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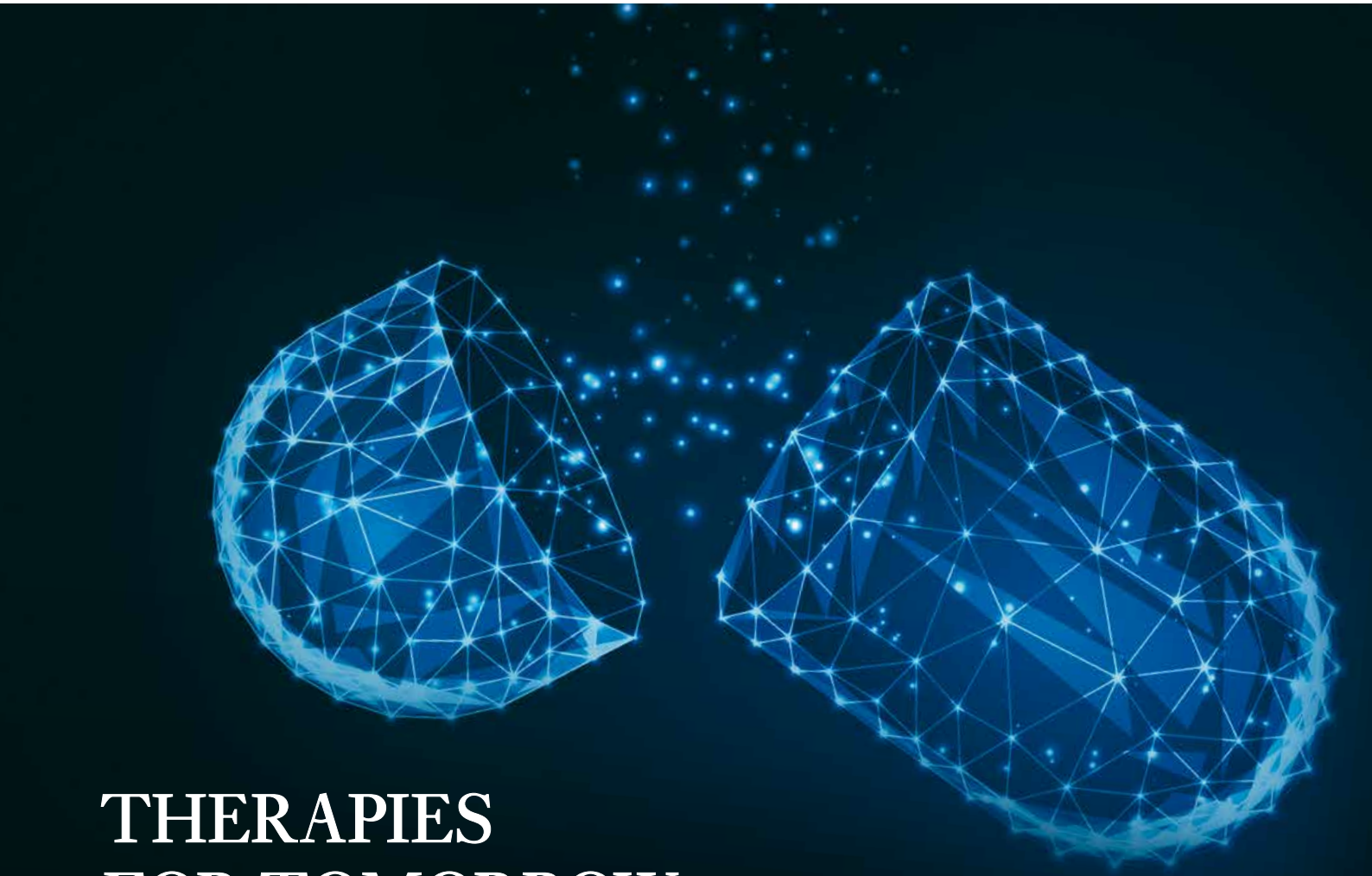

THERAPIES FOR TOMORROW

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EDITORIAL

Dear Reader,

Artificial intelligence will bring about fundamental changes to many aspects of social coexistence, social cohesion, and the economy, including the field of medicine. Consequently, AI forms a central part of the Focus section of this edition: “Therapies of Tomorrow.” But as the field of medicine makes particularly clear, just as this technology brings opportunities, it also presents challenges. Namely, when algorithms take on tasks that were previously carried out by humans. With the right training they can, in some cases, make a diagnosis more reliably than many doctors and also assist with treatment. But who is liable if mistakes are made? And can AI demonstrate the empathy that is expected of medical professionals? These issues also play a role when it comes to using chatbots to treat mental health conditions, particularly when psychotherapists are unavailable. Researchers at various Max Planck Institutes are working on this and developing relevant apps.

AI is also a great help when it comes to the development of new medicines. Researchers at the Max Planck Institute for Terrestrial Microbiology use it to search for new antibiotics, for example. They hope to produce promising substances using biochemical reactions based on the metabolic pathways of microorganisms.

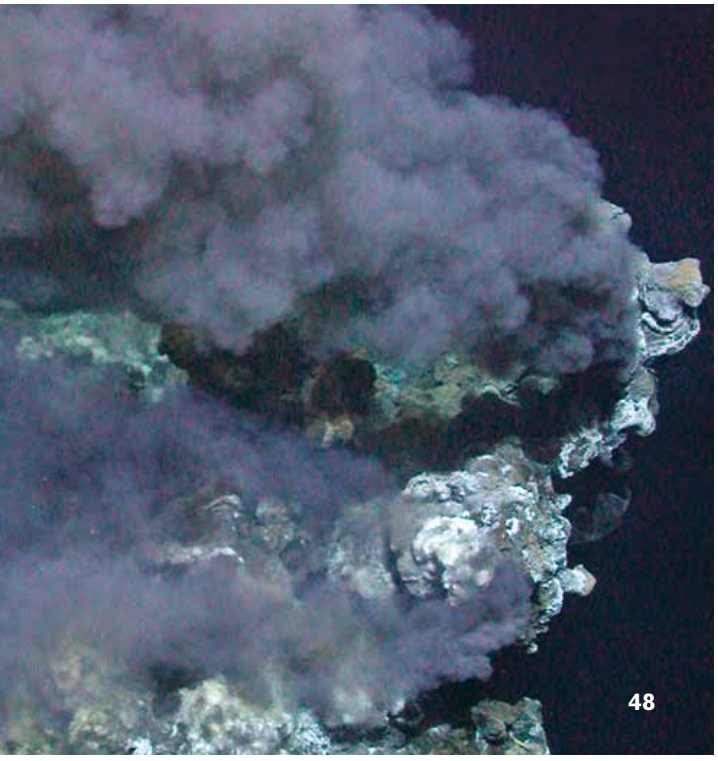
That said, it’s important to remember that medical progress is still possible even without AI. This is the focus of work carried out by a group at the Max Planck Institute for Dynamics and Self-Organization. The team has investigated the electromechanical causes of cardiac arrhythmias and, based on these findings, has developed a treatment method that is a lot gentler than the extremely painful electric shocks delivered by a conventional defibrillator.

The developments we describe in this issue are a testament to continued progress within the field of medicine. The fact that healthcare is constantly improving is sometimes overlooked in the debate about the healthcare system, where the focus is often on costs.

We hope you enjoy reading this issue!

Your Editorial Team

PHOTO COVER: INKOLY/ISTOCK PHOTO



IMAGES: KATRIN BINNER (TOP LEFT), MIA COLLIS FOR THE MPG (TOP RIGHT), GETTYIMAGES / UNIVERSAL HISTORY ARCHIVE (BOTTOM LEFT), PICTURE ALLIANCE/DPA | ANTONIO COSSIO (BOTTOM RIGHT)

34 | *CULTIVATED*

Microorganisms are being harnessed to produce new antibiotics.

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Mercy Akinyi aims to understand how health, the environment, and culture are interconnected.

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Life may have originated in black smokers in the deep sea.

60 | *ACCUMULATED*

Millions of metric tons of clothing are thrown away every year – and often end up in the Global South.

CONTENTS

RED-LIGHT DISTRICT,
AMSTERDAM

ON LOCATION

PHOTO: SJORS SWIERSTRA

A man at the bar, a camera, and a video monitor. Is a movie being shot here? Maybe it's a crime thriller. After all, the dimly lit bar is in Amsterdam's red-light district. Trouble's about to break out, because the film crew is looking to capture how crude jeering escalates into a fight. But the actors aren't doing a scene for an episode of Law and Order; they're here on behalf of the Max Planck Institute for the Study of Crime, Security and Law in Freiburg.

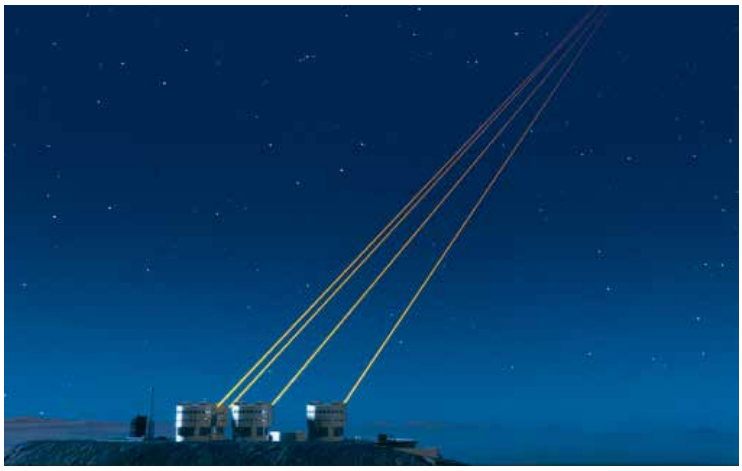
Researchers from the Department of Criminology are also on site. At the Institute's MaxLab, researchers use this footage to study how people behave in violent situations like a brawl – and how they make decisions in the heat of the moment. To do this, participants at the MaxLab in Freiburg put on a VR headset that immerses them in the situation. That means the film sequence has to be recorded using a special technique to create a 360-degree shot; the screen in the foreground shows this.

Alongside smaller booths, MaxLab also has a large room where several people can interact in virtual reality at the same time. The researchers measure their reactions using eye-tracking, physiological measurements, biometric data, and surveys conducted in virtual reality. The research focuses in particular on the effects of anger and sexual arousal on aggression, as well as the behavior of bystanders. The findings could potentially improve police training and assist in the development of new security strategies.

CLEAR SKIES FOR TELESCOPES

Research at the European Southern Observatory's Paranal Observatory in Chile will be able to continue uncompromised. The energy provider AES Andes had planned to build a green ammonia and hydrogen production facility just a few kilometers from the observatory, but the facility will not be built there after all. The company is searching for an alternative site. This reversal was driven by protests, which came primarily from astronomers and science organizations around the world. The industrial complex threatened to disrupt telescope observations through microvibrations and an increase in light pollution of up to 35 percent. ***www.mpg.de/25819822***

IMAGE: A. BERDEU/ESO



The four telescopes of the Very Large Telescope Interferometer use lasers to create an artificial star in the sky, which is used to correct for atmospheric turbulence.

AI BOOST FOR RESEARCH

Most researchers at the Max Planck Society and the Fraunhofer-Gesellschaft expect AI to have a major impact on their field, and many are already using AI tools. In a survey of more than 6000 researchers, nearly 70 percent expressed confidence that AI will change or even revolutionize their field within the next ten years. In addition, 25.9 percent reported using AI daily. Some 44.0 percent said they had used the systems a few times or more, and only 22.2 percent had never used them at all. Around half of the respondents use AI to speed up their work, primarily to test ideas, write program code, or draft text. The survey also shows that specific skills are required to formulate effective prompts – that is, instructions for the AI. In a test task, only about one in five participants succeeded in formulating prompts that resulted in the AI solving the task.

OUTSTANDING ✶

KLAUS BLAUM

PHOTO: STEFANIE AUMILLER

The director of the Max Planck Institute for Nuclear Physics in Heidelberg is to receive one of the Gottfried Wilhelm Leibniz Prizes, each carrying an endowment of EUR 2.5 million. Blaum's experimental research measures fundamental physical constants with greater precision, seeks a deeper understanding of the forces of nature, and tests the Standard Model of particle physics. Among other things, he studies the differences between matter and antimatter.

CHRISTIAN DOELLER

PHOTO: STEFFEN ROTH

The psychologist and Director at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig is to receive a Leibniz Prize for his work on how humans navigate and orient themselves in space. In this research, he also demonstrated that spatial relationships are re-encoded into abstract categories, thereby forming the neural basis for logical thinking, reasoning, and decision-making.

JOHANNES KRAUSE

PHOTO: THOMAS VICTOR

The Director at the Max Planck Institute for Evolutionary Anthropology in Leipzig is likewise to receive a Leibniz Prize, in this case awarded for his paleogenetic studies. Krause's studies contribute to reconstructing the history of both prehistoric and historic human settlement across multiple continents, and offer insights into how infectious diseases such as the plague have accompanied humanity throughout history.

IN BRIEF

PHOTO: OVO LABS

The people behind Ovo Labs: Oleksandr Yagensky, Agata Zielinska, and Melina Schuh (from left).

MAX PLANCK STARTUP AWARD FOR OVO LABS

A total of 14 start-ups were founded out of the Max Planck Society in 2025 – almost twice as many as in the previous year. One of these, Ovo Labs, is now being recognized by the Stifterverband (Donors' Association) with the Max Planck Startup Award. The spin-off from the Max Planck Institute for Multidisciplinary Sciences in Göttingen aims to use targeted therapeutics to reduce the errors that occur with increasing frequency in egg cell development with advancing age. In doing so, the company seeks to improve the odds of successful assisted reproduction. This approach is especially relevant now that couples are looking to have children increasingly later in life, often through assisted reproduction. Egg quality declines with age, however, which means that only about 30 percent of assisted reproductions result in a birth. The Stifterverband's Max Planck Startup Award is presented every two years to start-ups with particular societal relevance and is endowed with EUR 30,000.

www.mpg.de/26166244

EXPERTISE FOR EPIC GAMES

Meshcapade, a Max Planck start-up based in Cyber Valley in Tübingen, is being acquired by Epic Games, the US game developer behind the Unreal Engine, one of the world's leading software platforms for 3D development. Meshcapade is a spin-off from the Max Planck Institute for Intelligent Systems in Tübingen and develops technologies that enable the realistic creation and animation of digital humans. As part of the acquisition, Epic Games will establish a presence in Cyber Valley. The Meshcapade team is joining the company's AI research division. Going forward, they will co-develop technologies for the Unreal Engine as well as for MetaHuman, a software platform designed specifically for creating digital humans.

www.mpg.de/26082348

PHOTO: MPI FOR BIOLOGICAL INTELLIGENCE / GUADALUPE LOPEZ-NAVA

Scopoli's shearwater in a rock crevice. Widespread pollutants such as mercury and forever chemicals impair the birds' energy reserves.

ENERGY GUZZLERS

Alongside global warming, overfishing, and plastic pollution, pollutants such as mercury and per- and polyfluoroalkyl substances (PFAS) also threaten marine life. Because mercury bioaccumulates in marine animals, apex predators such as seabirds are often heavily contaminated. PFAS, found in non-stick coatings, resist breakdown in nature, which is why these substances are also known as "forever chemicals." New research now shows that mercury and forever chemicals can disrupt the cellular energy production of Scopoli's shearwaters. Researchers at the Max Planck Institute for Biological Intelligence in Seewiesen have measured elevated levels of pollutants in these seabirds and found that mercury makes the membranes of the energy-producing mitochondria in their cells more permeable. This means the cells experience energy loss – similar to a hydroelectric power plant where water flows past the turbines. High concentrations of persistent organic pollutants, in turn, block a protective mechanism against the accumulation of harmful molecules in the mitochondria, thereby hindering the cells' energy supply. Seabirds have a particularly energy-intensive lifestyle, so these toxins could affect their chances of survival.

www.mpg.de/25968037/0107

FEELING IT IN YOUR SKIN

Why do some people get goosebumps from music, poetry, or art, while others don't? A study by the Max Planck Institute for Psycholinguistics in Nijmegen shows that genes also play a role here. Aesthetic chills – that is, the goosebump moments you might experience in response to art – are particularly suitable for research because they link subjective feelings with clearly measurable physical reactions. Researchers are therefore using them as a model to investigate emotional reactions to art. For the study, the team analyzed genetic data and information on emotional responses to cultural experiences from more than 15,500 participants. According to the findings, about 30 percent of the differences in the experience of such aesthetic chills can be attributed to genetic factors. Some of the genetic variants affect the experience of music as well as poetry and visual art, and these are associated with well-known personality traits such as openness to new experiences, part of which is how a person generally responds to art. ***www.mpg.de/260101de***

A SILENT MAJORITY

The comment sections of online media, discussion platforms, and social media rarely reflect actual public opinion. More often than not, a small number of highly active voices dominate the debate, while the majority simply lurks. A team led by the Max Planck Institute for Human Development in Berlin conducted an experiment to examine the communication behavior of more than 500 participants in the US on the discussion platform Reddit, covering 20 political topics. To do so, the researchers analyzed nearly 70,000 comments, and also surveyed the participants directly. The results show that people who perceive a discussion as disrespectful or highly polarized participate in it less often, whereas those who engage do so all the more frequently. A heated debate, it seems, provides additional motivation for an active minority (power users). The study also suggests that platform operators can encourage lurkers to participate by offering positive incentives for a first contribution, as well as for particularly high-quality posts. A cap on comments and consistently enforced community guidelines could also help to make the actual landscape of public opinion on a platform more visible.

www.mpg.de/25857449

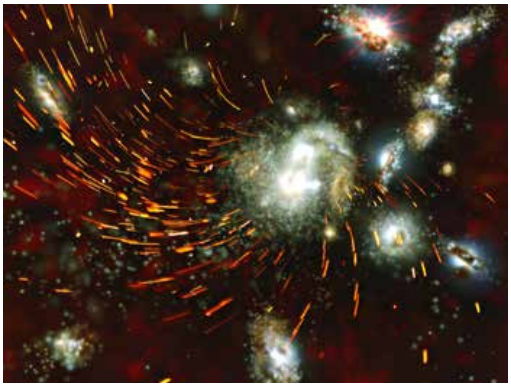


IMAGE: N. SULZENAUER, MPIFR

Young and dynamic: galaxies in a young galaxy cluster are subject to constant motion and mixing. At the center of the cluster SPT2349-56, a new star is born every 40 minutes in something like a cosmic firework display, while in the Milky Way only three or four stars are formed each year.

BIRTHING GROUND FOR MASSIVE GALAXIES

Not long after the Big Bang, there were already advanced and massive galaxies – and at their center, black holes whose masses ranged from millions to billions of solar masses. How these galaxies could have been so massive so early on remains unclear. In search of answers, a team led by the Max Planck Institute for Radio Astronomy in Bonn used the Alma radio telescope network in Chile to peer into the depths of space, and thus far into the past. In doing so, they were able to observe a galaxy cluster named SPT2349-56, located about 12.6 billion light-years away, as it existed 1.4 billion years after the Big Bang. Within the galaxy cluster, astronomers observed about 40 galaxies coming very close to one another in a galactic dance. The data shows that the dense core of the still-young galaxy cluster is rapidly collapsing. In less than 300 million years, most of the cluster's 40 galaxies will merge with one another, giving rise to a single, massive elliptical galaxy.

www.mpg.de/26119786

Katherine Kuchenbecker (left) and Andrew Schulz use an enlarged artificial replica of an elephant's tactile hair to demonstrate that its stiff base (dark green) and soft tip (white) enhance the sense of touch.

PHOTO: MPI-IS/W. SCHEIBLE

AN ELEPHANT'S TOUCH

Elephants have thick skin and a hefty trunk. Yet they can even pick up an object as fragile as a tortilla chip without breaking it. A research team led by the Max Planck Institute for Intelligent Systems in Stuttgart, which also includes researchers from Humboldt University in Berlin and the University of Stuttgart, has discovered why. About 1000 hairs distributed across the entire trunk give elephants an extraordinary sense of touch. As micro-computed tomography analyses show, these hairs have a stiff base and become more flexible toward the tip. Simulations show that these material properties make it easier to sense where something is touching the hair, and this is confirmed by experiments using an enlarged, artificially replicated hair produced by a 3D printer. The findings are now set to be incorporated into innovative tactile systems for robots. ***www.mpg.de/26113474***

THE LAST COMMON ANCESTOR

The coastal strip between Rabat and Casablanca in Morocco is known for its extraordinary cave systems and the bones of early human ancestors preserved within them. The dating of the finds, however, had long been uncertain. An international team, including researchers from the Max Planck Institute for Evolutionary Anthropology in Leipzig, has now succeeded in very precisely dating bones and teeth from the region to around 770,000 years ago. This means the remains date from the time when the evolutionary line of modern humans diverged from the line that led to Neanderthals and Denisovans. Anatomical examinations of the teeth have revealed that they differ both from those of the species *Homo erectus*, which existed even earlier, and from those of *Homo sapiens*, Neanderthals, and Denisovans. Researchers therefore suspect that the finds from Morocco belong to the last common ancestor of the three human species that came later. The oldest finds of modern humans are around 300,000 years old and also come from present-day Morocco.

www.mpg.de/25951868

A lower jaw fragment from the last common ancestor of *Homo sapiens*, Neanderthals, and Denisovans, found in Morocco.

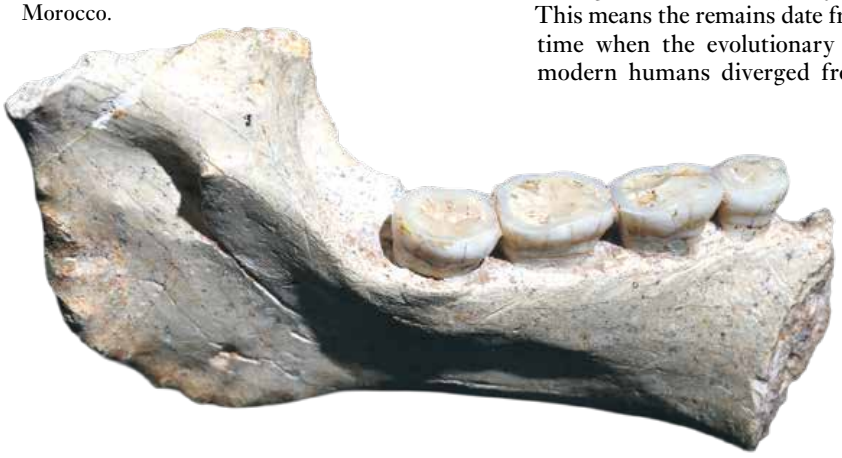


PHOTO: HAMZA MEHIMDATE, PROGRAMME PRÉHISTOIRE DE CASABLANCA

MOTIVATIONS FOR CLIMATE ACTION

Role models don't inspire people to do more for the climate. That is one finding from a study conducted by the Max Planck Institute for Tax Law and Public Finance in Munich. With the help of 3325 participants, the team examined why people donated all or part of their winnings from a dice game to the protection and rewetting of peatlands. The donation amount was then increased by either 20 or 50 percent depending on whether participants chose to make their contribution visible to others – an additional decision left to them. Visible engagement, however, came with the lower increase, and was further differentiated into two conditions: one in which participants could aspire to serve as a role model – in this part of the study, other participants then saw this decision before making their own; and another in which visible but less effective engagement could serve merely to project a green image, specifically when it was chosen after the other participants had already made their decisions. The result was that 67 percent chose the option with the higher increase when visibility was purely a matter of image. Meanwhile, 60 percent preferred the higher increase that came with invisible engagement in scenarios where they believed that acting visibly would allow them to serve as a role model. Yet the analysis of individual participant decisions made after seeing other participants' visible engagement shows: supposed role models have no influence whatsoever on whether and to what extent other people engage.

www.mpg.de/26037619

ARTIFICIAL CONSENSUS

A language model on its own has no malicious intent, but it can be misused to influence people. One example of such misuse is AI swarms: large networks of autonomous, AI-controlled agents. These could imitate human users on social networks, performing as eloquently as the language models that power them. And if a swarm of such agents were to spread false information in a coordinated manner, they could create the impression of a seemingly broad public consensus on a specific issue. In an article published in the journal Science, the authors – including Meeyoung Cha from the Max Planck Institute for Security and Privacy in Bochum – warn that the illusion of "everyone says so" could endanger democracy. This proved particularly problematic during the Covid pandemic, where misinformation spread across borders just as quickly as the virus itself. AI swarms could fuel this dynamic even further. To counteract this, the researchers propose not only moderating individual posts but also identifying coordinated patterns of behavior.

www.mpg.de/26044163

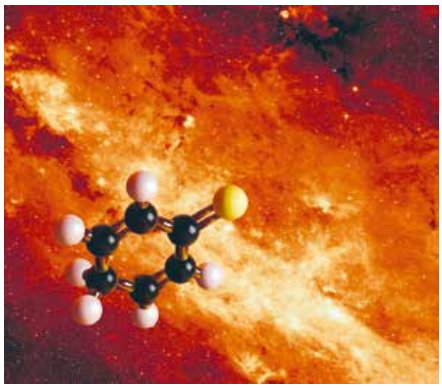


IMAGE: MPE/NASA/JPL-CALTECH

A sulfur-containing six-membered ring molecule has been discovered for the first time in an interstellar cloud in the Milky Way.

SULFUR FROM SPACE

Molecular building blocks that fell to Earth from space via meteorites may have given life an extra boost when it first emerged here around 4 billion years ago. A team that included researchers from the Max Planck Institute for Extraterrestrial Physics in Garching has now provided further evidence for this hypothesis. In a molecular cloud in the Milky Way located approximately 27,000 light-years away, they discovered 2,5-cyclohexadien-1-thione (C_6H_6S), the largest sulfur-containing molecule found in interstellar space to date. The researchers identified the molecule using the Iram and Yebes radio telescopes in Spain based on its characteristic fingerprint in the radio spectrum. The substance resembles compounds that have previously been detected in comets.

www.mpg.de/26040668

ODOR-BLIND

The global decline in insect populations may be due not only to the use of pesticides and habitat loss, but also to air pollution caused by ozone and nitric oxides. According to researchers at the Max Planck Institute for Chemical Ecology in Jena, elevated ozone concentrations destroy the odor compounds that male fruit flies use to recognize females, meaning they can no longer distinguish between females and males. It has now been discovered that ozone also breaks down the substances that ants use to recognize their nestmates: the researchers exposed individual ants to an ozone concentration commonly measured in polluted regions during the summer and then returned them to their nest. There, the ants were met with threats and aggression, even though they belonged to the same colony. Further observations revealed that adult ants in ozone-polluted colonies keep a greater distance from their larvae than in ozone-free ambient air. Under such conditions many larvae die, possibly because the adult ants neglected brood care. Since other social insects, such as bees and bumblebees, likewise communicate via pheromones that can be destroyed by oxidizing substances like ozone and nitric oxides, it is likely that they also suffer tremendously from such airborne pollutants.

www.mpg.de/26073819

IMAGE: MARKUS KNADEN, MPI FOR CHEMICAL ECOLOGY

A worker of the harvester ant species *Messor barbarus*. In the background is a gas chromatograph, which researchers use to analyze the odorous substances on the ants' body surfaces.

QUO VADIS, BAFÖG?

The number of Bafög recipients is at its lowest level in 25 years. Yet, many young people are eligible for this financial aid. Economist Sebastian Riedmiller is studying what deters students from applying. One insight: targeted information could help to ensure greater educational equity.

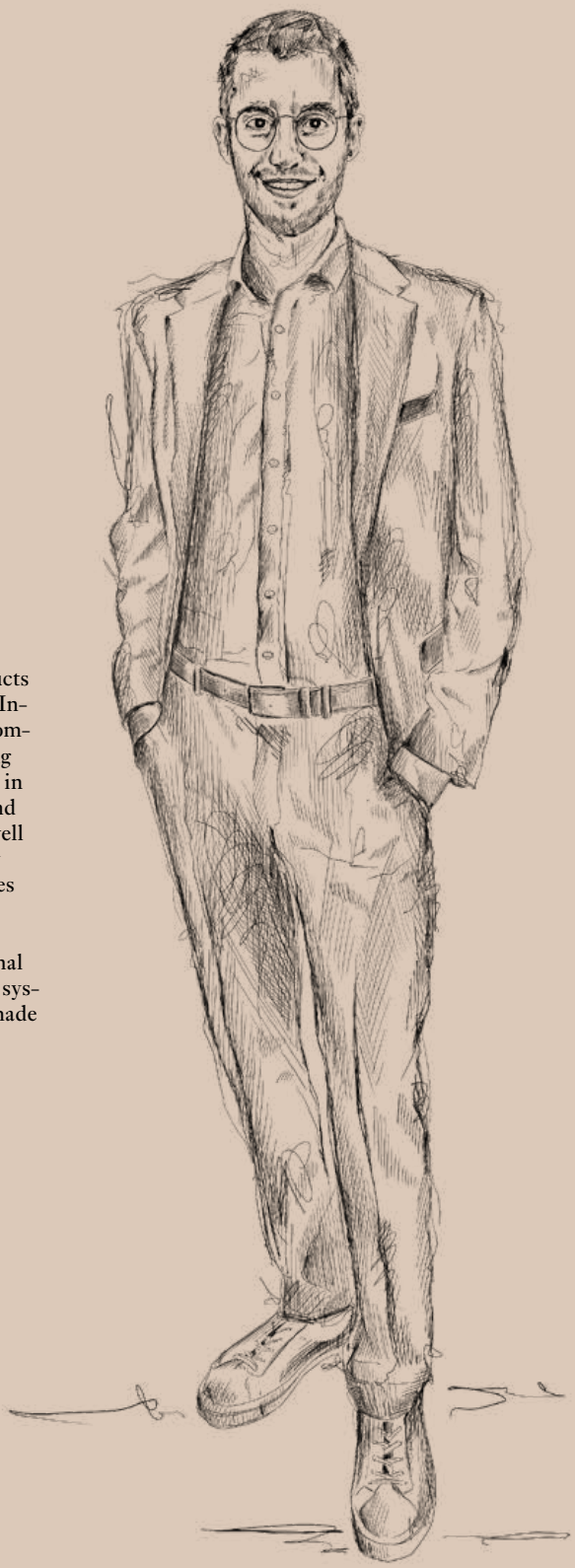
In Germany, education is regarded as a key driver of social mobility and equal opportunity. It should be possible to complete vocational training or obtain a university degree regardless of family background – at least in theory. That is precisely why the Federal Training Assistance Act – known as Bafög for short – was created. Hardly any other educational legislation in Germany is discussed as regularly and controversially as Bafög. Every two years, the German government publishes a report documenting the latest developments of this financial aid for students.

The 24th report, published in December 2025, made the situation abundantly clear: increasingly fewer young people are receiving student aid. The number of Bafög recipients is at its lowest level since 2000. Reforms enacted in recent years have in fact raised the upper income and asset caps, as well as other allowances on several occasions, thereby expanding the pool of eligible applicants. Unfortunately, these measures have failed to result in higher numbers of aid recipients. This raises the question: why do so many eligible students fail to apply for Bafög?

Until recently, there was no data on this in Germany. While previous studies and surveys have highlighted key reasons for the lack of applications, they have not distinguished between students eligible for Bafög and →

VIEW POINT

SEBASTIAN RIEDMILLER



Sebastian Riedmiller conducts research at the Max Planck Institute for Behavioral Economics in Bonn on issues relating to applied microeconomics, in particular on educational and labor market decisions, as well as on evidence-based policy design. His research includes investigating how a lack of information and financial barriers influence educational decisions, and how funding systems such as Bafög can be made more effective.

ILLUSTRATION: SOPHIE KETTERER FOR MPG

those who are not. Together with Sascha Strobl from the Fraunhofer Institute for Applied Information Technology (FIT), I examined this question in a study involving around 22,000 students from across Germany.

We asked the participants questions about their current financial situation and family background. Using this information, we were able to identify which students were eligible for Bafög but do not apply for it. We also recorded the reasons why students do not apply for Bafög, whether they believe they are eligible, and how they view the Bafög eligibility criteria – the income caps for parents, level of financial aid, and repayment terms.

Our findings are clear: up to 70 percent of students eligible for Bafög do not apply. The biggest hurdle is that students are completely unaware of their eligibility to receive financial aid. More than 80 percent of the students we identified as eligible mistakenly assumed, based on their personal and family circumstances, that they would not receive financial aid if they were to apply. If they were to apply, they could in fact receive around EUR 500 a month on average.

70 PERCENT OF ELIGIBLE STUDENTS DO NOT APPLY FOR BAFÖG

One of the main reasons students do not apply is the assumption that their parents' income is too high for them to be eligible for support. This is because most people massively underestimate the income caps for parents when it comes to receiving Bafög.

These misjudgments are not a marginal phenomenon: our survey revealed that almost all students have at least one misconception about Bafög – and often several. It is a particularly common misconception that Bafög is intended solely for families with very low incomes. This perception is based on past practice, but no longer reflects the current legal situation. In fact, many students from middle-class backgrounds are also eligible for financial aid. For students with a sibling, the parental income cap for Bafög eligibility is around EUR 120,000 gross per year; EUR 500 in support is available where the parents' combined income is around EUR 85,000.

The general lack of knowledge regarding this topic points to a structural information problem: many students simply do not realize at what level of parental income they are no longer eligible for Bafög.

On the other hand, around one in eight eligible students do not apply for Bafög, even though they are aware that they are entitled to it. The main reason for this is that they do not want to take on debt. However, many of

these students are unaware that only half of the funds, up to a maximum of EUR 10,010, needs to be repaid. So, they are overestimating the potential debt burden they would face.

The application process itself is also off-putting. Although the digitalization – and simplification – of the Bafög application process is ongoing, many students still find it too time-consuming and complex.

Ideally, young people and their parents would be informed in their final year of school that they are eligible for Bafög based on their income – simply via their tax assessment or pay slip. Admittedly, this would not be easy to implement, as the Bafög calculation would have to be carried out directly by the relevant tax authority, taking the family situation into account.

One way to simplify the application process would be to allow tax and income information held by the tax authorities to be shared with the Bafög offices, with the applicants' consent, so that students would only need to provide a small amount of supporting documentation themselves. However, this alternative would not solve the problem of applications not being submitted due to a lack of awareness regarding personal eligibility.

Another finding from our study illustrates just how significant this problem is. We asked students who do not receive financial aid how much it would need to be, at the very least, for them to apply. For two-thirds of the about 6200 respondents, this amount was less than what they were actually entitled to. It is likely, therefore, that some of these students would go to the trouble of submitting an application if they were better informed about their entitlement.

THERE ARE WAYS TO SIMPLIFY THE APPLICATION

This is precisely what we tested in the study with an intervention: at the end of the survey, half of the students not currently receiving financial aid were provided with information on the general Bafög eligibility criteria – namely the income thresholds for parents, the amount of aid available, and repayment conditions – as well as a personalized estimate of their expected Bafög entitlement. Compared with the other half, who did not receive any additional information, this intervention resulted in significantly more students receiving Bafög a year later. The increase in uptake can be directly attributed to a reduction in misconceptions regarding Bafög in general and regarding personal eligibility. One finding is particularly encouraging from a social policy perspective: it was mainly students from disadvantaged back-

→

grounds who responded to the intervention and submitted an application.

The findings of our study show that the political debate must not focus solely on higher allowances, supplements, and the amount of aid available – but must also address another issue: how can we bridge the information gap that prevents many eligible students from applying for Bafög?

One step in the right direction has already been taken. The 2026 federal budget allocates EUR 500,000 for a Bafög chatbot. It is precisely this AI-based chatbot that is currently being developed at Fraunhofer FIT and scientifically evaluated in collaboration with the Max Planck Institute for Behavioral Economics in Bonn. The aim of such a chatbot is clear: young people should be given the opportunity to find out about Bafög in an accessible and user-friendly way, without having to piece together bits of information from various sources themselves. In addition, the chatbot would allow people to calculate their own Bafög entitlement directly. Checking the applications for completeness could be the next step: as a result, the chatbot would not only help to reduce misconceptions regarding the Bafög eligibility criteria and personal entitlement, but would also make the application and processing procedures more efficient.

Many students have to wait a long time for their Bafög decision after submitting their application. According to the participants in our study, only one in two Bafög applications was processed within three months. If additional documents then need to be submitted, the final decision is further delayed – a period of time that young people will have to find ways to bridge. The Bafög chatbot can offer assistance here: it can help ease the burden on the system by ensuring that more complete applications are submitted, thereby reducing the workload for overburdened Bafög offices.

THERE ARE HIGH HOPES FOR THE BAFÖG CHATBOT

Despite all the talk about its problems, we mustn't forget the good news: Bafög works. Our study shows that students' income changes following a positive Bafög decision. Overall, they have more money to spend each month than before, even though the financial support they receive from their parents decreases. This, in particular, highlights a little-discussed, yet immensely important aspect of Bafög. Ultimately, it is not only the students themselves who pay for their living expenses, but also their parents. If, as our study shows, receiving Bafög also takes the financial strain off parents, the state benefits twice over. More people can afford to go to university

without significantly affecting their parents' purchasing power. So, Bafög serves its purpose and helps to promote greater social equity.

However, politicians must not become complacent. Data from recent years shows that around a third of students are at risk of poverty. In addition, the housing market remains tight, particularly in major cities. To ensure that students can continue to study independently of their parents, the Bafög system must also be further expanded and adapted to the current study environment, for example, by linking the basic allowance to the cost of living and the flat-rate rent allowance to local rent indices. However, the allocation for Bafög has been cut by almost 20 percent in this year's national budget. It is important that politicians do not view Bafög merely as an item of expenditure in the federal budget, but also recognize it as an investment in the future. Higher educational qualifications generally lead to higher incomes and, consequently, to higher tax revenues for the state. This makes it all the more important that as many eligible students as possible take advantage of Bafög.

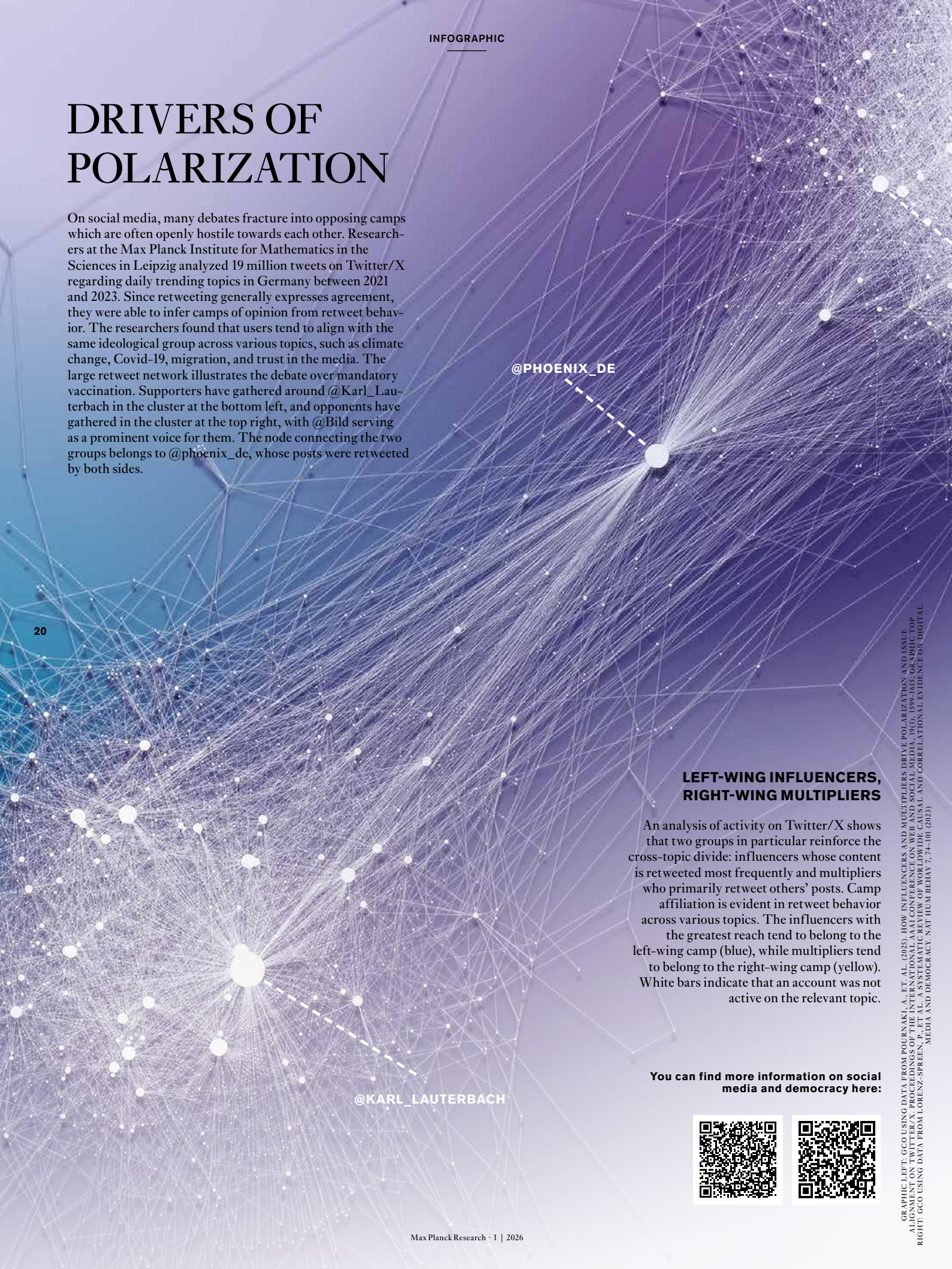
ONE THIRD OF STUDENTS ARE AT RISK OF POVERTY

If extrapolated to the whole of Germany, the increase in take-up that we have achieved would result in an additional EUR 180 million in Bafög payments each year – a sum that would be recouped in the long term through increased tax revenue. The Bafög chatbot could potentially offer even greater benefits.

At the end of the discussion, one simple but fundamental question remains: do we want Germany to continue to have a higher education system that is open to everyone who is capable of studying – or only to those who can afford to do so? There can be only one answer when it comes to educational equity in Germany. And this cannot be achieved without improving the Bafög system and ensuring information about it is easily accessible, so that it also reaches the many people who do not apply despite their eligibility.

DRIVERS OF POLARIZATION

On social media, many debates fracture into opposing camps which are often openly hostile towards each other. Researchers at the Max Planck Institute for Mathematics in the Sciences in Leipzig analyzed 19 million tweets on Twitter/X regarding daily trending topics in Germany between 2021 and 2023. Since retweeting generally expresses agreement, they were able to infer camps of opinion from retweet behavior. The researchers found that users tend to align with the same ideological group across various topics, such as climate change, Covid-19, migration, and trust in the media. The large retweet network illustrates the debate over mandatory vaccination. Supporters have gathered around @Karl_Lauterbach in the cluster at the bottom left, and opponents have gathered in the cluster at the top right, with @Bild serving as a prominent voice for them. The node connecting the two groups belongs to @phoenix_de, whose posts were retweeted by both sides.



LEFT-WING INFLUENCERS, RIGHT-WING MULTIPLIERS

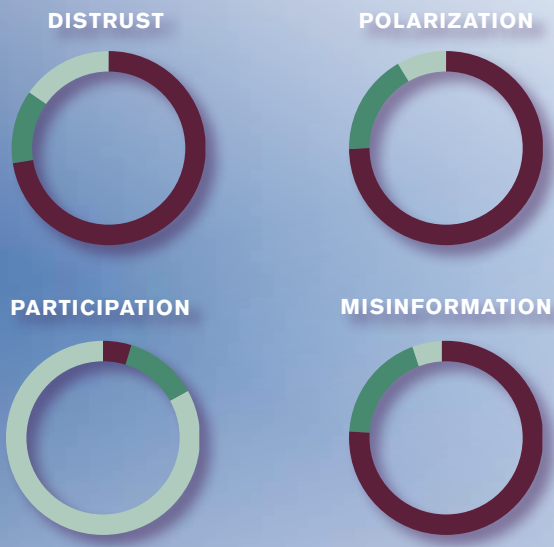
An analysis of activity on Twitter/X shows that two groups in particular reinforce the cross-topic divide: influencers whose content is retweeted most frequently and multipliers who primarily retweet others' posts. Camp affiliation is evident in retweet behavior across various topics. The influencers with the greatest reach tend to belong to the left-wing camp (blue), while multipliers tend to belong to the right-wing camp (yellow). White bars indicate that an account was not active on the relevant topic.

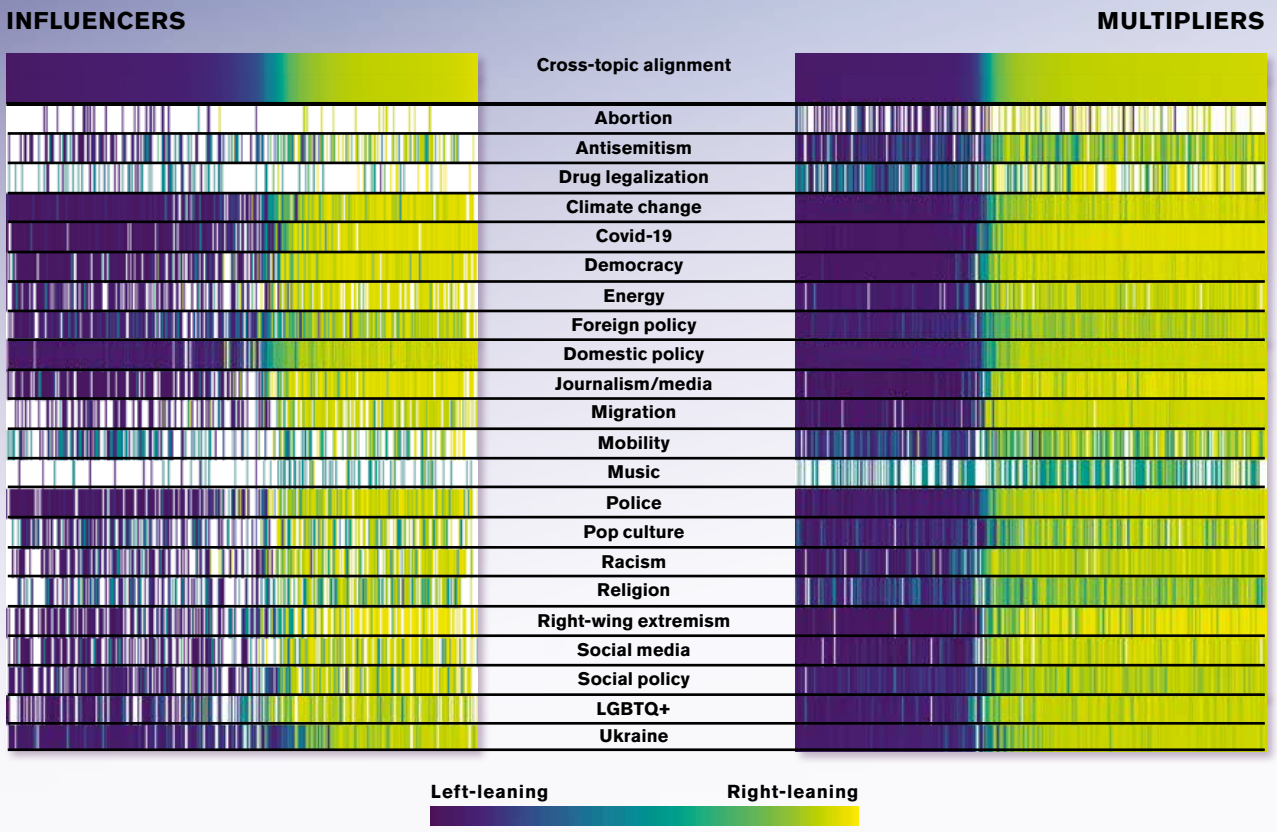
You can find more information on social media and democracy here:

GRAPHIC LEFT: GCO USING DATA FROM POURNAKI, A., ET AL. (2025). HOW INFLUENCERS AND MULTIPLIERS DRIVE POLARIZATION AND ISSUE ALIGNMENT ON TWITTER/X. PROCEEDINGS OF THE INTERNATIONAL AAAI CONFERENCE ON WEB AND SOCIAL MEDIA, 19(1), 1599–1615. GRAPHIC TOP RIGHT: GCO USING DATA FROM LORENZ-SPREEN, P., ET AL. A SYSTEMATIC REVIEW OF WORLDWIDE CAUSAL AND CORRELATIONAL EVIDENCE ON DIGITAL MEDIA AND DEMOCRACY. NAT HUM BEHAV 7, 74–101 (2023)

A THREAT TO DEMOCRACY

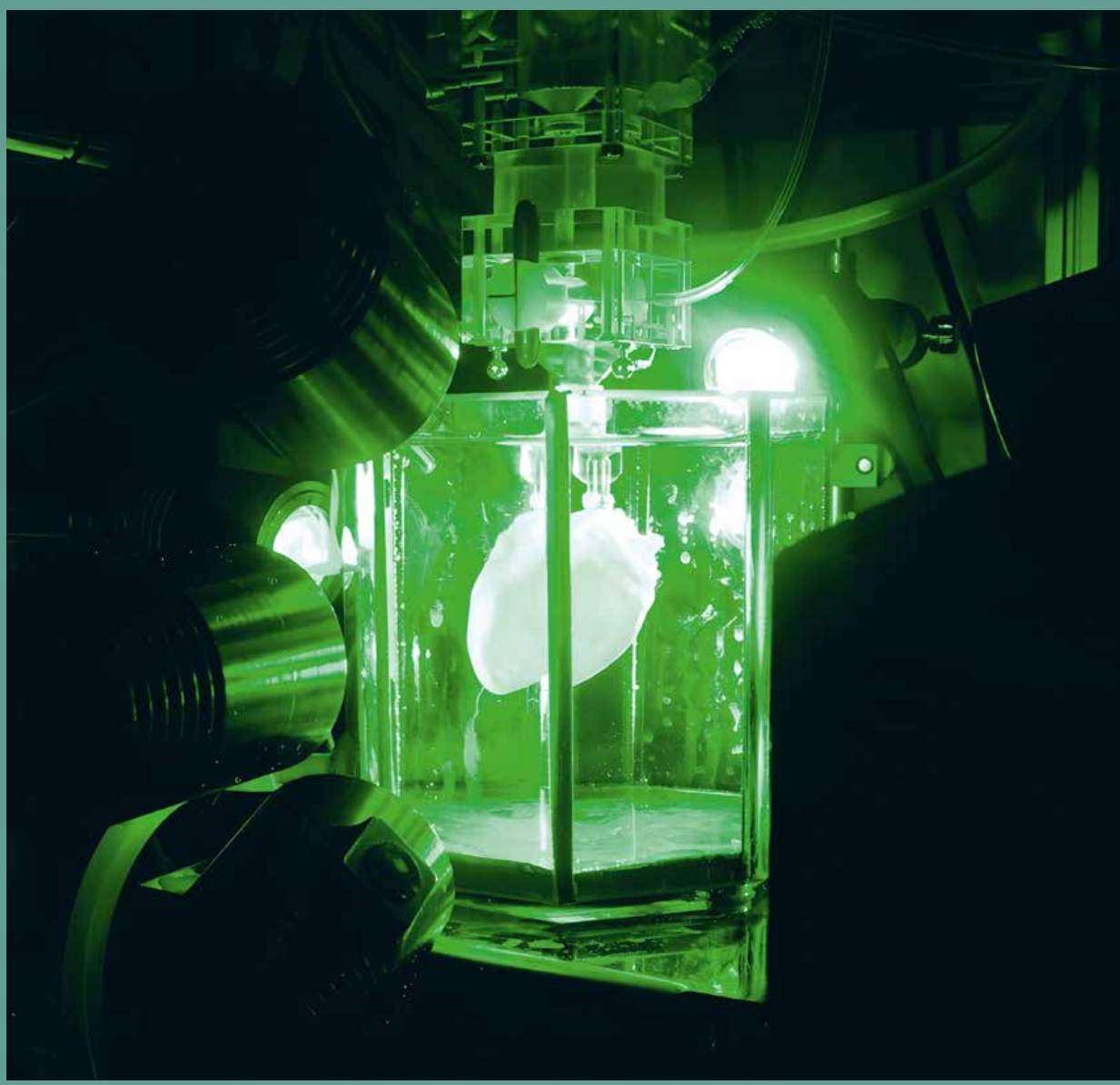
Researchers at the Max Planck Institute for Human Development in Berlin analyzed nearly 500 publications on the effects of social media on democracy. According to their findings, social media improves opportunities for everyone to participate in political debates. However, there are also many harmful aspects. For example, social media fosters distrust in politics, the media, and government institutions. It is also linked to growing polarization and the spread of misinformation.





FOCUS

THERAPIES FOR TOMORROW



A ray of light for heart patients: a Göttingen-based team conducted experiments on a rabbit heart floating in a nutrient solution, clarifying what happens in the heart muscle during arrhythmias. Researchers are using this information to develop gentler treatments.

PHOTO: EFIMOV, NIKOLSKI & SALAMA, CIRC. RES. (2004) / CHRISTOPH, SCHRÖDER-SCHETELIG, S.L. (2017)

A METRONOME FOR THE HEART

TEXT: TIM SCHRÖDER

Cardiac irregularities are among the leading causes of death in industrialized countries. They are frequently treated with defibrillators, which deliver painful electric shocks. Physicist Stefan Luther has discovered a gentler way to stop these arrhythmias. Together with partners in industry, he now aims to bring this technology to market.

The heart is a biological marvel. It beats for decades – without pause and without needing maintenance. No technical pump lasts as long. With every beat, it pushes around 80 milliliters of blood into the arteries; that's about five liters per minute, or roughly 7000 liters per day – equivalent to some 38 bathtubs full. Given this workload, it's hardly surprising that something occasionally goes wrong. For example, some people's hearts fall out of rhythm over the course of their lives. They develop an arrhythmia, such as atrial or ventricular fibrillation. In Germany alone, more than 65,000 people die annually from a severe cardiac arrhythmia.

Normally, the heart contracts in a steady, wave-like motion with every beat. First, blood collects in the two atria. From there, it's pushed into the two large ventricles, which press it into the arteries. The wave-like contraction begins in the wall of the right atrium, at the sinoatrial node and spreads from there across the entire organ. In people suffering from a cardiac arrhythmia, however, chaos breaks out. Instead of a regular wave of excitation, the heart moves uncontrollably. Instead of pumping blood, the muscle merely flickers (fibrillates).

SUMMARY

Until now, cardiac arrhythmias could only be stopped using strong and painful electric shocks.

A Max Planck research group has visualized the vortex-shaped contractions during arrhythmias using ultrasound and other methods.

A detailed understanding of the electromechanical processes involved in arrhythmias makes it possible to stop them via "Adaptive Deceleration Pacing" (ADP), which is a series of weak electrical pulses.

To bring the heart back into rhythm, medical professionals have so far relied on a rather forceful method: defibrillation, a powerful electric shock that causes every muscle cell to contract simultaneously, bringing them to a sudden halt. After a short recovery period, they begin to contract again. Often, this helps the heart get its rhythm back. "People who've experienced such an electric shock while fully conscious compare the pain to a horse kicking them in the chest," says Stefan Luther, Research Group Leader at the Max Planck Institute for Dynamics and Self-Organization in Göttingen and professor at the German Centre for Cardiovascular Research. "It's something you wouldn't want to go through again." There is no question that high-energy defibrillation saves lives. However, in addition to the pain, it can also damage tissue, which may lead to further heart problems. That's why Luther wants to develop gentler methods. And it looks as though he'll be bringing these to market in the coming years together with industrial partners.

It's been a long road to get here. For more than ten years, Luther has been studying "stimulus conduction in the heart." Initially, the goal was to understand and visualize the processes within the heart to derive concepts for treating cardiac arrhythmias. "For a long time, the heart was simply regarded as a moving organ," he says. "Of course, it was known that it could be stimulated electrically. But the precise relationships between electrical stimulation and movement were not understood. In contrast, our goal was to understand the heart as an electromechanical unit."

Electricity in the heart? Indeed: muscle cells are controlled via an electrical potential at their cell membrane. To achieve this, the metabolism stores ions inside the cell until an electrical voltage exists between the interior and exterior. Contractions are triggered by the abrupt transport of ions back and forth between the inside and outside, which changes the voltage.

But what goes wrong electrically in the heart when it no longer beats correctly? Luther realized he had to un-

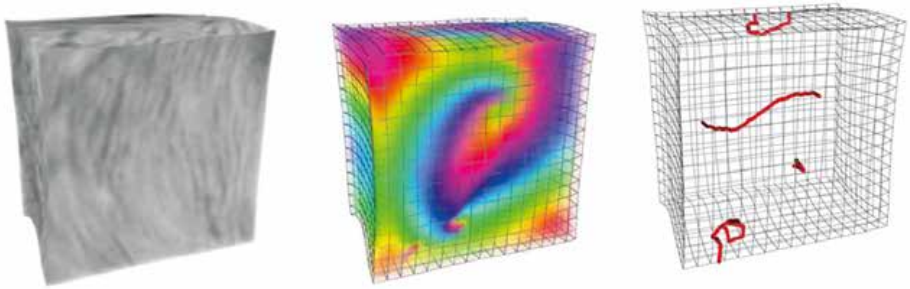


PHOTO: MPI FOR DYNAMICS AND SELF-ORGANIZATION

To the core of ventricular fibrillation: from ultrasound images (left), the Max Planck team reconstructs the vortex-shaped muscle contractions during a heart rhythm disorder (center). This also allows the paths of the vortex cores (rotors) through the muscle to be tracked (right).

derstand the entire system, from the entire organ down to the individual cell. One thing known for certain was that arrhythmia causes the heart to shift from an orderly state to a chaotic one. Luther was already familiar with this subject: at the start of his career, he had studied the chaotic movement of bubbles in liquids – a "physically complex, non-linear system." And that is exactly what occurs during an arrhythmia. During atrial fibrillation, for example, the heart muscle stands still except for minor twitching. The blood no longer flows properly, which can result in clots forming. These can cause thrombosis and block blood vessels. But how do you visualize this electromechanical chaos? Luther first ran computer simulations to investigate. These showed how an electrical pulse in the heart tissue triggers both tensile and compressive forces – much like an ocean wave pushes water ahead of it but also pulls it along. That's how the mechanical movement spreads throughout the entire heart.

The simulations also showed that, during an arrhythmia, the steady wave of excitation splits into many small waves. These mini-waves, or wavelets, each rotate around a central point called a rotor. Just as a tornado carves its path through a landscape, these rotors, along with their waves, wander chaotically back and forth across the heart. This is what creates the irregular twitching and flickering. To investigate the interaction between chaotic movement and its electrical excitation, Luther – along with medical researchers from Cornell University in the United States – conducted an extraordinary experiment several years ago. He placed a rabbit heart in a glass vessel filled with a nutrient solution. The solution provided the organ with all the essential nutrients it needed to continue beating outside the body. While the heart moved, it was filmed by cameras. They recorded two different things: first, the movement of the heart, including its contractions. At the same time, the cameras captured electrical information. To do this, the researchers had treated the muscle tissue with a special dye that changes color when the electrical potential at the membranes of the muscle cells changes. This meant that the dye provided a signal exactly where the muscle cells were currently being electrically stimulated.

At the Origin of the Wavelets

On the computer, Stefan Luther and his team linked the two image datasets together. It was fascinating: now it was possible to see exactly where the electrical impulses originated in the rabbit heart, how the electrical excitation circled the rotors, and how the heart muscle moved accordingly. The fusion of electrical and mechanical information was a success. This means that, using his computer models, Luther can now also work in reverse – deducing the electrical stimulation and the location of the rotors ⟶

PHOTO: GETTYIMAGES

Painful lifesaver: currently, cardiac arrhythmias are stopped in emergency situations by delivering strong electric shocks via the two electrodes of a defibrillator.

solely from the movement of a heart muscle, and thus identifying the origin of the chaotic wavelets. "This is the prerequisite for future arrhythmia treatment. Because you can then specifically treat those areas of the heart muscle where the chaotic movements originate."

Looking at the heart from the outside reveals what's happening electrically on the inside – this can now be done for humans too. Thanks to a collaboration with the University Medical Center Göttingen, Luther was able to record a beating heart during surgery some time ago. In this case, however, not with a camera, but with an ultrasound machine. The Göttingen team showed that this too can record the movement of the heart muscle in high resolution. When patients are connected to heart-lung machines during cardiac surgery, it's common for the heart chambers to begin to fibrillate. After the operation, the fibrillation stops. Arrhythmias can be studied effectively in this situation. The ultrasound recordings Luther made showed with millimeter precision how the tissue moves, swinging back and forth in fine waves. The rotors around which the waves circle are also recognizable. "The great thing about the new 4D imaging process is that, in the future, you'll be able to observe the electromechanical processes in the heart with a device that is standard in every hospital: ultrasound," says Luther.

Optimized Therapies

Precisely understanding what is going wrong in the heart is crucial because there are many different types of arrhythmias – atrial fibrillation, for example, but also ventricular fibrillation. In other cases, the ventricles beat too quickly. Doctors combat each of these diseases with specific procedures. In atrial fibrillation, the part of the muscle tissue where the arrhythmia originates is destroyed. This procedure is called ablation. The tissue is heated via a catheter or treated with a laser. However, this treatment is currently not very precise. During surgery, doctors use a catheter to insert measurement electrodes into the heart at the exact location in the muscle from which the arrhythmia originates. However, this measurement is relatively inaccurate.

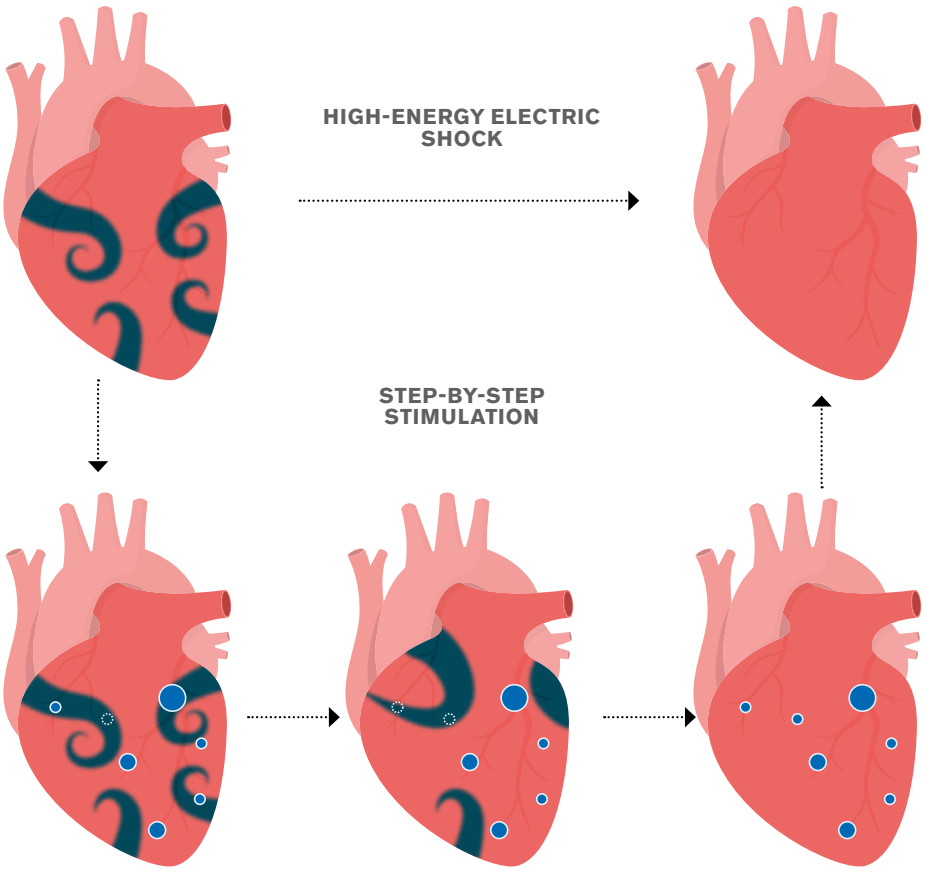
Meanwhile, defibrillators are implanted in patients to treat ventricular fibrillation, among other conditions. Thin electrodes run from this device into the heart. They deliver electric shocks if the heart loses its rhythm. "However, the electric shocks from implanted defibrillators are so painful that many patients have the devices removed," says Luther. "They would rather take the risk." Another issue is that the heart tissue often develops scarring at the points where the electrodes are attached, which can also lead to complications.

Luther is tackling the problems of current treatment methods in different ways. He is collaborating with Yale University in the United States on research into ablation. They intend to use the new 4D ultrasound soon to map arrhythmias right down to the rotors, in order to locate and ablate the origin of the rhythm disorder in the heart muscle more accurately than ever before. Luther's US colleagues are enthusiastic about the Göttingen approach: "Stefan's lab has done pioneering work," says Joseph Akar, an expert in cardiac electrophysiology at the Yale School of Medicine. "The new 4D ultrasound technology allows us to examine complex heart function non-invasively for the first time and with a previously unattainable level of detail. We're convinced that this technology can fundamentally change the diagnosis and treatment of life-threatening cardiac arrhythmias."

When it comes to defibrillation, Luther's goal is to reduce the intensity of the electric shocks to the point that they no longer cause any pain. This has already worked in the lab. In the early 2020s, one of his doctoral students first discovered, through a simulation of the rotors and wavelets, that the chaotic behavior can be stabilized by applying a regular sequence of weak electrical pulses rather than a single strong electrical shock. Shortly thereafter, Luther's team found that the effect is even greater if the pulses are not fired regularly, but specifically at varying time intervals. As experiments on rabbit hearts showed, the chaotic movement of the rotors and wavelets is slowly braked in this way – until the arrhythmia disappears completely. Luther calls this process adaptive deceleration pacing (ADP). With this process, he has succeeded in pushing the stimulation below the pain threshold: the decisive step toward a painless defibrillator.

"The new 4D ultrasound technology allows us to examine complex heart function non-invasively for the first time and with a previously unattainable level of detail."

JOSEPH AKAR



GRAPHIC: GCO BASED ON WORK BY THE MPI FOR DYNAMICS AND SELF-ORGANIZATION

Gentle treatment: vortex-shaped contractions during an arrhythmia can be stopped with several mild electrical stimulations instead of a single high-energy electric shock.

Together with manufacturers of defibrillator implants, Luther will now further advance the ADP principle. One goal is a defibrillator whose electrodes sit on the surface of the heart muscle. Such extravascular defibrillators have the advantage that the electrode cables are not anchored inside the heart, which avoids scarring and other complications. However, extravascular defibrillators also have a significant disadvantage: since the electrode is placed on the outside of the heart, a considerable amount of energy is required to restore the arrhythmic heart to a normal rhythm. The electric shock is correspondingly painful. This is another reason interest in defibrillation with gentle pulse sequences is so high.

On the journey to bringing this gentle therapy into medical application, Luther must master more than just the biophysics of the heart: "It's an immense challenge to transfer basic research results into clinical application. In addition to a good idea and an excellent team, you also need a lot of perseverance and plenty of support," he says. Successful technology transfer, he notes, is rarely as simple as stepping out of the lab; rather, it arises through long-term collaborations between research institutions and industrial companies. It also requires an environment that fosters applied research so that new ideas can be brought to market quickly. The Göttingen-based team has enlisted the support of Max Planck Innovation, the technology transfer subsidiary of the Max Planck Society, to commercialize this know-how with medical technology companies, or possibly through a startup. Luther is confident that it will work out. For him, the idea that correcting arrhythmias requires a single intense shock is outdated. He has made significant steps towards a gentler form of treatment.

GLOSSARY

ARRHYTHMIA
refers to various heart rhythm disorders, such as atrial or ventricular fibrillation.

ROTOR
refers to the central point around which wavelets rotate during an arrhythmia.

WAVELET
is a chaotic wave of excitation in the heart muscle. During an arrhythmia, the uniform excitation wave of a healthy heart breaks apart into several wavelets that travel across the heart muscle.

www.mpg.de/podcasts/medizin-der-zukunft (in German)

Waiting: anyone seeking therapeutic help must be patient. Waiting periods of up to five months need to be bridged. Digital helpers are designed to provide support in the interim.

IMAGE: ADOBESTOCK / MARTA LEBEK/STOCKSY

DIGITAL HELP IS COMING!

TEXT: JULIA MEYER-HERRMANN

Digital tools promise to fill a gap that has been widening for years: too few therapy slots, too many people with mental health issues, too much time between sessions. Yet apps, wearables, and language models differ fundamentally in function, benefit, and risk. That's why Max Planck researchers are working not only on new applications, but also on the criteria that should govern them: what works, and what's safe?

Hope runs high, but so does skepticism. Both attitudes are currently shaping the debate over digital technology in mental health care. Stress-management apps, self-monitoring programs, and chatbots: they all promise to ease the burden, bring structure to daily life, and offer companionship – all in a mental health care system that has been straining at its limits for years.

Mental illness has become one of the most widespread health problems in Germany. According to data from the German Association for Psychiatry, Psychotherapy and Psychosomatics (DGPPN), roughly a quarter of the adult population meets the criteria for at least one mental disorder – approximately 17.8 million people. Meanwhile, access to professional help is limited. On average, patients wait just under five months between their first contact and the start of psychotherapy, data from the German Federal Chamber of Psychotherapists shows.

Against this backdrop, digital support services are no longer merely a question of technical feasibility, but a matter of public health and social significance. What can these tools actually deliver today? Where do the boundaries lie in terms of substance, ethics, and legality? And what distinguishes a commercial product from applications that have emerged from independent research?

PHOTO: MPI FOR HUMAN DEVELOPMENT

Chatbots fighting loneliness: to use Elderbot, study participants need no prior digital knowledge, no smartphone of their own, and no app – they simply have to speak. In the image: researcher Rodrigo Schettino.

A Wide Range of "Help"

Digital mental health applications are often lumped together under a single label. In reality, they are a diverse array of systems that differ fundamentally in function and purpose. An app is not a chatbot. A chatbot is not a therapeutic counterpart. And a medically regulated product is worlds away from a freely available lifestyle or coaching app – not least in terms of the responsibility their providers bear.

"You cannot meaningfully discuss benefits or risks until you've clarified exactly what you're dealing with," explains psychologist Dirk Wulff from the Max Planck Institute for Human Development in Berlin. His research focuses on the classification of digital and AI-based systems, including the question of how such technologies can be used to address mental disorders.

Germany has had digital programs designed to support people with mental health conditions for years. These range from online courses and digital diaries to tools that explain behavioral patterns and their cause, offer self-monitoring exercises, and help structure daily life. Some of these services are regulated and available by prescription; others are freely accessible. There are numerous lifestyle apps – such as mindfulness, meditation, and mood-tracking apps – which are primarily aimed at promoting well-being and self-improvement. Some programs, on the other hand, such as Selfapy or HelloBetter, are officially approved as Digital Health Applications (DiGA) and offer modular, time-limited online courses on depression, anxiety, or panic disorders. The content consists of reading material, videos, and exercises; in some cases, they also offer accompanying support from psychological specialists. Doctors can prescribe them, and the costs are covered by health insurance. They can bridge the waiting time until a course of therapy begins.

But even once psychotherapy begins on a weekly basis, there remains a fundamental problem with regard to time: a week has 168 hours, but a therapy session typically lasts just 50 minutes. In between there is everyday life – filled with stress, loss of drive, social withdrawal, increased irritability, difficulty concentrating, sleep disturbances, and avoidance behavior. Digital tools are seen as a way to fill these gaps, acting as companions, reminders, or early warning systems. But how can their therapeutic benefit be reliably proven?

SUMMARY

Digital applications cannot replace psychotherapy, but they can bridge structural gaps such as waiting times or daily life between sessions. To date, the evidence of their effectiveness varies significantly depending on the specific system, target group, and context of use.

Dialogue-based AI systems, or chatbots, are sometimes seen by users as conversation partners, despite the fact that they feel no empathy, bear no diagnostic responsibility, and operate solely on probability calculations.

The true benefit of digital helpers depends not on their technical capabilities, but on the framework in which they are used: transparent development, verifiable evidence, and clinical integration.

Research groups worldwide are working to investigate digital interventions in a controlled manner, identifying objective markers of mental stress and better mapping their progression in daily life. Several Max Planck Institutes are also researching how mental states can be measured with more nuance and how digital tools can be tested on a sound scientific basis.

Victor Spoormaker, a Research Group Leader at the Max Planck Institute of Psychiatry in Munich, says: "Psychiatric diagnostics rely heavily on subjective reports, on conversations, interviews, and questionnaires. The end result is often a diagnostic label that lumps very different progressions and mechanisms – in other words, underlying psychological and biological processes – under a single umbrella term like depression." He notes that while this may not be wrong, it's insufficient. A diagnosis often says little about which physiological mechanisms – such as stress processing, arousal patterns, or emotional regulation – are actually affected, or which treatment would make sense for which person. Depression, for example, is not a uniform clinical picture. "Depression has nine recognized symptoms; meeting five of them is enough for a diagnosis. Factor in the additional criteria, and there are hundreds of possible ways to be depressed," says Spoormaker. Two people can receive the same diagnosis and yet have completely different symptoms and needs.

Spoormaker is critical of this diagnostic coarseness. In other medical disciplines, he notes, causal thinking is a matter of course: with persistent abdominal pain, for instance, doctors don't just name the symptom – they look for underlying causes such as inflammation, infection, or parasite infestation, and then offer treatment that differs according to the cause. In psychiatry, this differentiation has been missing until now. Spoormaker is investigating whether additional physiological information can be captured to help describe mental illnesses more precisely. This includes experimental measurements such as pupil responses (as indicators of cognitive load and lack of drive) as well as real-world data on sleep, activity, and reaction patterns. "We're looking for biomarkers – objective metrics that, in addition to self-reporting, can provide clues about the progression and subtype of an illness," says Spoormaker. "Only when we more precisely understand which mechanisms, patterns, and manifestations dominate in a person can we react in a more tailored way."

But which relevant data is measurable in everyday life? "With the rapid technological development of recent years – which is truly enormous – we now have options that simply didn't exist ten years ago," says Spoormaker. One option is wearables, such as commercially available smartwatches. They can record movement patterns, sleep-wake rhythms, and temporal changes in behavior. "Not all data is equally meaningful," Spoormaker cautions. He notes that while physical activity or total sleep duration can provide robust clues, detailed sleep phase analyses from many consumer devices are not scientifically reliable.

On the basis of this technical and methodical foundation, his team developed actiself: a smartwatch-based application that records objective behavioral data and makes trends visible over several weeks. It's designed as a low-threshold intervention. The approach is preventive: recognizing changes early makes it possible to take counter-measures – for example, in the case of sleep problems, loss of activity, or behavioral patterns that indicate the onset of a loss of drive. Actiself is intended to motivate and help alleviate symptoms through behavioral exercises. With the support of Max Planck Innovation, the spin-off company Biomentric was established with Victor Spoormaker and Markus Friedrichs as co-founders. It has licensed, advanced and brought to market the technology developed by the Max Planck Institute of Psychiatry. →

"We're looking for biomarkers – objective metrics that, in addition to self-reporting, can provide clues about the progression and subtype of an illness."

VICTOR SPOORMAKER

While wearables measure physiological reactions and make patterns visible, chatbots like ChatGPT, Character.AI, or Replika aim for something fundamentally different: conversation, closeness, and reaction. That's precisely why their impact is so powerful – and why their risks are so great.

When Machines Speak

"Language models are trained to generate plausible responses," says psychologist Dirk Wulff from the Max Planck Institute for Human Development. "They appear to be understanding because they calculate probabilities for appropriate phrasing based on large amounts of text." This is often mistaken for genuine understanding, he notes. "Strictly speaking, a language model doesn't understand anything. It reacts." Furthermore, many systems are optimized to generate agreement rather than contradiction. When people turn to these systems with personal or distressing questions, that has real consequences.

A cross-sectional study published in the US in 2025, drawing on data from multiple research and healthcare institutions, found that around 13 percent of 12- to 21-year-olds reported using generative AI to cope with stress, anxiety, or emotional problems. In other words, some people aren't just using chatbots as an information source, but are also seeing them as a kind of conversation partner. This creates the expectation of a relationship – even though the model feels no empathy, is incapable of professional diagnostic assessment, and takes no responsibility. Lawsuits in the US in which parents accuse providers of failing to adequately intervene when their children made suicidal statements to AI systems demonstrate just how sensitive this territory is.

"Strictly speaking, a language model doesn't understand anything. It reacts."

DIRK WULFF

Smartwatches and wearables can help identify early signs of psychiatric illness – provided the data is scientifically collected and processed.

PHOTO: PICTURE ALLIANCE / DPA THEMENDIENST | CHRISTIN KLOSE

Meanwhile, the market is growing rapidly. Billions of dollars are flowing into AI-based mental health applications worldwide. Dialogue systems are available globally, mostly without medical approval or clinical testing. Some providers are now working to improve safety mechanisms and moderation filters. "We still know far too little about how people actually use such systems," says Wulff. One reason for this is that many systems are not transparent: training data and specific usage data are generally not accessible for independent research.

Research Instead of Promises

To date, there has been limited research on how people in crisis situations interact with chatbots – and how the systems respond. Researchers in the Elderbot project want to change that. This dialogue-based system is being developed at the Max Planck Institute for Human Development in cooperation with the University Medical Center Hamburg-Eppendorf (UKE). It's aimed at adults over 60 who suffer from loneliness.

Psychologist Brooke Viertel works at the UKE and treats older patients on a daily basis. Many find it difficult to leave the house or join new groups, even though a city like Hamburg has many offerings for lonely seniors. "Many of them need more support, more encouragement – and this is exactly what we cannot provide on a long-term basis in daily clinical practice." This supply gap led to the idea of testing whether a conversational AI system could help.

"Elderbot is technically based on a large language model – the same type of AI system underlying ChatGPT," says Rodrigo Schettino, a computer scientist researching human-machine interaction. "The model itself wasn't developed from scratch. The decisive factor is how it's used and supervised." For Elderbot, the conversational guidance was also developed based on psychiatric findings. The goal is not diagnosis or therapy, but rather dialogic companionship. The usage itself is deliberately kept simple. Elderbot is not an app and does not require its own smartphone; instead, it's a standalone device specifically designed for older people. It features a significantly reduced interface and is designed to be operated via voice. The barrier is intended to be as low as possible so that people without prior digital experience can participate. Only when the interaction is accepted without it causing stress can its effectiveness be evaluated. Unlike freely accessible chatbots, every interaction takes place within a scientifically monitored study. Preliminary studies also specifically included problematic scenarios – such as suicidal or severely depressive statements – to test how the system responds. "We developed a monitoring system to observe the interactions," says Chaewon Yun, who investigates the safety of conversational AI. If a participant expresses intense anxiety or despair, for example, or if the system responds in a problematic way, these events are logged. In addition to automated checks, psychiatric professionals monitor the study in real-time and can intervene if a situation is deemed critical. Furthermore: "We are not just testing how the model responds, but how people deal with those responses."

The study is designed as a comparative trial: one group of participants speaks regularly with Elderbot for several weeks, while a control group does not. Following this, researchers will check if perceived loneliness or other areas of life have changed. Alongside the pilot and intervention studies, Elderbot will be tested with the public. On the MS Wissenschaft, the exhibition ship featuring exhibits related to the theme of Science Year 2026, "Medicine of the Future," visitors will be able to interact with the system through a brief conversation starting in May 2026. Afterwards, they provide assessments regarding the conversational experience, trust, and perceived usefulness. While these five-minute interactions are no substitute for an efficacy trial, they provide valuable data on the social perception of such systems – data that is stored exclusively on the Institute's research servers.

"Loneliness in old age is often associated with shame," says Viertel. "Many people don't speak openly about it because they don't want to reveal these feelings to another person." A digital access point might make it easier to start a conversation – but it doesn't replace therapeutic treatment. "A system like this can motivate people to try new things or to reach out to others more actively again," says Schettino. "It can boost self-confidence and help build social connections. But it can also lead to people becoming more attached to the bot and withdrawing from other people. That's precisely what we need to investigate." The coming years will show what role AI will play in mental health care. There will be those who – perhaps out of shame or practical reasons – prefer to confide in a technical counterpart. And there will be others for whom human relationships remain irreplaceable. The defining question for the years to come will not be if digital systems should be part of mental health care – but how.

www.mpg.de/podcasts/medizin-der-zukunft (in German)

Microorganisms are like tiny factories. They can be genetically modified to produce the desired compound in their cells. To make production easier, researchers have developed a process that won't require any living cells. This process can be used, for example, to synthesize peptides from their DNA blueprint in a very short amount of time.

PHOTO: KATRIN BINNER

GERM-FREE

TEXT: TILL HEIN

Comparing molecules to cars might seem like a bit of a stretch. They have certain similarities when it comes to their production process, though: some molecules are actually produced within a cell as if in an assembly-line. Helge Bode and Tobias Erb of the Max Planck Institute for Terrestrial Microbiology in Marburg are looking to modify these molecular production lines so that they can be used to make new antibiotics, which are urgently needed to fight resistant pathogens.

Even a common middle ear infection can now be fatal because many of the bacteria that can cause such infections have become resistant to antibiotics. And that resistance is growing: the World Health Organization (WHO) projects that as early as 2050, as many as 10 million people a year could lose their lives due to infections by multi-resistant bacteria. That's why new antibiotics are desperately needed. An increasing number of pathogens are becoming resistant to proven active ingredients because they are often used carelessly. To make matters worse, while the development of new antibiotics doesn't take any longer or require any more resources than that of other clinical drugs, it's less lucrative for the pharmaceutical industry.

PHOTO: KATRIN BINNER

Candice Jones is head of the MaxGenesys Biofoundry at the Max Planck Institute in Marburg. At the facility, large quantities of DNA and proteins can be designed and tested for various applications.

That's why Bode and Erb are looking for a new way to produce antibiotics and other medical agents, focusing on compounds that microorganisms produce themselves. Bacteria, for example, produce a wide variety of natural products within their cells that perform vital functions in metabolism, communication with other cells, and defense against competitors. Many of these compounds are known as peptides, which consist of amino acid chains just like proteins, except they are much shorter. Their versatility makes them ideal for use in medicine and industry. Peptides form the basis for the antibiotic penicillin, the cancer drug romidepsin, and the immunosuppressant cyclosporin. Roughly 60 percent of all therapeutic drugs used in human medicine today are based on biomolecules produced by bacteria and fungi.

The scientists in Marburg aim to harness the vast reservoir of naturally occurring peptides for new functions but also – drawing inspiration from nature – to develop entirely new peptides. "Unlike molecules produced in a lab without a natural model, peptides existing in the natural world can be assumed to have a specific function or effect. Otherwise, evolution would have weeded them out long ago," explains Helge Bode, Director at the Max Planck Institute for Terrestrial Microbiology. That's why he and Tobias Erb, fellow Director at the Institute in Marburg, see peptides derived from bacteria and fungi as a virtually inexhaustible reservoir of new active ingredients. "Bacteria and other microbes lived alone on Earth for 2 billion years before the first cells with a nucleus ever formed. So, they had plenty of time to produce new molecules for a wide variety of purposes," Erb explains.

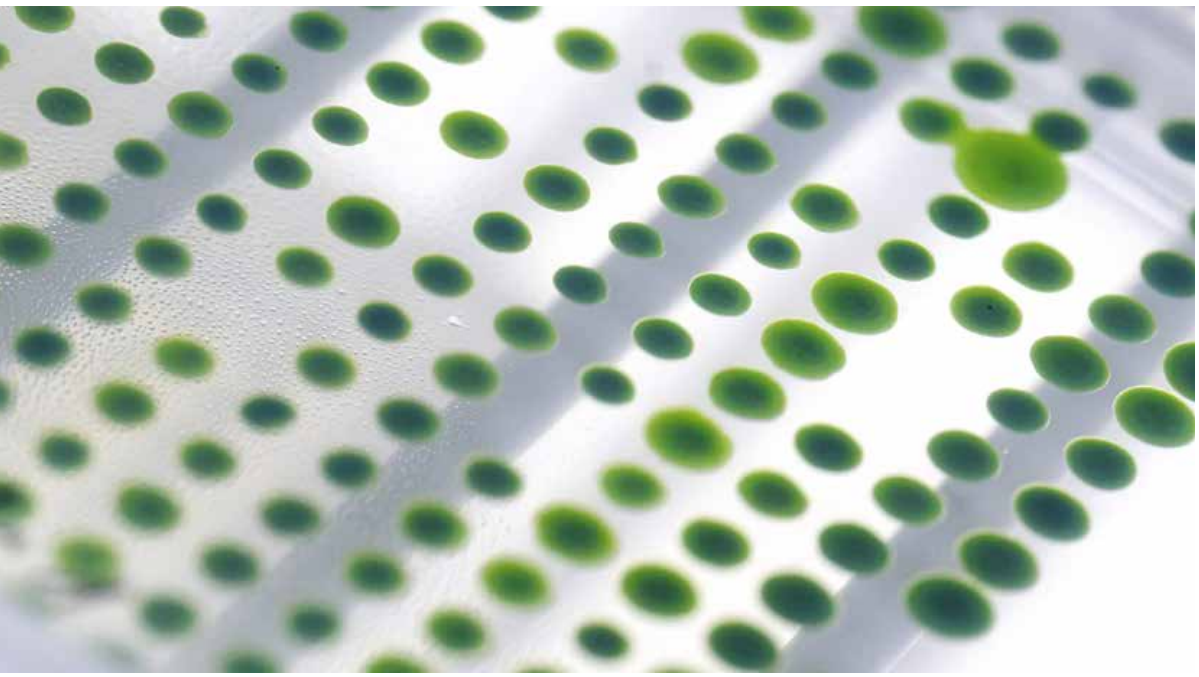
Better than Nature

Nevertheless, evolution has not always found the optimal solution, or else it has had to balance multiple requirements, leading to a compromise in the effectiveness of a given peptide. So, the Directors at MPI Marburg are interested first in optimizing peptides that are already known. For medical use in humans, peptides must not only be highly effective, but also distribute themselves rapidly and evenly throughout the body, remain available there for a long time, and be well tolerated. At the same time, their groups are also designing entirely new molecules. For all the diversity of peptides produced by microorganisms, there are still countless molecules that nature has not yet invented – and perhaps never will. "Evolution is rather conservative," Erb notes, "It mostly relies on tried-and-true methods; only rarely does something completely new emerge."

PHOTO: DAVID AUSSERHOFER

"It's like a car that starts out on the production line as a VW model but then is modified into a Tesla."

HELGE BODE



A microtiter plate containing *Chlamydomonas reinhardtii*. The researchers have developed a test platform that enables the production and analysis of thousands of genetically modified algae lines in parallel.

The researchers led by Bode and Erb are much more ambitious in this regard: they're aiming to synthesize the full range of peptides from all theoretically possible building blocks, and then identify which ones are suitable for use as drugs or raw materials for industry. To generate ideas for new peptides, Bode and Erb analyze natural production processes and functions of the molecules in bacteria and fungi. The proteins of a cell and the majority of its peptides are produced via specialized molecular machines called ribosomes. Peptides produced in this way consist of 20 different amino acids with a specific configuration, known as L-amino acids. These can be combined in a wide variety of ways. For peptides with a length of 40 to 50 amino acids, there are already more possible combinations than there are atoms in the entire solar system. How to go about finding new antibiotic peptides within such a vast pool? To this end, Erb is using artificial intelligence trained on known peptides to find new antimicrobial peptides. "It works in manner similar to training AI to write crime novels by having it read a few dozen Sherlock Holmes stories, the difference being that our AI is trained on thousands of variations," says Erb.

SUMMARY

Bacteria produce countless peptides which they use to communicate with each other, defend themselves against enemies, and assert themselves in their environment.

Many of these molecules, linear or cyclic short amino acid chains, are produced by modular enzymes. Researchers can assemble the individual modules into new enzymes to create peptides that do not occur in nature.

Researchers are working to produce antibiotics that kill bacteria via cell-free methods that do not require any living cells.

Bode, on the other hand, is interested in peptides that are not produced in ribosomes. "They contain other amino acids as well, such as D-amino acids, which are mirror images of L-amino acids, and amino acids that have been further modified," Bode explains. These peptides are synthesized by special enzymes called "non-ribosomal peptide synthetases." These act as catalysts in chemical reactions that join one amino acid after another to form a peptide. "A synthetase works on the same principle as an assembly line in the automotive industry," Bode explains. "The selection, activation, linking, and modification of the components take place at different modules of the enzyme. Each module is comparable to an individual robotic station in a factory, responsible for a specific production step."

Interestingly, the modules can be separated from each other and assembled into a new enzyme, which then produces a different peptide. And two different enzymes can also be coupled together. "So, we aren't just exchanging individual stations, we're connecting two conveyor belts in series. It's like a car that starts out on the production line as a VW model but then is modi-

→

fied into a Tesla," Bode elaborates. "We can install parts from BMW, Mercedes, or Volvo too if we want." With cars, that may be hard to imagine, but in enzyme engineering it's no problem. Strictly speaking, however, the researchers are not reassembling the enzyme modules themselves, but rather the genes that carry the instructions for their construction. To do this, they cut the DNA into small pieces using gene-editing tools and reassemble these in new combinations. The number of peptides that can be produced in this fashion is astronomical, as even a single molecule built from four amino acids has over 8 billion variants. This is because the peptides used at the Marburg Institute can consist of more than 300 different amino acid building blocks. These include not only the 20 amino acids found in proteins in all living organisms, but also numerous others found in natural biosynthesis pathways or those produced artificially in the lab. Peptides can also be further modified with sugar or fatty acid molecules, giving them additional properties. Together with ETH Zurich, Bode founded the Basel-based startup Myria Biosciences. Now in year three of operations, the company is engaged in further developing the enzyme engineering methods of non-ribosomal peptide synthetases.

Production Without Cells

To generate the quantity of a peptide needed for further study, researchers typically engineer bacteria that carry the corresponding gene. The cells then produce the desired molecule alongside their own. It gets tricky, however, when the target molecule is an antibiotic, whose very purpose is to kill bacterial cells. For this reason, antibiotics can often only be produced in bacterial cells using special methods, such as highly efficient export out of the cell or synthesizing them as inactive precursors. Erb and his team have thus developed a production process that does not require the use of any living cells. "What we have here is a cell-free transcription-translation system that can produce a peptide from its DNA blueprint within a few hours. This allows us to produce and analyze several hundred peptides per day, faster and more cost-effectively than through any other chemical or biological production method," Erb explains. The researchers can thus rapidly gather new data for analysis using AI. Erb's team runs these cycles of production, analysis, and data interpretation at the fully automated MaxGENESYS lab – built up in Marburg over the past three years with funding from the Max Planck Foundation.

Bode and his group are now developing a similar method for the large group of structurally more complex non-ribosomal peptides, which can be produced in bacteria without cells within a few hours instead of days, and in quantities that allow for precise analysis of the substances. In a collaborative effort with the Compound Management and Screening Center of the Max Planck Society in Dortmund, researchers then test, for example, whether a peptide is lethal to various pathogens, whether it can kill cancer cells, and whether it harms healthy human cells.

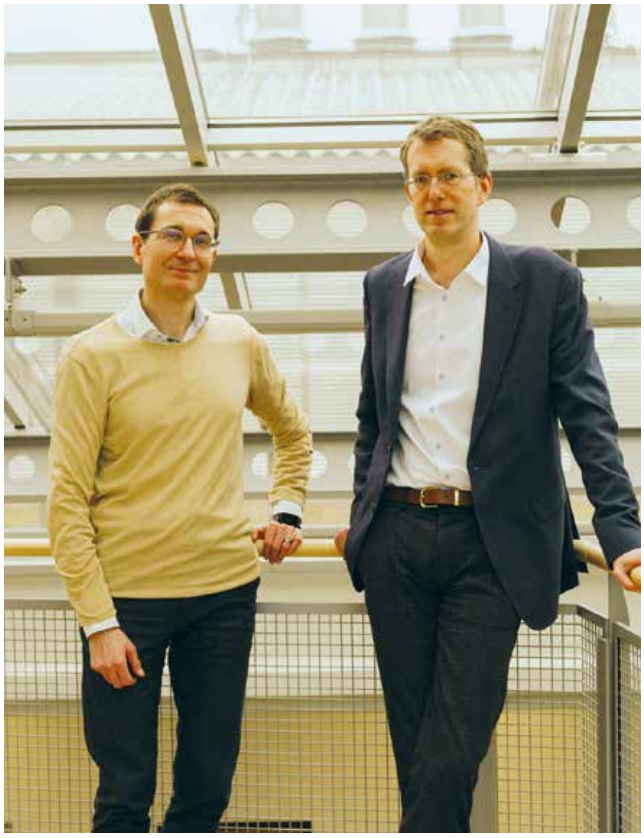


PHOTO: DAVID AUSSERHOFER

Tobias Erb and his colleague Helge Bode, together with their teams, are developing custom-made peptides for medicine and agriculture.

Bode and Erb see their scientific work as part of a long-standing tradition. "Humans have always been inspired by nature in designing technology, yet always made adaptations as needed," says Erb. "Take airplanes, for example. They employ wings to generate lift, just like birds do. But the wings have no feathers, and they don't move. And they have to be that way in order for humans to overcome gravity." The same principle applies to the design of new peptides: inspiration, not imitation.

www.mpg.de/podcasts/medizin-der-zukunft (in German)

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Sabine Schaefer*

Picture: Max Planck Institute for Evolutionary Anthropology

** The entrepreneur and donor – pictured here with Svante Pääbo and Julius Schaefer – provided the initial funding for a research group at the Max Planck Institute for Evolutionary Anthropology led by Nobel Prize winner Svante Pääbo.*

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For researcher Mercy Akinyi, getting out into nature is more than just a way to unwind – it's part of her job. Together with her Max Planck Society – supported group in Kenya, she investigates how environmental conditions and cultural factors influence the spread of pathogens, and what containment measures can be taken.

TEXT: BETTINA RÜHL

Mercy Akinyi pauses at the waterfall, enjoying its familiar roar. The veterinarian comes here often. The trees above her reach up into the sky, which happens to be gray this morning in Karen, a suburb of the Kenyan capital Nairobi. While Karen sits a mere 150 kilometers south of the equator, it's also some 1800 meters above sea level. Because of that, it rarely gets oppressively hot. In fact, it's often quite cool, as it is this morning. "There's something refreshing about being in nature," says Akinyi. "As a scientist, I spend so much time indoors, either at the computer or in the lab. Being outside helps me think about something other than work." You can instantly see it in her face, as she stands on a rock a few meters away from the falls, that this is a place of serenity for her. Sometimes she comes with her daughter; then the two of them sit together on the rock and toss stones into the water, and Akinyi listens to what the six-year-old has to say.

It's a bit of a paradox that nature helps her to stop thinking about work, because part of Akinyi's job is being in nature – and observing it closely. For years, she has been researching how diseases emerge and spread among humans, livestock, wildlife, and their environment. The concept of "One Health" has become more familiar to the general public since the outbreak of the Covid-19 pandemic in 2020, catching up to what Akinyi has long known to be true. But with millions dead and severe economic and social consequences reverberating worldwide, the question was suddenly making headlines in the international media: could it be that the virus known as Sars-CoV-2, which causes Covid-19, was transmitted to humans from bats, perhaps via one or more intermediate hosts? As the world grappled with the Sars-CoV-2 virus, memories came flooding back of the deadly Ebola epidemic in West Africa, with its death toll of over 11,000 between 2014 and 2016 in Guinea, Liberia and Sierra Leone. The Ebola virus is also believed to have been transmitted from animals to humans. →

VISIT TO

MERCY AKINYI

PHOTO: MIA COLLIS FOR MPG

A place of personal serenity: Mercy Akinyi often goes walking through the forest near the Kenyan Institute for Primate Research, where she works.

PHOTO: MIA COLLIS FOR MPG

Time-consuming lab work: microscopic examinations are an essential part of Mercy Akinyi's "One Health" research. She studies interrelationships between human and animal health and the attendant role of environmental conditions.

The theory of pathogen transmission between humans and animals has become a matter of great concern worldwide in view of the extremely deadly nature of such epidemics and pandemics. In contrast, the scientific community has long held the conviction that the health of humans, animals, and the environment can only be understood and protected in a holistic manner – this is the fundamental principle of "One Health." The increasing importance of this approach over the past few decades is partly due to research findings that support its validity, such as those by Akinyi. Equally crucial is the fact that massive population growth is bringing humans and animals, both wild and domesticated, into ever closer

contact. Climate change is further exacerbating this trend, altering the environment in ways that can facilitate the spread of pathogens, such as by causing more frequent flooding. This allows certain pathogens to spread to much larger areas than would be possible under less extreme weather conditions.

Now Akinyi is sitting on a bench in the forest above the falls. Long-tailed monkeys are frolicking through the treetops above, but Akinyi ignores them for now, not letting anything distract her from her story. As a scientist, she is normally very interested in the behavior of monkeys and the pathogens they carry. Akinyi lives and works on the nearby campus of the Kenya Institute of Primate Research (KIPRE), which is a state research station situated in the Ololua Forest in Karen. Her research group receives funding from the Max Planck Society and the Alexander von Humboldt Foundation. Akinyi lives in one of the staff residences with her husband and two children. It's easy to follow her story as she sits here under the trees, recounting her journey into academia and describing her research. The sparkle in Akinyi's eyes, her sweeping hand gestures, and her laughter all speak volumes – she loves to laugh, and she laughs from the heart. In fact, it's hard to imagine this scientist – with her long braids and colorful blouse – spending all her time in the lab and in front of a computer. She seems to belong here, outdoors.

Her first steps into science began when she was six years old, sparked by a dream that many children share: "I loved watching doctors and nurses and seeing how they helped people get well," she recalls. "So, from very early on I knew I wanted to get into the medical field somehow." Her favorite subjects in high school were Biology and Chemistry, and her good grades were noticed. When she got the opportunity to study at the University of Nairobi, she chose veterinary medicine. She was a quick learner, and she soon realized that many of the books she was studying were widely used by medical students too. She went on to earn a master's degree in medical Physiology: the science of functional processes in the human organism. Her studies confirmed what she had suspected for some time: "There aren't many differences between animals and humans." Not when it comes to the basic systems, at least.

Her master's degree project focused on baboons living in the wild. The question was how parasites affected their health and what that meant in interaction with other infections. At the same time, Akinyi wanted to know why the parasite load was worse in some baboons than in others. The significance of this question, i.e., why different individuals react differently to infection with pathogens, has been understood by millions of people, at least since the coronavirus pandemic. In search of answers, Akinyi began analyzing ticks (which transmit the Babesia pathogen to baboons). The pathogen attacks and destroys red blood cells, creating malaria-like symptoms. She also observed the animals' social lives: who was being groomed and cared for by others and how often, who pushed the others aside, who was usually being dominated. She found that the females in the group were groomed by others much more frequently than the males. They had a more stable social network and, thanks to frequent grooming, were less infested than the males with parasites such as ticks. Social rank also played a role: females of higher social standing were better cared for and had fewer parasites than those of lower social standing. Akinyi also observed that female baboons are born into their social rank, whereas males have to fight for it. Combat is stressful, and stress makes you sick – another reason the females, with their predetermined social rank, enjoy better health. Those near the top of the pecking order, at any rate. →

"From very early on I knew I wanted to get into the medical field."

Asked whether, after spending so much time studying animal behavior, she now finds herself unconsciously observing the people around her and applying the insights she's gained from her animal studies to their behavior, Akinyi again had to laugh. No, she doesn't think so, but there is one definite parallel: "People who are socially well connected get the support they need." Which generally makes them healthier.

Asked whether it's fair to say that her research interests and her curiosity essentially know no bounds, Akinyi laughs. "I guess you're right!" How could it be otherwise, if we start from the conviction that the health of all living things is interconnected? Akinyi lights up again, hand gestures and all. The core idea of "One Health" shaped her very first research project, for which she received funding from the Kenyan government in 2011 to conduct disease surveillance in primates and to educate humans on zoonoses risks. Akinyi is not solely interested in obtaining sound research results; she also wants to understand why, despite public awareness campaigns, these findings fail to reach many people – or at least why they don't translate into action. As part of her research project at the time, the scientist and her team spoke with people from the surrounding villages about their findings, in the interest of curbing the spread of diseases. These awareness-raising efforts were unsuccessful, but this was a real learning experience. She relates, for example, how they had distributed mosquito nets to reduce infection with the malaria pathogen, but people didn't use them when they went to bed. So Akinyi asked the people why and received a plausible answer: "We don't earn much. We need our chickens so we have enough to eat." They had put up the nets over their chickens instead of protecting themselves from mosquito bites. "That's how they secured their food supply," Akinyi explains. "It was a higher priority for them than potential infection."

She relates another example: the team had built a latrine to reduce the spread of pathogens, but people weren't using it. So, the researchers asked why. The answer: people considered it improper to share a latrine with their in-laws. So, they kept on using the bushes. The conclusion is obvious, though in the rush of scientific inquiry it's often forgotten: "You also have to consider the cultural and social context," Akinyi advises, "if you want to contain the spread of pathogens."

Analysis: Akinyi's team prepares stool samples in glass tubes to look for pathogens and parasites like worms under a microscope. The researchers also analyze animal fecal samples.

PHOTO: MIA COLLIS FOR MPG

Akinyi is leading us along a wide forest path toward the Institute, toward the lab. Every now and then, other people pass by, out for a walk. The Oloolua Forest is open to the public, and a popular destination for people living in Nairobi. Nestled among trees, the campus features several low, rectangular lab and administration buildings built in the late 1970s. Akinyi's assistant, Sam Momanyi, is waiting for her in the lab. In one ongoing project, Akinyi's team is examining what diseases affect people in Tana River County in far eastern Kenya and how these relate to their living conditions. The researcher dons a white coat over her colorful blouse, and she and her assistant get started. Momanyi has already mixed stool samples taken from children with a sugar solution and processed them in a centrifuge. Now he takes several glass tubes out of a carrier, one after the other. "This might be interesting," he says, carefully placing some of the sample onto a glass slide, covering it with a cover slip, and handing it to Akinyi. After setting up the microscope, she looks for signs of worms' eggs and single-celled or-

ganisms called protozoa. Some of these cause diseases like malaria and sleeping sickness.

"Here's a nice egg," she declares after a couple of minutes. Every now and then she finds more. "You have to spend many hours looking into a microscope," she says, without taking her eyes off the sample. It's tiring having to maintain concentration while looking through a high-powered magnifying glass. After ten slides, she's done for the day. That's the only way she can be sure she doesn't overlook anything.

There is little that could distract her in the lab, with its wooden cabinets dating from the late 1970s or early 1980s. In her mid-40s, Akinyi has spent at least five years of her life working at the microscope, maybe as much as ten. The samples she is analyzing this morning are from the Tana River area. The landscape there is barren and in places almost desert-like. "It's quite an exciting area!" says Akinyi.

Having established her research group last year, she now plans to gather even more data in the Tana River region on diseases transmitted between humans, wildlife, and livestock. She wants to more precisely understand how prevalent certain intestinal worm infections are, what factors contribute to their spread, how widespread antibiotic-resistant bacterial genes are, and what the composition of the gut microbiome looks like. The data from her first project in 2011 forms the basis for these new research efforts. The Tana River area is of such interest to researchers because the people there face many of the same challenges that confront large swathes of the Global South: alternating drought and flooding, food scarcity, and exposure to many pathogens. Due to widespread poverty, housing is poor, Akinyi notes, with people and farm animals living in close quarters. Because there are few schools, the level of education is low, and educating people about the spread of disease is a challenge. The project involves not only collecting data on pathogens, but also sharing this data with local communities and working with them on ways to curb the spread of disease.

Meanwhile, Akinyi and her research group face many obstacles. Funding is a constant struggle. Akinyi considers herself fortunate to have secured five years of funding for her project. "People always ask why we are only looking at pathogens in primates. We would have liked to launch a significantly broader project back in 2011." They simply didn't have the money for it. However, the lack of funding is not the only challenge her research faces. "Almost all of the supplies we need for the project are imported," she reports, "In one of my funded projects, it took almost six months to get a single reagent shipped in." On top of that, there is also the issue of cost; scientific materials are not exempt from customs duties.

"You have to consider the cultural and social context if you want to contain the spread of pathogens."

One thing she certainly doesn't lack is resilience. She says she doesn't mind living outside her comfort zone. That comes in handy for her current project. Accommodation in the area is very modest; the researchers stay in the villages overnight. Nor is there much choice regarding food. Even so, Akinyi is delighted to be working in the Tana River area. ←

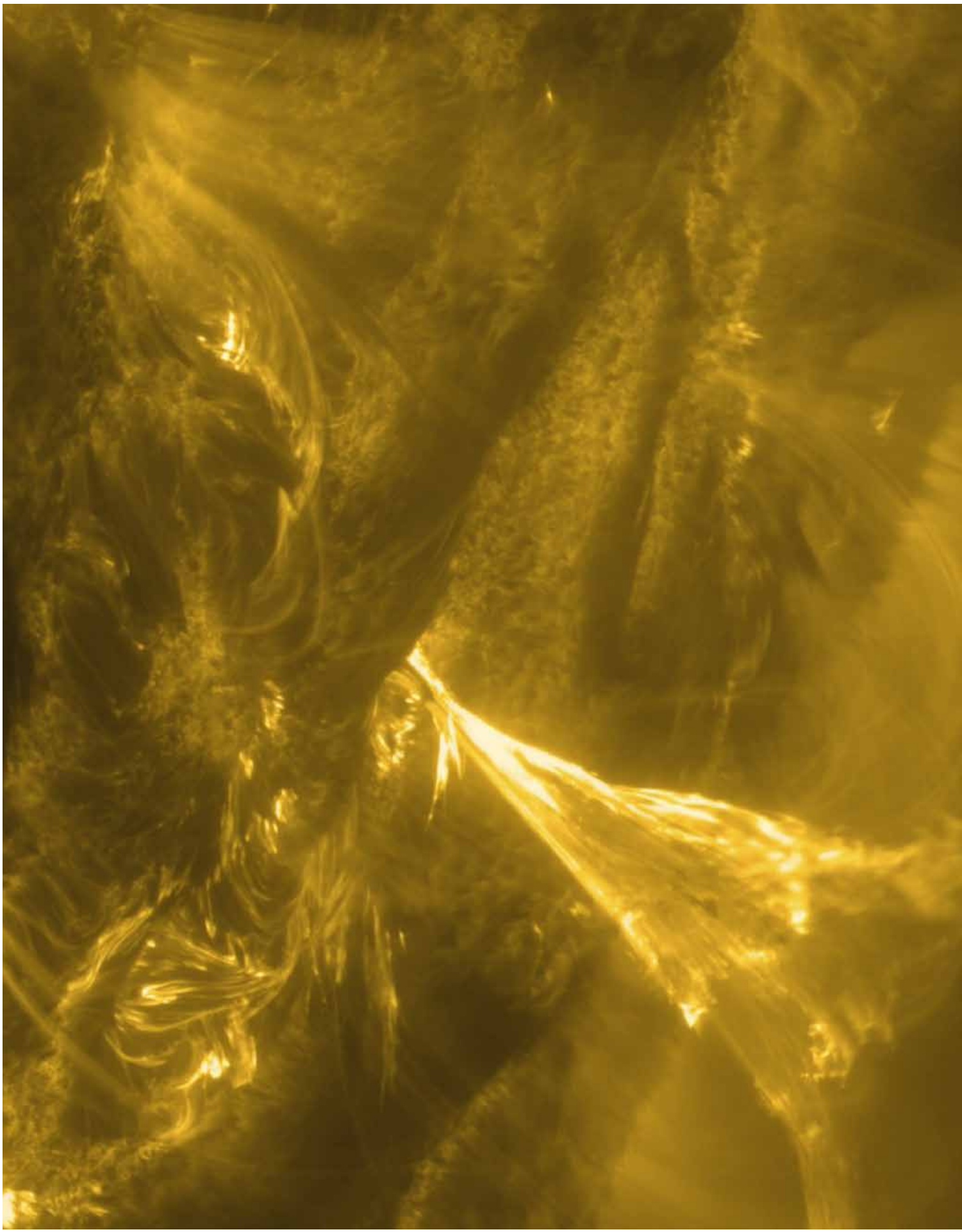


PHOTO: ESA & NASA/SOLAR ORBITER/EUI TEAM

DOUBLE TAKE

MAX PLANCK INSTITUTE FOR SOLAR SYSTEM RESEARCH

On September 30, 2024, there was a violent eruption on the surface of the sun. It discharged a huge amount of magnetic energy and hurled solar plasma – charged particles – in a wide arc out into space. This arc was recorded by the Solar Orbiter space probe, which was developed by the European Space Agency (Esa) and Nasa (left). When large masses like this are ejected towards Earth, the charged particles usually only take a few days to reach the Earth's magnetic field. The solar particles are then guided along this magnetic field towards the poles, but depending on the force of the impact, they can also reach Europe. On their way, the particles cause the oxygen in the atmosphere to glow, among other things, and the resulting red, violet, and green colors that appear in the sky – as photographed on January 19, 2026, at Heidelberg's Königstuhl (right) – are a beautiful spectacle. Geomagnetic storms also disrupt GPS satellites and power grids and have already caused Starlink satellites to crash.

PHOTO: CAROLIN LIEFKE

LIFE'S PRIMORDIAL BREW

TEXT: AENEAS ROOCH

If a space probe were to land one day on Saturn's moon Enceladus or another distant world, would humanity recognize life there if it existed? The building blocks of life, amino acids and nucleobases, are certainly abundant in space. But what exact ingredients and environmental conditions are needed for life to emerge? Researchers at the Max Planck Society hope to find the answer by looking back and asking: how did living biology emerge from lifeless chemistry on Earth in the first place?

The quality of "being alive" seems obvious: a bacterium is alive, a stone is not. But as soon as specialists try to formulate a universal definition, biology, chemistry, cosmology, and philosophy begin to jostle for position. One possible compromise is to require three core properties.

First, life must have a metabolism. A living cell, for instance, takes in energy and uses it to construct complex molecules. Second, a living entity must be distinguishable from its surroundings. Molecules drifting around do not constitute life, however complex they may be. Only when they have a membrane that holds them together and separates inside from outside does a system capable of life emerge. Third, the system must pass information on to its offspring during reproduction, whether through DNA, RNA, or some entirely different mechanism. Otherwise, each generation starts from scratch.

These three criteria sound elegant, but they immediately raise new questions. Do all of them always have to be met? Viruses have genetic information but no metabolism – yet aren't they alive in some sense? And what, exactly, counts as a metabolism? Could a hypothetical life form on a distant moon not draw on energy in ways entirely unlike life on Earth? "I look at life as it exists here on Earth, because it is the only life we know," says Martina Preiner. The chemist leads the Geochemical Proto-Enzymes →

PHOTO: GETTYIMAGES / UNIVERSAL HISTORY ARCHIVE

KNOWLEDGE FROM

BIOLOGY & MEDICINE

Habemus vitam! At least that is what researchers believe: life, or at least the first metabolic reactions, may have formed at hydrothermal vents. At the Iguanas hydrothermal field near the Galápagos Islands, water heated to hundreds of degrees Celsius emerges from the Earth's crust, carrying dissolved minerals that account for the black color of the emissions and deposit along the vent chimneys.

working group at the Max Planck Institute for Terrestrial Microbiology in Marburg and investigates how life on Earth may have originated.

From the moment the first functioning microbe existed, the rest of the story becomes easier to follow. It is still not entirely clear how single-celled organisms without nuclei gave rise to ones with nuclei, or how multicellular life then evolved from them. But "science has many ideas and pieces of evidence," as Preiner puts it. What came before that, though? How did that first functioning microbe arise? Here the trail disappears into the mists of the distant past: 4 billion years ago, in fact. Researchers are approaching that distant past from two directions.

Meet Luca!

The first approach is genetics: starting from single-celled organisms alive today, researchers reconstruct the tree of life. At its root sits the hypothetical ancestor of all life on Earth – the Last Universal Common Ancestor, known as Luca. It is a theoretical construct, the bare minimum a functioning cell must once have required. "What did Luca live on?" asks Preiner. "Probably carbon dioxide as a source of carbon, probably hydrogen to provide energy and electrons, and probably transition metals such as iron, cobalt, and nickel." Single-celled organisms with exactly this metabolism still exist today, in marine sediments and the stomachs of cows.

The second approach to getting closer to Luca is chemistry: starting with simple chemical compounds, researchers use calculations and experiments to work out how the primordial cell could have emerged from them. "We do not know exactly what Luca looked like or how it could have arisen," says

Chemistry of the young Earth: hydrogen (H_2), carbon dioxide (CO_2), and methane (CH_4) escape from hydrothermal vents on the ocean floor. H_2 forms through rock alteration, known as serpentinization, where magma meets seawater penetrating the crust and carrying dissolved atmospheric CO_2 and N_2. In the atmosphere, CO_2 then reacts with H_2 to form CH_4. The sun's UV radiation splits CH_4 and N_2, and rainwater fills ponds with newly formed HCN molecules. Organic material thus forms at vents and in puddles. Complex molecules from space may also have landed in puddles, carried there by meteorites.

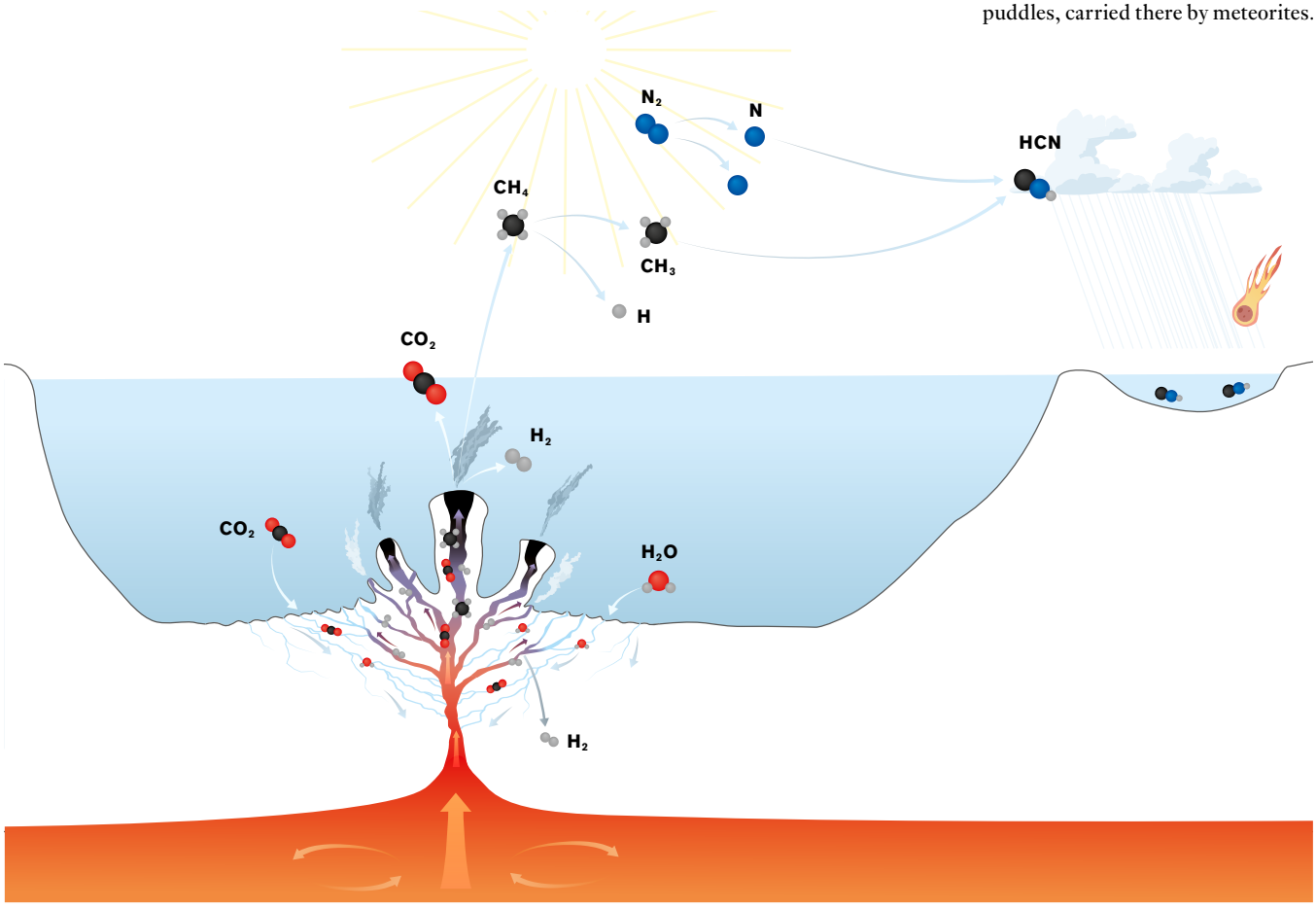


DIAGRAM: GCO, BASED ON MAX PLANCK INSTITUTE FOR MARINE MICROBIOLOGY / MEIER ET AL. 2017; KLAUS PASCHEK ET AL. 2025, APJ 985, 50

Preiner. Two schools of thought dominate the debate: the RNA-first hypothesis and the metabolism-first hypothesis.

The RNA-first theory assumes that life began with RNA molecules that carried information. RNA can reproduce itself and act as a catalyst, serving both as genetic material and as a driver of metabolic reactions. The idea is that once such a molecule existed, everything we now think of as metabolism followed almost automatically. Chemists have since discovered pathways describing how RNA building blocks formed on early Earth before life existed. Even so, many questions remain unresolved, including how the complex metabolism found in living organisms today emerged from RNA.

"I cannot imagine how something as complex as RNA could give rise to the smaller-scale components of a metabolism," says Preiner. She researches the metabolism-first theory. This hypothesis holds that there were small chemical cycles – sequences of chemical reactions that run entirely on their own using whatever ingredients happen to be available. They are pure geochemistry. Genetics may have emerged from these chemical cycles. "This view seems plausible to me because it proceeds in smaller steps: simple chemistry gives rise to chemical cycles, which gradually become denser and more complex." But science can't say whether one approach is superior to the other. "The only evidence we have for the origin of life is life as it exists today," Preiner says. It is entirely possible that both mechanisms played a role.

The chemist is interested in a specific detail of the metabolism-first theory. A cell separated from its environment needs an exchange between inside and outside in order to draw energy from its surroundings. Lipid membranes are among the oldest structures in life that make this process possible. "But Luca did not yet have those at its disposal. So how did the first cell draw energy from its surroundings?" Preiner asks. The answer may lie in rock pores: tiny cavities in early iron-rich silicate rock found at hydrothermal vents, which are chimneys on the ocean floor from which hot water escapes. "Luca's basic metabolic reactions could occur there spontaneously," Preiner says. One explanation would be this: the porous rock acts as a kind of crucible for such a metabolism. Water reacts with the iron present in the rock to produce hydrogen gas (H_2). Minerals found within the porous rock – among them iron ores and nickel-iron compounds – accelerate the reaction of H_2 with CO_2, just as in Luca's metabolism. Similar ingredients can still be found in modern enzymes today.

In laboratory experiments, Preiner and other researchers have also observed these reactions between CO_2 and H_2 in water on mineral surfaces. Overnight, they produced the same organic molecules that form the backbone of LUCA's metabolism: formic acid, acetic acid, and pyruvate. With ammonia, and again with the help of minerals, these compounds can go on to form amino acids, the building blocks of proteins. From there, it is only a short step to the first nucleobases that make up genetic material.

The rock pores offer another advantage: they create an environment that is moist but not wet. "Water is indispensable for life, but when life is forming, water also gets in the way," says Preiner. Too much water washes molecules away before they can combine. Around hydrothermal vents, however, much of the water is chemically bound within the rock. The pores, just a few nanometers in size, are moist enough for chemistry to occur but dry enough not to tear fragile molecules apart. "This kind of setting, with alternating wet and dry conditions, allows different chemical reactions to occur one after another and may therefore have been a key factor in the origin of life."

SUMMARY

Martina Preiner of the Max Planck Institute for Terrestrial Microbiology and Klaus Paschek of the Max Planck Institute for Astronomy are investigating two hypotheses that could explain how life arose on the early Earth.

Preiner studies simple metabolic cycles in the environment around hydrothermal vents on the ocean floor. Paschek examines the early formation of RNA molecules in moist surface ponds. Meteorite impacts in such puddles may have provided a chemical boost.

Both processes were probably at work at the time. Although no life beyond Earth has yet been detected, the prerequisites – such as liquid water – may also exist on other planets and moons. Saturn's moon Enceladus, for example, has already yielded early signs.

It Rained Hydrogen Cyanide

While Preiner investigates how early biochemical compounds develop in porous rock, Klaus Paschek at the Max Planck Institute for Astronomy is exploring a different possibility in the laboratory and on the computer: life from exhaust gases. The early Earth was covered by a vast ocean, its seafloor alive with hydrothermal vents belching hot, mineral-rich water, hydrogen, and methane. The gases rose into the atmosphere, where they encountered the UV radiation of the young sun. "UV radiation was more energetic back then than it is today," says Paschek. "That set photochemical reactions in motion and turned those gases into our favorite building block: HCN, or hydrogen cyanide. Rain then washed the hydrogen cyanide onto the land, into small pools and puddles, where water repeatedly evaporated, and more →

PHOTO: KATRIN BINNER / MPG

PHOTO: ANNA ZIEGLER / MPG

rain repeatedly replenished it." The wet-dry cycles in these "Darwinian puddles" resemble the cycles that may also have occurred in the rock around hydrothermal vents. Warm, chemically rich puddles of this kind offer an ideal environment for simple chemical ingredients to combine into something new and complex. So, whether life began in deep-sea rock or in surface puddles, the two hypothesized birthplaces of life appear to have much in common.

A Cosmic Boost for Life

"Perhaps the puddles also got a boost from space," says Paschek. "A fragment of an asteroid may have crashed into a Darwinian puddle and brought along some of life's building blocks." Asteroids are not simply dead lumps of rock: many were heated from within in the early solar system by radioactive decay, and some even contained liquid water. According to the hypothesis, simple molecules in these warm, water-rich rocks, including hydrogen cyanide (HCN) and ammonia, gave rise to more complex organic compounds, among them precursors of RNA building blocks and sugars. For Preiner, the fact that biomolecules also form in space shows just how naturally such molecules come together.

Another share of these organic compounds probably formed much earlier in the protoplanetary disk where the sun and planets took shape: dust grains coated with water and methanol ice were irradiated by UV light and chemically altered. According to this scenario, basic chemical ingredients formed there and later turned up in asteroids too. If a meteorite broke off such an asteroid and fell into a puddle on the early Earth, it could have brought with it a cocktail of chemicals: building blocks of DNA and RNA, simple sugars, and more, from which the first biological molecules formed. "Our theory is unconventional," Paschek admits. In a warm puddle, terrestrial and cosmic chemistry may then have come together and shaped the first faint stirrings of life from inanimate matter.

"In principle, a molecule like HCN can be used to cook up almost everything a cell needs," says Paschek, and both outer space and the early Earth could supply the necessary ingredients, whether in asteroids, hydrothermal vents, or warm ponds. Earth's atmospheric chemistry had one decisive advantage, however: "Meteorite impacts were isolated events, brief chemical jolts. Volcanoes, by contrast, continuously pumped gases into the

Left: Martina Preiner stands in front of glove boxes in the laboratory of the Max Planck Institute for Terrestrial Microbiology. These devices help to simulate the anaerobic conditions of the early Earth.

Right: at the Max Planck Institute for Astronomy, Klaus Paschek (red T-shirt) shields himself from a UV laser that excites artificially produced molecules of the kind that could form in space. Michael Hermann (center) and Tushar Suhasaria (front) are preparing to analyze those molecules.

atmosphere, UV radiation set reactions in motion, and rainstorms carried the products down into puddles." Geochemistry thus provided a steady supply of ingredients. That made it less of a problem if a handful of early life forms fell victim to hostile environmental conditions such as intense UV radiation. Preiner believes, in any case, that all the earliest building blocks must have originated on Earth: "Even if amino acids or nucleobases reached us from space on asteroids, life on Earth would still have had to find a way from the very beginning to forge this material itself, without relying on outside supplies. Life is the interplay of building blocks within metabolism, not the sum of the molecules themselves."

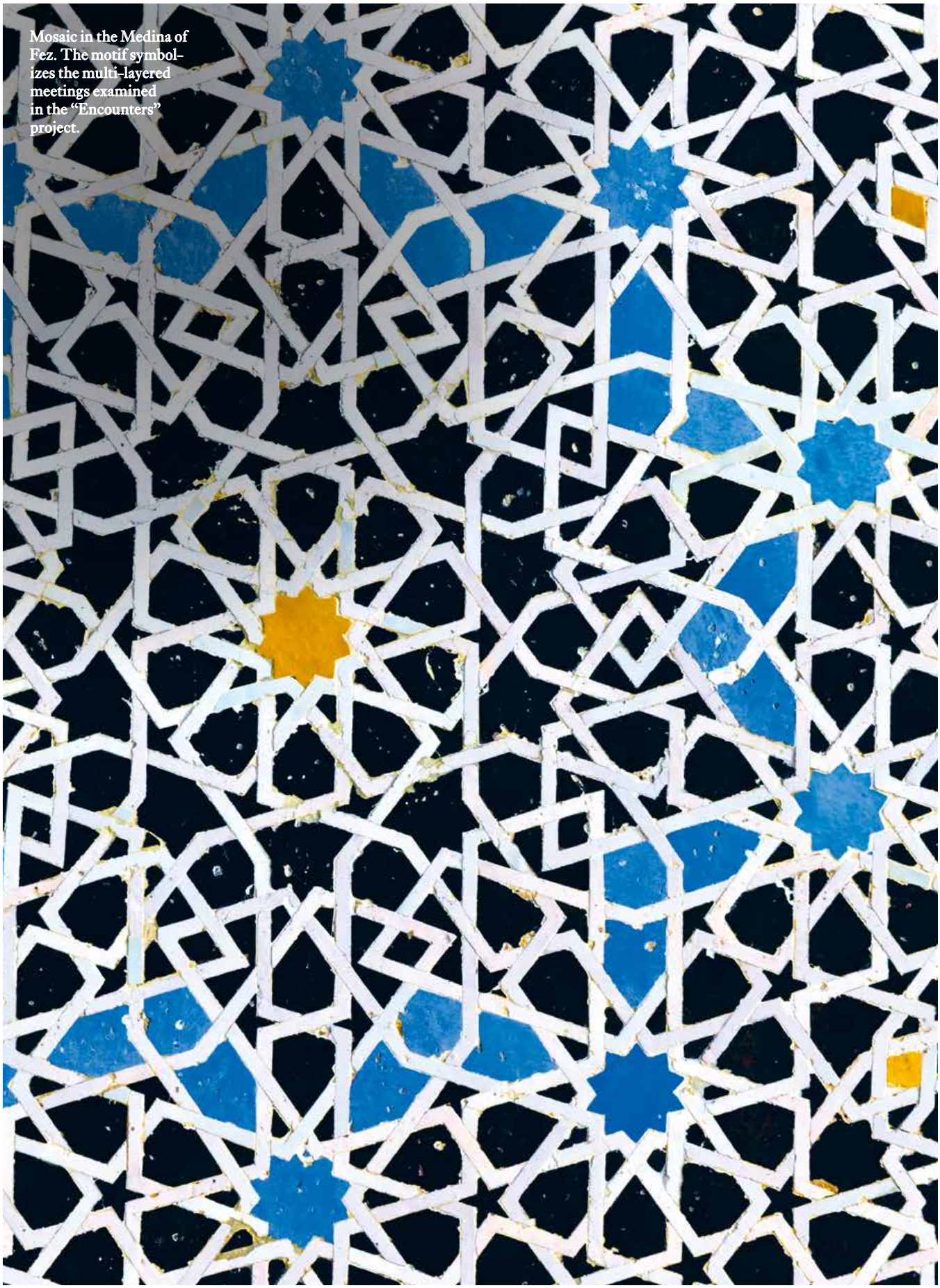
Could a meteorite possibly crash into a warm puddle on another planet or moon, thus giving rise to life? At minimum, liquid water would be required and with it an atmosphere. On Earth, the pressure of the atmospheric layer above the surface keeps water liquid. Solar radiation causes parts of the ocean to evaporate, while the exchange of air between regions of differing atmospheric pressure produces winds that carry water vapor away before it condenses again as rain. Wet-dry cycles of this kind can therefore occur only on Earth-like planets.

So far, no telescope has found liquid water on rocky planets the size of Earth. Either Earth is truly exceptional, or researchers have simply had bad luck with the planets studied so far. Super-Earths – rocky planets more massive than Earth – are easier to detect on account of their greater mass. Many of them are likely to be more geologically active and even to have atmospheres. There are at least indications of water vapor in the atmospheres of such planets. Water vapor would also be easier to detect than liquid water, but researchers are not yet certain. The Extremely Large Telescope, which within a few years will become Earth's largest eye on the universe and will study exoplanet atmospheres, could bring greater clarity. If water exists there, the processes Paschek is investigating could be happening.

Liquid water and trace elements associated with life are fairly reliably found in less hospitable places too, such as beneath the thick ice shell of Saturn's moon Enceladus, where the Cassini spacecraft detected organic molecules in the water vapor and erupting ice plumes. These molecules could have arrived via protoplanetary dust grains or asteroid fragments. There also appear to be hydrothermal vents on the floor of an ocean inside Enceladus, piercing the moon's continuous ice shell. In that environment, water, rock, and energy come together, providing the foundation for the kind of life Preiner studies.

"I believe simple microbes probably exist elsewhere as well," Paschek says. "Complex life forms probably do not. After all, it took 4.5 billion years on Earth for *Homo sapiens* to emerge." Preiner also considers extraterrestrial life possible: "I am optimistic that we could find precursors of life on Mars."

Biology versus chemistry, RNA versus metabolism, hydrothermal vents versus Darwinian puddles: Paschek sees no clear front-runner. "The origin of life is so improbable that nature probably exploited every available advantage and used everything it could get its hands on." Perhaps there is no single primordial soup, but several. Perhaps different precursors of life developed alongside one another simultaneously – multiple Lucas, of which only one lineage survived? Humanity, then, may not be unique, but simply one of many outcomes of the same cosmic experiments, while somewhere else a new metabolism is at work on its own version of this accidental history. ←



Mosaic in the Medina of Fez. The motif symbolizes the multi-layered meetings examined in the "Encounters" project.

PHOTO: ISTOCK / HADYNYAH

PATTERNS OF ENCOUNTER

TEXT: STEFAN HUNGLINGER

Vanessa Rau and Dekel Peretz, together with researchers working on the international "Encounters" project, have examined encounters between Muslims and Jews in six European cities. One thing they didn't anticipate at the beginning of the project: the events of October 7, 2023, and their consequences.

Wearing a burgundy sports jacket, Dekel Peretz wanders through the *Maybachufer* market in Berlin's Neukölln district. The stalls are lined with fragrant mint and thick bunches of dill and parsley, and next to them are watermelons – whole, halved, and quartered. People from many different backgrounds buy and sell here, long-standing Berliners and newcomers alike jostle their way through the stalls alongside tourists, and a rooster crows from the shoulder of a blond woman. "What does a typical Jewish woman look like?" asks the long-bearded Dekel Peretz, observing the crowd, "and what does a typical Muslim man look like? And what's a typical encounter between a Jew and a Muslim?"

The scientist wants to raise awareness regarding prejudice based on appearance alone, the complex nature of group identities, and how they are perceived. Over the past four years, co-founders Vanessa Rau and Dekel Peretz, together with 15 other social scientists from Germany, France, and the UK, have taken a detailed look at "Jewish and Muslim Encounters, Diversity & Distance in Urban Europe" as part of the "Encounters" research project. The Max Planck Institute for the Study of Religious and Ethnic Diversity participated in the project alongside German, French, and British universities. But there's one thing they didn't anticipate at the beginning of the "Open Research Area": the events of October 7, 2023, and their consequences.

When Peretz moved from Israel to Berlin in 2002, he very consciously made his home here, in one of the most ethnically diverse neighborhoods in the German capital. "It had to do with my family's background," he says. "Some of us are from Eastern Europe, others from Morocco. And it also had to do with the way I look." He felt that the population in other districts of Berlin was worryingly homogeneous. Even worse, Friedrichshain was going through a surge in neo-Nazi attacks. "In Neukölln and Kreuzberg, I felt safe. I looked like everyone else there." As it turns out, many Jewish Israelis and Jewish migrants from the US have ended up joining him, moving to Berlin districts with a strong Muslim presence.

From the weekly *Maybachufer* market, it's just a few steps across the Kottbusser Bridge to the *Fraenkelufer Synagogue*. Standing beneath the trees along the canal, Dekel Peretz, who completed his doctorate at the University of Potsdam on the Jewish sociologist Franz Oppenheimer, explains that this spot has been shaped by migration from the very beginning, including by Jewish immigrants. "At the beginning of the 20th century, many Jewish workers moved to Berlin from the Russian Empire, and an Orthodox synagogue was built here for them." After the Holocaust came a wave of immigration by Polish Jews who had been liberated from the concentration camps. Today, this conservative synagogue has once again become a meeting place for the growing number of Jews who move to Berlin from Israel, the USA, and Latin America.

For many years, Dekel Peretz was the Program Director at the *Fraenkelufer Synagogue*: today, he is responsible for the rebuilding of the main synagogue, which was set on fire by the →

Nazis in 1938. That means he's not just a researcher; he occupies several roles, which he tries to handle in a transparent and productive manner. British-Palestinian Encounters researcher and anthropologist Alyaa Ebbiary likewise occupies several roles. For 15 years, she was involved in interfaith neighborhood projects and continues to be involved in educational initiatives to this day. Most researchers involved in the project also have personal ties with the research field.

Analyses were carried out by "community media" and social media on all sub-projects of Encounters, and some researchers also used quantitative methods. All researchers, including Dekel Peretz and Alyaa Ebbiary, used the ethnographic method of participant observation. This method is very different from comparative lab analyses, says Ebbiary in an episode of the podcast accompanying the project, initiated and presented by Vanessa Rau, which Dekel Peretz has helped to organize.

The observers themselves played a role and elicited reactions that then had to be reflected in the research. Ebbiary is a Muslim and wears a headscarf, which has been read as a marker of belonging in Muslim spaces but has sometimes caused unease in Jewish ones. Others in the research group have Christian backgrounds or are secular-Christian – and this does not make them any less "involved." After all, according to the final report, Jews and Muslims do not come across each other "in a purely bilateral context, but always in relation to a European social ethos that is structured by the power of the secular-Christian majority and the secular-Christian state at both local and national levels." In France, for example, a strict separation between state and religion is ensured through republican *laïcité*, while in the UK, society is shaped by conservative pluralism, with social cohesion deliberately promoted through political measures.

State and Tradition

These traditions defined how the interfaith activities of state institutions, foundations, and other institutions were structured. "They also helped to open up or close off the possibility for less formal encounters to take place, by establishing the language in which claims can be formulated, conflicts can be articulated, or coalitions can be formed."

Religious communities in the UK are often actively involved in local activities, while in France they would be perceived as communitarian, i.e., anti-liberal and thus suspicious. In Germany, with its "flawed separation of state and religion," says Dekel Peretz, political discourse on the concept of the "Judeo-Christian West" and "core cultural values" has long been influential in interfaith dialogue. Also, much has changed in this regard in the meantime.

Vanessa Rau joins them in front of the *Fraenkelufer Synagogue*. The sociologist completed her doctorate at the University of Cambridge, with a thesis on the growing scene of young Jewish Israelis since around 2010 and a new Jewish scene in Berlin. Rau is the co-founder and herself a researcher in the Encounters project. When her British colleagues Ben Gidley and Sami Everett suggested the idea of initiating an international research project on Jewish-Muslim relations, Rau saw this as an important signal. She says that an examination of daily life and real situations in which Muslims and Jews interact in large European cities could contribute to mutual understanding and to breaking down stereotypes. In addition to Berlin, subprojects were also

PHOTO: ALAMY / TRAVELSTOCK44.DE / JUERGEN HELD

The *Maybachufer* market in the Kreuzberg district in Berlin, a meeting place for people from different origins.

carried out in Frankfurt am Main, London, Manchester, Paris, and Strasbourg.

After the Holocaust, says Rau as she walks along the canal, the relationship between German politics and the Central Council of Jews in Germany was shaped for decades by a very clear political stance, which was defined in turn by the wish for reconciliation on the one hand and security on the other. This "negative symbiosis," a term coined by historian Dan Diner when referring to German-Jewish relations after the Holocaust, at times led to irritation among Muslims. "And this was even more the case with immigrants who initially knew nothing of this 'symbiosis,' than it was for people of Muslim background who were raised in Germany."

In the 1970s and 1980s, a "second generation" of Jewish figures, among them Frankfurt natives like Micha Brumlik and Cilly Kugelmann, had already shaken up the status quo by drawing attention to political structures and antisemitism. But it was only with the influx of newcomers from Israel and other countries that a larger Jewish community developed in Berlin, one whose Jewish practice, self-understanding, and political positioning could diverge significantly from those of the established institutions. At issue were attitudes toward Israel, toward Muslims and anti-Muslim racism, toward sexism, queer concerns, patrilineal Jews – that is, people with a Jewish father – and interfaith marriages. According to Rau, "Where the minority expresses itself in multiple ways, it is more difficult for the dominant culture to exert control over it, and also much more difficult for the state to manipulate."

In her subproject, Rau examined intimacy in Muslim-Jewish relationships. One strand of her study looked at how encounters between Jews and Muslims unfold on apps designed to facilitate dating and/or casual sexual encounters. Another involved interviewing Muslim-Jewish couples, only some of whom are open about being an interfaith couple. For other couples, their Muslim and Jewish identities are imposed on them from the outside. Describing one of the results of her research, Rau says: "While public discourse often focuses on 'cultural differences,' thereby posing an obstacle for a functional relationship, it is evident that migration regime, social discourse, and structural socio-economic inequalities are factors that have the greatest impact on intimacy." Romantic relationships face real challenges when one partner's legal status in Germany is uncertain, when politics fuels racism, and when the gap between rich and poor grows ever wider.

SUMMARY

Muslim-Jewish encounters in European cities tend to be marked by ambivalence, indifference, or a mere "coexistence," not by harmonious dialogue.

Political traditions, migration regime, and social inequalities shape these relationships much more than religious differences.

Peretz has primarily examined cultural and grassroots initiatives. The "summer of migration" in 2015/2016, as well as the right-wing terrorist attacks in Halle (2019) and Hanau (2020), led to new alliances in many of these groups. In view of the antisemitic and racist violence, these alliances focused on the collective goal of establishing a post-migration, democratic society. When the Covid-19 pandemic forced dialogue formats to shift to virtual settings, it intensified the performative harmony. At Iftar celebrations or other intercultural gatherings, such harmony has also been celebrated in an artistic and culinary fashion, for example, at institutions in Neukölln. So, is it all a matter of Shalom and Salaam?

In the final Encounters project report across all six cities examined, the most common patterns for of Muslim-Jewish encounters are ambivalence, indifference, and avoidance. According to the report, "in neighborhoods where both Jews and Muslims live, relationships are most often marked by a 'parallel co-existence' – next to but not with each other." In places where there is actually some contact, this can mean anything from sociability and solidarity to conflicts and hostility. Peretz says: "It is not scientifically tenable to think that encounters, contact, and dialogue always bring something good, a feel-good story, a happy ending."

Conflict and Dialogue

The massacre carried out by Hamas in Israel on October 7, 2023, and the war crimes Israel's government has committed in the Gaza Strip since then, have also transformed the situation in Europe – including in Berlin. In antisemitic incidents, bans on protests, and even physical violence, the political conflict with its Muslim-Jewish connotations has made itself felt here too. Especially here in Neukölln.

"Many things have changed since then," says Rau. "But just like the Covid crisis, October 7th and the Gaza war became a sort of catalyst for conflicts that may already have existed beneath the surface." Peretz reminds us of the escalation in the Israel-Gaza conflict in May 2021. At the time, the joint open letter initiative (*muslimisch-jüdische Briefaktion*) was launched by Jewish and Muslim organizations, under the title "We will not be divided" (*"Wir lassen uns nicht trennen"*). The aim was to separate everyday local inter-community relations from the events in the Middle East, and to hold demonstrations in which conservative Jews would protest side-by-side with Iranian opposition members, Kurdish groups, and Muslim critics of Islam, to take a position in the conflict. Both were forms of Muslim-Jewish alliances, with very different political agendas.

On a personal level, following the events of October 7th, both researchers →

PHOTO: ALAMY / TRAVELSTOCK44.DE / JUERGEN HELD

The *Fraenkelufer Synagoge* in Berlin's Kreuzberg district. It is a meeting place for Jews who move to Berlin from Israel, the USA, and Latin America.

met with a great deal of disappointment across different communities. "From the Jewish perspective, many had expected more support from Muslims," says Rau. "From the Muslim perspective, it soon felt as if they were all being treated with blanket suspicion."

Since October 7, "performative disharmony" has been far more present on social media than "performative harmony," says Peretz. As he explains in his research report: "On the one hand, social media channels exacerbated the narrative of hostility between Muslims and Jews and filled the feeds of users with scenes of violence between these two groups. At the same time, these channels circulated images of solidarity between Muslims and Jews and acts of resistance in Germany, Israel, and Palestine."

Peretz noted that even non-religious Jews expressed their solidarity with Palestine at demonstrations by wearing a watermelon-patterned kippah. The watermelon is used as a symbol for Palestine, due to its red, green, white, and black colors. As Rau reports, since October 7, 2023, more and more watermelon emojis have been found on gay and non-gay dating and hookup apps, although this was less a sign of solidarity than an expression of a clear political stance. Rau reports that these symbols created a lot of uncertainty among Israeli Jews, and in some cases led them to ask a question in the chat before a hookup: "Hey, I am Israeli is it ok for you?"

Peretz and Rau consider the macro-political reactions to the events of October 7 as critical. "It is difficult to maintain dialogue when there is mounting criticism and pressure on the dialogue, both within and outside the communities," says Rau. This also applies to the political appeal of "distance yourselves!" made to Muslim communities after October 7, which took on elements of violence, as people cannot be held accountable for geopolitical events simply because of their faith and background. The unreflective conflation of religious affiliation and the Middle East conflict carries great potential to exacerbate tensions and adds to societal polarization, which are dangerous in times like these.

Peretz says: "Since then, I have often been asked if October 7 marks the end of any dialogue between Muslims and Jews. I am of the view that it is precisely times of crisis that make dialogue possible. If there were no gap to overcome, people wouldn't define this exchange as dialogue." Sometimes these formats are more visible and public, while at other times, the debate happens behind closed doors. Then again, it is often individuals who facilitate dialogue as "entrepreneurs of encounter." Dialogue is still taking place, however.

Peretz and Rau both agree that the claim that "the dialogue has failed" is a politically dangerous expression, and that, provided they do not escalate into violence, conflicts are simply a part of genuine encounters and long-lasting dialogue. ←

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Wissenschaft im Dialog

2026 Wissenschaftsjahr Medizin der Zukunft

As far as the eye can see: jeans, T-shirts, and dresses from all over the world pile up in the Atacama Desert in Alto Hospicio, northern Chile. This photo was taken in 2022. For years, about 20 metric tons of used clothing that nobody wants anymore have been ending up here every day.

PHOTO: PICTURE ALLIANCE/DPA | ANTONIO COSSIO

FASHION FOR THE FUTURE

TEXT: KATHARINA MAU

New regulations aim to promote the circular economy within the EU and reduce raw material consumption and waste in a particularly resource-intensive sector – the fashion industry. Antonia Sommerfeld from the Max Planck Institute for Comparative and International Private Law in Hamburg examines the legal framework necessary to enable a circular economy.

Can a single designer make a difference in the fashion industry? That's the question Reet Aus, an Estonian fashion designer, asks herself in the documentary Out of Fashion. She travels to Bangladesh, sees how jeans are produced for fast-fashion brands, and learns just how much waste is generated during production alone, either from fabric scraps or over-production. She begins collaborating with the factory she visits with the aim of producing clothing from fabric that would otherwise be discarded. It's upcycling in grand style. Reet Aus hopes to team up with one of the major fashion brands so she can really make a difference, but it doesn't work out and a collaboration never materializes.

At the end of the documentary, Antonia Sommerfeld poses herself the question: why not? A qualified lawyer, Sommerfeld is a senior research fellow at the Max Planck Institute for Comparative and International Private Law and conducts research on the fundamental elements of the circular economy – a way to reconcile sustainability and economic viability. But what would it take for not just one or two suppliers to produce sustainable fashion, but for an entire industry to discover the potential behind the circular economy? She soon concludes that private law has the potential to change things on this front. It's a perspective on the circular economy that has barely been explored.

To grasp the legal possibilities, it helps to understand the fashion industry's massive environmental footprint. Every year, the textile sector accounts for between two and eight percent of global greenhouse gas emissions across the entire value chain. It consumes significant amounts of water in the process – an annual amount that would fill 86 million Olympic swimming pools. That translates to about 115 bathtubs per person per year in Germany.

This is because our approach to clothing and other consumer goods follows a linear principle: produce – buy – wear (far too rarely) – and throw away. One possible solution to curb resource consumption without sacrificing →

profits for businesses or the economy is the concept of the circular economy. Broadly speaking, there are two sides to this concept: first, measures that slow down the cycle, and second, those that close it.

With regard to the fashion industry, that means designing and producing clothing so that it lasts a long time and can be repaired. It also means developing secondhand business models for the mass market – so that clothing one person no longer likes ends up in someone else's closet and is worn for longer.

Closing the loop requires systems for turning old, damaged garments or fabric scraps into new clothing, either through upcycling or recycling. That means shredding scraps to recover the fibers from them and then using these to produce new materials.

Pioneering Work

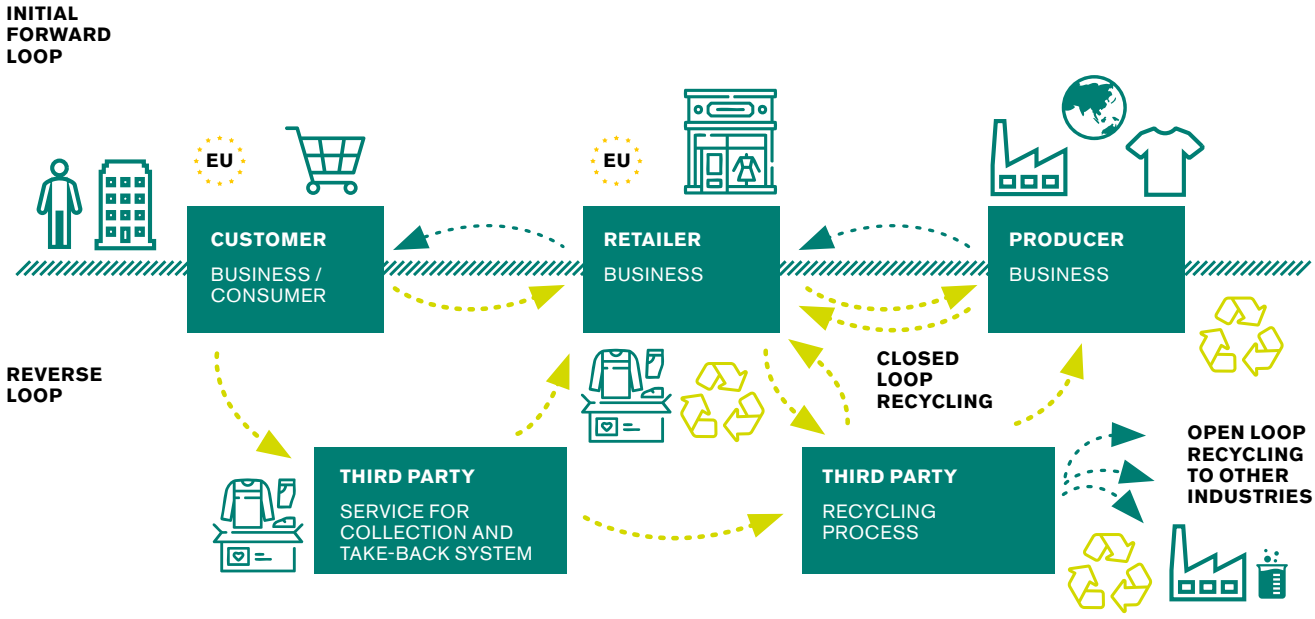
Some fashion houses are already experimenting with circular business models. For example, Reet Aus, the Estonian fashion designer, has followed through with her approach, producing clothing from leftover materials under her own label. She has also developed a certification program to share her knowledge with other manufacturers. Meanwhile, Belgian company HNST produces jeans made largely from recycled fibers. And they're designed to be easily recycled themselves – for instance, you can simply twist off the buttons. The Italian fashion company Rifo recycles wool and cashmere fibers, and the Trützschler Group also processes fibers for reuse, to name just a few labels and companies.

The outdoor outfitter Patagonia offers a free repair service and sells used Patagonia clothing through its own online store. The manufacturer Napapijri has developed its "Circular Series" collection, with garments made from a single material rather than a blend. "Blended fibers are hard to recycle into clothing of equivalent quality," says Burcu Gözet, who researches the circular economy in the textile industry at the Wuppertal Institute. "The process is much easier with monomaterials," adds Sommerfeld, "and the technology is already more advanced."

Yet despite isolated examples, circular business models are still far from reaching the mass market. Less than one percent of our clothing is recycled into new garments. Taken together across the entire world, people throw away a full garbage truck's worth of clothing every second. Used clothing from Europe ends up mainly in Africa and Asia.

The fast-fashion industry produces as cheaply as possible and outsources many of its production steps to countries in the Global South – causing harm to people and the environment in the process. Yet in linear economic competition, businesses in this industry benefit. At the moment, circular products are often more expensive than linear products, whose negative environmental costs are not factored into their price. Nor does it make financial sense for companies to change. Circular business models therefore currently work only in niche markets – for companies with customers who value sustainability and have enough

In a circular economy, producers, retailers, and customers, as well as return systems, are all interconnected. For example, when clothing from collection points or containers ends up back at the manufacturer and they then refurbish it or recycle the fibers, the cycle is closed. In the fast-fashion industry, by contrast, the majority of discarded items end up in incinerators or landfills.



GRAPHIC: GCO BASED ON ANTONIA SOMMERFELD, VERÓNICA RUIZ ABOU-NIGM

money and time to buy sustainable fashion or secondhand clothing. When a company like Patagonia offers a free repair service, this can help it to retain a specific customer segment for the brand. "But there is by no means a level playing field between linear and circular business models, which is currently hindering a circular transformation," adds legal expert Sommerfeld. And that's where legislation comes in. At present, it tends to favor a linear economy: the purchase of products is clearly regulated, for example, but companies are not obligated to take them back at the end of their lifespan. There are various different ways to help level the playing field for companies committed to the circular economy, ranging from a general take-back obligation for end-of-life textiles to tax incentives for circular products. "We are seeing some companies doing pioneering work, trialing circular business models and thereby implementing the model of the circular economy," says Antonia Sommerfeld. "Our task, and that of policymakers, is now to consider how these models can be scaled in a way that is attractive and legally sound."

Private Law as a Lever for Circular Fashion

So how can this be achieved? And how can a single country like Germany use legislation to favor circular products manufactured in international supply chains without disadvantaging its own economy? After all, different rules might apply to German companies and international companies. These are the questions Sommerfeld tackled together with her co-author Verónica Ruiz Abou-Nigm, a law professor at the University of Edinburgh, in their 2024 study. They run through a hypothetical example: a customer buys a garment at a shop in Berlin or from an online store targeting the German market. The seller is a Swedish company. The garment was manufactured by a producer in Bangladesh. The authors also imagine that Germany has introduced a new law: if clothing is labeled as circular, companies benefit from tax breaks. This boosts the economic incentive and creates a competitive advantage. At the same time, this entails a responsibility for companies, who need to ensure that customers can return used clothing to the company free of charge and with minimal effort. In this way, the clothing can then be repaired, upcycled, or recycled to its highest material value and reused.

SUMMARY

The fashion industry follows the model of the linear economy; fast fashion thus causes massive environmental damage, for example, through increasing textile waste.

Legal scholar Antonia Sommerfeld from the Max Planck Institute for Comparative and International Private Law is researching an alternative model: the circular economy.

While a few manufacturers are already leading the way by recycling or refurbishing textiles, Sommerfeld is exploring new legal frameworks that could make the circular model attractive to the entire fashion industry.

The circular model combines economic and ecological advantages, for example, through take-back obligations, tax incentives, and Extended Producer Responsibility in the EU.

If these rules applied only to domestic companies within the German market, these businesses would be at a disadvantage compared to international companies selling their products in the same market because they would be the only ones having to handle the return shipping and reuse of the materials. But this is where the EU's private international law comes into play. It works like a signpost, explains Sommerfeld. It determines which law applies and which court has jurisdiction for cross-border contexts. It ensures that all companies operating in a comparable manner on the German market are subject to the same regulations in their dealings with consumers. The same then applies in Spain, for example. Thus, disadvantages for domestic companies are specifically avoided. "In our case study, all companies wishing to sell on the German market would have to ensure that consumers can return used clothing easily and at low or no cost," says Sommerfeld. This would apply to businesses in Germany, but also to online stores targeting the German market – be it Reet Aus, Patagonia, or future circular economy providers.

"We demonstrate that a national legislator can be bold and promote the transition to a circular economy," says Sommerfeld. Ideally, such regulations would be adopted at the EU level, but individual member states could take the lead in this way without putting their companies at a disadvantage compared to foreign competitors. Circular economy approaches are also interesting because they can help with the achievement of national climate goals and make countries and supply chains less dependent on raw materials from abroad – an advantage not to be underestimated in times of geopolitical crises.

When Sommerfeld and Ruiz Abou-Nigm present their research findings at conferences, they are met with tremendous interest internationally. Sommerfeld is convinced: "The negative environmental impacts of the fashion industry are felt worldwide, particularly in the Global South, and the circular economy is a promising solution – both economically and ecologically."

The EU is likewise seeking solutions. With its strategy for sustainable and circular textiles, it has set ambitious goals: by 2030, all textile products on the EU market shall be durable, repairable, and recyclable, and consist largely of recycled fibers. Since 2025, it has been mandatory in the EU to collect textiles separately, with local authorities obliged to provide →

PHOTO: TOM PINGEL / MPG

Circular meets social: Antonia Sommerfeld in front of the raw materials used by the company Bridge & Tunnel in Hamburg, which, among other things, manufactures designer products from textile waste. In addition to ecological sustainability, the label is committed to social responsibility and provides a visible platform for socially disadvantaged women and refugees to become textile workers and talents.

dedicated containers for this purpose. In the future, this will apply as a general rule for worn-out clothing as well. While Berlin at least offers dedicated containers for this (albeit for a fee), in Munich the only option is to dispose of such items in the general waste bin. According to its statements, the district authority there is still awaiting a coherent and implementable overall concept. Another factor compounding the problem is that the quality of clothing is declining, particularly in ultra-fast fashion. This makes it ever more difficult to reuse or recycle.

Starting in July 2026, companies will no longer be allowed to destroy clothing, headwear, and shoes that they have not sold. According to the European Commission, they will instead be required to manage their inventory more efficiently and to prepare returns for resale or donate them. Furthermore, the European Parliament has adopted an Extended Producer Responsibility (EPR) scheme for companies selling textiles in the EU, which obligates them to pay for collection, sorting, and recycling. Member states must transpose these requirements into national law by mid-2028. "If the fees are structured so that companies producing non-recyclable clothing have to pay more, that would create an economic incentive," says Burcu Gözet of the Wuppertal Institute.

Turning Old into New

The EU has introduced the right to repair not for fashion, but for devices like smartphones, tablets, or washing machines. The directive is to be transposed into national law by summer 2026 and will then apply in Germany as well. As yet, however, the EU has not introduced any obligation for companies to take back old clothing – in contrast to what the researchers propose and recommend in their publication. How this might work is also the subject of legal scholar Antonia Sommerfeld's postdoctoral thesis. Her aim is to examine how German private law would need to be amended to support a circular economy – for example, through circular sales contracts, which also make companies and their supply chains more crisis-resistant. This would include the proposed obligation for companies to take back their own products. In this way, they can recycle the raw materials used or refurbish and resell the garments.

German private law is based on the German Civil Code (Bürgerliches Gesetzbuch – BGB), the provisions of which first came into force in 1900 and largely remain in effect today. Over its 126-year history, it has witnessed many social and technological changes – and adapted accordingly. ←

GLOSSARY

LINEAR ECONOMY
Describes the conventional form of economic activity. It's also referred to in professional circles as the "take-make-waste economy." Product life cycles have a clear beginning and end, and recycling or reuse is not, or only partially envisaged. The linear economy relies on a constant inflow of resources and continuously generates waste.

CIRCULAR ECONOMY
An alternative model to the linear economy. It combines economic and ecological goals. In this system, materials never become waste, but are kept in circulation through maintenance, reuse, refurbishing, restoration, recycling, or composting. The circular economy combats climate change and other global challenges such as biodiversity loss, waste, and environmental pollution by decoupling economic activity from the consumption of finite resources: materials in the cycle contribute to value creation on a permanent basis.

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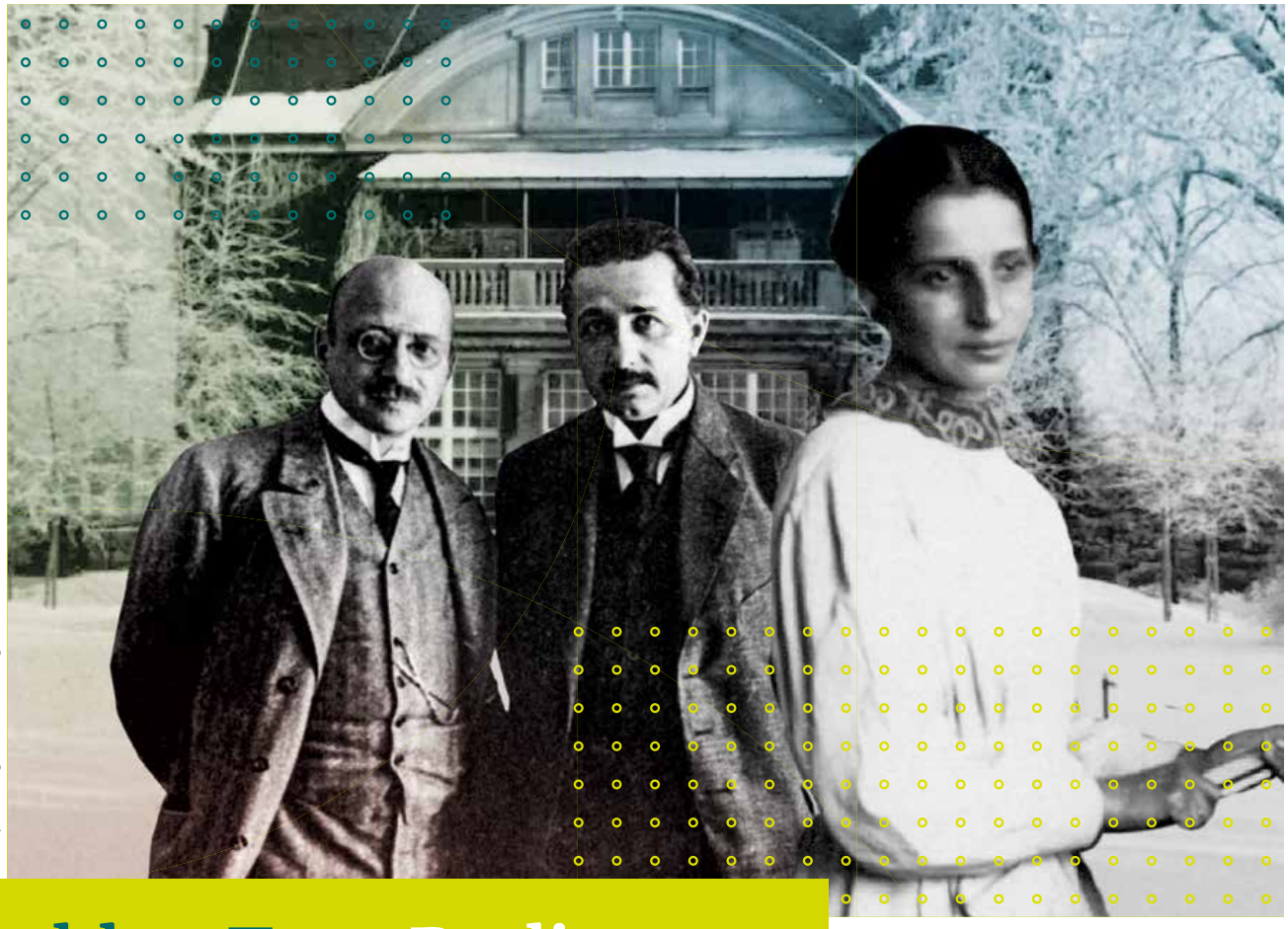

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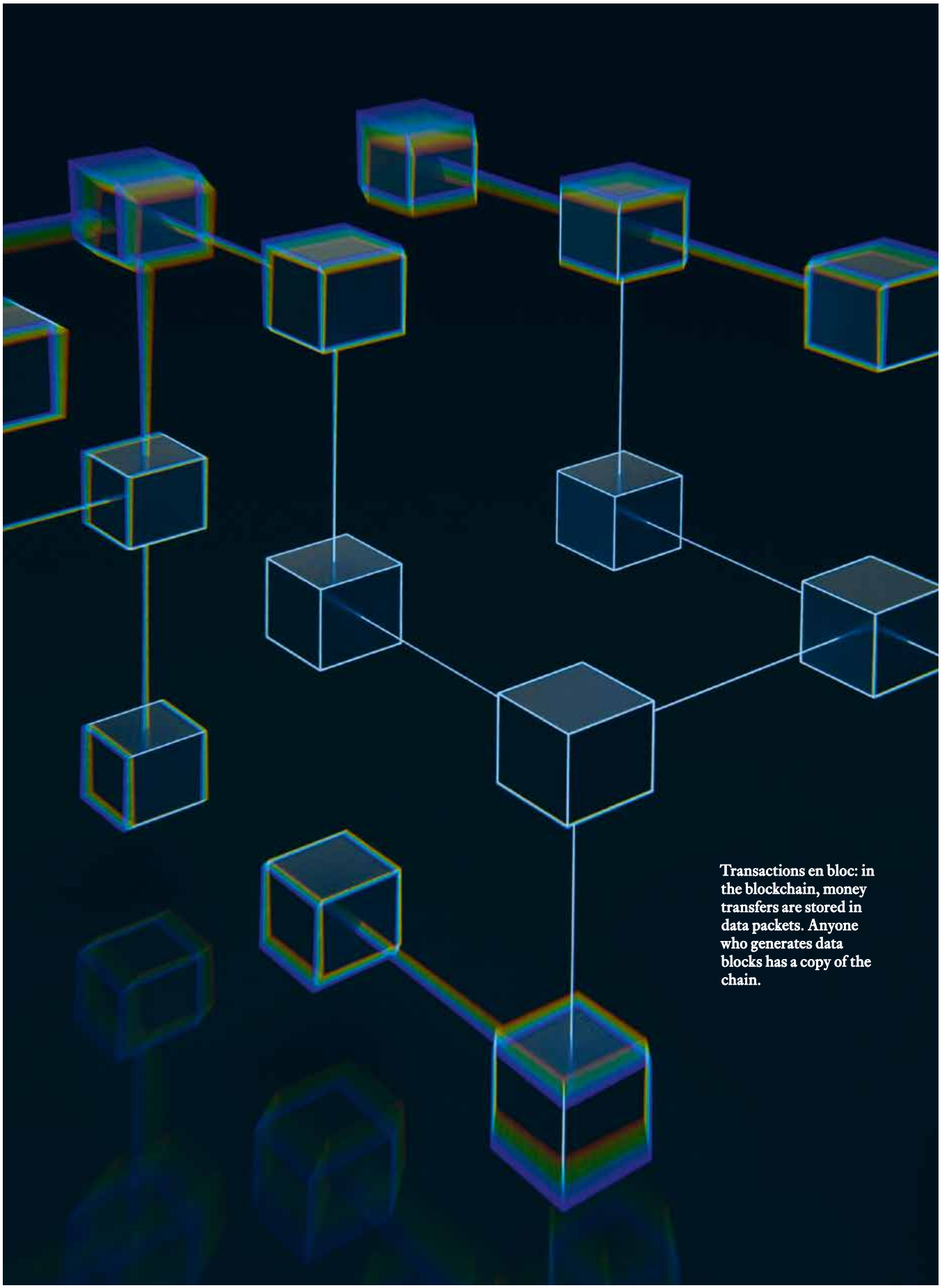


Transactions en bloc: in the blockchain, money transfers are stored in data packets. Anyone who generates data blocks has a copy of the chain.

PHOTO: UNSPLASH / SHUBHAM-DHAGE

GAPS IN THE BLOCKCHAIN

TEXT: THOMAS BRANDSTETTER

Blockchains form the backbone of cryptocurrencies such as Bitcoin, but they can also be used to process all kinds of transactions. They not only avoid the need for institutions such as banks or notaries, but they are also designed to be inherently secure against theft and fraud. However, blockchain-based applications are by no means invulnerable. Clara Schneidewind and her team at the Max Planck Institute for Security and Privacy in Bochum are identifying security vulnerabilities in applications of this kind.

It is an attempt to reorganize the world of business: blockchains take on functions normally performed by banks or notaries, such as confirming transactions and documenting digital ownership. The most prominent examples are cryptocurrencies such as Bitcoin and Ethereum. Blockchains are, in essence, a form of digital authentication – carried out not by individual institutions, but rather by a multitude of participants who neither know nor need to trust one another. This technology is based on encrypted, or at least digitally signed, data packets that are managed and monitored in a decentralized manner. Trusted central authorities are therefore no longer needed. Additionally, the blockchain aims to enhance the security of certain transactions through smart contracts.

The blockchain is in fact based on state-of-the-art cryptography. Data blocks are linked together like beads on a necklace. In addition to their content, they contain the cryptographic fingerprint of all previous blocks. Once the chain is created, it can no longer be altered. Any manipulation of a block would be immediately noticeable because the subsequent blocks would no longer match the original block. Additionally, identical copies of the blockchain are stored on multiple independent servers. When blocks store a history of money transfers, what you have is a cryptocurrency. This includes private individuals as well as institutional players, such as companies and public institutions.

So far, so secure. However, the blockchain is not the end of the story, despite being the flawless backbone of its applications. "The cryptography →

is secure, but it only ensures that no one can retroactively alter the history," says Clara Schneidewind, who heads the Heinz Nixdorf Research Group for Cryptocurrencies and Smart Contracts at the Max Planck Institute for Security and Privacy. The mechanisms for generating the chains are not nearly as secure as the result. The same applies to the interfaces with the outside world, through which Bitcoins can be exchanged for other currencies, for example. And when blocks contain not only simple transactions, but also more complex constructs, such as digital contracts, hackers repeatedly find vulnerabilities. As a result, Schneidewind and her team have set out to find solutions to the security challenges posed by blockchain applications.

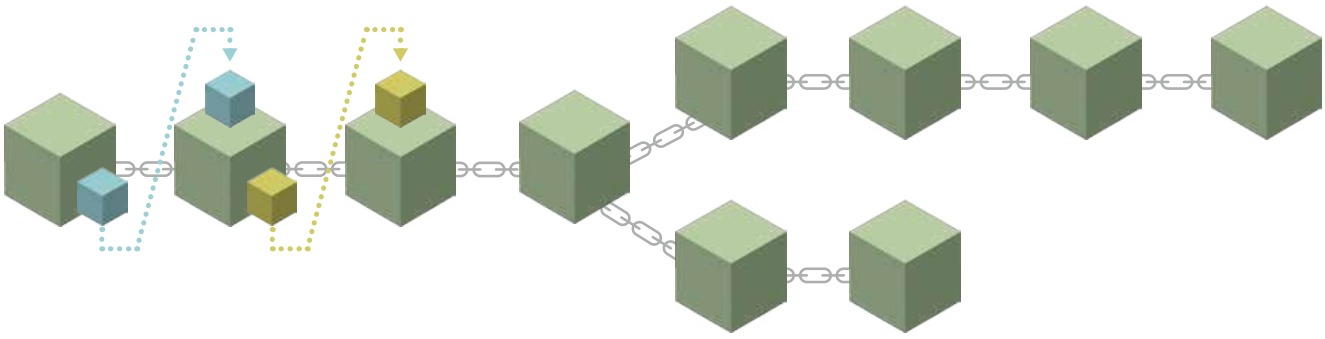
One vulnerability stems from the blockchain's most fundamental characteristic: its decentralized structure. All participants have the same information about its content because the blockchain exists as identical copies on multiple different servers, known as nodes. Participants are also equal in other respects. Unlike government-issued currencies, there is no higher authority that can make decisions or adjudicate disputes. Nevertheless, someone must document current transactions in a new block and add them to the chain to keep the blockchain running.

Computing Power Wins

"Ideally, the system should randomly select someone to generate the next block of transactions," says Schneidewind. This would ensure that the expansion proceeds fairly and that no one is censored. In practice, however, random selection is difficult because individual participants could create multiple identities to gain an advantage during selection. Interest in creating blocks is high because participants are rewarded with new cryptocurrency for doing so. Therefore, the participant who gets to create the next block must be determined by other means. For example, the proof-of-work mechanism that powers Bitcoin does not select participants at random but rather based on their available computing power.

This computing power is required for a process known as mining. The blockchain automatically generates a complex mathematical puzzle, and the first person to solve it is allowed to create the next block containing the transactions that took place during the calculation. This computational task simultaneously produces the cryptographic fingerprint of the chain to date. These calculations consume enormous amounts of energy, making any potential manipulation extremely costly. This is precisely the core of the blockchain's security. "Back then, it was a very elegant solution to Bitcoin's challenge of selecting people at random," says Schneidewind.

However, if an attacker had more computing power than all the other participants combined, they could throw the system into chaos. They could secretly build their own private chain in parallel to the public blockchain. Although this chain's content would largely match that of the public blockchain, the attacker could hide their own transactions. Meanwhile, they could continue making purchases via the original blockchain, and these



GRAPHIC: GCO

An encrypted chain: each new link in the blockchain contains a cryptographic fingerprint of the previous one, as shown by the blue and yellow blocks. Forking may occur when new data blocks are created. After a short time, however, one branch gains the upper hand and is continued exclusively.

transactions would initially be confirmed. However, due to their superior computing power, the attacker's chain would grow faster than the public one. If the decentralized versions of the blockchain stored by the various participants are not the same length and are not equally up to date, the consensus protocol stipulates that work should always continue on the longest existing chain. Therefore, as soon as the attacker publishes their version, the collective will automatically regard it as the valid chain and adopt it, even if the attacker omitted their own transactions. Their previously confirmed payments would never have occurred in the new blockchain, yet they could keep the goods purchased with them. "However, it's unclear whether there actually are actors who can concentrate enough power to carry out such an attack," says Schneidewind.

Danger in the Dark

Another way to attack blockchain networks is what is referred to as an eclipse attack. In this scenario, an attacker deliberately isolates a single participant from the rest of the network. The attacker surrounds the victim with manipulated nodes, cutting them off from the real blockchain – hence the name "eclipse." The isolated victim then only receives information controlled by the attacker, which presents a distorted view of the blockchain's state. For instance, the attacker can falsify a payment to trick the victim into delivering goods without receiving any actual compensation. "However, such attacks require enormous infrastructure and involve attacking routers or specific locations," says Schneidewind. "That makes them very complex and often simply too expensive."

However, cryptocurrencies can be more easily manipulated, at least in theory. In addition to its exorbitant energy consumption, the proof-of-work mechanism has another drawback: there can be long wait times until the current puzzle is solved and a new block is generated. Current transactions cannot be recorded immediately in the blockchain and remain in limbo for a while. "If you want to use cryptocurrencies for instant payments, you'd theoretically have to wait minutes at the till until the payment is secure," says Schneidewind. "Otherwise, there's a risk of fraud." For example, by displaying a freshly sent but still unconfirmed transaction in their wallet app, a malicious user could trick a merchant into believing that they have already paid for an item, only to use the same coin – a specific digital unit of currency that is often the subject of cryptocurrency transactions – again shortly thereafter. If the fraudster also has a good connection to a miner, they might succeed in having the second transaction recorded in the blockchain first. Thus, they would have effectively used the same coin twice. "That would render the first payment attempt invalid," says Schneidewind. "So, you can only be truly certain once the transaction is firmly recorded in the blockchain."

If payment recipients always wait for the transaction to be recorded in the blockchain before providing the goods or services, such an attack is highly unlikely to occur. This is illustrated by the history of the most prominent cryptocurrency: Bitcoin. Launched by anonymous developers, Bitcoin was the first functioning implementation of the proof-of-work mechanism. "That was over 17 years ago, and although Bitcoin is a highly lucrative target, its blockchain has never been hacked," says Nils Urbach, a professor of business informatics at Frankfurt University of Applied Sciences and a Director of the Fraunhofer Blockchain Lab.

However, the reasons for this are not only technical but also economic. Even if an actor had the computing power required to mount an attack, doing so would harm their own interests. The market value of the affected currency would likely plummet, causing the value of the bad actor's coins and mining-specific hardware to decrease as well. Rapid technological progress does not currently pose a threat to Bitcoin either. Quantum computers, for example, which are currently under development, are said to have the potential to undermine traditional cryptographic methods. "Theoretically, they could crack the signature methods used by blockchains," says Urbach. These signatures serve as proof that someone is authorized to own a specific unit of currency. If they are cracked, an attacker could spend other people's money. However, cryptocurrencies benefit from the fact that quantum computer development is progressing slowly, and in any case, alternative, quantum-secure signatures already exist.

Artificial intelligence, on the other hand, cannot compromise blockchain encryption. Still, it could be used to search through large amounts of data for vulnerabilities in the →

SUMMARY

Blockchains form the backbone of cryptocurrencies and perform the functions of institutions like banks and notaries for multiple participants. They are designed to be secure. However, security vulnerabilities can arise during their creation and in the applications running on them.

For instance, attackers with significant computing power could hijack nodes in the participant network and trick individual participants into making payments. The biggest security vulnerabilities arise from poorly programmed applications, such as smart contracts. Cybercriminals have stolen millions of US dollars through these vulnerabilities.

A team at Max Planck identifies security vulnerabilities in blockchains and develops protocols designed to secure transactions, such as those between different blockchains.

applications built on top of blockchains. Minor security flaws in cryptocurrencies have already been identified even without the use of AI. This often affects the interface between blockchain technology and the rest of the digital world, such as when traditional currencies are exchanged for Bitcoin, for example. "These are often entry points for hackers, as has already happened in the past," says Urbach.

Automated Transactions

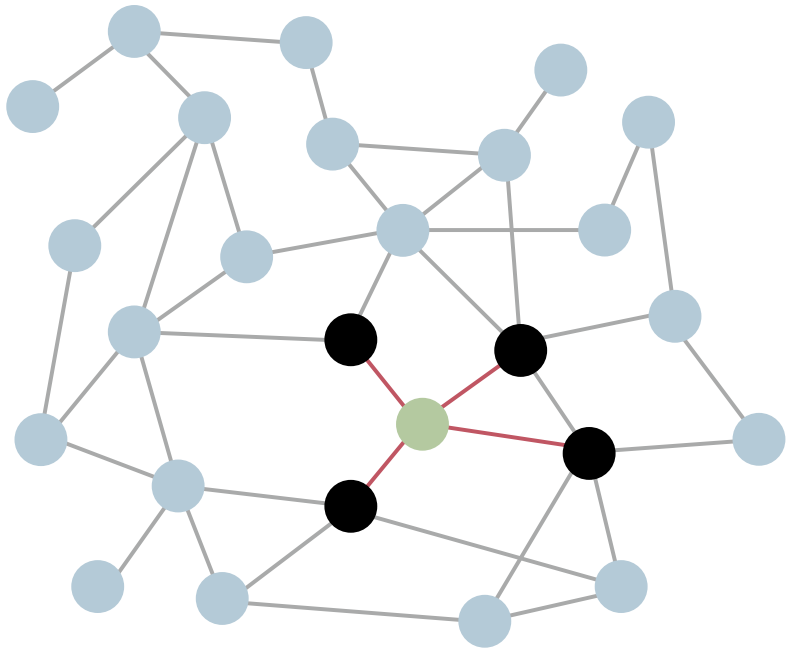
The use of blockchains is not limited to managing cryptocurrencies. Automated processes for all kinds of transactions, or smart contracts, can also be stored in their blocks. Smart contracts are nothing more than program codes on a blockchain that act as automated trustees. This means you can specify in advance what should happen to a sum of money, and the system will execute these instructions exactly. A typical example of this is crowdfunding. Multiple people transfer funds to a recipient, who can only withdraw the money once the funding goal has been reached. If the goal is not met, everyone automatically gets their money back. However, for this to work reliably, the contract's programming must be airtight. "Unfortunately, security risks arise time and again due to errors that creep into the contracts," says Urbach.

A prominent example of this is the 2016 DAO hack. The DAO, a decentralized autonomous organization based on blockchain technology, wanted to raise money through crowdfunding. However, attackers found a software bug and exploited it. The smart contract was programmed so that all parties involved could request an advance refund of their deposited funds. However, the sequence of events was incorrect. To prevent fraud, the new account balance should have been recorded first, and then the funds should have been transferred. But, due to an error in the program, the account balance was only updated afterward. This created a brief window during which the attacker could initiate another refund before the contract registered the first payout. This allowed the attacker to steal cryptocurrency worth USD 50 million by getting the money refunded multiple times in a row.

Problems with smart contracts are one of Schneidewind's primary areas of research. In a current study, she and her team at the Max Planck Institute for

PHOTO: JUDITH WALLERIUS

Searching for gaps in the chain: Clara Schneidewind investigates security vulnerabilities on the blockchain and its applications.



GRAPHIC: GCO

Compromized neighborhood: fraud on the blockchain is possible through methods such as an eclipse attack. In this scenario, cybercriminals in the participant network can hijack a participant's neighboring nodes and use a manipulated blockchain to trick the participant into believing that payments have been made.

Security and Privacy have been examining a particularly challenging case involving smart contracts designed to function across different blockchains. "It's hard enough to write the code correctly for a single blockchain," says the researcher. "But it becomes a whole lot more complicated when different cryptocurrencies are involved." In this case, two contracts – one on each blockchain – must communicate with each other. Complex cryptographic protocols are required to ensure that users can interact securely. Schneidewind's team developed BitMLx, a protocol for cross-chain communications. It can be simply illustrated by the example of exchanging different cryptocurrencies: Person A has Bitcoin, and Person B has an equivalent amount of Ethereum. They want to trade but don't trust each other. This issue can be resolved with a cryptographic secret, which is like a password that must be known to withdraw the other person's funds and prevent third parties from accessing them. Initially, only Person A knows the secret, and they are the first to deposit their money into a sort of escrow account on the blockchain. Then, Person B also deposits their funds into an escrow account. Once Person A withdraws the funds deposited by Person B, the secret automatically becomes visible to Person B, who can then withdraw the funds deposited by Person A. "We have proven that with our protocol, an honest user will never lose money when executing such a contract, no matter what other parties do," says Schneidewind.

In this way, Schneidewind and her team are gradually closing existing security vulnerabilities in smart contracts and cryptocurrencies. Nevertheless, she herself says she would not want to invest in Bitcoin or similar cryptocurrencies. As a researcher, she finds that it's more important for her to remain unbiased. After all, anyone who holds large amounts of a currency can quickly find themselves in a conflict of interest. Who would disclose a security vulnerability that could wipe out their fortune? There is another reason for her reluctance, though: "When you look at it from a research perspective and consider everything that could go wrong, it's easy to want to stay away from it." ←

GLOSSARY

BLOCKCHAIN
A decentralized database of financial and business transactions stored across all participants. Money transfers and other changes in ownership are stored in newly generated, cryptographically secured blocks.

PROOF OF WORK
A method in which participants in a blockchain network must demonstrate their computing power. In a blockchain, this involves solving a cryptographic puzzle, which simultaneously generates an encrypted fingerprint of the existing chain. The first person to solve the puzzle is allowed to create the next block and is rewarded with cryptocurrency for doing so.

SMART CONTRACT
A program that maps an automated business process, such as a change in ownership, onto the blockchain.

PHOTO: ADOBESTOCK / NIKOLAI SOROKIN

The longest structure in the world: the Great Wall of China is easily reached on a day trip from Beijing. The higher sections are often shrouded in clouds.

Max Planck researchers collaborate with partners in more than 120 countries. Here they write about their personal experiences and impressions. Jinyi Shangguan, formerly a scientist at the Max Planck Institute for Extraterrestrial Physics in Garching, has taken over as head of a Max Planck Partner Group at the Kavli Institute at Peking University. Together with his team, he is researching supermassive black holes – mysterious objects from the early days of our universe.

The Paranal Observatory in Chile's Atacama Desert is a dream come true for astronomers: far away from any light pollution and located at high altitude, the observation conditions are among the best in the world. It's different in my homeland: I come from Guiyang in southwestern China. It's often foggy there, and the sky is overcast – challenging conditions for stargazers. So, my enthusiasm for astronomy as a child was genuinely written in the stars. But I was interested in the natural sciences from an early age. My parents encouraged me and gave me books on a wide variety of topics. Both of them worked in a factory. Becoming an astronomer was a stroke of luck: I was offered a place at the renowned Kavli Institute at Peking University and seized the opportunity.

Today, I lead my own research group at the Kavli Institute. My team and I are dedicated to researching black holes. We collect our data at the Paranal Observatory, whose centerpiece is the Very Large Telescope Interferometer (VLTI). This combines the light from several telescopes into a single, extremely sharp "virtual" telescope. It becomes even sharper thanks to GRAVITY+: an optical instrument that serves as an upgrade for the VLTI. It was designed and built by a European consortium led by the Max Planck Institute for Extraterrestrial Physics. With this ingenious technology, we are able to make the invisible visible: black holes remain hidden from direct view, but reveal themselves through their enormous gravitational pull, which deflects passing stars, causes gas to glow, and even distorts space. The heaviest black holes reach billions of times the mass of our sun and originated in the early days of the universe. But how could they have formed so soon after the Big Bang? This remains one of the great mysteries of astronomy. To solve this problem, we plan to build more telescopes and expand the VLTI to improve the resolution by a factor of ten. Thanks to its long-term funding, the Max Planck Society offers ideal research conditions for such an ambitious project.

POST FROM

BEIJING, CHINA

Before I came back to Beijing, I spent six years as a postdoc at the Max Planck Institute for Extraterrestrial Physics in Garching – an exciting and rather turbulent time. One particular highlight of my time at the Institute was the day our Research Group Leader and Institute Director Reinhard Genzel received the Nobel Prize for observing the black hole at the center of our Milky Way. It was 2020, during the coronavirus pandemic. Our entire department had gathered in the conference room to watch the announcement live on screen. Everyone was wearing masks. But despite the distance, the feeling of being part of this team was incredible! It was a turbulent time due to all the traveling: our research group had been granted 17 nights of observation time at the VLTI to observe black holes outside the Milky Way, spread over two years. On the long journey from Munich to Chile, I usually made a stopover in Paris to visit my wife, who had a job in the financial sector there. When our two sons were born, things got really complicated. I would have loved to split myself in two to do everything justice!

Fortunately, since I've been living with my family in Beijing, things have calmed down. A lot has changed at the local university during my absence: there are several new buildings, and access to the campus is now controlled by automatic facial recognition. Our astronomy team is now larger and more diverse. I am still in close contact with my colleagues in Garching. Just recently, some of them were here in Beijing for a working meeting. We listened to lectures, sat together, and made plans. Of course, a visit to the Great Wall of China was also a must. It was a rather foggy day. But since we were traveling privately and not as astronomers, the fog didn't bother us.

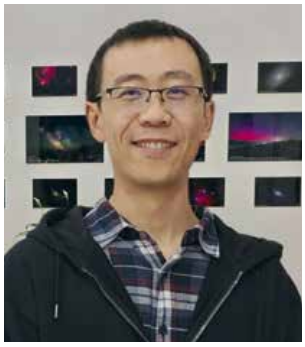


PHOTO: PRIVATE

Jinyi Shangguan

36, has been leading a Max Planck Partner Group at the Kavli Institute for Astronomy and Astrophysics in Beijing since March 2025. His home country of China is a focal point of the Max Planck Partner Group program: 17 of the more than 80 groups worldwide are based there. When Jinyi Shangguan is not conducting research, he enjoys walks with his family and exercising on campus.

FIVE QUESTIONS

ON SURVEILLANCE TECHNOLOGY IN THE US AND GERMANY

WITH CARMELA TRONCOSO

Ms. Troncoso, according to media reports, US Immigrations and Customs Enforcement (ICE) uses Palantir software called Elite to track down migrants who might be living in the United States without valid residence permits. How does the app work and what is so problematic about it?

First of all, I am not a lawyer and can only answer on the basis of my knowledge and expertise. Elite allegedly has access to extensive information from public and private sources. This information is then utilized by AI to infer a probability score on whether a person could be a target for ICE. *A priori*, they do not know who the targets could be, which is a key difference to how law enforcement normally works – identifying a suspect and then getting information on them after a court order. The app also infers a confidence score on a particular address for a person of interest after processing data like bills, social media posts, family links, economic status, future plans, or hobbies. This is extremely problematic, as it allows the creation of arbitrary criteria which can then be applied without transparency or control.

AI reasoning and decision-making processes are often criticized for being opaque and inexplicable. Are human outcomes now at the mercy of this black box?

The inferences the app makes are not certain by definition. "A confidence score" means that there is always a chance that people may be targeted without reason. A system that uses automated targeting cannot be built in a proportional, reasonable manner, in contrast to the kind of targeted surveillance that we have nowadays. What's more, such an AI system is not interpretable, meaning that it is not possible to understand why errors happen.

The far-right AfD party in Germany is sympathetic to the idea of establishing a task-force like ICE in Germany. Would the use of an app like Elite be possible in Germany, despite the fact that this would contravene Germany's Basic Law?

The use of an identical app would be difficult as the same sources of information do not exist in Europe. Sensitive medical data, banking data, or telephone records cannot be freely accessed or processed for the purpose of profiling and targeting people. But the data exists and thus can be accessed with subpoenas, or by penetrating the system. However, there is a lot of available information around that can be crawled or acquired. Even with less extensive information, very damaging applications could be created. For example, individuals have data footprints on social media and the web that could be used to infer a movement profile. Similarly, we have shown that even AI tools which are designed to automatically moderate online conversations and filter false information, bullying, or hate speech, will be biased or work based on confidence. So, in some cases, they cannot distinguish right from wrong. We must always be very careful when making decisions based on AI.

The company Palantir that supposedly built the app used by ICE, also built Vera, which is used by the German police. What is the difference between Elite and Vera?

Looking at news reports, Vera only uses information from police records. This is in contrast with Elite, which gathers external sources to make inferences. So, in my view, Vera is not a light version of Elite. In my understanding, repurposing data from records to train AI models is prohibited by the General Data Protection Regulation. However, Vera uses AI and it suffers from issues similar to those experienced by Elite: data collected for purposes other than surveillance and targeting is reused for this purpose without consent, transparency, or control. In addition, inferences made by Vera will have errors and will be systematically biased towards certain subgroups. As is the case with Elite, Vera is not a proportional tool, as it will generate surveillance on and cause harm to innocent people.

Do we need to guard against autocratic/dictatorial tendencies in data protection?

From my perspective, autocratic tendencies are not the reason we should be better protecting our data. We need to protect it better because having data that is accessible and usable by anyone creates a world in which manipulation is easier – potentially by governments but also by private parties that use this data for their own profit. Protecting personal data should be a high priority in any case.

Interview: Tobias Beuchert

Carmela Troncoso is Scientific Director at the Max Planck Institute for Security and Privacy in Bochum

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