already experiences a five-month dry season.

In addition, scientists are examining the extent to which the remaining forest on the edge of the savanna is affected – and whether it stands a chance of recovery on land that has been cleared. In order to answer these questions, a team of experts from Brazil, Germany and the Woods Hole Research

Underestimated threats: fires on forest floors are invisible to satellites. Based on smoke measurements, ATTO can register these fires, too (left). Grasses can spread on cleared land and invade adjacent forests (right). They can grow even taller than Susan Trumbore, and they take light away from seedlings. They therefore hinder the forest's regeneration and they also make the forest more vulnerable to fire.

Center in the U.S. launched an unusual project in the early 2000s: fire experiments carried out in three forested 50-hectare areas in the transition zone to the savanna.

Between 2004 and 2010, the researchers set one plot on fire every year, and another one only once every three years. The third plot remained untouched. They then allowed the forest to recover. In the meantime, they analyzed the climate conditions and substance flows on the burned plots, and compared these to corresponding data from a nearby soy field, from the edge of the forest, and from a measuring station located deeper in the forest.

The researchers found that the fires did not overly affect the forest in humid years. In dry years, however, and these have become increasingly common in recent years, the fire burned a large number of trees. As soon as the fire had created large gaps, the surrounding forest thinned out, as it had become more vulnerable to wind, and because the more open forest dried out more quickly. This effect continues to this day, eight years after the last fire. A noticeable number of trees are still dying from the consequences of the fires. Furthermore, the now more open forests have become invaded by various grasses. These prevent trees from growing back, as they take away light and nutrients from seedlings.

FIRES ARE MAKING FORESTS MORE VULNERABLE

Measurements show that as in the ATTO region, trees that are growing back can perform vital ecosystem services after just a few years, especially compared to a dry soy field. Evaporation and photosynthesis, and therefore the absorption of carbon from the air, had normalized once again by 2017. Evaporation also has a cooling effect in this hot region, and this shows how important it is to conserve forests, at least in part, in areas used for agriculture. However, significantly less carbon is now stored on these plots.

Ten years after a fire, the forest has not fully recovered: a young, bushy forest that grows after a fire does not provide the conditions for the same ecosystem as the original one. Even worse: in some areas, the forest may disappear completely after a fire. "We can observe that fires make forests, and particularly their edges, more vulnerable," says Susan Trumbore and goes on to explain that a main driving question of the research is to find out whether repeated fire will eventually turn the forest into savanna. "We assume that there are tipping points, beyond which a forest is no longer able to recover by itself and will disappear," she explains. The exact tipping point has not been identified to date.

This is why Susan Trumbore and her team also want to find out which species of trees stand a chance of survival in the increasingly dry and hot region around the Tanguro Ranch. "It is quite possible that species that grow back quickly will also die again quickly," she says. "We do not know yet

Photo: Paulo Brando

Photo: Paulo Brando

which species have what it takes to form a new, robust forest under these tougher climatic conditions."

Susan Trumbore was also shocked by the extent of the fires that afflicted this region a few months ago. However, she points out that the land that is cleared every year has somewhat decreased in recent years. Significantly bigger forest areas were still disappearing every year in the early 2000s. The scientist cannot tell to what degree the devastating fires of 2019 are linked to the policies pursued by the Brazilian president Jair Bolsonaro. "The long recent drought period is likely to have contributed to this, too."

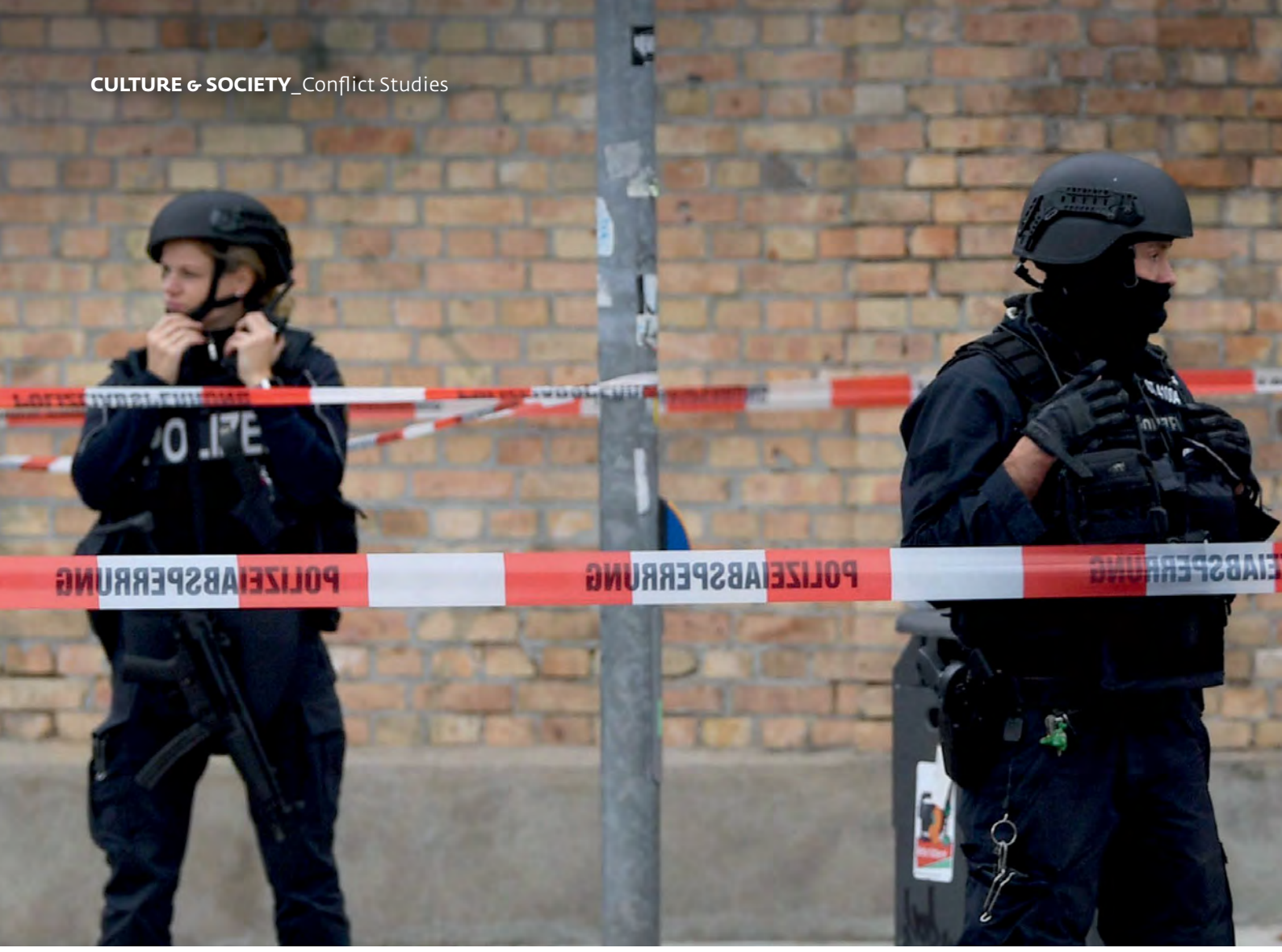
At any rate, in her view, Brazilians are not solely responsible for conserving the Amazonian rainforest. "People from industrial nations are good at telling others how to do it right. At the end of the day, we citizens of industrial countries have contributed to creating this situation," she says. Around 80 percent of soy imported to Germany comes from South America, according to the environmental foundation WWF. However, China is the biggest importer of soy, accounting for 60 percent of global production. About half of this is produced in Brazil.

The predecessors of president Bolsonaro, Luiz Inácio Lula da Silva and Dilma Rousseff, had promoted improved farming methods to exploit the soil more effectively, and in so doing to increase production and reduce the pressure on the forest. Jair Bolsonaro, however, is promoting an expansion of the areas used as farmland. Susan Trumbore believes that import nations are partially responsible: "The situation is not going to change unless they urge Brazil to treat the remaining forest with greater care."

It goes without saying that people in industrial countries must pay more attention to the origin of resources used to make the food that they buy – and promote products and practices that recognize the value of rainforests. After all, finger-pointing is not going to save the Brazilian rainforest from further destruction. ◂

SUMMARY

- **In summer 2019, an extraordinarily large number of fires raged in the Amazonian rainforest. Many of these were started deliberately and were boosted by increasingly dry conditions.**
- **Teams working with the Max Planck researcher Susan Trumbore are examining the ways in which the rainforest and the climate affect each other, at both the Amazon Tall Tower Observatory (ATTO) in the heart of the rainforest and on the Tanguro Ranch in the State of Mato Grosso.**
- **In areas that have been cleared, and where much less water evaporates, it is getting hotter and drier. This also has an impact on rainfall in other areas, as the Amazonian rainforest determines the water balance of the entire region. The CO_2 that is released through clearing has an impact on the global climate.**
- **If the forest is allowed to grow back on cleared land, the exchange of carbon dioxide and water between the vegetation and the atmosphere can reach almost its original level after just a few years. However, far less carbon is stored in degraded forest, which remains more vulnerable to heat, drought and windthrow. This in turn can lead to further die-off and a rapid shift to a new stable state of savanna vegetation.**



Patterns **of terror**

Terrorism awakens fear and anxiety. We feel particularly helpless because the perpetrators' actions seem so incomprehensible. But there is actually a certain logic behind the actions of terrorist groups. **Carolin Görzig** and her group at the **Max Planck Institute for Social Anthropology** in Halle have set themselves the task of discovering the rules by which terrorists act. Their findings are shedding more light on the enigma of terrorist plots.

TEXT **MECHTHILD ZIMMERMANN**

In the aftermath of the crime: police officers secure the location where a woman was shot in front of the synagogue in Halle. The perpetrator had planned an attack on the Jewish community.

Photo: Filip Singer/shutterstock

Halle (Saale), October 9, 2019. Noon. An armed man tries to enter the synagogue where the Jewish community has gathered for Yom Kippur, the highest Jewish holiday. The locked door resists his efforts; it could easily have been otherwise. The murderer then shoots a passer-by on the street and, a bit further on, a customer at a kebab shop. This was an act of terror, as the Public Prosecutor General of the German Federal Court of Justice would later describe the incident.

That same afternoon, at the Max Planck Institute for Social Anthropology – just one and a half kilometers from the crime scene – we have an appointment with the terrorism researchers to talk about their work. The key questions are: what motivates terrorists? How do terrorist groups develop? What ways out of violence are there?

But the city is paralyzed and the perpetrator is still on the run. The interview will have to take place another day. For now, our questions, more urgent than ever, remain unanswered.

ATTACKS ARE NOT RANDOM OR INDISCRIMINATE

Two weeks later, on the way from Halle train station to the Institute, the tram passes the kebab shop that was the site of the shooting on October 9. An elderly woman points to the closed snack bar, in front of which the people of Halle have laid out a carpet of flowers and candles. The woman sitting next to her just shakes her head silently. The topic being studied by the Max Planck Research Group "How 'Terrorists' Learn" has come hauntingly close to home.

"This proximity does indeed make a difference," says Research Group Leader Carolin Görzig. She has been conducting research into terrorist groups for the past 15 years and has been working on the subject with her team at the Institute in Halle for four years. "For me, the topic has always been intriguing, something that can be analyzed in order to understand the connections. But having it suddenly happen practically on our doorstep is a shock." Görzig knows colleagues who eventually turned to other issues because they could no longer bear the constant examination of violence and terror. "I think the more involved you become with the subject, the more challenging

it becomes to conduct research in this field," says Görzig. She has empathy for her interviewees, but is careful to maintain a professional distance.

This is fortunate for us, because without researchers like Görzig, terrorism would remain as much a mystery as ever. Contrary to popular belief, terrorists do not engage in rampages of blind violence against everything and everyone. Rather, their actions follow certain patterns, and it is possible to identify the logic behind them. Terrorist organizations plan and set themselves objectives, but they also have things they will not do and lines they will not cross. Another important question for Görzig and her team concerns the dynamics that unfold within a group and its leaders – dynamics that can even result in a renunciation of violence.

ATTACKS SHOW MEMBERS: "WE ARE DOING SOMETHING"

However, it is not always possible to identify clear patterns in the behavior of terrorist groups. Both the groups and the contexts in which they operate can vary significantly, even within Europe. This becomes evident when one considers how terrorism develops in the first place. As Michael Fürstenberg, a political scientist in Görzig's group, explains, one commonality is generally a sense of injustice. "Many terrorists feel like victims and see themselves as fighting against oppressors." That is why they never refer to themselves as "terrorists". They often form part of a mass movement with popular support, or at least that's how they see themselves. Often, the decision to sympathize with or even join a terrorist organization is also influenced by an individual's personal circumstances and the wish to belong.

In West Africa, especially in Niger and Nigeria, where the Islamist terrorist group Boko Haram is active, there are additional contributing factors: the terrorists there benefit from bleak prospects for the future among the local population, and from the weakness of the state. For many years, Florian Köhler, an ethnologist at the Institute, has been observing the situation on the ground for many years. "Initially, one of Boko Haram's strategies was to fulfill functions that the state was failing to provide. The group presented itself as a social movement, issuing microloans for example, which won them a lot of support." However, sentiments turned against the group as they increasingly resorted to violence against civilians.

Boko Haram's objective is to introduce Sharia law, the Islamic legal doctrine based on the Koran. The group also rejects democracy and Western-style education. In this respect, it resembles al-Qaida, the "Islamic State" (ISIS), the Taliban and many smaller groups of the jihadist movement, which operate in numerous countries around the world. These groups are so named because of the central importance they ascribe to jihad, which they interpret as the spread of Islam through armed struggle.

Thus, terrorist violence is generally not arbitrary. Fürstenberg emphasizes the great importance of political objectives. "In the case of ISIS, one could see how important the concept of the Caliphate was – also in terms of the group's 'branding'." But another central priority is often ensuring the continued existence of the organization. "The group must survive, spread and grow. Thus, the violence initially serves to legitimize the unit and, as it were, to bomb it into the public consciousness. An attack also demonstrates to its own members: we are doing something."

Thus, at the lower levels of these organizations, violence can become an objective in itself. The management level usually has more of an instrumental understanding of violence, notes Fürstenberg based on his observations of the al-Qaida terrorist network: "They have espoused a set of guidelines by legitimizing certain types of violence whilst clearly rejecting others. It was quite interesting that the leader of al-Qaida spoke out following the murders in Christchurch, when a right-wing extremist caused a bloodbath in two mosques. He demanded revenge for the deed in an audio recording, but explicitly refused to attack churches, suggesting that they don't do things like that; it's completely beyond the pale."

QUESTIONING THE NEED FOR VIOLENCE

In order to promote their mission, terrorist groups deliberately seek publicity. It's easy enough to find out what their objectives are. Fürstenberg explains: "There are a surprisingly large number of documents from terrorist groups, including books, pamphlets and letters. Or there are semi-public forums on the Internet in which terrorists exchange information." The research group uses sources such as these to gain insights into the inner workings of various organizations.

Research Group Leader Carolin Görzig has conducted extensive research into the Egyptian Islamist movement Gamaa Islamija, among others. The group actively engaged in terroristic activities from the 1970s to the 1990s. Members of the Gamaa Islamija carried out a massacre in an ancient Egyptian temple complex in Luxor in 1997, as a result of which the Egyptian state undertook a major crackdown against the group. Numerous leaders and thousands of followers were arrested, and many were killed.

While in prison, the leaders began to question their violent actions. "They came to realize that their means had become an end in themselves," Görzig explains. "And that this ran counter to their actual objective, which was to lead people in accordance with Islam." This self-reflection in prison was stimulated by experiences such as conversations with liberal and secular fellow prisoners.

Görzig analyzes this process of reflection using a concept developed by organizational researchers Chris Argyris and Donald A. Schön. According to this theory, if a company wants to develop further, it is not sufficient to look at individual decisions. Instead, it is also necessary to question the underlying routines and unwritten rules. In many companies, for example, mistakes are covered up rather than being addressed – thus making problems even worse. Managers therefore need to try to question and shake up such routine practices.

Görzig's findings suggest that the leaders of the Gamaa Islamija engaged in similar reflection processes, the results of which they recorded in several books. As she notes, their self-criticism is surprisingly far reaching: "They realized, for example, that as a leader, one can easily become reluctant to correct one's course for fear of losing followers or losing ground to competing organizations. And nevertheless, they reflected on their views and made a decision to renounce violence."

COMPETITION BETWEEN TERRORIST GROUPS

This is an important insight, Carolin Görzig thinks, with particular relevance for how negotiations with terrorists are conducted. "Anyone who demands that a terrorist group first completely abandon its objectives is essentially asking

Photo: Mohammed Elshamy/picture alliance/AA

Traces of terror: the Islamist group Boko Haram is known for its brutal actions in Nigeria. The group benefits from the weakness of the state. In its more peaceful early years, it even assumed functions that the state was not fulfilling.

Politics rather than violence: it is no coincidence that Nelson Mandela's picture adorns a wall in Belfast, Northern Ireland. The South African freedom fighter served as a role model for the IRA, an Irish Republican terrorist organization, when it abandoned violence in the early 2000s.

for complete surrender. Instead, negotiations should aim to encourage terrorists to reflect upon their means."

Self-critique by terrorist organizations is not as rare as one might think, as Görzig's findings have shown. The Irish Republican Army (IRA), a terror organization which fought for decades for the unification of the Republic of Ireland with the British-ruled Northern Ireland, similarly renounced violence at the turn of the millennium. In doing so, they in turn drew inspiration and guidance from the African National Congress (ANC). During the 1970s, this organization, whose most prominent leader was Nelson Mandela, also used violence to fight discrimination against the black population in South Africa. After the end of apartheid, however, the ANC transformed itself into a political organization. The IRA learned from the ANC that change can be achieved peacefully and that it is also possible to accomplish victories through political means. For example, the ANC representatives taught IRA members how they could implement a change of direction without losing their base.

DRONE ATTACKS HAVE FUELED VIOLENCE

As Florian Köhler reports, the Islamist terror group Boko Haram in West Africa has also engaged in internal discussions about the use of violence. "The comparison shows that the level at which such debates are initiated is of central importance. In the case of Boko Haram, it was resistance to leadership that resulted in the formulation of such ideas. The result was that the movement split and the core group became more radical."

Generally speaking, when a terrorist group becomes more moderate, this often results in an escalation elsewhere. A split into multiple groups is one possible outcome. Alternatively, some members may migrate to other organizations, Görzig reports. "There is always competition between groups striving for similar objectives. And they refine their profiles through their actions, as it were. They want to show their followers that they are on the right side."

For example, some Gamaa Islamija members switched to al-Qaida following Gamaa Islamija's deradicalization. And al-Qaida in turn expanded their activities by directing violence against their "distant enemy", the U.S., which eventually culminated in the series of attacks on September 11, 2001.

Violence can also escalate when a state responds to terrorist activities with massive countermeasures. According to the researchers' findings, the "War on Terror" declared by U.S. President George W. Bush following the September 11 attacks, and the numerous

Photo: alamy

civilian victims of U.S. drone attacks, especially in Pakistan, have been responsible for driving many young people into the arms of terrorists.

Thus, there is reason to believe that the spiral of violence will continue and that the Islamists will carry on their struggle. The research group sees one of the main problem areas as being the unresolved issue of how terrorists captured in Syria and Iraq can be reintegrated into society. There is no functioning state in Syria, and certainly not a situation of law and order that is capable of addressing the crimes in fair trials, punishing the perpetrators, and ultimately rehabilitating them. In Iraq, too, thousands are being held in camps and the state is overwhelmed. One thing that the researchers see as particularly problematic is the fact that European states are not prepared to take back any of their own nationals who have supported ISIS. "The next generation of jihadists is growing up right there," says Michael Fürstenberg.

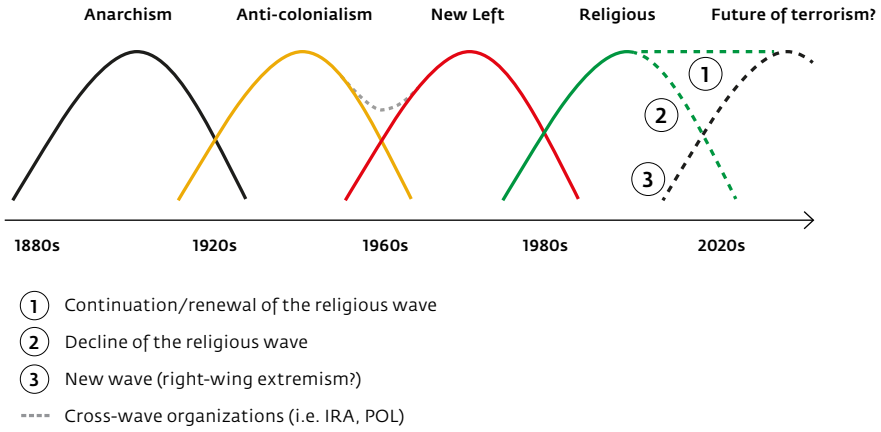
In July 2019, Carolin Görzig and Michael Fürstenberg published an article, based on a model by U.S. political scientist David Rapoport, in which they discuss how terrorism will likely develop in the future. Terrorism, according to Rapoport's model, has taken the form of four overlapping waves since 1880. The anarchist wave, which lasted until about the 1920s, was followed by an anti-colonial wave between the 1920s and 1960s. Then came the New Left wave from the 1960s to the 1990s, whilst the current, religiously motivated wave began in the early 1980s. According to Rapoport, the fact that each of these waves last around 40 years is due to a generational effect: terror waves peter out because their energy is not enough to inspire the younger generation to pursue their objectives. According to this thesis, Islamist terror should soon gradually begin to lose steam.

RIGHT-WING EXTREMISTS AS "LONE WOLVES"

Görzig notes, however: "Rapoport himself is skeptical as to whether the same rules apply to the end of the religious wave as to the ideologically motivated waves." One reason is that political developments usually contributed to the end of the previous waves. The objectives of the anarchists were at least partially realized by political upheavals in the wake of the First World War. The anti-colonial groups achieved their goals when the colonized states were given their independence. And the New Left became obsolete with the end of the Soviet Union. However, the Islamists have made little progress in achieving their objectives. "There is some evidence to suggest that the jihadist movement could succeed in maintaining the energy of the wave or transforming it into a new one," says Fürstenberg.

But both he and Görzig see another scenario as quite probable: a completely new wave of terror by right-wing extremists. There are already signs of growing violence from the right around the world, beginning with the series of attacks by the German terrorist group National Socialist Underground (NSU) between 2000 and 2007 and continuing with the attack on a synagogue in Pittsburg, U.S., in October 2018 and the terrorist attack on two mosques in Christchurch, New Zealand, in March 2019 – and, most recently, the attack in Halle.

However, in certain respects, the right-wing extremists differ substantially from the previous waves. For them,



The ebb and flow of violence: according to political scientist David Rapoport, terrorism has developed in a series of waves, each lasting some 40 years. It remains to be seen how the pattern will continue.

Graphic: Michael Fürstenberg based on Rapoport, D. C.: The four waves of modern terrorism; In: Attacking terrorism: elements of a grand strategy (Eds. Cronin, A. K.; Ludes, J. M.). Georgetown University Press, Washington, D.C. (2004)

Right at their doorstep: people bring flowers and candles to the synagogue following the right-wing extremist attack in Halle. For the researchers at the Max Planck Institute in Halle, it is a shock to suddenly be confronted with the subject of their topic so close to home.

violence is not only a means to an end, but an essential part of their ideology, says Fürstenberg: "They want to bring about a kind of civil war of whites against everybody else, a race war." The fact that many attacks are committed by lone perpetrators is also striking. In the early 1990s, the American neo-Nazi Louis Beam, a former member of the Ku Klux Klan, spread the concept of "leaderless resistance" among right-wing extremists, calling upon individual perpetrators or small groups to carry out attacks as "lone wolves".

A concept such as this is problematic for ensuring rule of law in Germany, because the legal definition of terror in this country requires a terrorist attack to be backed by an association comprising at least three people. The relevance of this definition is questionable in the Internet era, says Fürstenberg: "The traditional distinction between group and individual perpetrators cannot really be maintained, because the 'lone wolves' form part of a digital pack. Their ideological and tactical equipment is drawn from the online community."

Görzig also sees a clear connection between the increasingly aggressive language used by right-wing politicians and terrorist activities. "For example, rhetoric such as that used over and over by the AfD gives people the feeling that hostility against religious groups, migrants or political dissidents is acceptable, and in such a climate a few feel called upon to resort to violence."

The research group members are anything but happy to receive corroboration of their prognosis so quickly and almost right on their own doorstep. "We weren't trying to tempt fate with our prediction," says Görzig, "but the attack in Halle does make us think." The researchers are revisiting many ethical questions that they had already dealt with in workshops and training sessions in previous years. Are we focusing too much on the perpetrators and ignoring the victims? How much understanding can and should we show for the terrorists we are dealing with? Are we at risk of allowing ourselves to be used as propaganda tools?

However, the group does not want to simply sit by and watch as the new developments unfold. "We're planning to intensify our research into right-wing terrorism," says Görzig. Some of the group's findings on Islamist terror can be applied to right-wing extremists. Thus, insight into these patterns could perhaps also help to counteract right-wing terror. ◀

SUMMARY

- **Terrorists do not view themselves as perpetrators of violence, but instead see themselves as resisting oppression and pursuing political objectives.**
- **They see violence as a means to achieve these objectives. But violence also helps maintain the cohesion and public visibility of the group.**
- **In the past, terrorist groups have renounced violence when the leaders realized that these means were not appropriate for achieving their actual political goals.**
- **There are currently signs that a new wave of right-wing extremist terrorism is beginning.**

Photo: Hannibal Hanschke/Reuters

The observer

Following her arts degree, multi-talented **Mathilde Hertz** pursued a career in science. In the 1920s and 1930s she conducted research in the fields of animal psychology and sensory physiology at the **Kaiser Wilhelm Institute for Biology** in Berlin – until the Nazi regime put an end to her career.

TEXT **ELKE MAIER**

The hermit crab is in a hurry. It has just been expelled from its mollusc shell and is now teetering around the water basin without protection. To ward off possible predators, it needs a new shelter as quickly as possible. But which one to choose?

To learn about the criteria that crabs use to select their dwelling, Mathilde Hertz would chase the animals out of their shells and then offer them different alternatives – both natural ones and models made from plaster. She meticulously recorded her subjects' reactions.

It was the winter of 1932/33, during which the scientist spent a number of months studying hermit crabs at the Laboratorio biológico-marino in Majorca. She normally worked at the Kaiser Wilhelm Institute for Biology in Berlin-Dahlem, where she conducted research on carrion crows and jays, as well as honey bees and cabbage white butterflies. She was extremely productive and her work was published in renowned specialist journals. Nobody thought that her career would soon be over.

Extraordinarily talented: Mathilde Hertz was a visual artist and animal psychologist, and one of just a few women in Germany to qualify as professor in 1930.

Nowadays, only few people know about Mathilde Hertz, while the complete opposite is true for her father. The physicist Heinrich Hertz is famous for proving the existence of electromagnetic waves, thus paving the way for wireless communication. The frequency unit 'hertz' was named after him. His daughter, Mathilde Carmen, was born in Bonn on January 14, 1891. She was just under three years of age when her father died at only 36.

After graduating from high school, Mathilde Hertz took up art studies in Weimar, Karlsruhe and Berlin and then worked as a sculptor. Unable to live off her art alone, she accepted a job at the library of the Deutsches Museum in Munich in the fall of 1918. The zoologist and privy councilor Ludwig Döderlein, who became the Director of the Bavarian State Collection of Zoology in Munich in 1923, noticed her drawing and sculpting skills. He instructed her to help with the preparation of sculptural reconstructions of fossil sets of teeth. This was not just an opportunity for the young woman to practice her observation skills; she also developed an interest in the animals' phylogenetic history. She attended lectures in zoology and palaeontology and conducted scientific studies of prehistoric teeth. In 1925, she obtained her doctorate with her thesis *Observations of primitive mammalian teeth*. Her doctoral supervisor, the zoologist Richard von Hertwig, awarded her the top score of summa cum laude.

This was how Mathilde Hertz gained entry into the world of science. She moved on from fossil mammalian teeth to modern day echinoderms: under Döderlein's supervision, she worked on brittle stars that were discovered in the German deep-sea expedition of 1898 and 1899 and the German Antarctic expedition of 1901 to 1903.

The researcher was then granted a scholarship that took her to the Bavarian State Collection of Zoology in Munich, and she eventually moved to Berlin in 1927. The Kaiser Wilhelm Institute for Biology offered attractive working opportunities, including for women. Mathilde Hertz conducted research in the Department for Animal Genetics and Biology that was led by Richard Goldschmidt. The quality of her work was so impressive that she was not only awarded a position as an assistant, but a building was fitted out especially for her, where she was able to conduct independent experiments without any further work duties.

Inspired by the work on the problem-solving behavior of chimpanzees by the psychologist Wolfgang Köhler at the anthropoid research station in Tenerife, Mathilde Hertz began to research the area of animal psychology. She was particularly interested in the abilities and achievements of animals. Hertz believed in what was known as Gestalt psychology, according

Photo: TU Darmstadt

Busy as a bee: in hundreds of individual experiments, Mathilde Hertz observed the flight patterns of bees and the food sources that attracted them most.

to which animals and their interaction with their environment must be considered as a whole. The approach of Gestalt psychologists is based on the notion that "the whole is greater than the sum of its parts." Perception could therefore only be understood as a whole, and not by breaking it down into ever smaller units.

Mathilde Hertz made a name for herself in expert circles, especially with her comprehensive work on the visual perception of honey bees. She placed different black-and-white figurines on a table, interspaced with bowls of sugared water. In hundreds of individual experiments, she observed the flying patterns of bees, and noted down the food sources the bees were particularly attracted by. This allowed her to draw conclusions regarding the shapes and patterns to which bees respond most strongly.

In 1930, Mathilde Hertz was one of only a handful of women in Germany who obtained the qualification for professorship, for her work entitled "*The organization of the optical field of honey bees*". Assessment committee member Wolfgang Köhler praised "Miss Hertz' outstanding talent" and the relevance of her research: "Each of her projects has significantly advanced animal psychology, as well as general Gestalt psychology."

Jüdische Allgemeine (a Jewish newspaper), January 4, 2008

» The president of the Kaiser Wilhelm Society an undisputed authority figure of science in Germany, Max Planck, campaigned on her behalf. He explained that Ms Hertz should be classified as "Aryan" due to her family background, and also pointed out that the dismissal of the famous scientist's daughter would make a bad impression overseas.

She was then granted full authorization to teach zoology at universities. Between 1930 and 1933, she gave various lectures at Berlin's Friedrich Wilhelm University as a senior lecturer. She held colloquia, conducted research, and supervised staff members and doctoral researchers at the Kaiser Wilhelm Institute. Mathilde Hertz appeared to be destined for a distinguished career.

Then she received a letter from the Prussian Minister of Science, Arts and National Education, dated September 2, 1933: "To Miss Dr. Mathilde Hertz in Zehlendorf, Andréezeile 69: Pursuant to § 3 of the Law for the Restoration of the Professional Civil Service of April 7, 1933, I hereby revoke your authorization to teach at the University of Berlin." An "Expert for Race Research" had classified her as non-Aryan.

Mathilde Hertz was doubly affected, as the new civil service law also applied within the Kaiser Wilhelm Society. As a result, she was also threatened with expulsion from her research institute. Unlike at the university, however, she had a prominent advocate there. She was supported by Max Planck, the President of the Kaiser Wilhelm Society. In a letter to the Reich Minister of the Interior, he appealed for the "urgent reconsideration of the administration," pointing out that it would be "gratefully acknowledged at home and abroad, if the daughter of Heinrich Hertz, the sole discoverer of wireless waves, could continue her scientific work." Surprisingly, the answer was positive: Mathilde Hertz was permitted to stay on at the institute.

However, for her, this was only a deferral. The situation in Germany affected her so strongly that she decided to emigrate to England a year later. In January 1936, she set up her new workplace at the Researcher Department of Zoology at Cambridge University. She moved into a little terraced house on 3 St. Margaret's Road, Girton, Cambridge. Her mother and her sister, the paediatrician Johanna Hertz, who was four years older than Mathilde, followed her six months later.

The working conditions at Mathilde Hertz' new research unit were favorable, but even so, her productivity decreased rapidly. She gave up her work entirely around 1939/40 and never returned to it. It remains unclear to this day what prompted her to abandon science. Possible triggers may have been severe family problems, such as her mother's death or her sister's mental illness, as a result of which she was eventually institutionalized. In 1942, Mathilde Hertz described herself as "sick and unable to perform any scientific work, now or in the future." Her emigration, and in particular the fact that Germany and England were at war, were a cause of great sorrow to her.

Mathilde Hertz spent the following years living in impoverished circumstances: "Visiting her made me sad. The daughter of a great scientist is living in a miserable and reclusive state, and is dependent on the charity of a foreign people," a visitor wrote in 1956. He reported that the old lady was living in complete seclusion in two little rooms, and that she was almost blind in one eye. He described her as being too proud to accept any money, simply because she was Heinrich Hertz' daughter.

This prompted the physicist and Nobel Prize winner Max von Laue to step in – with success. Mathilde Hertz was granted a modest pension and a compensation, based on the fact that under other political circumstances in Germany, she would most likely have been appointed Associate Professor. Mathilde Hertz died in Cambridge at the age of 84 and was buried next to her father in the family grave in Olsdorf Cemetery in Hamburg.

She authored more than 30 scientific publications, all of which were written between 1925 and 1935. Mathilde Hertz also left her mark as an artist: the Hall of Honor of the Deutsches Museum is home to a marble bust of her father that was made based on her designs.

Photo: Damien Tupinier/Unsplash

Next generation Max Planck Center opened

Researchers from Germany and Sweden are studying the impact of human-generated environmental changes on insects

Co-directors (cd) and group leaders (gl) of the Max Planck Center "next Generation Insect Chemical Ecology" (from left to right): Silke Sachse (gl, MPI-CE, Jena), Martin Andersson (gl, Lund University), Christer Löfstedt (cd, Lund University), Rickard Ignell (cd, SLU Alnarp), Mats Sandgren (gl, SLU Uppsala), Peter Anderson (gl, SLU Alnarp), Bill Hansson (cd, MPI-CE Jena), Markus Knaden (gl, MPI-CE Jena), Sharon Hill (gl, SLU Alnarp), Susanne Erland (nGICE coordinator).

Anthropogenic changes in the environment also affect insects. The Max Planck Society, the University of Lund and the Swedish University of Agricultural Sciences now work together to study interactions between insects, the climate and humans at the new Max Planck Center "next Generation Insect Chemical Ecology". Together, they hope to find out how climate change, greenhouse gases and air pollution influence the chemical communication between insects. The collaborative center was officially launched in January.

Over the past 100 years, the influence of humans on ecosystems and the climate as a result of industrialization has become increasingly obvious. The climate is heating up, and sea levels are rising. Mass occurrences of pest insects such as the bark beetle are more frequent, and pests are spreading to ever wider areas. At the same time, there has been a drastic decline in total insect biomass everywhere in Europe. While pollinating insect species, which play an important role in our ecosystem, are threatened with extinction, diseases transmitted by insects are on the rise due to climate warming.

"As a result of climate change, entirely new challenges emerge with regard to pest and vector insects. Our new research cooperation aims to find out what impact these global changes have on insects, and why," says Bill S. Hansson, Director at the Max Planck Institute for Chemical Ecology. "Our collaboration at the Max Planck Center opens up new opportunities to systematically study the effects of environmental changes caused by humans," adds Christer Löfstedt, Professor of Biology at the University of Lund.

The scientists in the research center mainly want to examine how higher temperatures, greenhouse gases and air pollution impact the olfactory system of insects, and how insects adapt to these changes in their environment. This research could make a significant contribution towards solving global problems in the context of the climate crisis, global nutrition and combating diseases.

"Europe has been spared diseases transmitted by insects for a long time. However, in recent years, diseases such as West Nile fever and Chikungunya have spread further north. The spread of malaria and dengue fever is also facilitated by global warming. We hope that through the new cooperation at the Max Planck Center, we can develop better methods to combat these diseases," explains Rickard Ignell, Professor of Plant Protection Biology and an expert in the ecology of vector insects at the Swedish University of Agricultural Sciences.

Three research groups are involved in the Max Planck Center: the Max Planck Institute for Chemical Ecology in Jena, with its Evolutionary Neuroethology Department, the pheromone research group at the Department of Biology at the University of Lund, and the chemical ecology research group in the Department of Plant Protection Biology at the Swedish University of Agricultural Sciences.

The three organizations also benefit from each other in terms of methodology. While at Max Planck, researchers in Bill Hansson's lab are studying odor-guided behavior in insects and the underlying neurobiological substrates of odor perception, the research group at the University of Lund is well known for its research into the role of chemical signals for the communication between insects. In turn, the scientists at the Swedish University of Agricultural Sciences have excellent knowledge in the field of vector biology and are focusing particularly on the question of how the behavior of disease-spreading insects is mediated by external chemosensory cues and internal physiological processes.

All three research organizations contribute 500,000 euros each to the Center every year. Doctoral researchers and postdocs will mainly conduct research at one of the three institutions, while at the same time having access to the infrastructure and expertise of the other groups.

Photo: Mårten Svensson

Commitment to greater climate protection

Max Planck Society to focus on work-related air travel

Global warming concerns us all – the federal government's Climate Action Program 2030 states: "Climate protection is a task for society as a whole." German research organizations are also currently investigating how they can reduce their CO_2 footprint. The area under scrutiny is work-related air travel.

According to a study by ETH Zurich, 55 percent of the higher education institution's carbon dioxide emissions are generated by flights taken by its staff. In order to make work-related travel throughout the Max Planck Society more climate-friendly, the Max Planck Sustainability Network is asking staff to sign a voluntary commitment to dispense with air travel. So far, 380 staff have agreed not to use air transport for distances of less than 1,000 kilometers, provided the rail journey can be completed in less than twelve hours.

"We are delighted that so many colleagues are already involved even though we have not really publicized the campaign as yet. We hope that even more colleagues will take part and we can top one thousand signatures," says Julian David Rolfes, doctoral researcher at the MPI for Coal Research in Muelheim an der Ruhr. In mid-October, more than 1,800 employees at the higher education institutions in Berlin responded to a similar call by the Scientists for Future movement.

However, not every symposium can be reached by rail, and not every trip can be replaced by a video conference. For this reason, the Sustainability Network has issued a position paper on compensating for carbon dioxide emissions. In it, the authors describe the advantages and disadvantages of various ways of counteracting the harmful effects of the carbon dioxide emitted during work-related trips.

Photo: Samuel P. / Unsplash

Trains instead of planes: the Max Planck Sustainability Network is calling for climate-friendly business trips.

The most widely used carbon dioxide compensation concept currently involves the payment of credits to non-governmental organizations, which then use the money to pay for measures to offset the emissions. These organizations carry out evaluations of the climate protection projects they fund and are themselves certified by independent national and international institutions. Alternatively, the funds can be used to sponsor internal measures for reducing carbon dioxide.

According to the position paper, the concept most suitable for the Max Planck Society should be investigated carefully. Until then, the authors recommend cooperating with the non-governmental organizations and imposing a levy on work-related trips depending on the means of transport used. The position paper is supported by the Chairman of the Scientific Council, Tobias Bonhoeffer of the MPI of Neurobiology in Martinsried: "It would show the Max Planck Society in a positive light if we were to take on a pioneering role when it comes to sustainability. This topic will therefore be on the agenda for the Scientific Council's next meeting in February 2020."

However, most research organizations are currently unable to compensate for the CO_2 emitted during work-related trips; as yet, there are no regulations that apply to all employees in the Civil Service. In its strategy paper on climate protection, the Max Planck Society therefore says that it is in favor of asking the Joint Science Conference (GWK) for legal clarity. This initiative is expressly supported by Max Planck Secretary General Rüdiger Willems: "The key strategies for work-related travel should be avoidance, reduction – and if these are not possible, compensation. For this, we urgently need legal certainty."

Call for personal commitment to climate-friendly work-related travel at
https://t1p.de/mpg-selbstverpflichtung (in German)

Email address for signatures
kurzflugverzicht@lists.mpg.de

New PhDnet steering group ready to start

The doctoral researchers used the three-day conference to engage in exhaustive discussions of what happened in 2019 and what 2020 has in store

Looking forward to new challenges: the freshly elected members of the PHDnet steering group.

"I'm looking forward to another year with the steering group during which we will intensify our dialog with Administrative Headquarters and enhance the experiences of junior scientists within the Max Planck Society," emphasized the newly elected spokesperson for 2020, Lindsey Bultema of the MPI for the Structure and Dynamics of Matter (photo above: 3rd from right). In 2020, special attention will once again be paid to equal opportunity, communication and open science. There is still a lot to do in all of these areas. "One of the things I appreciate about the General Meeting and our work for PhDnet is that we are constantly called upon to deal with new and previously unfamiliar topics, for example with regard to the problems experienced by international doctoral researchers," added Nikki van Teijlingen Bakker of the MPI of Immunobiology and Epigenetics (3rd from left), who is the BM section's new representative for 2020.

The other members of the new steering group are Simon Hofmann (HSS, MPI for Human Cognitive and Brain Sciences, left), Sarah Young (CPT, MPI of Colloids and Interfaces, 2nd from left), Cornelia van Scherpenberg (Deputy Spokesperson, MPI for Human Cognitive and Brain Sciences, 2nd from right) and Julia van Beesel (General Secretary, MPI for Evolutionary Anthropology, left). In January 2020, they will take over from their predecessors chaired by spokesperson Alexander Filippi of the MPI for Chemistry.

The Annual General Meeting of PhDnet took place from November 4–6 on the Max Planck Society's Fassberg campus in Goettingen. Representatives of all the Max Planck Institutes took advantage of the three-day conference to engage in intensive dialog, discuss the work carried out in 2019, set goals for 2020 and form new working groups.

Welcome to the Planck Academy

As of February 2020, the Max Planck Society offers all employees Max Planck-wide, target-group-specific opportunities for further training and personal career development. Whether special welcome and support offers for managers, coaching for Directors or postdocs, professional and personal career development for early career researchers or advanced training opportunities for science managers, the Planck Academy bundles all these offers under one roof. Its portfolio will be gradually expanded over the coming months.

Access is easy and user-friendly. Various learning, development and network formats are used, as are presence and online formats, coaching, mentoring and self-reflection tools. In the Planck Academy, presence formats are linked with virtual offerings, for example with e-learning modules, how-to videos or webinars. The basis for this is the Learning Management System (LMS).

Photo: Maria Eichel / MPG (top)

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

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- Nijmegen

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- Rome
- Florence

USA
- Jupiter, Florida

Brazil
- Manaus

Luxembourg
- Luxembourg

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