

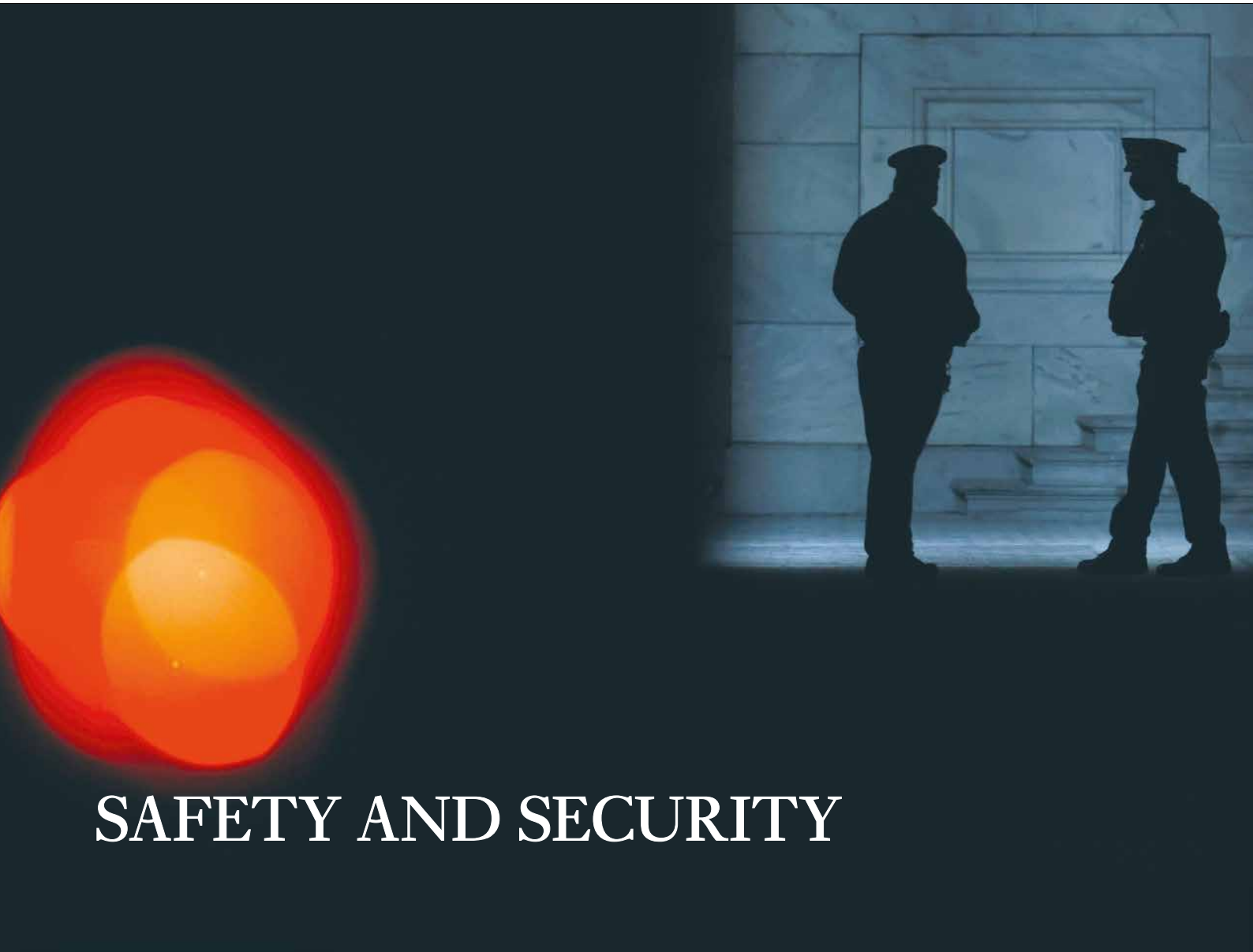
# MAX PLANCK

## *Research*

**75**<sup>YEARS</sup> OF THE MAX PLANCK SOCIETY  
A Mirror of Its time

**BIOLOGY**  
Hunger – It's All in the Mind

**ASTRONOMY**  
How the Milky Way Was Born



# SAFETY AND SECURITY



PHOTO: REUTERS/CARLOS BARRIA

**T**ribute for protecting democracy: police officers pay their last respects to Brian Sicknick at the Capitol in Washington. The police officer defended the U.S. Congress against an onslaught of Trump supporters on January 6, 2021. He died a day later as a result of two strokes. These were judicially classified as natural causes of death, but it is unclear whether the storming of the Capitol contributed to triggering the strokes.

# EDITORIAL

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Dear Reader,

The Capitol in Washington is the quintessential symbol of democracy. The storming of this inner sanctum of American democracy in early 2021 illustrated just how vulnerable democratic societies are. Willingness to engage in violence against state institutions has also risen in other countries over the past few years. Incidents often seem to be unrelated to one another in any discernible way; experts speak of “stochastic terrorism.” However, rather than depicting socially isolated individual perpetrators at work, the latest evidence points to a strategy of interconnected and like-minded actors. With lies and conspiracy theories, they create a psychological environment that makes such acts of terror possible.

The dissemination of malware programs is a relatively new form of criminality, which allows electronic devices to be spied upon. Since security is often a secondary concern during the development of new software, programs frequently contain vulnerabilities that can be exploited by criminals. Researchers are hopeful that a new method will help to detect these security holes more efficiently.

The security of a society is contingent upon how it deals with its criminals: “Lock them up – forever!” This is how former German Chancellor Gerhard Schröder asserted sex offenders should be dealt with in 2001. Other violent crimes also elicit calls for tough sentences. But do longer prison terms reduce an individual’s propensity to commit acts of violence? Findings from social psychology and neurological research suggest that a sentence based on retribution, deterrence, and exclusion encourages the very violence it seeks to prevent.

This issue of *Max Planck Research* is the first following a huge change. Our long-standing chief editor and highly valued colleague Helmut Hornung has recently entered retirement. His favorite bon mot, “the gap he leaves in his absence is a worthy replacement,” does not apply in his case: we miss him! But we promise to continue running the magazine with the same enthusiasm for exciting stories about science.

We hope you enjoy this issue!

Your editorial team



32



38



54



60

IMAGES: ALESSANDRO GOTTARDO (TOP LEFT); ANTHONY SAJDLER (TOP RIGHT); ADOBESTOCK / COMOFOTO (BOTTOM LEFT); SVEN DÖRING FOR MPG (BOTTOM RIGHT).

**32 | PAINFUL**

The experiences undergone by prisoners make it more difficult to resocialize them.

**38 | TRUSTFUL**

Hannah Pool's research was only made possible by her close ties to refugees.

**54 | FLAVORFUL**

The reward system in the brain is particularly drawn to foods that are heavy in fat and sugar.

**60 | POWERFUL**

The interconnected neurons of the brain provide the model for artificial neural networks.

# CONTENT

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## 03 | EDITORIAL

## 06 | ON LOCATION

Palazzo Chiaramonte in Palermo

## 8 | IN BRIEF

## 14 | VIEWPOINT

### Getting to the Meat of the Matter

To curb climate change, we must also change our diet. A mix of soft and hard measures could reduce climate-damaging meat consumption.

## 18 | INFOGRAPHIC

The Evolution of the House Mouse

## FOCUS

### Safety and Security

## 20 | From Sparks To Fire

It often appears that increasing political violence is the result of individual actions. But ‘random terror’ also follows patterns – and understanding them can help prevent attacks.

## 26 | Program Vulnerabilities

A new method makes the search for security vulnerabilities in software much more efficient – and companies such as Google are already using it.

## 32 | Life Sentence

The way the penal system is put into practice in many countries makes reintegration into society more difficult – but there is another way.

## 38 | VISIT TO

Hannah Pool

## 46 | DOUBLE TAKE

## 48 | 75 YEARS OF THE MAX PLANCK SOCIETY

### A Mirror of Its Time

Known for its scientific achievements, the Max Planck Society has also been – and continues to be – a player in contemporary history, for example, German reunification.

## KNOWLEDGE FROM

## 54 | Hunger – It’s All in the Mind

Hunger and appetite are controlled by processes in the brain that have long given us humans evolutionary advantages – which makes them difficult to control.

## 60 | Intelligence with a Plan

A mathematical theory of artificial neural networks could help to better understand and optimize artificial intelligence.

## 66 | How the Milky Way Was Born

Our galaxy’s first few billion years were turbulent – this history can be reconstructed with a kind of cosmic archaeology.

## 72 | POST FROM ...

Grenada, Caribbean

## 74 | FIVE QUESTIONS

On ChatGPT and Copyright

## 75 | PUBLISHER’S INFORMATION



# ON LOCATION

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PHOTO: SISTEMA MUSEALE DI ATENEIO DELL'UNIVERSITÀ DEGLI STUDI DI PALERMO

**T**he late Gothic Palazzo Chiaramonte in Palermo, also called *Lo Steri* (Fortress Palace), has a checkered history. Today, it is one of Palermo's tourist attractions, but in the 17<sup>th</sup> and 18<sup>th</sup> centuries, the *Steri* was the center of the Inquisition court and its dark prisons. People of various religions and backgrounds were imprisoned here; the walls of the cells are covered with drawings – multiple layers of them in some cases. Depictions of religious scenes are accompanied by maps and inscriptions in many languages, including Italian, Sicilian, Hebrew, Latin, and English.

7

The picture shows Christ's descent into the underworld, iconography that is still very significant today, especially in the Eastern Orthodox Church. During the time between his death on the cross and his resurrection on Easter night, Christ descends into the realm of the dead. There he redeems the souls of the righteous – personified here by the patriarchs of the Old Testament – from the jaws of Leviathan, the biblical monster that devours sinners. A small gate on the left side of the drawing symbolizes the entrance to the dungeons. The inscription below corresponds to the one written on the gate to Hell in Dante's *Divine Comedy*, usually translated as "Abandon all hope, ye who enter here." However, Christ gives believers hope for redemption.

Housed at the Kunsthistorisches Institut (Art History Institute) in Florence, the project, called Graffiti Art in Prison, is an international partnership led by the Università degli Studi di Palermo to explore both historical and contemporary graffiti and murals. It delves into places of captivity, deprivation, and censorship – prisons, concentration camps, psychiatric clinics – and the creative reactions to these environments: material, physical, psychological, political, social, religious, spatial, and temporal.

# HIGH-RANKING VISITORS HIGH ABOVE THE GROUND

During a trip to Brazil at the beginning of January 2023, German Federal President Frank-Walter Steinmeier and Federal Minister for the Environment Steffi Lemke visited the Amazon Tall Tower Observatory (Atto), a joint project between two Max Planck Institutes and two Brazilian research facilities. Researchers at Atto are studying the com-

plex interactions between the world's largest tropical rain forest, the atmosphere, and the global climate. Susan Trumbore, Director at the Max Planck Institute for Biogeochemistry, the German coordinator of the Atto project, took the delegation on a tour of the research station. As part of the tour, Steinmeier and Lemke visited the 325-meter

tower that gives the observatory its name and climbed 54 meters to the first platform. Both guests were impressed by this state-of-the-art technology situated in the heart of the Brazilian rain forest. The Federal President summarized his thoughts by saying, "This is the place to check the pulse, so to speak, of the world's climate." [www.mpg.de/19713821](http://www.mpg.de/19713821)



Above the trees: on the Atto platform 54 meters up, Max Planck researcher Stefan Wolff explains to the Federal President the questions that are being investigated at the research station.

## WENDELSTEIN 7-X SETS RECORD

Despite being restarted only recently, it has already achieved a milestone. The Wendelstein 7-X reactor has spent the last three years being rebuilt. Among the additions were a more powerful heater and a water-cooling system. Now, researchers at the Max Planck Institute for Plasma Physics have succeeded in holding plasma stable for eight minutes within the reactor. Prior to the rebuild, it had only been possible to maintain the plasma for 100 seconds. Ultimately, the goal is to maintain plasma for 30 minutes to prove that Wendelstein 7-X is capable of continuously sustaining nuclear fusion. In the process, the researchers will heat the plasma to 60 million °C. This would correspond to the 100 million °C required in a larger facility to start a nuclear fusion reaction. In the current experiment, they heated the plasma to 17 million °C, and in shorter experiments had already achieved 30 million °C. Wendelstein 7-X is a stellarator, a type of fusion reactor used to generate energy by fusing light atomic nuclei. In addition to the stellarator, the Max Planck Institute for Plasma Physics also studies the tokamak, an alternative type of fusion reactor. Iter, the world's largest fusion experiment to date, is an example of this type of reactor.

[www.ipp.mpg.de/5322229/01\\_23](http://www.ipp.mpg.de/5322229/01_23)

## OUTSTANDING ★

*BRENDA SCHULMAN*

This year, one of the most prestigious honors in biomedical research, the Louis-Jeantet Prize for Medicine, is being awarded to Brenda Schulman, Director at the Max Planck Institute of Biochemistry. She receives this honor alongside Ivan Đikić from Goethe University in Frankfurt for her contributions to research into the protein ubiquitin, which is crucial for the health of our cells.

Ubiquitin attaches to other proteins to ensure that a variety of cell processes take place in the correct sequence. If the protein does not function correctly, this can cause illnesses such as cancer and lead to infections. Brenda Schulman and Ivan Đikić discovered ubiquitin's important function in controlling such processes.



PHOTO: MPI FOR BIOCHEMISTRY / DAVID AUSSERHOFER





PHOTO: ANNA SCHROLL FOR MPG

Joachim Gauck, former Federal President of Germany and Max Planck Senator, spoke at the 75<sup>th</sup> anniversary of the Max Planck Society.

## LOOKING BACK WITH A FOCUS ON THE FUTURE

On February 26, 2023, the Max Planck Society celebrated its 75<sup>th</sup> anniversary. More than 200 guests came to a ceremony at the Deutsches Museum in Munich, including German Federal Research Minister Bettina Stark-Watzinger, Lower Saxony's Minister of Science and Culture Falko Mohrs, and U.S. Consul General Timothy Liston. The opening speech was made by Joachim Gauck, former Federal President of Germany, and Senator of the Max Planck Society, who spoke about how we are more reliant on research today than ever before in the history of humanity. He also emphasized how our current crises, with climate change first among them, had clearly demonstrated the importance of science,

even outside the scientific community. In his speech, historian Jürgen Kocka, member of the research committee "History of the Max Planck Society," presented scientific development as part of contemporary history. You can read an abridged version of the speech starting on page 48. Max Planck President Martin Stratmann shared his wishes for the Society's anniversary, including the courage to make something of our own talents, the ability to forge new paths, a healthy dose of independence, and the yearning for intellectual fulfillment and curiosity. The exhibition "Pioneers of Science – the Nobel Laureates of the Max Planck Society" was opened after the ceremony.

[www.mpg.de/19903234](http://www.mpg.de/19903234)

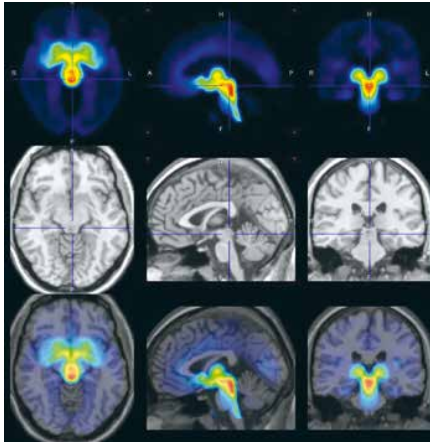
## EFFECTIVE TEST

Reliably diagnosing latent tuberculosis, an asymptomatic and noninfectious form of the disease, would be an important milestone in fighting the pathogen, since people with this latent form are a reservoir for tuberculosis bacteria. The illness can also emerge when the immune system is weakened, meaning patients must be tested for latent tuberculosis before immunosuppressive therapies, such as before an organ transplant or chemotherapy. The available tests often show false positives in people who have been vaccinated against tuberculosis or have had tuberculosis in the past. The Swiss startup Clemedi is now working to develop better tests. They are using a method that was developed at the Max Planck Institute for Infection Biology in Berlin and the Medical University of Vienna, which allows the pathogen *Mycobacterium tuberculosis* to be extracted from the blood of patients with a latent infection. In December 2022, Clemedi concluded a licensing agreement with the Max Planck Society and the Medical University of Vienna for the use of this technology.

[www.mpg.de/19677532](http://www.mpg.de/19677532)

Strong fluctuations: some women suffer from considerable psychological distress in the days before menstruation. The cause is a relatively rapid change in the transport of the neurotransmitter serotonin in the brain.

IMAGE: MPI FOR HUMAN COGNITIVE AND BRAIN SCIENCES



## PERIOD OF DEPRESSION

10

Many of us are aware of premenstrual syndrome. The more serious form, premenstrual dysphoric disorder (PMDD), has a particularly negative impact on those who suffer from it. Symptoms include insomnia, depression, aggressive behavior, and difficulty concentrating. Up to eight percent of women of childbearing age are affected. A research team from the Max Planck Institute for Human Cognitive and Brain Sciences and the University of Leipzig Medical Center have discovered that the level of the neurotransmitter serotonin in the brains of women with PMDD declines shortly before menstruation. This discovery is surprising, because it was previously thought that the regulation of serotonin was an individual characteristic that did not change in a period of time as short as two weeks. Typically, slight changes were seen over a timeframe of ten years. This knowledge can now be used to treat PMDD by providing patients with antidepressants for just a few days. These drugs inhibit the reuptake of serotonin, keeping the serotonin level more consistent.

[www.mpg.de/19818475](http://www.mpg.de/19818475)

## THE MENTAL TOLL OF MUSIC

Many people believe intuitively that making music is good for the soul. But it turns out this may not be the case. In 2019, a team of researchers identified a connection between musical engagement and psychological problems for the first time. According to the study, musically active people reported symptoms of depression, burnout, and behavioral issues at a higher rate than people who did not make music. The team, which now conducts its research at the Max Planck Institute for Empirical Aesthetics, has another study examining the genetic correlation between musicality and the predisposition for mental illnesses. Their work has shown that people with a

higher genetic risk of depression and bipolar disorder were on average more likely to be musically active, practiced more, and achieved a higher level of artistry. These correlations occurred regardless of whether these individuals were actually suffering from mental illness. At the same time, participants with a higher genetic predisposition for musicality had on average a somewhat higher risk of developing depression, regardless of whether they actually played a musical instrument or not. These results support the hypothesis that some of the same genes influence musical engagement and mental health.

[www.mpg.de/2023011en](http://www.mpg.de/2023011en)

## NO WEEDS WITHOUT AGRICULTURE

Intensive agriculture exerts a strong selective pressure on wild plants, leading them to develop into weeds that are difficult to control. This has been demonstrated in a study sup-

ported by researchers from the Max Planck Institute for Biology in Tübingen. The scientists compared the genomes of hemp agrimony from today with examples in museums from 200 years ago. In the present day, the plant is a pest feared by farmers in North America. In today's plants, genes responsible for fast growth and protecting the plants from drought and herbicides exhibited a particularly high rate of mutations. In addition, the frequency of gene variants that allow the plants to adapt to modern agriculture has risen quickly since the intensification of agriculture in the 1960s. Of the seven genes in today's hemp agrimony that provide resistance to herbicides, five of them were not found in the historical examples. Plants that have one of these seven mutations produce almost 20 percent more offspring than plants from 1960.

[www.mpg.de/19623601](http://www.mpg.de/19623601)



PHOTO: UNIVERSITY OF BRITISH COLUMBIA / JULIA KREINER

Corn plants growing alongside hemp agrimony (right) fare worse than they would in the absence of the weed (left).

## THE RIGHT DROPLET

Proteins in a cell often collect into droplets known as condensates, similar to droplets of oil in salad dressing. In this concentrated form, the proteins can do their jobs better. Special sections of the amino acid chain of a protein act as a type of address label and guide the protein to the right droplet. If a protein ends up in the wrong droplet, this can lead to illness. Researchers from the Max Planck Institute for Molecular Genetics and other institutions have found the sec-

tions in protein molecules that function as labels. They have also discovered that mutations in the gene for the protein HMGB1 change the part of the protein that hangs off it like a loose rubber band. The protein then mistakenly wanders to a condensate in the nucleus, clumps up, and can no longer do its job. This causes BPTA syndrome, a rare genetic condition that results in malformation of limbs and the brain.

[www.mpg.de/19845284](http://www.mpg.de/19845284)



PHOTO: XUE ZHANG/MPI FOR POLYMER RESEARCH

Solid-state batteries could offer many advantages in the future, including for the use in electrically powered cars.

## METAL TREES IN BATTERIES

They could be the next generation of battery: so-called “solid state” batteries. They are made entirely of solid materials and have no liquid medium between their poles, as today’s batteries do. These types of batteries could extend the range of electric cars and make them safer, as they can store more electricity and are less flammable and more robust. So far, however, they have suffered from limited lifetimes, because lithium dendrites grow between the positive and negative poles of the battery during each charging process. A team from the Max Planck Institute for Polymer Research has now observed that the lithium dendrites start growing mostly at the negative pole. They also clarified that the growth process is initiated by electrons, which assemble at the grain boundaries of the solid electrolyte. These findings could help to prevent or at least delay the growth of the metal trees in batteries.

[www.mpg.de/19995577](http://www.mpg.de/19995577)



PHOTO: MPI FOR CHEMICAL ECOLOGY / DINESHKUMAR KANDASAMY

A newly hatched bark beetle surrounded by fungal spores in its cell.

## ATTRACTIVE FUNGI

Bark beetle infestations are increasingly damaging Germany’s forests, which are already being weakened by high temperatures and prolonged periods of drought. One of the most significant pests is the spruce bark beetle, also known as the typographer beetle. Once the beetles have found a suitable tree, they release pheromones to attract other members of their species. The beetles then team up with fungi

in the bark in order to reproduce inside the trees. The fungi provide the beetles with nutrients and protect them from pathogens. They also help the beetles overcome the tree’s defenses. An international research team led by the Max Planck Institute for Chemical Ecology has found that the typographer beetles are attracted to substances that the fungi release when breaking down spruce resin. The in-

sects detect the gaseous compounds with special sensory cells on their antennae. Infestations are presumably more likely in trees that are home to specific fungi that are beneficial to the bark beetle. The researchers are now testing whether the pheromone traps used to defend against the bark beetles are more effective if they contain substances from the fungi’s metabolism.

[www.mpg.de/19883184](http://www.mpg.de/19883184)

## AN EXOPLANET MIGHT PERMIT LIFE

A newly discovered exoplanet could be worth searching for signs of life. Analyses by a team led by astronomer Diana Kossakowski of the Max Planck Institute for Astronomy describe a planet that orbits its home star, the red dwarf Wolf 1069, in the habitable zone. This zone includes distances around the star for which liquid water can exist on the surface of the planet. In addition, the planet named Wolf 1069 b has an Earth-like

mass. Very likely, this planet is a rocky planet that may also have an atmosphere. This makes the planet one of the few promising targets to search for life-friendly conditions and biosignatures. Whether the conditions on Wolf 1069 b actually permitted life, however, is subject to some uncertainties. And only in a few years astronomical research will be able to study exoplanets closely enough to clarify this. [www.mpg.de/19798012/](http://www.mpg.de/19798012/)

## STEEL FOR LIGHTER CARS

In the future, car bodies could become lighter and still be safe. A team from China's Northeastern University and the Düsseldorf-based Max Planck Institute for Iron Research have created a new type of steel that makes this possible. It allows sheet metal for cars to be rolled thinner, thus reducing their fuel consumption. By forging the steel several times and processing it at low temperatures, the researchers modified the microstructure of so-called medium manganese steel in such a way that it became both strong and ductile, allowing it to absorb a lot of energy in the event of an accident. Until now, steel producers have only achieved this combination of properties by adding relatively large amounts of expensive manganese. Alongside the low manganese content, the newly introduced steel contains only a few readily available components and is also easy to process.

12

[www.mpg.de/19761404](http://www.mpg.de/19761404)

Exoplanet systems of red dwarf stars hosting Earth-mass planets. The green rings indicate the habitable zones.

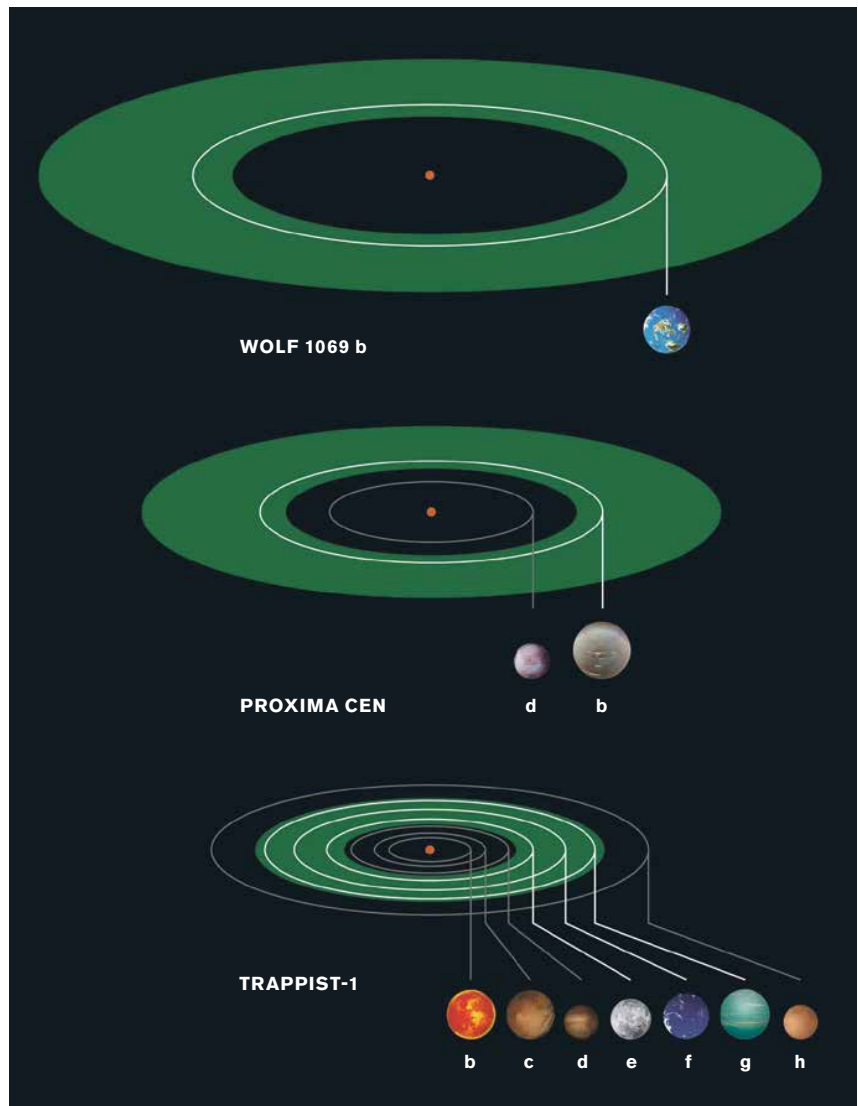


IMAGE: MPA-GRAPHIC DEPARTMENT/J. NEIDEL

## PROTECTION FROM THE CUCKOO

The cuckoo lays its egg in the nest of another bird, and then lets this other bird incubate it and raise it once it hatches. The brood parasite is a great danger for the host parents, because it usually causes them to lose their entire clutch of eggs. Together with colleagues from China, researchers at the Max Planck Institute for Biological Intelligence have discovered a behavior that allows Daurian redstarts to avoid becoming victims of a cuckoo. Once cuckoos arrive in the redstarts' breeding territory, potential hosts build their nests closer to human settlements than before their arrival. Presumably, this is how they try to keep the parasites away from their nests, because cuckoos avoid contact with humans. The cuckoo, in turn, does not lay its eggs in the nest of every Daurian redstart, because some pairs lay blue eggs, others pink. The researchers were able to show that the cuckoos lay their – also blue – eggs twice as often in host nests containing blue eggs. This means that their eggs go virtually unnoticed by the host parents and often remain completely undetected. [www.mpg.de/19913030](http://www.mpg.de/19913030)



PHOTO: MPI FOR BIOLOGICAL INTELLIGENCE / JINGGANG ZHANG



PHOTO: DGHAYES/ISTOCK

With their enigmatic honeycomb patterns, salt deserts have even served as backdrops for alien planets.

## HONEYCOMB IN THE DESERT

The structures look so exotic that they even served as an alien backdrop in the Star Wars movie “The Last Jedi”. Salt deserts around the globe are covered by honeycomb networks of bead-shaped salt deposits. A team featuring researchers from the Max Planck Institute for Dynamics and Self-Organization in Göttingen is now using simulations, laboratory experiments, and field studies to explain how the structures form. These show that convection beneath the surface drives roll-shaped circular

currents of water containing varying amounts of salt. Water evaporates at the surface, causing the salt concentration to increase and the water to sink, while less saline water rises next to it at the same time. The closely spaced convection rolls arrange themselves in a honeycomb pattern, as this is the most physically efficient form. In places where a particularly large amount of salt accumulates underground, more salt also crystallizes and forms the distinctive beads on the ground. [www.mpg.de/19957475](http://www.mpg.de/19957475)

A cuckoo egg (right) in a nest with a clutch of blue Daurian redstart eggs.

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# GETTING TO THE MEAT OF THE MATTER

To combat climate change, we need to do more than just stop burning coal, oil, and gas. We also need a change in other areas, such as our diet. Eating meat also harms the climate, yet most politicians are hesitant to intervene here. Lawyer Saskia Stucki explains why food is a taboo and how the state could effectively intervene.

14

The meat question – whether, how much and what kind of meat we want or ought to eat – is traditionally considered a private matter. Our diet may reflect our culinary, cultural, religious, or even moral predispositions, but whatever the reasons are, this is a personal decision made by the consumer. The idea of political intervention in this area of the private sphere makes people uneasy and quickly leads to accusations of overregulation or government overreach. A perfect example of this is the Veggie Day controversy in 2013, when Germany's Green Party proposed the introduction of a vegetarian day in government canteens, sparking fears of a “meat ban” and stirring up a hornet's nest.

Nevertheless, the conception of our freedom of consumption and the knee-jerk reaction to constraints placed upon it are short sighted. This is made clear by even a cursory glance at the externalized costs of our unbridled meat consumption. Its harmful effects on public health, animals, and the environment are well documented. Animal husbandry is a breeding ground for global health risks, such as the emergence of zoonotic diseases and antimicrobial resistance. Our meat consumption also comes at the expense of the 750 million animals slaughtered annually in Germany, many of which live their short lives in the dismal conditions of industrial factory farming. Animal husbandry is also one of the main drivers of worsening environmental crises: climate change, loss of biodiversity, deforestation of rainforests. These detrimental impacts on public health, the environment, and animal welfare signify that the meat question can no longer be regarded as a purely personal matter – it has become political.

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# VIEW POINT

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SASKIA  
STUCKI



ILLUSTRATION: SOPHIE KETTERER FOR MPG

The legal scholar has been a Senior Research Fellow at the Max Planck Institute for Comparative Public Law and International Law since 2016. Saskia Stucki studied and received her doctorate at the University of Basel, where she is now also a Habilitation candidate with the project “Transformative Greenstreaming: Greening Non-environmental Law.” In 2018/2019, she was a visiting researcher at Harvard Law School. Her research interests include environmental and climate law, food governance, animal law, human rights, and legal theory.

## CLIMATE POLICY CANNOT IGNORE THE MEAT QUESTION

The climate crisis has contributed significantly to the politicization of meat. The top priority of climate policy is to achieve climate neutrality by 2045 in Germany and 2050 in the EU. Rapid and drastic reductions in greenhouse gas emissions are required in all sectors, including agriculture. Globally, the food system causes 21 to 37 percent of anthropogenic greenhouse gas emissions (depending on the estimate), with up to 80 percent of that coming from animal production. In order to reduce agricultural greenhouse gas emissions, it seems logical to start with their primary source: meat production.

The scientific literature is in broad agreement that the urgently needed sustainable food transformation requires a massive reduction in animal production and consumption, given that the emission intensity of animal products consistently exceeds that of plant-based foods – many times over in fact. This is especially true of beef and milk due to methane emissions from ruminants. Moreover, animal husbandry is increasingly viewed as inefficient because of its extensive use of land and resources. A large-scale dietary shift would offer two-fold potential for mitigating climate change. First, a primarily plant-based diet has by far the greatest potential to reduce direct agricultural greenhouse gas emissions. Second, it can also have indirect effects by renaturing land no longer used for feed cultivation and pastureland, which could function as a natural carbon sink.

The climate transition will not succeed without a dietary transition – meaning that climate policy cannot avoid the issue of meat. The meat question today vacillates in an ambivalent state of limbo between politicization and political marginalization. The term “meat paradox” is a reference to the phenomenon of cognitive dissonance in social psychology; knowledge of the harm caused by meat consumption does not prevent people acting as if this were not the case. This contradiction has also manifested itself in our paradoxical collective approach to the meat issue. Although we are aware of the massive problems for humans, animals, and the environment, as well as the need for systematic meat reduction, there have been few government measures aimed at reducing animal production; on the contrary, we continue to preserve and promote it.

On the one hand, for example, the EU’s “Farm to Fork Strategy” – a focal point of the “European Green Deal” – aims at a comprehensive transformation of the food system and emphasizes the importance of a predominantly plant-based diet for health and sustainability. The climate protection measures in agriculture developed by the Federal Ministry of Food and Agriculture also mention the promotion of sustainable dietary habits as



one of their ten priorities. On the other hand, such goals coexist and compete with far more powerful structures that point in the opposite direction. Compared to other sectors, the livestock industry remains under-regulated in terms of its ecological costs. At the same time, it shares with the oil industry the dubious honor of being the largest recipient of environmentally harmful subsidies. Estimates in Germany range from five billion euros (solely through value-added tax reductions for animal products) to thirteen billion euros per year. Such climate-harming subsidies undermine climate goals, as the German Federal Audit Office (Bundesrechnungshof) stated in its 2022 report on climate protection management in Germany.

There is fundamental agreement that the necessary dietary transformation must be framed, facilitated, and expedited by political and legal measures. The state's previous failure must now be rectified through the development and implementation of a coherent set of meat (reduction) policies. What is meant here is nothing so crude as the dreaded meat ban. Rather, the state has a whole range of instruments at its disposal to implement a more sophisticated and transformative meat governance (aligned with dietary transformation). This spans a mix of soft and hard measures – including voluntary efforts, fiscal tools, regulations, and bans.

17

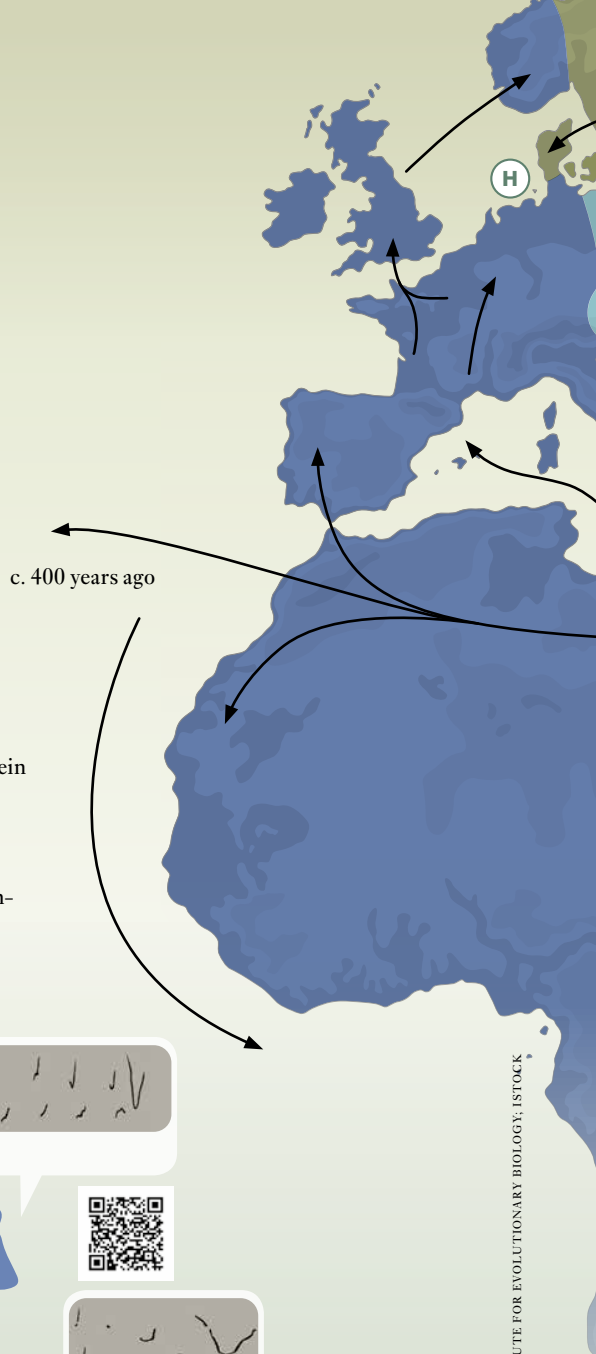
THE STATE  
CAN STEER  
INDIVIDUAL  
CONSUMPTION  
TOWARDS  
MORE SUSTAIN-  
ABILITY

For example, the state has various means to steer individual consumption decisions towards greater sustainability. These include, for example, information campaigns, dietary recommendations, sustainability labels or green nudges. However, fiscal measures are likely to be more effective, such as repurposing agricultural subsidies by diverting them away from animal production and investing them in plant production instead. Another option is to establish the true cost of meat by internalizing ecological costs in market prices with an environmental tax on animal products (meat tax). Public procurement – in government canteens, cafeterias, and hospital kitchens, for example – can also be more geared towards sustainable diets. Recently, the city of Freiburg decided to offer only a uniformly vegetarian menu in kindergartens and primary schools. A ban on meat advertising, as announced recently in the Dutch city of Haarlem, is also conceivable. Finally, alternative proteins – such as plant-based alternatives to conventional animal products or cultured meat – are a real cause for optimism here. Their (ongoing) development can be specifically promoted by state investments and the reduction of regulatory obstacles. Market analyses suggest that, with the right political and legal framework in place, Europe could reach “Peak Meat” – the point from which the consumption of animal products declines – as early as 2025, while preserving individual consumer choices, of course.



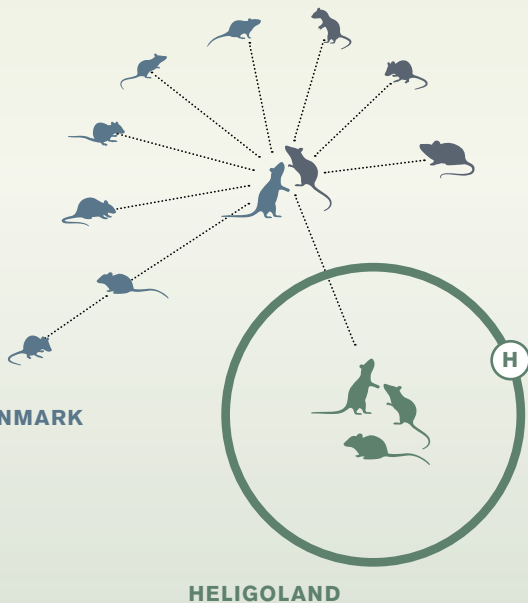
# THE EVOLUTION OF THE HOUSE MOUSE

The origins of the house mouse lie in present-day Iran. From there it divided into several subspecies, three of which have spread across the planet. The Eastern European house mouse (*Mus musculus musculus*) and the Southeastern Asian house mouse (*Mus musculus castaneus*) began their spread to northern and southern Asia around 9000 years ago, while the Western European house mouse (*Mus musculus domesticus*) set off about 6000 years ago and reached Western Europe 3000 years ago. In the last few centuries, the house mouse has travelled on ships from Europe to the Americas, southern Africa, and islands in the Atlantic and Pacific oceans. Along the European climatic divide, the ranges of the Western European and Eastern European house mouse merge.



## SCHLESWIG-HOLSTEIN

## THE HELIGOLAND MOUSE



The various house mouse populations in Schleswig-Holstein and Denmark differ from each other only slightly. The living conditions on the island of Heligoland, however, are so specialized that in just a few hundred years, a new species has emerged there: the Heligoland mouse.

18

DENMARK

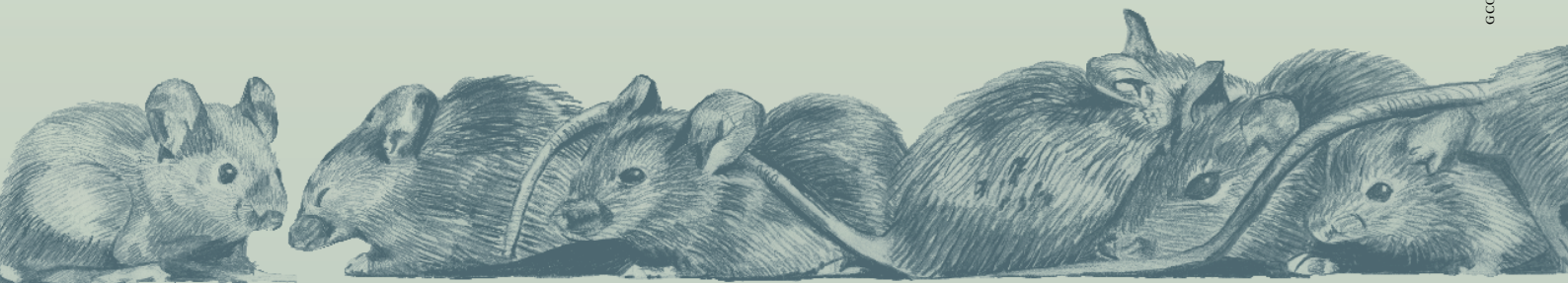
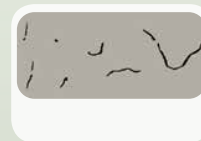
HELIGOLAND

## MICE WITH CHARACTER

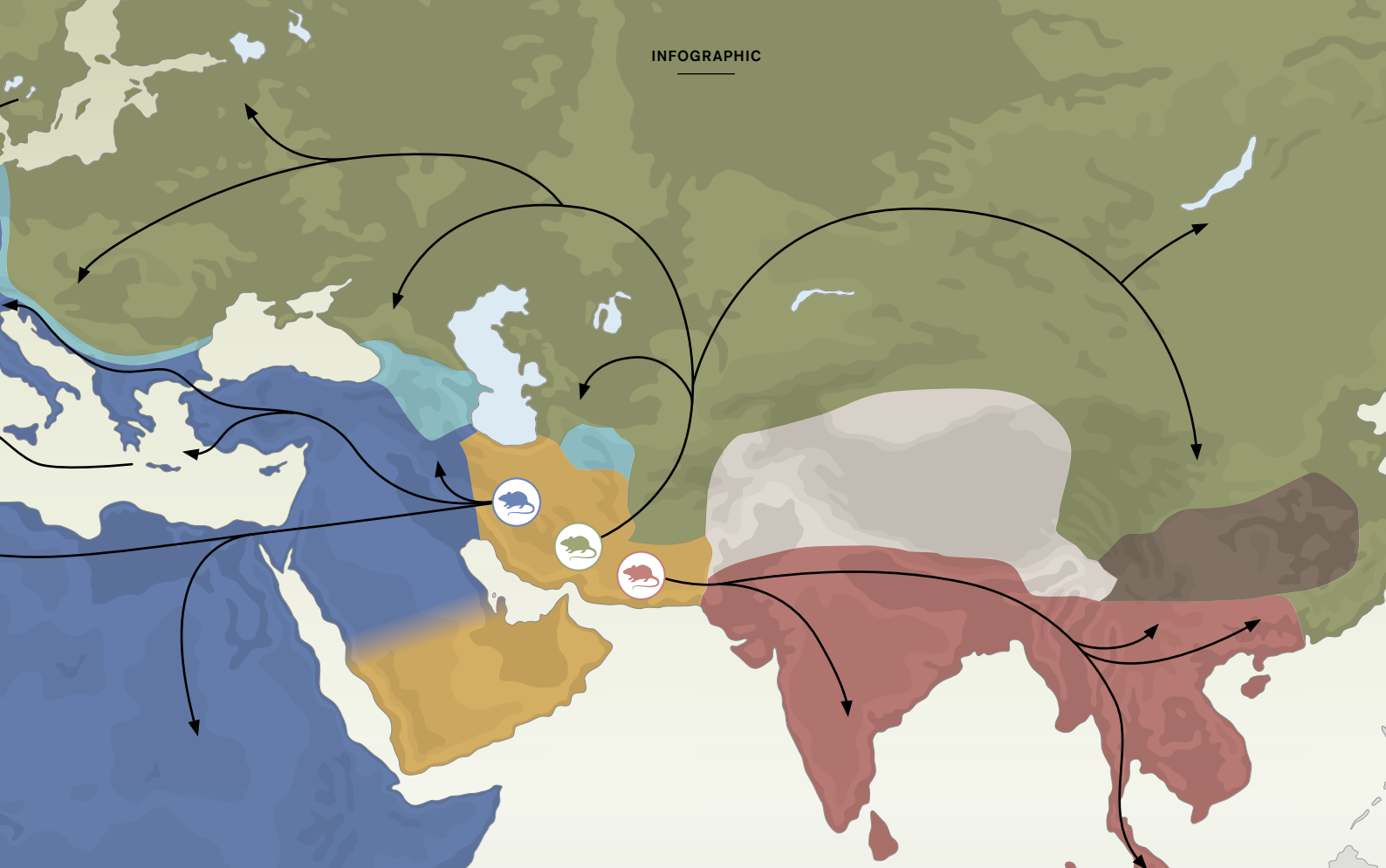
Mice have individual personalities. As with humans, some individuals are brave and some are fearful, some are peaceful and some are aggressive, some are shy, and some are inquisitive.


## MOUSE LANGUAGE

Mice communicate using ultrasound, with an innate “language” comprising very complex sequences of sounds. These sounds differ between subspecies. Females are particularly communicative with other females.



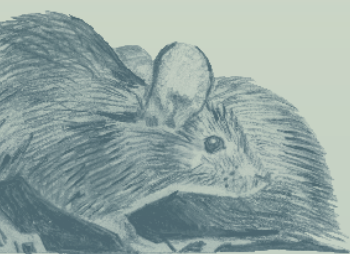
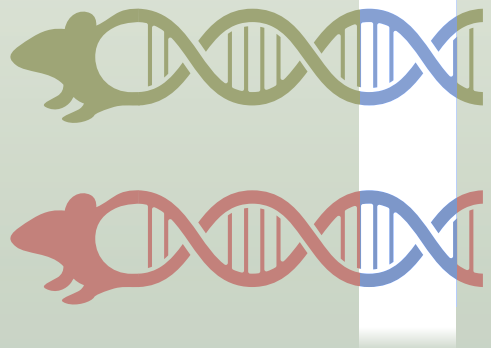
GCO ACCORDING TO DIETHARD TAUTZ / INSTITUTE FOR EVOLUTIONARY BIOLOGY, ISTOCK



-  Heligoland mouse
-  Western European house mouse
-  Eastern European house mouse
-  Mixing of Western European and Eastern European house mouse
-  Southeastern Asian house mouse
-  Different, partly still unknown subspecies
-  Mixing of Eastern European and Southeastern Asian house mouse
-  No house mice

**FOREIGN GENES IN THE GENOME**

The subspecies of the house mouse have diverged genetically as they have adapted to different environmental conditions, although an exchange of adaptive gene regions still takes place.



# FOCUS

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## SAFETY AND SECURITY

20 | From Sparks to Fire

26 | Program Vulnerabilities

32 | Life Sentence

ILLUSTRATION: ALESSANDRO GOTTARDO



Arson through social media: extremist narratives in posts and forums incite physical violence against individuals, groups, or the state.

# FROM SPARKS TO FIRE

*TEXT: MICHAELA HUTTERER*

Stormed parliaments or racist attacks in the US and Germany: politically motivated violence is on the rise. Most of the time, these incidents seem to be isolated, the actions of individual perpetrators. Nevertheless, researchers do recognize terrorist patterns in these acts. James Angove at the Max Planck Institute for the Study of Crime, Security and Law is exploring the question of how this “stochastic terrorism” arises and how it can be countered.



A pre-announced attack: the storming of the U.S. Capitol on January 6, 2021, by supporters of the outgoing U.S. President Donald Trump was anything but spontaneous and random. As early as December, Trump had called for protests on that day; in his speech on January 6, he then sent those present straight to the Capitol.

“Stop the steal,” an angry crowd chants as they make their way to the Capitol in Washington D.C. at around 12:45 p.m. on January 6th, 2021. In a moment, the count of the Electoral College ballots during a joint session of the Congress will begin, and Joe Biden will be confirmed as President-elect. Earlier, the election’s loser, Donald Trump, had spent over an hour railing against Democrats and “weak Republicans,” fueling the memorable narrative of the stolen election. He exhorted then Vice President Mike Pence to “do the right thing” in the Senate and called on his faithful to give “weak Republicans [...] the pride and courage they need to take back our country.” At the end, he sends his supporters across Pennsylvania Ave. to the Capitol, and he himself drives back to the White House. Hours later, he appeals to them via Twitter to “remain peaceful.” By then, his supporters had already spent two hours

battling with security guards, storming barricades, smashing windows, and chanting their way through the building: “This house is ours,” they shout, filming themselves. “Stop the steal.”

“When political violence occurs, it is often tempting to point the finger at those who committed the violent act,” James Angove, senior researcher at the Max Planck Institute for the Study of Crime, Security and Law in Freiburg, explains. “However, on closer examination, the phenomenon of modern political violence today proves to be extremely complex.” Angove, who has a Ph. D. in philosophy, approaches the topics of terrorism and security policy through a philosophical lens at the Max Planck Institute. What is it that incites people to commit acts of violence against minorities, dissidents, or state institutions? Is it the charismatic



PHOTO: REUTERS / JIM URQUHART

leader who has a hypnotic effect on their followers? Or is it their rhetoric, which calls for violence vaguely and indirectly in coded language, often referred to as “dog whistles” and thus remains below the threshold of criminal incitement?

“We are seeing an increase in political violence worldwide, which is characterized by this indirectness,” James Angove explains. These acts of violence can be statistically modelled and predicted, but individual, concrete cases cannot. The acts appear random, disjointed, and seemingly without any discernible network or group identity. Nevertheless, a pattern can be discerned. This phenomenon is being discussed under the term “stochastic terrorism,” which refers to the terrorist strategy of using extremist narratives, lies, conspiracy theories, and hate speech in the media and online fo-

ums to instigate physical violence against individuals, groups, or the state itself. There is no question that Donald Trump incited the January 6 attack on the US Capitol two years ago with his speech. In 845 pages, the House committee collected evidence of Trump’s involvement and recommended that the Department of Justice bring criminal charges against the former president, accusing him of a “multi-part conspiracy” for issuing false claims regarding election results, obstructing congressional proceedings, conspiracy against the US government, and inciting violent sedition in a precedent-setting case.

Whether there will be a prosecution or even a sentence is a matter of debate. Trump wisely never shouted “storm the Capitol” and has always denied any intellectual authorship. In light of this, the committee members conducted more than 1,000 interviews, held 10 public hearings – some even on prime-time TV – and collected more than a million documents that shed light on Trump’s role on the day of and in the run-up to the events of January 6. So, what is Trump’s legal culpability? Is he as much a perpetrator as the more than 800 individual Capitol rioters who have been investigated so far (according to media reports)? Is he obliged to take responsibility for the violence?

## Kindred spirits meet on the Internet

23

For experts, this precisely demonstrates the pattern of stochastic terrorism: individuals seemingly direct their violence against the state system, its representatives or institutions, or against people of a certain race, origin, religion, sexual orientation, or political persuasion – spontaneously, in isolation and without any connection to known terrorist groups. “In terrorism research, the idea of the socially isolated lone perpetrator who does not seem to belong to any political group has persisted for a long time,” Angove reports. But in the meantime, there are findings such as those of a research group at the Max Planck Institute for Social Anthropology in Halle on the development of terrorist groups that point in a different direction: right-wing violence forms not only in groups with strong personal ties, such as the traditional neo-Nazi scene or the *Reichsbürger* movement, but also in Internet subcultures. This entails like-minded people exchanging ideas primarily online in forums and via messenger services, explains Michael Fürstenberg, a political scientist and member of the research group.

When an 18-year-old shot ten people and injured three others outside and inside a supermarket in the US city of Buffalo in mid-May 2022, he streamed his crime for at least two minutes before the streaming service



stopped the broadcast. Investigators believe the suspect had a racist motive – eleven of the thirteen victims were people of color. On the internet, the perpetrator referred to right-wing conspiracy theories and previous acts. U.S. President Joe Biden condemned acts like this “perpetrated in the name of a repugnant white nationalist ideology.” This white supremacist terror is based primarily on one narrative: the so-called “Great Replacement” or “White Replacement.” This is understood by adherents of right-wing ideologies to be the deliberate and orchestrated “replacement” of “white” Americans and Europeans by immigrants. It has also been described using the term “immigrant invasion,” or in German “*Umvolkung*” or “*Personalwechsel*.” According to media reports, the Buffalo shooter was a fan of Fox News, whose former anchor Tucker Carlson is said to have spoken of “replacement theories” more than 400 times before the shooting. The perpetrator who killed 51 people in Christchurch, New Zealand, in 2019 also referred to this right-wing doctrine, just like the perpetrators of the El Paso (2019) and Pittsburgh attacks (2018), and before that the Utøya murderer in Norway (2011).

24 This racist doctrine is not a new one and has frequently shaped U.S. immigration policy over the past 150 years, experts say. Ideological and pseudo-scientific texts have often been used to justify social resentment and methods of discrimination, such as Madison Grant’s book *The Passing of the Great Race* (1916), which is said to have influenced Roosevelt’s policy and entered into petty dinner conversation in F. Scott Fitzgerald’s social novel *The Great Gatsby*.

According to a May 2022 AP Research poll, one-third of Americans surveyed believe in “the threat of replacement.” The FBI sees domestic terrorism as one of the main threats for the future. Attacks such as the one in Buffalo are classified as belonging to this form of terrorism. In total, the FBI investigated 850 cases of domestic terrorism in 2019. Yet white populist hatred is certainly not a uniquely U.S. problem. In 1973, Frenchman Jean Respaill wrote *Le Camp des Saints*, a cult book of the new right, almost at the same time as Jean-Marie Le Pen founded the Front National. In 2011, Renaud Camus once again addressed the fear of immigration with his book *Le Grand Remplacement*. Last August, Hungary’s Prime Minister Viktor Orban spoke openly at the annual summer camp of his right-wing populist Fidesz party about the danger of “replacement by migration” and “a multiracial world.” “The phenomenon

should be seen as a global one – not least because an effective ‘influencer’ can act and broadcast from anywhere to spark this political violence,” James Angove explains. “Technological means and cultural trends also enable this form of violence in the UK and Germany – or in Brazil, as witnessed in January after Jair Bolsonaro was voted out of office.”

But why is extremist hatred able to spread so widely? A study by the Max Planck Institute for Human Development shows that, especially in established democracies such as Europe and the USA, digital media foster polarization and populism and hence have a destabilizing effect. According to the study, trust in politics and democratic institutions such as parliaments is particularly damaged. Trust in the traditional media is also on the decline. Crucially, this also increases the overall

level of ignorance within society. After all, many social media users obtain their information according to the mantra “news finds me”: they no longer actively inform themselves using a variety of sources, instead expecting important news to reach them via their network and sophisticated algorithms. This promotes exchange among like-minded people within their own “echo chambers,” and as a result, the danger of radicalization increases and the restraining threshold for openly articulated hatred decreases.

In this context, acts of violence that seem random but exhibit terrorist characteristics flourish. According to studies by the Terrorism Research Group at the Max Planck Institute for Social Anthropology, there is growing international recognition of an impending wave of right-wing terror. The researchers are working on the basis of a model developed by

the U.S. political scientist David Rapoport. According to this model, terrorism has developed since 1880 in four overlapping waves, each lasting about 30 to 40 years. The anarchist wave (until the 1920s) was followed by an anti-colonial wave that lasted from the 1920s to the 1960s. The wave of the New Left (1960 to 1990) was followed from 1980 by the current, religiously motivated wave of Islamist terror. This is likely to weaken gradually, and a new era could be about to begin. “The strengthening of anti-liberal and right-wing extremist forces is a trend that has already become apparent with the rise of populists like Victor Orbán and Donald Trump and has been confirmed in the recent attacks in Christchurch, Halle, and Hanau,” Carolin Görzig, head of the group, wrote in a feature article in the *Frankfurter Allgemeine Zeitung* in 2020.

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## SUMMARY

The strategy behind stochastic terrorism is to use mostly far-right extremist narratives to spark physical violence against individuals, groups, or the state itself.

Social networks and increasingly sensationalist reporting in the traditional media facilitate the spread of such acts and fuel the ideology behind them.

The research recommends strengthening democracy, ensuring understanding between hostile camps, and fostering people’s resilience to incitement online.

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How can we respond to such a wave of unpredictable terror? “There are several options,” says James Angove. For him, the worst approach is to hastily tighten laws, as demonstrated by the fear-driven anti-terrorism legislation passed in the U.S. in the wake of the 9/11 attacks, which increased Islamophobia and in turn fueled the spiral of violence. “Stochastic terrorism is an expression of authoritarian violence within a democracy,” Angove recognizes. Against this, he says, the most effective countermeasures is strengthening democracy and reinforcing its underlying values. These include, first and foremost, the importance of truth in political discourse. “Stochastic violence is a consequence of the crisis of truth, reason, and deliberation,” Angove says. In speeches, targets are maligned, dehumanized, and often portrayed as a threat to the safety of the audience; conspiracy theories help to reinforce or characterize this threat.

## Media as an accelerant

“In addition, governments have always used a kind of moral panic or fear of ‘folk devils’ to justify authoritarian decisions,” Angove says. According to studies by the British sociologist Stuart Hall, the British government created a supposedly new enemy image of the “mugger,” essentially young and black, in the early 1970s in order to enforce stricter laws in their own country. Thanks to several reports in the media, the population soon classified muggers as a new and growing threat. The government thus achieved a broad social consensus to tighten the law, despite the fact that existing laws already provided for

the punishment of robbery. This mechanism is also used by radical leaders, who create ideological images of their enemies and opponents and lower the inhibition threshold for violence through consistent demonization and even dehumanization.

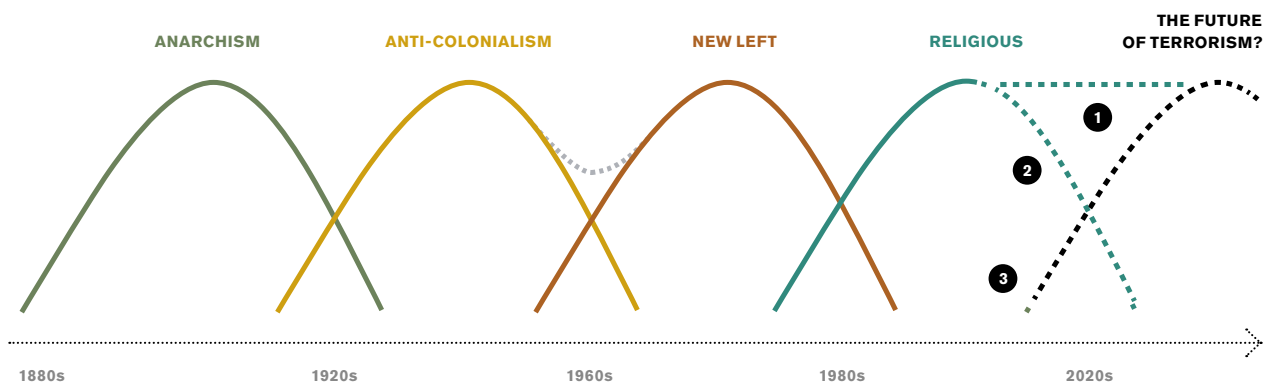
Angove sees great importance in promoting factual exchange between opposing camps, ensuring that conspiracy theories find less of an audience, rabble-rousers are unmasked, and rhetorical excesses of political personalities on the web meet with greater public criticism. Each and every individual must take responsibility for this, as must the media. In particular, they must not become the accomplices of right-wing assassins by reporting uncritically, insensitively, or through a sensationalist lens. Perpetrators seek attention for their deeds and look to bolster their reputation among peers by filming their acts and leaving footprints behind. By showing film clips, naming perpetrators, or even describing their confused and incoherent thoughts about their acts of terror as a “manifesto,” the media behave – consciously or unconsciously – exactly as the perpetrator hopes they would. A report in the evening news on TV, or at least in the online news, promises enduring notoriety. Reporting becomes an accelerant.

At the same time, citizens themselves must become resilient against hate speech and hostility to democracy. Science makes an important contribution to this. It reveals patterns, recognizes connections, and seeks solutions without rashly restricting freedoms.

[www.mpg.de/podcasts/sicherheit](http://www.mpg.de/podcasts/sicherheit) (in German)

The ups and downs of violence: terrorism has gone through several waves, each lasting about 40 years, according to political scientist David Rapoport. The terrorism research group in Halle sees signs of an impending wave of right-wing violence.

- ❶ Continuation/renewal of the religious wave
- ❷ Waning of the religious wave
- ❸ New wave (right-wing extremism?)
- Cross-wave organizations (e.g., IRA, PLO)



Entry point for cyber-criminals: software generally has security vulnerabilities. The automated testing procedure developed by a Max Planck team effectively and efficiently checks programs for them.



# PROGRAM VULNERABILITIES

*TEXT:*  
*THOMAS BRANDSTETTER*

Attacks on software not only create billions of dollars in damage, but also threaten the privacy of users. Cybercriminals infiltrate programs through security holes. Marcel Böhme and his team at the Max Planck Institute for Security and Privacy have undertaken the task of closing entry points to attackers – and their approach has even caught the attention of companies such as Google.

Programming is a creative process. It starts with a programmer having an idea to implement a desired feature and ends with working code. But it is by no means certain what will work. The devil is often in the detail, and it can prove to be a serious threat. The Heartbleed bug, for example, which resulted in access data to numerous online services being made public in 2014, was based on a security vulnerability in software with a very straightforward task: the small program was called Heartbeat and was designed to solve the problem of a browser sometimes continuing to send encrypted data when surfing the internet or banking online via a secure connection, even though the protected connection had long since been terminated. Heartbeat makes it possible for the browser to ask the server whether the connection is still secure. To do this, the software regularly sends a string of characters, including the number of those characters, to the server and expects the same string of characters as a reply. The developer of course assumed that the browser would always give the correct number of characters. But counter to standard practice with other software, he did not build in a mechanism to check this. The attacker exploited this loophole and manipulated Heartbeat to make it send a short string of characters indicating the maximum length. Then, when the server reads the number of characters out of its memory, it copied considerably more data than the original combination of characters – including sensitive information. Experts refer to this case as memory corruption.

All too often, the programmer's intention to solve one particular problem is subverted by malicious hackers; the hacker asks themselves how they can use the software's code for their own purposes. Attacks by cybercriminals who encrypt all files in order to demand a ransom for their release are also notorious. These types of ransomware attacks are responsible for most of the economic damage caused by cybercrime. According to the industry association Bitkom, this totaled more than 220 billion euros in Germany alone in 2021.

The problem of IT security is further compounded by the fact that modern software systems are seldom developed by a single person or even by a single company. Rather, they are often assembled from a variety of components that come from different sources. And each of these components in turn consists of small individual contributions from independent programmers who have varying approaches to security.

“There are an awful lot of small open-source software systems that were perhaps developed by someone in their spare time one afternoon, but over the last 20 years have become incredibly critical and fundamental to our digital economy,” says Marcel Böhme, head of the Software Security Group at the Max Planck Institute for Security and Privacy. But, aside from the original developers, no one feels responsible for the security of all these individual components. And after such a long time, some of the developers are simply no longer interested in further developing their program. Despite this, there are still some advantages to publicly available software elements, especially in terms of security, as many experts can check them. This is another reason why companies such as Google use open-source code. Google is now working with Böhme and his team to detect security vulnerabilities in its own software.

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## SUMMARY

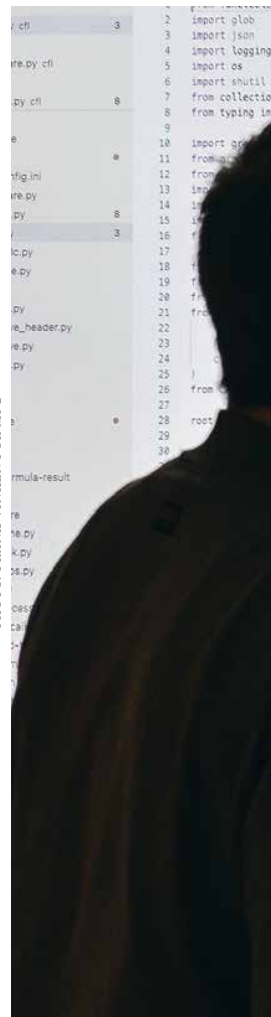
Software developers need to make sure that their programs are not vulnerable to attack. Software that is not tested for security vulnerabilities often has critical errors. Researchers at the Max Planck Institute for Security and Privacy have dramatically accelerated automated vulnerability scanning using greybox fuzzing. Companies such as Google, Bosch, and Oracle Labs are already using the method and discovering new bugs all the time.

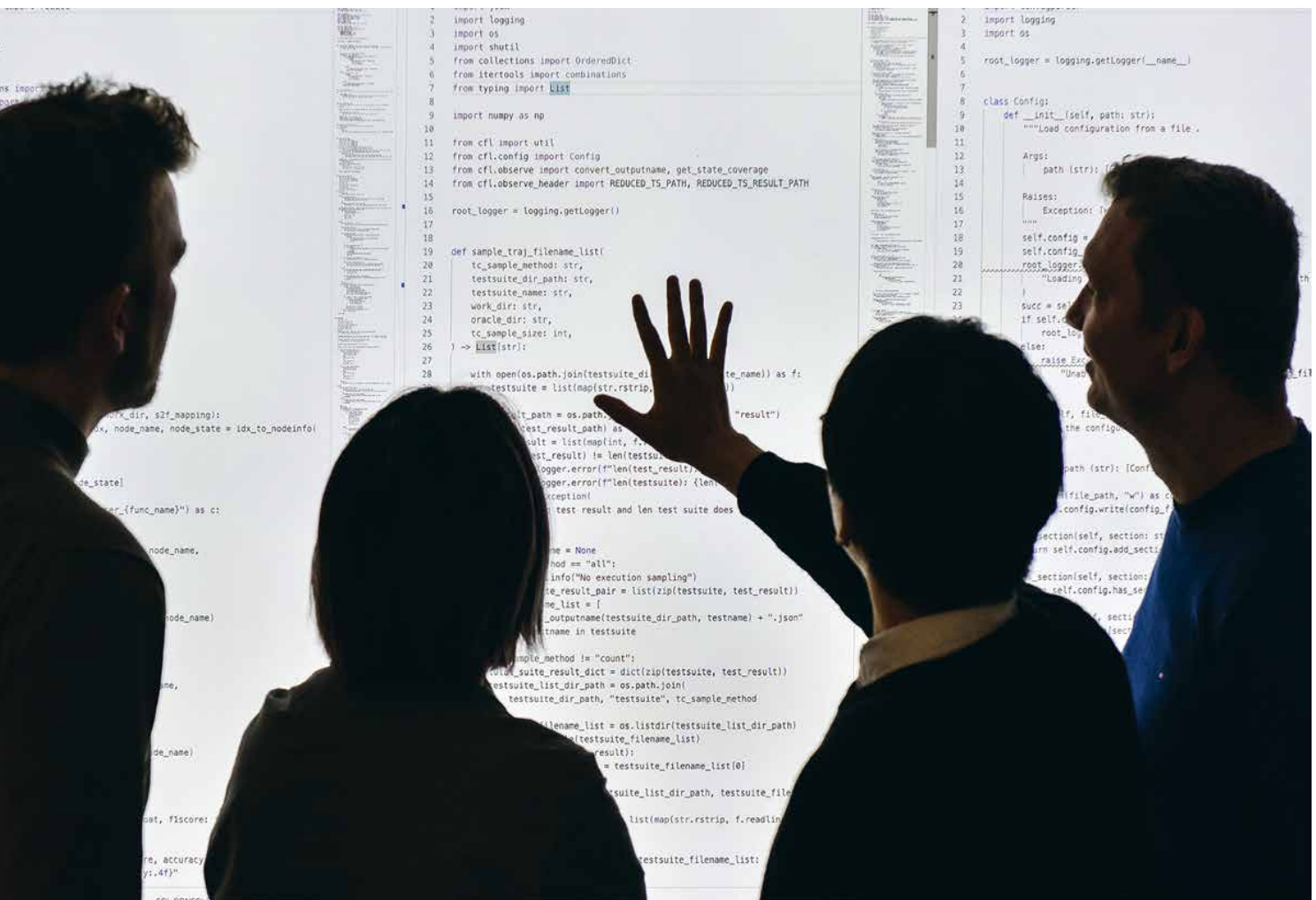
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One of the major problems of software security is that the chain of program components is only as well protected as its weakest link. And this leaves even large commercial systems vulnerable to attack. In some cases, all it takes for a resourceful hacker to take over the entire system is to identify a single poorly protected component. “This is often because this aspect was not very important at the time the program was created,” explains Böhme. “Many of the major security vulnerabilities we find in systems that are in use around the world today can be traced back to these kinds of ‘small’ vulnerabilities.” Memory corruption is particularly critical here, he said. Not only can it be exploited to spy on and steal data – as in the case of Heartbleed – but it can also be used to smuggle commands into a program that, in the worst case, allows an attacker to take control of the computer.

In the same way that more can be read from memory than is specified, more can also be written to it than is intended by a program – provided that the software is not programmed to check the specifications for the amount of data requested or transferred. In order to detect problems like this in the program code, current systems, even when already in use, are extensively tested for critical holes over weeks, months, and sometimes even years – and repaired if necessary through security updates that are distributed with priority. This is also true of software that many people use at home. If, for example, a security vulnerability was to emerge in Google Chrome that could be used to spread malware, countless users around the world would be affected and could become victims of ransomware attacks. “But personal data, passwords, or browsing be-

PHOTO: FRANK VINKEN FOR MPIC





Many hands make light work: the more people check programs, the more likely it is that security-relevant errors will be discovered – especially when experts like those in Marcel Böhme’s team are the ones doing the checking. That said, automated tests speed up the search.

## “Greybox fuzzing combines the best of both worlds.”

MARCEL BÖHME

havior, for example, could also be stolen,” Böhme warns. “Fortunately, the likelihood of that happening with Google Chrome is very small,” he says. “After all, Google has many ways of protecting its systems.”

There are a number of approaches to finding dangerous flaws in a program. The simplest approach is for people

to take a close look at the software and look for bugs. “But machines that do this automatically increase the chances of success,” explains Böhme. With automated methods, a distinction is made between static analysis and so-called “fuzzing.” Static analysis methods start by examining a program’s code and using it to create a model that describes its behavior. Marcel Böhme illustrates this with a comparison to biology. In one branch of this discipline, bioinformatics scientists might, for example, replicate a cell on a computer, simulating the interaction of its various components according to biological rules. “In a similar way, you can also create a model of a program,” Böhme explains. “This is done by simulating its behavior based on the syntactic and semantic rules used to write the software.” This model is then used to try to predict all conceivable inputs and ultimately prove that none of them can lead to a critical error.

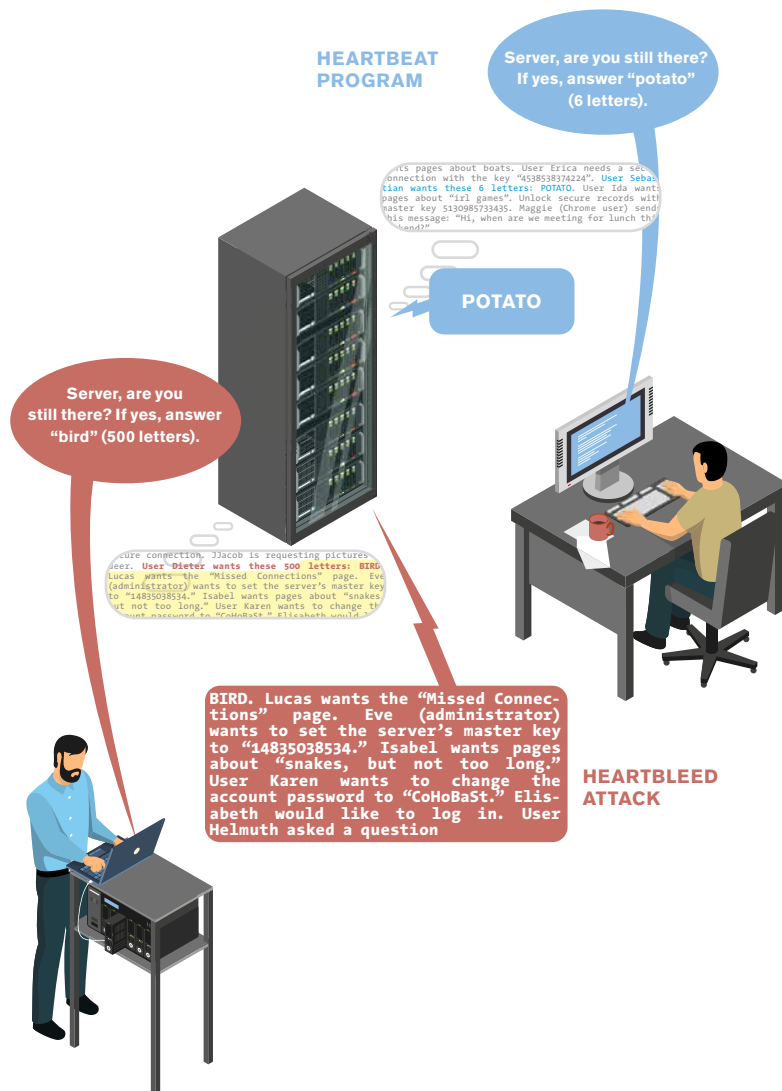


Just like the cell replicated on the computer, however, the model of a program is missing its real environment – which in the case of a program is all the other programs with which the tested program communicates.

## Systematic random input

By contrast, fuzzing – which is what Böhme and his team have devoted themselves to – involves running the program under real conditions and subjecting it to as many randomly generated inputs as possible. “Fuzzers essentially simulate a user who is not doing what the programmer envisioned,” Böhme explains. In its purest form, black-box fuzzing, no meaning is attributed to the interrelationships in the code of the program under study, and errors are detected solely by random input. Blackbox fuzzers, however, also frequently test program parts that are executed during use much more often than necessary, which is not very efficient. But what’s worse: the black box also rarely tests program parts that are seldom in demand, or in the worst case it does not test them at all, meaning that security vulnerabilities in them remain undetected. This problem can be solved with whitebox fuzzing: here, the code is also analyzed and, similar to the static methods, converted into a formal model, which is then systematically examined down to the last detail. “This is very effective, but takes far too long for modern programs,” says Böhme.

Consequently, at least at the beginning of debugging, randomly generating input values is more efficient than systematically exploring the program’s behavior. However, as testing progresses, the whitebox approach gains ground because of its ability to learn and not have to revisit behavior that has already been tested. The black box approach, on the other hand, does not care whether or not it has already tested a particular behavior. “As a scientist, it is somewhat counterintuitive for a bombardment of strictly randomly generated inputs to yield better results than a deep analysis,” Böhme says. “So at the end of my PhD, I became interested in the question of whether this behavior could be explained.” Besides security, another factor to consider is the amount of time required. While a whitebox approach creates just one or two inputs per second, a blackbox fuzzer can easily create hundreds of thousands of randomly generated inputs per second. “We have figured out which approach works best under which conditions,” Böhme tells us. “That then led us to greybox fuzzing, which combines the best of both worlds, in a sense.” A greybox fuzzer generates input just as fast as a blackbox fuzzer, but also uses additional feedback about the parts of the program that have already been executed, just like a whitebox fuzzer. In doing so, greybox fuzzers avoid the repetitive testing of the same software elements, which slows down the whole process. At the same time, they also ensure that parts of the software with niche functions aren’t overlooked.



Manipulated echo: the Heartbeat program checks for a secure connection by regularly requesting changing character combinations, each time indicating the number of characters. In 2014, cybercriminals tricked the software into retrieving significantly more characters from a server’s memory than the requested response. This was how they tapped into sensitive data.

The greybox fuzzer is a great error hunter: “When a piece of software is subjected to fuzzing for the first time, we find an average of two to three bugs, including security vulnerabilities, per day,” says Böhme. “After a few weeks, this reduces to three or four new bugs a week and then stays constant, since new bugs are introduced all the time.” The combination of efficiency and secu-

rity is also winning over tech companies: at Google alone, 100,000 computers are now devoted to running a greybox fuzzer and using it to test over 500 software projects around the clock.

The fuzzers developed at the Max Planck Institute are exclusively open-source applications, which means that they are freely available on the Internet. “By taking this approach, we’re also making it available to small-scale programmers to help them troubleshoot their own programs,” Böhme says. Furthermore, larger open-source projects are also being scanned. Just recently, for example, Böhme’s fuzzers uncovered a serious security hole in OpenSSL, a free software program for encrypted communication in browsers and e-mail applications. “The security hole our team found would have allowed an attacker to take over computers sending encrypted e-mails,” the computer scientist explained.

## Security for the Internet of Things

Despite many collaborations with large companies such as Bosch and Oracle Labs, Google is still the most important collaborative partner for Marcel Böhme’s research group. The American tech giant has a strong interest in the security of open-source projects, as they also represent essential components of its own products. “The cooperation with Google is interesting for us because they are the market leader in this area and have extensive re-

sources that we would otherwise not have access to,” explains Böhme. “It’s a kind of symbiosis.” After all, even though Google could use the freely available fuzzers anyway, the group is always close to the current state of development due to our close cooperation. Despite all the current successes, Böhme also plans to take on new challenges in the future. After all, digitalization and artificial intelligence are turning the world of data processing upside down, necessitating completely new security concepts. Industry 4.0, for example, is a trend that moves away from large, centralized computing units and toward many small devices that have various sensors and can, therefore, perform smaller tasks. “They usually have relatively little computing power, which is why security is often considered to be of very little relevance during the development of such systems,” Böhme explains. These small units often exchange data with other devices, for example, to allow them to perform calculations on their own. “To ensure that the small devices in this Internet of Things work properly on a large scale, you could try, for example, to designate one of them to test all the other devices,” Böhme says. The security of machine-learning algorithms, or artificial intelligence, is also becoming an increasingly important issue in society. “These systems operate on completely different principles than classical computer programs,” says the researcher. “But unfortunately, we don’t yet have any techniques for ensuring that the likes of an AI assistant actually does what it’s supposed to do.” Böhme believes that changing this is an important task, one that he and his team would like to devote more time to in the future.

[www.mpg.de/podcasts/sicherheit](http://www.mpg.de/podcasts/sicherheit) (in German)

31



PHOTO: FRANK VINKEN FOR MPG

Race against the attackers: Marcel Böhme and his team are working to make the Internet of Things and artificial intelligence secure. He discusses a new idea with Kirandeep Kaur to close loopholes for cybercriminals.

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## GLOSSARY

### *FUZZING*

(derived from fuzzy) refers to automated testing procedures that check software for security vulnerabilities using random input.

A distinction is made between purely random blackbox fuzzing, whitebox fuzzing with additional model analysis, and greybox fuzzing, in which a program is systematically tested with mass random inputs.

### *STATIC SOFTWARE ANALYSIS*

attempts to prove mathematically that no possible input can lead to a critical error in the program.

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The stigma of jail: all too often, there is a failure to re-socialize prisoners, which is supposedly the primary goal of the penal system.

ILLUSTRATION: ALESSANDRO GOTTARDO



# LIFE SENTENCE

*TEXT:*  
*MARTIN TSCHECHNE*

What objectives should a modern, enlightened penal system pursue? And how compatible is the idea of reintegration with the option of handing down a life sentence? Federica Coppola, a jurist at the Max Planck Institute for the Study of Crime, Security and Law poses questions that lead her to the conceptual limits of legal practice. And she provides some surprising answers.



been suspended, and some were being held in pre-trial detention. But the minister did not let up: she continued investigating and collecting material. When the trial began last November, 105 prison guards were facing charges ranging from abuse of office, false testimony, and concealment of criminal offenses to assault – in one case resulting in death.

Federica Coppola followed every detail of the investigation and trial from Freiburg. For the jurist, born in southern Italy, now working at the Max Planck Institute for the Study of Crime, Security and Law, the minister's move was a bold start, and at least an attempt to open up the justice system to alternative aims including restoration, reintegration, and respect for human dignity. Penal policy is still determined by superficial political calculations, as Coppola sees it. Those who dole out and threaten people at risk of being impacted by the justice system with severe punishments make a show of strength and determination, perhaps even creating a feeling of greater security, albeit a fleeting one. Coppola, meanwhile, felt vindicated by the quelled protests. No reform proposal had yet really addressed the premises underpinning the penal system: the understanding of what it means to be human and the function of justice.

The European Commission intervened and demanded an “in-depth and independent investigation of the incidents,” Cartabia, a minister with no party affiliation and former president of the Italian Constitutional Court, recognized a “betrayal of the constitution.” But Matteo Salvini, leader of the conservative Lega Nord, seized the opportunity to show solidarity with the violent guards. Dealing with criminals has always been a good way to bolster a populist image. He later backtracked when it became clear that public outrage over the excessive violence had turned against him. Giorgia Meloni, head of the post-fascist Fratelli d'Italia party, also demonstratively backed the prison staff. This did her no harm: today she is the Prime Minister of Italy.

The evidence Coppola collects is scientific. And from the very beginning, she knew that she was entering a vacuum with the interdisciplinary approach of her work. Everyday criminal law and penal practice are based on an old, very insular conception of guilt and atonement – ritual banishment and the belief in purification through pain. The word “punishment” derives from the Latin “poena” for pain, the jurist explains. Reconciliation and reparation, including insight and active

remorse on the part of the perpetrator and healing for the victims and survivors, remain the projects of a form of restorative justice that has to prove itself against a punitive system – and not just in Italy.

## Restriction and isolation breed hostility

One Enlightenment thinker, Cesare Beccaria, is still considered the most important reformer of legal practice. His magnum opus *On Crimes and Punishments* was published in 1764. In it, the Milan-born representative of a utilitarian philosophy condemned public executions and torture out of revenge and religiously inflamed popular outrage. Instead, he called for limiting punishment to a level that ensures humanity and public order. In practice, that meant prison, which in Beccaria's time represented a progressive development. His book challenged an age-old culture of retribution, helping to abolish its most extreme forms in many countries and saving lives in the process. Federica Coppola praises him as a revolutionary. But the object that jurisprudence sought to protect remained solely life outside of prison.

Coppola, a 35-year-old legal scholar, is entering new territory by combining social psychology, behavioral research, cultural sociology, and, above all, the findings of modern neurological research. She uses such empirical knowledge to advocate against solitary confinement, against the institutional violence in prisons, against the rituals of exclusion and stigmatization toward incarcerated people practiced around the world, and against the archaic practice of capital punishment in countries such as the United States. She points out that a society that permits, demands, and perhaps even hails inhuman cruelty as justified punishment

is exposing itself to a concrete danger: the danger of losing sight of any prospect of social development, human rights, and morals, and of regressing into brutality and violence.

Coppola refers to a strategic paradox. With its focus on retribution, deterrence, and exclusion, she argues, the practice of criminal law creates, or at least fosters, the very problems it purports to remedy. Isolation does not give rise to a sense of humanity and responsibility; humiliation does not give rise to the need to join a community, to help others, to be useful, and to seek help for oneself. The threat of punishment does not lead to an understanding of the morality of togetherness. And

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### SUMMARY

Criminal law and the penal system are based on an archaic conception of guilt and of atonement through pain.

Findings from neuroscience, psychology, and sociology confirm that conventional prison sentences have a negative impact on prisoners.

The supposed goal of reintegrating incarcerated people into society is not served by daily life in most prisons. There is a need for fundamental reform of the criminal justice system.

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anger cannot be broken by prison guards' truncheons. Findings from the laboratories of neurological physiologists and experimental psychologists confirm this time and again. Mice behave peacefully and normally when they have enough space, contact with other mice, and a few objects to play with. In confinement and isolation, they become hostile and aggressive, their emotions are blunted, and their cognitive abilities regress. Coppola rejoices, saying she couldn't think of a more fitting starting point for her argument: "The brain is a social organ," she says, summarizing the research scholars have spent decades developing and presenting. "Humans are created to engage with each other. The nervous system can only function in an exchange with a social environment. If that exchange is blocked, the nervous system regresses. To put it plainly: the brain shrinks."

## Reconciliation as a benchmark

36 Researchers have studied children in orphanages, inmates of closed institutions, and people who have been subjected to abuse, violence, and continuous rejection. Their observations confirm, expand upon, and differentiate the finding that the human brain remains malleable throughout a person's life. Most importantly, they provide evidence of a basic need for stimulation, contact, and dynamic change that is as vital as the need for physical integrity. The brain is plastic and extremely hungry for movement, Coppola says – but it can be resentful, too. Every experience and every new impulse are inscribed on the brain, often permanently and at all levels of the system, from affect control in the hippocampus and amygdala, to the processing of the stress hormone cortisol, to action control in the prefrontal cortex. Solitary confinement, the legal scholar cautions, constitutes torture.

Research in the natural and social sciences provides the concept of punishment with a new, functional basis. It explains what makes for a healthy sense of participation and responsibility, and it warns against what can cause that sense to atrophy. Self-worth stands at one end of the spectrum in opposition to restlessness and fear; openness and empathy are likewise plausible alternatives to hostility and moral blunting. What this means is that the success of reintegration and reconciliation with society could be used to assess the quality of penal system measures. It's quite simple, really. And yet, the jurist with honors and teaching experience at Columbia University in New York complains that the findings of neuroscientists, psychologists, and sociologists, together with the knowledge and expertise of (formerly) incarcerated people, do not play the role they deserve to. Penal law, she contends, is stuck firmly in a conceptual dead end. "I graduated university," she says, "with, unfortunately, only a very vague idea of how the law is implemented in everyday practice and of

what prison really is." On November 29, 2022, Kevin Johnson was executed by lethal injection in the United States. Coppola cites the still-fresh case as an example of a punitive state power that seems to have lost all interest in balance and rehabilitation. "In no other democratic country in the world," she says, "is there a higher percentage of the population in prison: more than 500 per 100,000 inhabitants, around 2 million in all. Too many people are simply locked away."

## "Solitary confinement constitutes torture."

FEDERICA COPPOLA

For Johnson's Missouri state judge, the case was unquestionably clear: 17 years earlier, the then 19-year-old African-American man had shot and killed a white police officer in a St. Louis suburb. There had been pleas of mental instability on the part of the perpetrator, and two of the jurors considered him too young for a death sentence, but in the end, the Republican governor of Missouri and the U.S. Supreme Court – again with two dissenting votes – rejected an appeal. The victim's relatives, the court declared, were entitled to satisfaction and had waited far too long for it. Coppola dismisses such reasoning as atavistic. How, she asks, does a state-backed desire for retribution square with an enlightened society's claim to rehabilitation?

"Beccaria was against the death penalty," she says. "That was progress. But how is it actually any different from a life sentence without the possibility of parole? Isn't a sentence that in principle excludes any pardon or any chance of resocialization, itself like a sentence of death by incarceration?" Indeed, in the U.S., a life sentence often means prison until death. About one in four people sentenced to life in prison are never released. In the German system, a life sentence is initially a sentence for an indefinite period. After 15 years at the earliest, parole is possible. However, the safety of the general public takes precedence. A person may stay in prison if they continue to be assessed as dangerous. On average, a life sentence in Germany lasts about 19 years, but even in this country there are people locked up for decades. Like Kurt Knickmeier.

In Geldern on the Lower Rhine, he has been serving 37 years for kidnapping and triple murder and is fighting for his right to die a self-determined death. So far, the Kleve Regional Court has rejected his claim. In Belgium, the conditions for assisted suicide during life im-

PHOTO: WOLFRAM SCHEIBLE FOR MFG

prisonment are being discussed, and in Canada it is already being practiced. The discourse is in full swing, but has yet to make a real impact. “In Italy, last year alone, there were 84 cases of suicide in prisons,” Coppola adds, “without support from the authorities.” Many took their own lives at an early stage of their sentence, and by no means were all of them serving life sentences.

“In my eyes, this is disconcerting,” says the jurist, “a declaration of the system’s bankruptcy.” She points to Norway as an example of a humane penal system geared toward reintegration into society from day one. Prisoners live in open housing communities, receive visitors, and have paid work and contact with the community outside the prison. The Scandinavian concept is a confirmed success: there is significantly less violence among inmates, including against guards and by guards, there are fewer escape attempts, and, ultimately, the recidivism rate is less than 20 percent compared with 50 percent or more in countries with a conventional prison system focused primarily on incapacitation and punishment.

## A right to new opportunities

Yet even in Norway, a mass murderer like Anders Breivik, who killed 77 mostly young people in Oslo and on the island of Utøya twelve years ago, sits in solitary confinement. The conditions of his incarceration are hu-

mane, and he even has comfortable furnishings, yet the door is firmly locked. Federica Coppola shrugs. Resocialization is an extremely complex process, she says. It relies on everyone involved seeing a chance to succeed and being willing to work at it. “Above all else, the vast majority of people in prison are not Breiviks; they are people who have committed property crimes, or perhaps fraud or tax evasion. Or perhaps they just rode the train without a ticket a few too many times. Many of those who are in prison, including those who are in prison for committing serious crimes like homicide, have histories of severe trauma and social adversity. All of them are entitled to a right to opportunities for change and social rehabilitation.”

The case of Kevin Johnson in the United States sparked consternation around the world when his 19-year-old daughter asked to hold her father’s hand in the execution chamber. She was a toddler when the sentence was handed down; it was only during her visits to the prison, she explained, that a relationship of affection and trust was able to develop between them. The request was denied: witnesses to an execution must be at least 21 years old under current law. A photo shows her with her newborn son during a visit to death row. The new grandfather is beaming.

Federica Coppola shakes her head. “Any state response to crime,” she demands, “must actively aim for reintegration into the community. Anything short of this is inhumane.” [www.mpg.de/podcasts/sicherheit](http://www.mpg.de/podcasts/sicherheit) (in German)



Justice, reimagined: against the backdrop of neuroscientific findings, Federica Coppola questions the conventional concept of penal confinement.

Hannah Pool, Senior Researcher at the Max Planck Institute for the Study of Societies, became acquainted with Afghan migrants as a student in Iran and assisted refugees during the migration summer of 2015 before she turned the subject of life on refugee routes into her field of research. Crossing borders is both an academic and a personal matter for her.

38

TEXT: SABINE FISCHER

Spending an afternoon behind barbed wire: a group of people fleeing Afghanistan are stuck at the EU border. They have passed through much of what is known as the Balkan route: border crossings with smugglers, a trip across the Mediterranean, months or even years of uncertainty. Now, they wait together at the border with Greece. Families, women, the elderly – and Hannah Pool, a sociologist from Germany. For ten months, she accompanies the group on their dangerous and costly journey to Europe, becoming an academic observer of their sometimes multi-generational flight. The sociologist still has the scenes she witnessed during her field research play out in her mind. One of the older women in the group told Pool, for example, that she had already seen this kind of grey felt blanket from the UN refugee agency in which her grandchildren were wrapped – back when she was a child and fled to Pakistan.

What role do financial resources and social skills play in crossing borders? And how does the journey shape the concept of home and origin for refugees? *Doing the Game: The Moral Economy of Coming to Europe* is the title of the dissertation that resulted from Hannah Pool's observations and has won five awards. For her research at the Max Planck Institute for the Study of Societies, Pool accompanied people fleeing from Afghanistan through Iran and up the Balkan route, conducting interviews with them at various points along their journey.

The issues that Pool addresses in this research have intrigued her for a long time. Since childhood, her curiosity about the world has repeatedly brought her into contact with topics such as origin, migration, and fleeing. "I often combined this curiosity with travel and developed small research projects from it," she says. After finishing her secondary school leaving exams, she travelled for two months in Turkey with a scholarship from the ZIS Foundation and visited a former school friend who had moved there with her Turkish family. "I wanted to know what it was like for her to live in the unfamiliar homeland of her grandparents," Pool explains. While earning her bachelor's degree in international relations at the Technical University of

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# VISIT TO

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HANNAH  
POOL

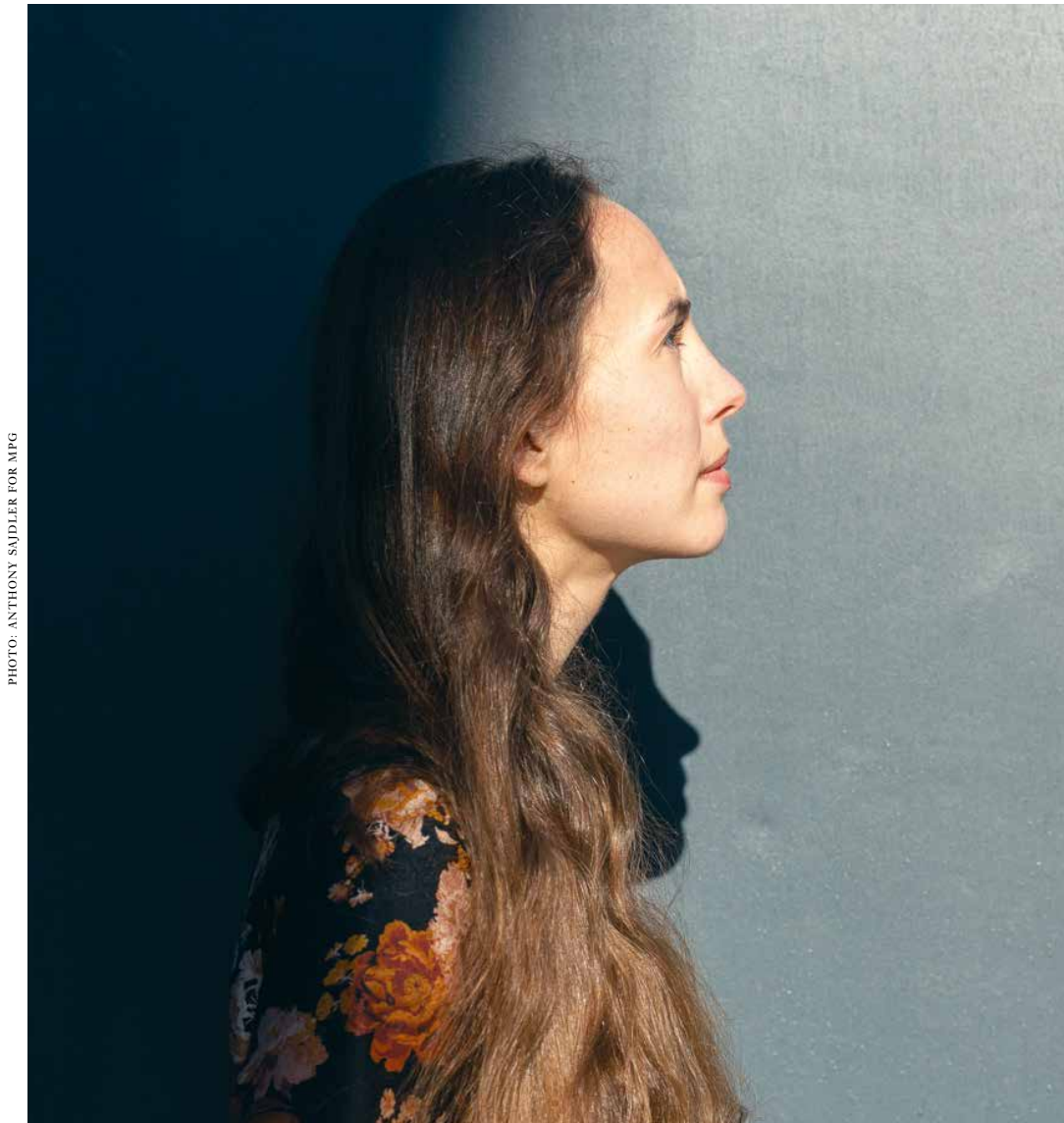


PHOTO: ANTHONY SAJDLER FOR MPG

39

Another view of economics: Hannah Pool researches the lives of refugees on their way to Europe, particularly how these people manage the difficult economic situation on the route.



40

At a prestigious address: the University of Oxford has invited Hannah Pool to work on turning her dissertation into a book as a Visiting Fellow at the Refugee Studies Centre there.

PHOTO: ANTHONY SAJDLER FOR MPG



Dresden, she also spent an academic year abroad in Iran as a DAAD scholarship recipient. At the University of Tehran, she met people who had migrated to the country themselves and had a hybrid concept of home.

“My circle of friends in Iran was diverse, but also Afghanistan-centric. Many of my friends were Hazara, a minority persecuted in Afghanistan. They had to flee to Iran in the early 1990s due to their situation. Through their eyes, I began to learn about a different perspective, and question life in Iran in a more nuanced way,” says Pool. During this time, the sociologist became fluent in Farsi. She used her language skills in 2015 as a volunteer translator on the island of Kos and along the Balkan route to help refugees there – a social commitment that led her on a winding path and ultimately brought her to the Max Planck Institute.

there: “My research was only possible because we trusted each other.”

For her doctoral thesis, Hannah Pool held a total of 66 qualitative interviews and took notes on informal conversations with more than 350 people. She followed many of the people – especially the core group of 22 individuals who make up the main part of her observations – through several stages of the journey, from Iran to Turkey and then up to Germany. Sometimes she spent several days or weeks with them, living in the same place and being with them from breakfast to dinner: the scholar with the recording device, listening and putting things into context. During her field research, Hannah Pool became a welcomed guest, immersed in the impossibility of fleeing. Pool does not fail to appreciate what people shared with her during such a challenging time. “I am very grateful for the trust that was placed in me

**“It would be presumptuous to think that I could fully understand what people really experience on such a journey.”**

41

Together with the documentary photographer Felix Volkmar, she prepared various photo exhibitions after her time at the borders of the EU. In cooperation with Afghan and Syrian activists, the two showcased their work at exhibitions throughout Germany. One stop was the Max Planck Institute for the Study of Societies in Cologne. “I gave a lecture here and was asked if I could imagine working on the topic academically. I was also encouraged to apply for the IMPRS Program,” Pool recalls. The International Max Planck Research Schools (IMPRS) graduate program offers talented doctoral students the opportunity to carry out their research project with the support of a supervisory team. Seminars, workshops, summer schools and conferences complement the program. This created the academic framework for Pool’s dissertation. The content was built on the relationships that the sociologist had already established during her time in Iran – because she knew some of the people she accompanied to Europe from her time studying

and for the stories they told me,” she says. She still handles them with care today: when she speaks, she chooses her words very carefully. She describes many encounters with caution and kindness towards the people who let her participate in their experiences, exceptional situations and thoughts. Often, the people would actively invite her to events on their journey that could be relevant to her research, Pool recounts. For example, she was invited to a conversation with a lawyer on the subject of residence rights. The sociologist was often able to help the refugees in turn by acting as a translator. The relationships that developed are close ones: she was in constant contact with the people who form the main focus of her doctoral thesis throughout their entire journey.

Hannah Pool was always aware of the complexity of her role for and in the group. “I have a German passport; I am an EU citizen and could leave at any time. It would be presumptuous to think that I could fully

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PHOTOS: FELIX VOLKMAR

42



Families on their way to the EU: even before her doctoral thesis on migration routes, Hannah Pool followed and supported refugees in the summer of 2015 together with photographer Felix Volkmar. The pictures were taken, among others, on the Greek island of Kos (above) and at the Hungarian border (below). The two then shared their experiences in exhibitions and lectures at various locations in Germany.

understand what people really experience on such a journey.” The sociologist reflected on this limited perspective at length: her dissertation includes 20 pages contextualizing her viewpoint as that of a young European person. In addition, her role repeatedly changed with the different stages of the group’s journey. “In Iran, for example, people clearly welcomed me as a guest in their lives,” Hannah Pool recalls. She was often invited to events such as birthdays or weddings where she could meet other Afghans. “In Turkey, by contrast, we were all strangers – and although they did their best to make me feel comfortable, the roles shifted. At the European borders, I was also perceived as an EU citizen and confronted with questions about why the EU allows such a situation to exist.” The brutality at the borders of Europe is one of the most poignant memories Hannah Pool has of her field research. She is particularly struck by a situation that occurred be-

cesses and shed light on the complexity of migration routes, Pool adopts an ethnographic approach for her work: the focus is participatory observation through intensive field research in the social space. As a researcher, she took part in the everyday life of the groups she observed and gathered data using various collection methods. This approach let Pool think through her research topic in detail at the micro-sociological level and highlight connections in small examples.

Finally, she relied on coded interviews, field notes, information from institutions and academic literature to analyze her research and identify various patterns. One of them is the structure of the “moral economy” on the journey to Europe. This contains a trove of questions such as how social relationships are used to access, exchange, or obtain financial resources, how both aspects relate to each other and what sig-

## “The route with its stages, frequent returns and restarts must also be considered as a separate factor.”

43

tween Bosnia-Herzegovina and Croatia. Around 120 people were camping near an abandoned factory in the city of Bihać, far from the attention of Western media. When Pool arrived, she met asylum seekers who were hungry, had open wounds and frostbite, but were cut off from medical care. Their attempt to cross the border to Europe had reached a brutal halt for the time being. “The conditions there were defined by violence. It is hard to describe the brutality with which people in uniform treated those who wanted to apply for asylum,” Pool says.

Her dissertation explores connections and interdependencies along the refugees’ journey’s: what does mutual support, including financial support, look like between people who illegally make their way from Afghanistan or Iran to Europe? What is the significance of their social relationships for obtaining, exchanging, or borrowing the necessary money on this journey? To understand such decision-making pro-

nificance they have for crossing borders on the journey. On the one hand, for example, refugees grind to a halt at certain points along the route due to violence at a border or a lack of money, which they then have to earn as day laborers or in agriculture to pay smugglers. On the other hand, the lending and exchange of money between people who are fleeing together plays an important role. For example, when one woman’s cell phone broke, another in the core group Pool observed immediately stepped in to provide funds for a new one – because both women were aware of the crucial importance of the phone as a means of communication on the journey.

Similarly, Hannah Pool grasped the ambiguity that the term “origin” has for someone who exists in an intermediate stage for so long. “In traditional migration research, the focus is on either the country of origin or the destination country. But the significance of the route with its stages, frequent returns

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and restarts must also be considered as a separate factor,” she says today. In addition, the concept of origin is multidimensional and often develops over generations. “For example, many people from Afghanistan had to flee their original homeland in the 1980s and have been living in Iran since then. When they apply for asylum in the EU, it is now very difficult to provide documents such as birth certificates or passports that prove their origin. Moreover, many of the people I accompanied referred to themselves as Afghans, but this term and their sense of belonging are naturally individual and fluid, and include various places of residence,” the researcher explains.

Today, Hannah Pool is a senior researcher at the Max Planck Institute for the Study of Societies in Cologne. Recently, she moved to a new office: a bright room with little furniture and nearly empty bookshelves. Only Pool’s awards are neatly arranged on a

ugee’s journey.” Crossing borders also continues to define Hannah Pool’s research interests. As a Fellow of the Karlspreis Foundation, she recently participated in a project on the perception of borders during the Covid-19 pandemic. She studied various forms of migration and explored questions such as how the forced curtailment of mobility caused by border closures changed the perception of European solidarity.

However, she has not quite finished her doctoral thesis yet: in the spring of 2023, she will work as a Visiting Fellow at the Refugee Studies Centre at the University of Oxford to publish her dissertation as a book. Then the people who shared their stories with Pool during her research will be able to read the insights the sociologist gained from their experiences. To this day, Hannah Pool has stayed in touch with most of the refugees she spent time with. When she talks about them, she radiates joy. For example, one of

## “Hannah Pool’s work is a breakthrough in research on Afghan refugee migration to Germany.”

JENS BECKERT

shelf – the sociologist is very pleased with the recognition her dissertation has received from the academic community. Five awards have already been conferred for her work, including the Dissertation Award from the German Sociological Association (Deutsche Gesellschaft für Soziologie) and the Otto Hahn Medal from the Max Planck Society.

Jens Beckert, Director at the Max Planck Institute for the Study of Societies, does not consider these awards surprising: “Hannah Pool’s work is a breakthrough in research on Afghan refugee migration to Germany. For the first time, a researcher tracked refugees from their point of departure in Iran to Germany,” he says. “By focusing on the financial relationships during the journey, Pool also manages to provide a particularly informative perspective on the social exchange relationships that characterize a ref-

them is now politically active and has become part of the Berlin Citizens’ Council. Another makes successful TikTok videos. “Now that they have reached Germany, they invite me to their homes. It’s a great feeling to see them settling in here and finding their own way – and I enjoy that they still let me be part of their lives,” says Pool.

The researcher is very pleased with the recognition from the academic community. However, what the other audience – the refugees themselves – think of her work is equally important to her. “Some said that their children should read the book to understand their parents’ story,” she says. Two of them already have a copy of her dissertation on their shelves. “The bound book will be another, even bigger step. I am looking forward to their feedback,” says Hannah Pool.



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**ABOUT THE PROJECT** With "Pioneers of Science," the Max Planck Society is showcasing the research of its Nobel Laureates in a comprehensive digital story for the first time. On the occasion of the Max Planck Society's anniversary year in 2023, a selection of topics and laureates from the Digital Story will also be featured in a traveling exhibition at the Science Pavilion, which will visit various cities across Germany.



46

PICTURE: NASA, ESA, CSA, STSCI, IMAGE PROCESSING: JOSEPH DEPASQUALE (STSCI), ALYSSA PAGAN (STSCI)



# DOUBLE TAKE

*MAX PLANCK INSTITUTE  
FOR ASTRONOMY*

The pillars of creation seen in a new light: the James Webb Space Telescope takes a look at the cradle of stars in the middle of our Milky Way. The Mid-Infrared Instrument (MIRI) camera captures mid-wavelength infrared light emitted by gas and dust (right). The darker the gray-blue structures, the colder and denser the gas and dust – an indication of regions where new stars are forming. A second look taken by James Webb's Near Infrared Camera (NIRCam) at slightly shorter infrared wavelengths (left) makes the cocoon partially transparent, revealing the light of young stars. The camera also offers a glimpse of the pulsating process of star formation itself. The top of the center column shows shock waves (deep red) that a young star uses to slowly make room for itself. The Max Planck Institute for Astronomy was instrumental in the development of the MIRI camera.

47

PICTURE: NASA, ESA, CSA, STSCI; J. DEPASQUALE, A. KOEKEMOER, A. PAGAN (STSCI)

# 75 YEARS



A celebration of science: on February 26, 2023, the Max Planck Society celebrated its 75<sup>th</sup> anniversary at the Deutsches Museum in Munich.

48

PHOTO: ANNA SCHROLL FOR MPG





# A MIRROR OF ITS TIME

TEXT: JÜRGEN KOCKA

Since its foundation in 1948, the Max Planck Society has not only established itself as a globally recognized research organization, but has also become an influential part of contemporary German and European history. Historian Jürgen Kocka demonstrated this at a ceremony to mark its 75<sup>th</sup> anniversary in Munich. Here is an abridged version of his lecture.

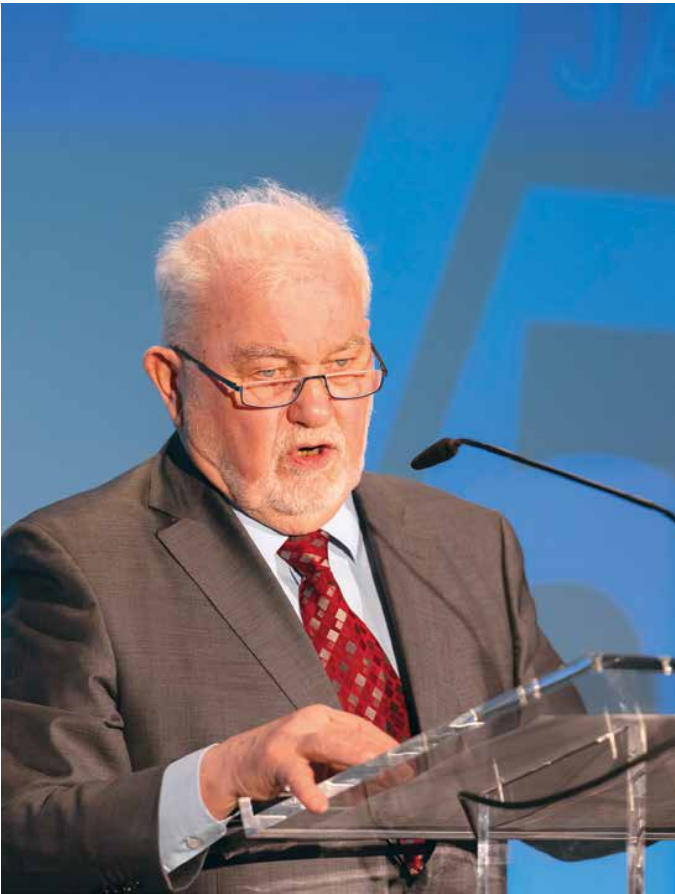
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The Max Planck Society (Max-Planck-Gesellschaft, MPG) was founded between 1946 and 1949 in the western occupation zones of post-war Germany as a modified continuation of the Kaiser Wilhelm Society for the Advancement of Science (Kaiser-Wilhelm-Gesellschaft zur Förderung der Wissenschaften, KWG), founded in 1911. This was by no means a matter of course, as it was the aim of the occupying powers to weaken the defeated country's scientific potency in the long term. Moreover, knowing how deeply the KWG had been intertwined with the National Socialist war and extermination policies, they pushed for its dissolution and advocated alternative organizational models for non-university research in their zones. The fact that the legacy of the KWG nevertheless survived was due, in part, to the commitment of the German side. KWG scientists like

Otto Hahn and Werner Heisenberg fought for its preservation. They both enjoyed high international prestige and good international connections, especially with Great Britain. Despite the prevailing shortage of funds, the West German States were prepared to jointly assume the long-term financing of national research institutions, including the MPG – after all, they were counting on scientific excellence as a means of economic recovery and social reconstruction.

The occupying powers initially pursued different goals, but the emerging Cold War and the associated efforts of the Western Allies to bolster West Germany as a full ally against the Soviet Union proved decisive. It was only then that the Americans accepted the stance taken by the British, who had already been willing to accept German preferences in their





50

Critical view: Jürgen Kocka emphasized, among other things, the MPG's role in relations with Israel and during the reunification, but also its political restraint.

zone. This cleared the way for the foundation of the MPG on February 26, 1948, in Göttingen.

The basic structure of the MPG was inherited from the basic structure of the KWG. On the one hand, it follows a corporatist blueprint: independent as a registered society; close to the state, but not a public authority or state agency; free-market-friendly, but not a free-market player. In these ways, it was positioned somewhere between the state and the free market. On the other hand, it is also characterized by the “Harnack principle,” a distinctly person-centered management structure that grants institute directors a considerable degree of freedom, decision-making leeway and responsibil-

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## JÜRGEN KOCKA

is Professor Emeritus of History of the Industrial World at the Free University of Berlin. He was President of the Social Science Research Centre Berlin. Together with Carsten Reinhardt and Jürgen Renn, he headed the research program “History of the Max Planck Society (GMPG)” from 2014 to 2022.

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ity. Remarkably, this basic structure has endured for more than a century, despite changes in the details. While the first structural element is typical of the Federal Republic and can also be found in other areas of life, the Harnack principle is atypical of today's Federal Republic, is in a certain sense old-fashioned and, in this re-

spect, suitable for defining a unique selling point of the MPG. Both characteristics entail certain disadvantages, but at the same time are extremely advantageous as a prerequisite for the MPG's performance and success. It is worth retaining and carefully developing both. In its first decade under President Hahn, the MPG was one thing above all in terms of its objectives, its management personnel, its organization and its elitist self-image: a continuation of the KWG. The transition to the MPG did not mark a real break, but rather showed a great deal of continuity, as was the case in the West German economy and society as a whole.

However, the Allies required more than just a name change from Kaiser Wilhelm to Max Planck: they also prohibited the new organization from engaging in any kind of research that could be used for military purposes. This served to influence its policy decisions, away from certain areas of nuclear research, for example, and towards a focus on other fields, such as astrophysics, which soon became one of the MPG's most successful fields of research. They also demanded that the MPG conduct less industry-oriented research than had been undertaken by the KWG in the past. This demand supported the MPG's internally desired commitment to basic research.

The extent to which the MPG's development depended on broad historical conditions was also evident later, during the major turning points in 1972 and 1990/91. The year 1972 saw more than just a change in the organization's presidency. Looking back, the new President, Reimar Lüst, recalled that at the time of his election the MPG was “in a state of turmoil.” It was still dealing with the repercussions of the student protest at the end of the Sixties, and with the demand for co-determination raised internally by staff, especially assistants, and reinforced in heated public debates initiated by media critical of the MPG, and probably also supported by the in-

cumbent social-liberal government that called on German institutions and civil society to strive for more democracy. At a controversial general meeting in Bremen, the MPG finally succeeded in adopting new by-laws that anchored a measure of co-determination within the MPG, albeit reduced to co-consultation and to a much lesser extent than had been demanded in many cases and was enforced at the universities, for example.

Above all, however, 1972 marked the end of more than a decade of rapid growth at the MPG, and the beginning of a decade and a half of shrinking, stagnating, or at least barely growing budgets. The MPG had to learn to reallocate resources internally if it wanted to undertake new research and avoid stagnation in terms of content – a task with which it had remarkable success. This turning point resulted from the now far more frugal funding policies of the federal and state governments and ultimately from the overall crisis-ridden macroeconomic development.

## “In its first decade, the MPG was above all one thing: a continuation of the KWG.”

JÜRGEN KOCKA

In 1990, the MPG became a major player in the internal unification policy in relation to the sciences. The fact that German reunification took place primarily as an extension of the Federal Republic's body politic to the acceding new States, and not as a negotiation of a new order between West and East, benefitted the MPG: the MPG was able to preserve its own structure almost unchanged and extend it to the eastern part of the country. It ac-

cepted the task entrusted to it of establishing a density of Max Planck Institutes in the eastern part of the country comparable to that in the west of the republic within the space of ten years. It also accepted – as in its earlier years – political intervention in the decisions about where the new institutes should be built. But it was strong enough to reject further restrictions on its decision-making powers. Thus, it asserted that it would maintain its autonomy to decide on research subjects and substantive issues, as well as on the recruitment of the institute directors, according to its own established rules. It also almost entirely refused to take over existing facilities – a controversial political issue in the context of the unification process.

As a result, 18 new institutes were established in the eastern federal states within a decade, largely financed by newly provided funds, but also partly through internal redistribution from West to East. In the West, every tenth established post had to be cut within

a matter of years after 1990. The reconstruction of East Germany thus entailed a certain dismantling of the West, which succeeded without major internal upheaval. Overall, the number of Max Planck Institutes increased by almost 30 percent between 1990 and 2005, and the total workforce by more than 50 percent. This was an extremely rapid increase. Its consequences for the organization's capacity to control its own actions

and internal cohesion cut both ways. The management staff was recruited from outside to a greater extent than before. It became more international, more heterogeneous, and gradually began to open up to women as well. However, East German scientists were rarely recruited to the management levels, a practice that remains controversial to this day, but which corresponded with the thoroughly asymmetrical nature of German unification policy.

These examples may suffice to illustrate how much the development of the MPG was defined by the circumstances of contemporary history in general. However, they also show that the MPG always countered the initiatives and pressures acting on it from outside with its own standpoint and was never a pawn in major historical processes. It is significantly more difficult, however, to determine the influences and effects of the MPG on the economy, society, and politics, and thus its contemporary historical significance.

The fact that the MPG as a basic research institution – unlike the KWG after its founding in 1911 – is predominantly publicly financed can be interpreted as recognition of the economic, social and political importance of science in the knowledge society of the 20th and 21st centuries. The MPG's tasks and its eligibility for funding were and are founded, in particular, on the important role of scientific research for ensuring the competitiveness and prosperity of the country (or individual regions). This is undoubtedly entirely justified, even if – or even because – the MPG's focus is on basic research. This is because basic research can drive innovation. Moreover, its official entreaty has never prevented close ties between individual institutes and individual industrial companies.

Examples include the Max-Planck-Institut für Kohlenforschung which had close ties to the early plastics industry thanks to the discovery of a

catalyst for the mass production of polyethylene, and the Max-Planck-Institut für Eisenforschung as well as materials sciences in general, at times nuclear energy, and, to this day, the life sciences. Overall, the open endorsement of industry-related activities in the MPG has increased over the decades, both practically and rhetorically, especially since the 1990s. Earlier reservations about the market-based application of scientific findings have since declined.

today in the calls for proposals of the European Research Council. The fact that the Federal Republic opened itself unreservedly to Western political culture after the Second World War and anchored itself in the West is considered an important pillar of its relatively successful history to this day, and not only in a historical science context. Through its early and intensive contacts – via studies, exchange, mobility, and cooperation – above all with American but also with Western

ranks with the Western countries and the economic upswing since the late 1940s, prestigious scientific excellence promised to meet this need to some extent. The MPG embodied such scientific excellence with its big names, its internationally recognized successes, and its policy of remembrance, which so emphasized the glorious tradition of German science in the KWG. Addressing its role during National Socialism and the destructive potential of modern science would only have been a hindrance; all this was suppressed for a very long time.

## “Science is increasingly expected to take a socio-political stance.”

JÜRGEN KOCKA

52

The MPG also left its mark on contemporary history through its services to the state and politics, for example, through its diverse advisory services. With their extensive expertise in comparative law, the Max Planck Institutes of Law provide governments and parliaments with valuable legal expertise in many areas of domestic and foreign policy. In the first decades of the Federal Republic, the MPG at times took on quasi-diplomatic tasks when full diplomatic relations had not yet been established or were difficult, for instance with Israel prior to 1965. In some respects, it acted as a pioneer in establishing scientific, but also political relations across national and system boundaries. In addition to business, science was and still is an important driver of European integration. The MPG participated early and regularly in the major relevant projects of the European Community, such as Euratom, the European Space Agency (Esa), or

European scholars and scientific institutions, the MPG and some of its scientists made a significant contribution to this fundamental Western orientation of the Federal Republic – before the accelerated globalization since the 1990s contributed to a broader, worldwide internationalization of MPG relations. Now the constellation is changing again due to the war in Ukraine.

In terms of national history, the role of the MPG is also worth mentioning. After 1945, following the devastating defeat in the war, the disastrous self-discrediting caused by the crimes of National Socialism, and in view of the division of the country, the young Federal Republic could not draw on an intact national tradition to strengthen its identity, develop self-confidence, and find recognition. It had to look for ways to return to the community of states as an equal member. In addition to the closing of

If one reads how Max Planck presidents portrayed themselves, the speeches of German presidents and other top politicians, as well as the commentaries of domestic and foreign media from the early decades of the Federal Republic, one senses something of the high esteem in which the MPG was held as a place of prestigious, civilized, and sustainable science, albeit more between the lines than explicitly. Such overtones and nuances can also be perceived recently when one follows how the Nobel Prizes brought to Germany are celebrated in public and in the media – Nobel Prizes that are frequently and regularly awarded to scientists from the MPG, as is common knowledge. The MPG benefits from all this. But it has to earn it through continuous excellence, something it succeeds in maintaining. However, there is a limit to its historical effectiveness: the MPG is home primarily to the natural and life sciences, but also to law, the humanities, and the social sciences. It likes to promote interdisciplinary constellations because it prefers research areas at points of overlap that are not recognized at the universities, where they are not yet established, or at least not well established. As a result, it is actually well equipped for the scientific treatment of major contemporary and future problems, including the discussion of corresponding questions and answers in civil society.



A fresh start at a location with a tainted past: the Max Planck Society was founded in 1948 in the “Kameradschaftshaus” of the former Aerodynamische Versuchsanstalt (Aerodynamics Research Institute) of the KWG, which had conducted extensive military research for the Nazi regime. Standing to the left of Otto Hahn, the first Max Planck President, Adolf Grimme, then Minister of Education and Cultural Affairs, attended as a representative of the state of Lower Saxony.

53

However, the MPG remains very reserved in these respects. Even after the failure of the Starnberg Max Planck Institute for the Study of the Scientific-Technical World in 1981 and the dismantling of the Berlin Institute for Educational Research, which was very close to politics, socially committed, and multidisciplinary in its work, also around 1980, Max Planck scientists did not stop advising politicians and political bodies. They also succeeded time and

again in transforming central social issues such as nutrition, health, the environment, energy, Europe, or capitalism into scientific problems and working on them. But in an effort to achieve objectivity and normative neutrality, scientific and political argumentation were relatively clearly separated. For this reason, too, the MPG refrained from taking a public position on major issues of the day. Even in Earth system research, one of the MPG’s flagship projects since the

1970s, the public relations role remained limited to Paul Crutzen for a long time. Initiatives that would have involved political commitment, such as the proposal to set up a World Hunger Institute, did not find sufficient support.

Here, it is not possible to discuss further whether this restraint is the necessary prerequisite for fruitful scientific work in a normatively heterogeneous society like ours, or an act of self-restraint that overcautiously stands in the way of the full utilization of scientific potential. At present, the public increasingly expects science to take a socio-political stance. The MPG is devoting its attention to pressing big issues, for example with the planned research on the Anthropocene at the MPI for Geoanthropology in Jena. It remains to be seen to what extent the distancing of research from direct social influences can be maintained.

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### THE “HISTORY OF THE MAX PLANCK SOCIETY” RESEARCH PROGRAM

Between 2014 and 2022, independent historians reconstructed the development of the MPG between 1948 and 2002, placing the history of the MPG within the history of the Federal Republic in the context of European and global developments.

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# HUNGER – IT’S ALL IN THE MIND

TEXT: NORA LESSING

54

Feel hungry, grab a pudding, enjoy it, and have another. Many different electrical and chemical signals ensure that the body and the brain cooperate in the area of nutrition. Marc Tittgemeyer and his team at the Max Planck Institute for Metabolism Research in Cologne are studying the implications of such coordination.

Balance is essential in all things: this philosophy is the heart of Aristotle’s Ethics, but we see the same principle at play in our body’s efforts to maintain metabolic homeostasis. Ideally, behavior and metabolism are precisely attuned to avoid excessive fluctuation in blood sugar, oxygen saturation, and other physiological needs. Until now, however, little research has been done on how regulatory processes operate in humans and on the

role of the brain in controlling bodily homeostasis. Neuroscientist and metabolism specialist Marc Tittgemeyer and his working group at the Max Planck Institute for Metabolism Research are on a mission to change this situation. Their approach: give study volunteers different foods, have them complete intricate behavioral tasks before eating, and measure serum blood levels together with nerve cell activity in the brain.

Tittgemeyer is looking at a photo on the computer screen in his office, taken on Brighton Beach in 1976. Hundreds of people in bikinis and swim shorts enjoying the sunshine. “This photo impressed me; you notice immediately how thin everyone is. This picture would look very different if it you took it now, 50 years later.”

Six times more people are obese nowadays than in the 1970s. In the OECD countries, roughly half of adults and one in six children are overweight, and the trend is rising. The consequences are anything but harmless, ranging from shortness of breath and joint problems to high blood pressure, diabetes, and cardiovascular disease. What has gone wrong?

## Metabolism in balance

Maintaining balance is crucial for keeping our bodies healthy. Various signals tell the body whether energy and hydration levels are still stable, and those signals are reported to the brain by a variety of distinct sensors. For in-



# KNOWLEDGE FROM

— BIOLOGY & MEDICINE



Sweet and fatty: a combination that rarely occurs naturally in foods. Modern diets are full of such foods, however, which has grave health consequences.

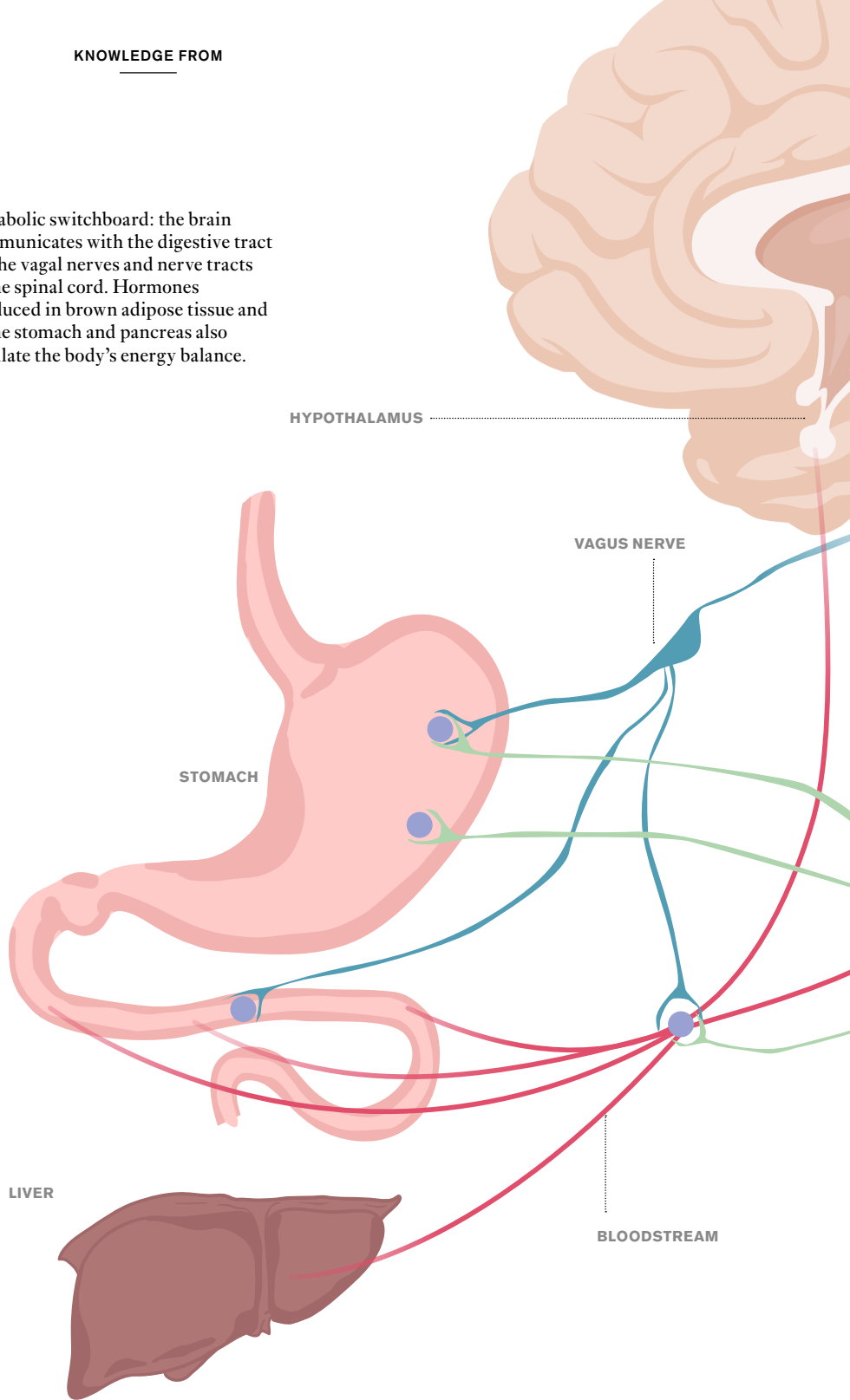
stance, if there is an imbalance between energy intake and expenditure, the body reacts with hunger. Then, pressure-sensitive cells in the stomach signal when the stomach is full, and the brain creates a feeling of satiety to keep us from overeating. The purpose of other signals, however, is to create reserves. These signals can outwit the forces striving for balance, pushing us to take in more calories than we need.

## Adaptation to insufficiency

To understand the widespread problem of obesity today, one has to consider the past – more precisely, the evolutionary history of human metabolism. Our brains and bodies, after all, work the same way they did for our ancestors. They did not swim in lakes of sugar or pick chocolate bars from trees; instead, food was often meager, and people often suffered from starvation. Our metabolism adapted to these living conditions over the course of centuries. “Evolution taught the brain and body that food is not always available. Whenever there is an abundance of food, we learned to fill our stomachs in order to be prepared for lean times,” explains Tittgemeyer. Signals of satiety may be overridden, for example, by activating our reward system even if the stomach is already full. The neurotransmitter dopamine plays an important role in this. Another signaling system estimates the energy content of a meal and prepares the body accordingly before your mouth takes the first bite. Nerve cells located in the hypothalamus of the brain, called “hunger neurons,” are involved in this process. “These cells only fire a little bit when we are full. But when we are hungry, they become very active,” Tittgemeyer elaborates.

Research has shown that the hunger neurons of mice calm down immediately when they start nibbling on a piece of chocolate. These nerve cells

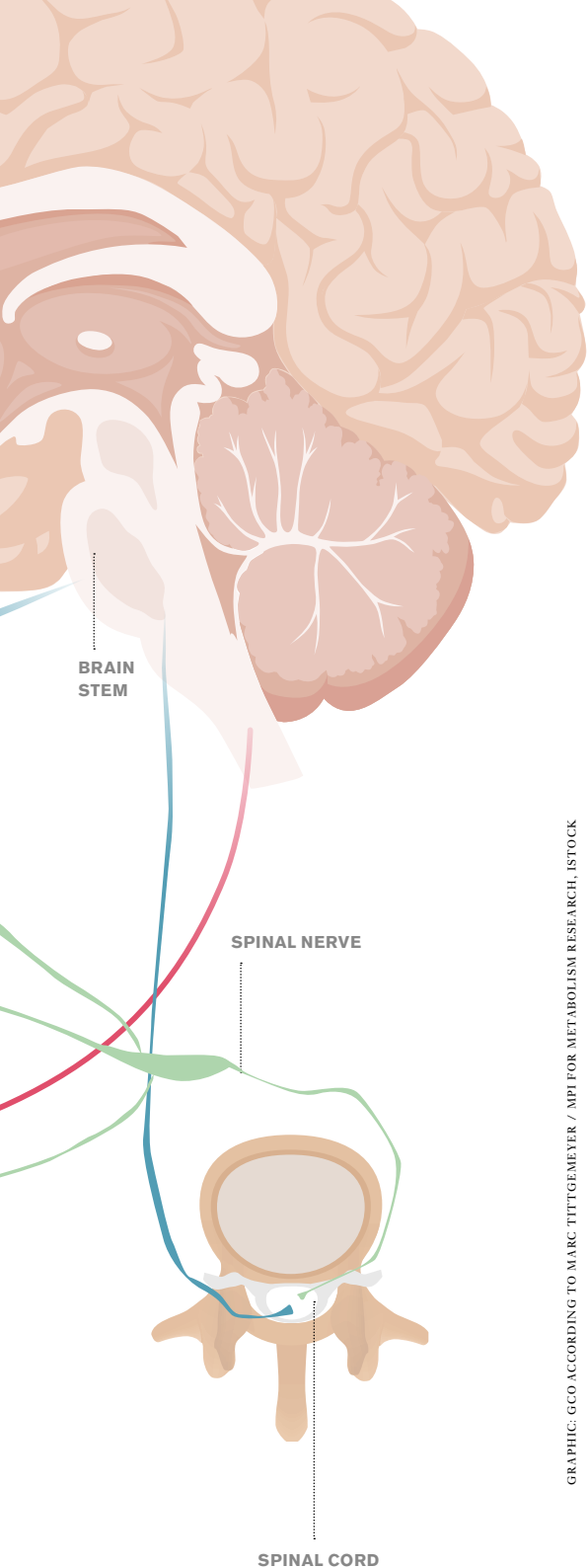
Metabolic switchboard: the brain communicates with the digestive tract via the vagal nerves and nerve tracts in the spinal cord. Hormones produced in brown adipose tissue and in the stomach and pancreas also regulate the body’s energy balance.



also mute themselves when the mice can merely smell chocolate, but are unable to eat it. The neurons will resume activity after a while if the snack does not end up in the mouse’s stom-

ach, however. “This indicates that the body, be it of mice or of humans, anticipates that foods will have a certain calorie content and prepares itself accordingly.”





GRAPHIC: GCO ACCORDING TO MARC TITTEMEYER / MPI FOR METABOLISM RESEARCH, ISTOCK

ranging from society's moving away from physical work to the idea that we eat more today than in ages past," Tittgemeyer explains. "We now know that the primary factor behind the dramatic rise in obesity is that we eat differently today than we used to." Ultra-processed products, for example, trick the body's hunger signals in several ways. These are often calorie-packed foods, such as ready-made pizza, 100 grams of which contains roughly five times more calories than 100 grams of apples. But there's no metabolic signal that tells us to reduce portion sizes accordingly. And the mechanoreceptors (a sort of "pressure sensor") in our digestive tract are of no help here either because they do not differentiate whether fullness is due to apples or pizza. What is more, the combination of proteins, sugars, and fats characteristic of processed products stimulates multiple signal paths simultaneously that activate the reward system in different ways. This results in a strongly felt increase in reward stimuli.

## Sweeteners can make you hungry

Sweeteners are another potential problem. Though they are intended to save calories by replacing sugar, our internal calorie forecasting program throws a wrench into the works: "When the body is used to sugar in your coffee, it expects to get a certain number of calories. The body prepares accordingly, for example, by increasing the insulin level," says Tittgemeyer. "When there is no sugar at all, contrary to expectations, the body reacts with a feeling of hunger. This is how sweeteners can lead to increased calorie consumption, when really, they should accomplish the opposite."

Another example of how modern foods can throw our metabolism off kilter is the intoxicating effect of sugar and fats in combination. Tittgemeyer and his team have found out why we find it particularly difficult to resist foods

like ice cream, buttered noodles, and cream cake. The researchers showed test subjects pictures of foods with the same calorie count but with differing macronutrient content. Some of the foods were particularly high in sugar, others in fat, and some in both. The test subjects were asked to assign a monetary value to the respective foods based on their degree of preference. The subjects assigned the highest values to foods rich in both sugar and fat.

The reason for this is that the reward stimuli our brain releases when we consume sugar or fat are irresistible. The respective signal paths run on differing routes from the digestive tract to the brain. The Cologne-based researchers were able to show that both of these pathways end in the site of reward processing – the midbrain, where they have tremendous impact through the release of dopamine. "Foods containing either sugar or fat cause a release of dopamine in the midbrain. When a food contains both at the same time, the effect is amplified," says Tittgemeyer. "This effect is referred to as 'super-additive.'" Pasta alone or a cream sauce on its own will make the brain happy, but pasta in a cream sauce creates a real sense of euphoria. Why this is so remains a mystery. Only very few foods occur in nature containing large amounts of sugar and fat at the same time — breast milk, for example. This is the first food we consume, and is of major social significance to us, which could be what exhibits the necessary evolutionary pressure and makes us so receptive to that combination of nutrients. This theory is not easily proven, however.

The researchers measure changes in metabolic processes via positron emission tomography to observe the reward reactions that foods trigger in the brain, such as a high-fat, high-sugar milkshake. Beverages of this kind give you a dopamine kick from the first sip. When the stomach then begins to digest the shake some 15 minutes later, the messenger substance is released a

What role do these metabolic signals, which have come about through the course of evolution, play in today's rising bodyweight worldwide? "There were several speculations about this,

second time. “The signal from the stomach is transmitted via nerve cell networks in the brain that control motivation and learning behavior. These associate the milkshake with a reward, which leaves us inclined to have another shake next time around,” Tittgemeyer explains.

Thus, what we eat influences our preferences, which in turn influence what we eat – in a feedback loop that can turn into a vicious circle. This concept has also been shown in another experiment conducted by the Cologne-based researchers in which the study subjects added half a cup of high-fat, high-sugar pudding to their daily diet. After eight weeks it was evident that the subjects were neither gaining weight nor reacting any differently to the body’s messenger substances than at the start. The pudding

did however give test subjects a stronger inclination toward fatty foods, and they also learned differently than the control group. The researchers conclude that regular consumption of foods rich in carbohydrates, fat, and sugar can rewire nerve cell networks in the brain without a change in body weight or metabolism.

## Learning via the brain stem

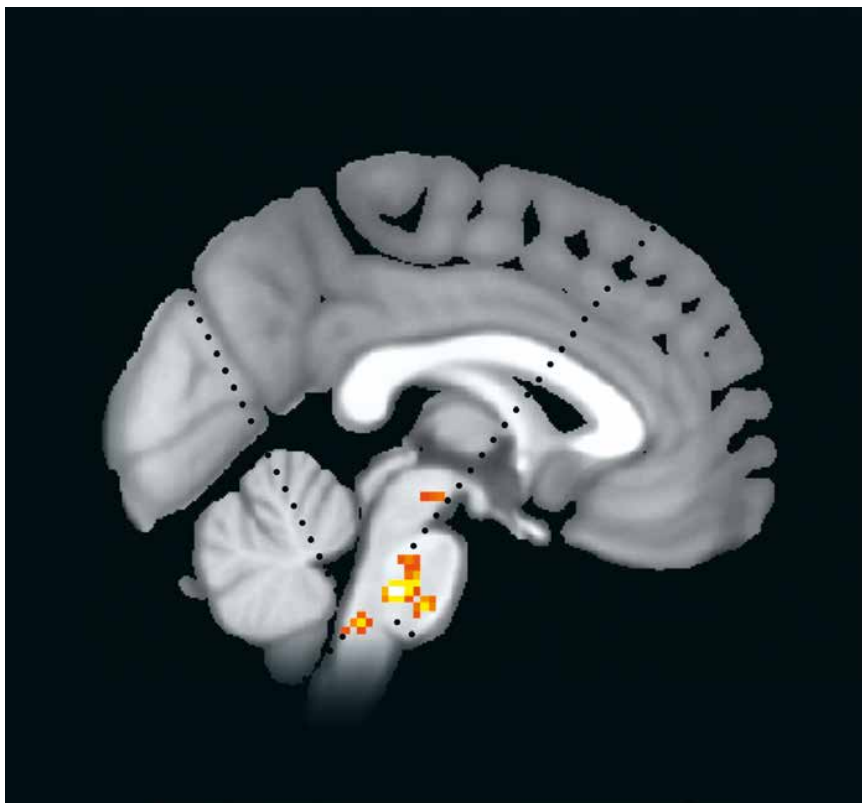
Does eating high-fat pudding generally lead to mental decline? “Certainly not,” explains Tittgemeyer, “but it does seem to change the way people learn associations.” Importantly, learning to change our food preferences involves the brain stem – one of the oldest parts of the human brain.

### SUMMARY

Changes in the foods we eat are partly behind the increasing prevalence of obesity worldwide. Added fats and sugars pack foods with calories, and moreover have a mutually amplifying effect on the brain’s reward center.

Fatty and sugary foods release lots of dopamine in the brain, which promotes learned behavior and a preference for such foods.

It has been observed in mice how poor eating habits and acquired preferences can be changed, but it remains unclear to what extent the same is possible for humans.

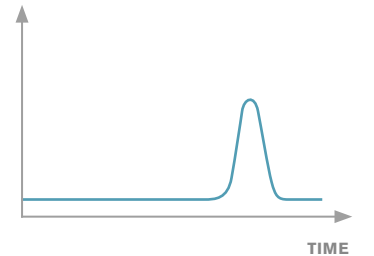
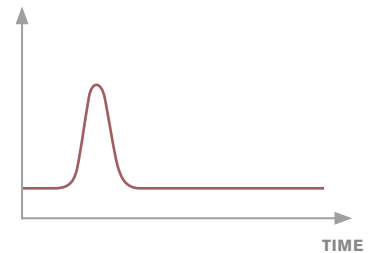


The vagal nerves serve as a signal switchboard between the brain and the internal organs, transmitting information from the digestive tract to the brain, among other functions. Areas in the brain stem can be activated through artificial stimulation (yellow, red).

A milkshake releases dopamine: the release of this messenger substance in the brain is observable via positron emission tomography. Taste receptors in the mouth trigger the first dopamine wave immediately upon tasting, then higher brain areas release a second wave a short time later.



DOPAMINE RELEASE



Changes in that area of the brain influence our perception and behavior across the board.

Is it possible to change eating habits once they have been acquired? Shrugging his shoulders, Tittgemeyer declares: “That’s the question, right there! At any rate, experiments with mice have shown that eating habits are not set in stone. Mice will switch to low-fat eating habits if a low-fat diet is imposed on them over an extended period of time.” More research will have to be conducted to find out how long a human being would need until mentally adopting an initially externally imposed diet.

Our brain rewards our surplus calorie intake – be it high-calorie ready-made meals, our love of sugar combined with fat, or other eating habits we hold so dear – with feelings of happiness. There can be serious consequences to this, as unhealthy eating and being overweight can lead to diseases like type 2 diabetes, which causes the body to become increasingly resistant to insulin. The primary purpose of this hormone is to maintain stable blood sugar levels. Insulin resistance

means the cells of the body can no longer sufficiently absorb sugar from the bloodstream. Insulin also affects the brain’s reward center by inhibiting the release of dopamine. “As a result, more and more fat and sugar are needed to achieve the same reward effect,” Tittgemeyer explains.

Thus patients with type 2 diabetes have to consume more calories than healthy people in order to feel good, which causes them to gain even more weight. Being overweight in turn promotes the formation of inflammatory substances in the body that inhibit drive and motivation. It is difficult to get out of this vicious circle once caught in it.

## Medication alone is not enough

Can modern drugs provide a solution? Active ingredients known as GLP-1 receptor antagonists have recently been hailed as a sensational new treatment for obesity. These drugs regulate blood sugar and insulin and restrain the appetite. The stomach

empties more slowly, and thus a feeling of fullness come more quickly. Tittgemeyer and his research team have furthermore shown that such drugs also affect the brain’s reward system. “However, I do not believe that obesity can be cured solely through medication,” he elaborates. “Without changing one’s behavior and modifying eating habits, it just won’t work.”

In their research, Tittgemeyer and his associates have demonstrated how metabolic disorders are behind numerous other health conditions besides obesity and related diseases, including dementia and possibly Parkinson’s.

“The more I learn in this field, the more I come to understand how being overweight has nothing to do with lacking willpower or discipline,” says Tittgemeyer, “If the metabolism goes haywire, it is extraordinarily difficult to take control. Our body dictates what we eat.” A person who chooses to have a chocolate pudding rather than a salad, against their better judgment, has a midbrain addicted to dopamine to thank for that decision.





The interconnected neurons of the brain serve as a model for artificial neural networks, which a team at the Max Planck Institute for Mathematics in the Sciences is researching.

PHOTO: SVEN DÖRING FOR MPG

# INTELLIGENCE WITH A PLAN

TEXT: THOMAS BRANDSTETTER

Self-learning algorithms are turning our society upside down. But all too frequently, even their developers do not fully understand how they work. Researchers at the Max Planck Institute for Mathematics in the Sciences want to remedy the situation with fundamental theories of machine learning.

PHOTO: REED HUTCHINSON / UCLA



Guido Montúfar conducts research at the Max Planck Institute for Mathematics in the Sciences and the University of California in Los Angeles.

Learning algorithms are taking over more and more tasks that, until recently, only humans seemed capable of. No online service can do without them, even if they are simply used to place advertisements. Artificial intelligence, or AI for short, can translate texts or even write them itself. One such example is the chatbot ChatGPT,

which assembles astonishingly meaningful answers to almost any question from countless texts available on the Internet. Artificial intelligence is also trying its hand at art and, when installed in driver assistance systems, becomes a more careful road user than the person behind the wheel. The current boom in AI is primarily explained by the continuing advancement of artificial neural networks, which are loosely modeled on the human brain. The functioning of the brain is simulated on computers as deeply branched networks of artificial neurons, whose connections dynamically adapt to new experiences in order to recognize patterns in data or learn new behaviors. And just as with the brain, it is often difficult to understand exactly what is happening in its electronic equivalents. While it is true that their success serves as proof of their validity and, for many purposes, it may be sufficient to merely view them as a useful black box, experts believe it is necessary to provide AIs with a sound theoretical foundation in order to further exploit the technology's enormous potential. This would allow them to get a detailed understanding of how the algorithms learn.

Guido Montúfar and his team at the Max Planck Institute for Mathematics in the Sciences and the University of California, Los Angeles, are also working toward this goal.

“We’re investigating the mathematical side of artificial neural networks,” the researcher explains. According to Montúfar, much of their development has taken place on a practical level, while theories have often been lacking. “People have tried a lot of things,” he says. “Sometimes their intuitions have been spot-on and sometimes less so.” Together with his colleagues, the mathematician is now working on a theory of neural networks.

## Large networks even for small amounts of data

In essence, the current triumph of artificial intelligence can be attributed to three factors. The first factor is that developers have access to a constantly increasing amount of computing power in the form of improved hardware located in ever larger data cen-



ters. This allows ever larger neural networks to be created, in which countless artificial neurons are connected today. Just as the number and strength of the synapses – the connections between the nerve cells – are important in the brain, the connections in an artificial neural network are also

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**SUMMARY**

In many cases, we simply have no idea how artificial neural networks learn to solve a task and what criteria they use to do so. This can be problematic when artificial intelligence is applied in medicine or image recognition for autonomous driving, for example.

A theory of artificial neural networks would help to make their decision-making comprehensible. It could also speed up the search for suitable algorithms.

Neural network training identifies mathematical functions that solve a problem. Normally, many functions are suitable for this, but not all are equally good. To find the optimal function, a theory should also consider other properties of the functions beyond their ability to solve the training problem.

62

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crucial. For example, GPT-3, a precursor of ChatGPT, is said to have 175 billion connections – the human brain has 100 trillion. The second factor is the increased availability of data for training artificial neural networks thanks to advancing digitalization, which has given AI a significant boost. And third, international cooperation in the development of new algorithms is making software ever more complex as a result. “One surprise in AI development, for example, was that large neural networks can produce meaningful results even with relatively lit-

tle training data,” Montúfar explains. In the past, he continues, it was believed that the high flexibility of large networks was only beneficial when using correspondingly large data sets. This is due to the fact that huge neural networks are by definition exceedingly complex. And accordingly, he says, this could easily lead to poor decisions when training is implemented with only a small amount of data. “This is an expectation which is actually mathematically sound,” explains Guido Montúfar. “But the theory on which this expectation was based was incomplete.” Even without theory, he says, it was soon observed in practice that the larger neural networks are, the better they function.

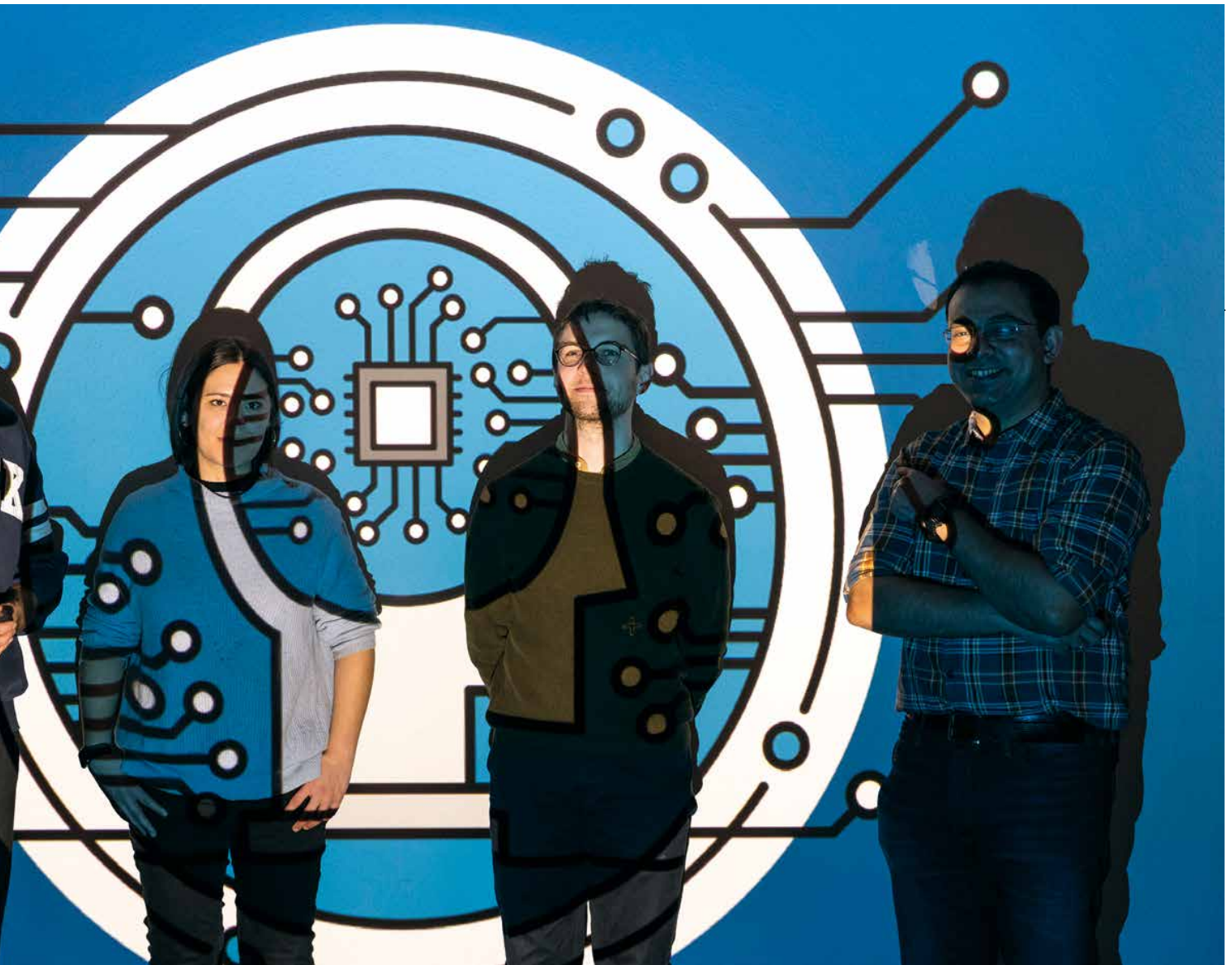
So you could very well argue that the reasons why a network works are not that important – the main thing is that it works. “Ten years ago, quite a lot of people were convinced that you didn’t need much theory,” Montúfar says. He thinks this may have been because a theoretical understanding truly isn’t needed in some cases. Developing a mathematical theory isn’t for everyone, even for people who successfully program AI algorithms. But if you have no theory to build on, you simply have to try out numerous different ideas. This is a laborious process that consumes time and resources. Montúfar gives the example of a chemist who has no idea about elements and molecules and mixes different substances together at random just to see what happens. On top of that, AI could increasingly be used in sensitive areas, such as to support medical diagnoses or autonomously drive vehicles. In these cases, it would be useful to know exactly how it reaches decisions.

There is also the fact that, despite all the successes of AI, there is certainly still room for improvement. For example, the dangers posed by malicious attacks, such as in the area of autonomous driving, are particularly worrying. These attacks could trick the AI

system that recognizes and interprets traffic signs, and cause accidents as a result. Even a minimal but targeted change to a road sign can, in some circumstances, cause the system to believe that the speed limit is 120 miles-per-hour instead of 50. To the human eye, by contrast, the change to the road sign would be barely perceptible. But why is it possible to put an artificial neural network on such a fatally wrong track? “To answer this question and ultimately prevent such



PHOTO: SVEN DÖRING FOR MPG



63

Illuminating artificial intelligence: Johannes Müller, Marie-Charlotte Brandenburg, Pierre Bréchet, and Pradeep Kumar Banerjee (from left) are working on a theory of artificial neural networks to help better understand how AI works.

attacks, we need a deeper understanding of how networks function,” Montúfar says.

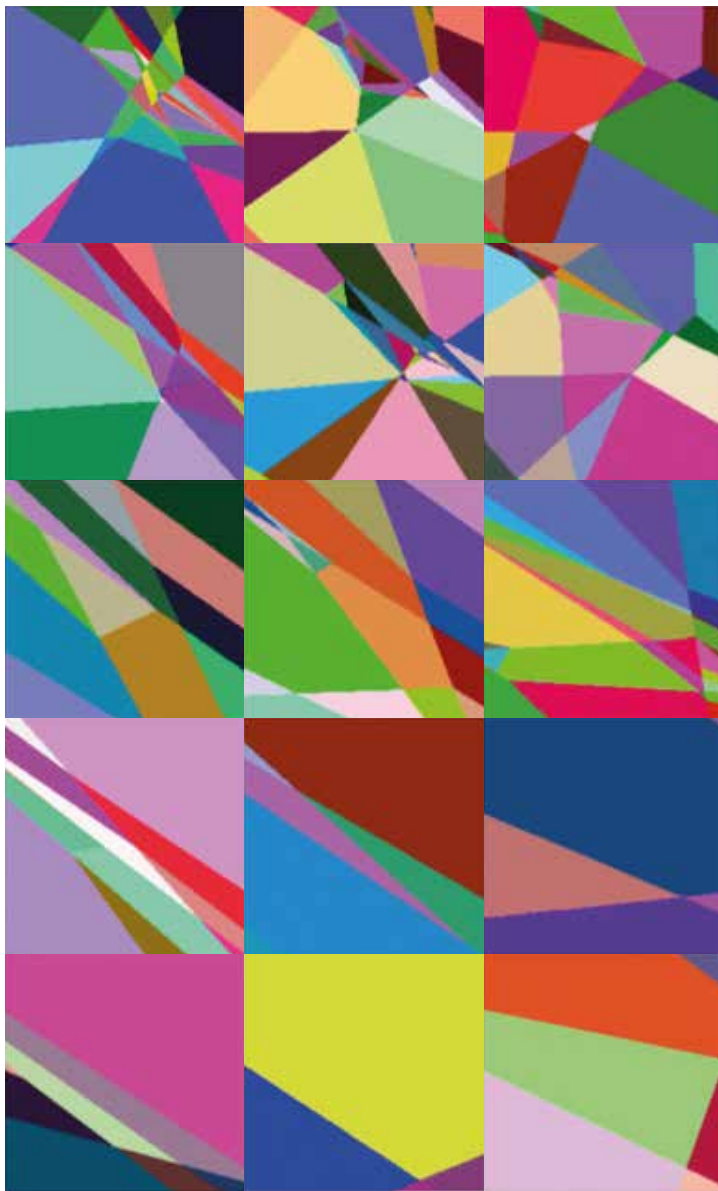
## Understanding how to improve data protection

In addition, there is still much to be desired when it comes to protecting privacy. For example, machines designed

to predict whether and how quickly a patient will recover in a hospital are pre-trained using data from real patients. “As a result, this data is in the system in one form or another,” says Montúfar. “And a customer who buys this system could try to open it up and read this private data.” To guarantee that something like this is not possible, he says, you would have to know very precisely what goes on inside such a system. Currently, the Mathematical Machine Learning group is looking at

the phenomenon in which neural networks prefer to find solutions with certain mathematical properties. “Even if there are several options, ultimately the network will usually choose solutions with certain characteristics,” Montúfar says. “We’re trying to characterize exactly what those preferences are.” The researcher illustrates the interrelationship by comparing the search for a suitable solution to a hike through a landscape. The network, or rather the algorithm





GRAPHIC: GUIDO MONTÚFAR / MPI FOR MATHEMATICS IN THE SCIENCES

Sample solutions: the individual charts correspond to different configurations of an example neural network that is supposed to identify tables in pictures. The greater the number of colored areas in a chart, the more complex the associated function the network uses to solve the task. The Leipzig-based mathematicians are investigating the conditions on which the complexity of the determined function depends.

“Conversely, it would be absurd to look for lines that are totally jagged.” In order to stop choosing the starting point for the search completely arbitrarily and instead systematically select suitable areas for it, the researchers want to know what the landscape of solutions looks like. “We have already made a lot of progress in this area,” Montúfar says. “We are now working on a precise mathematical theory that allows concrete predictions about the behavior of a neural network under different conditions.”

## A theory for faster training

Another factor is that theories of complex phenomena are sometimes oversimplified, and important aspects of the actual facts are lost. For example, mathematical theories are often less complicated if the artificial neural networks they describe are considered infinite for the sake of simplicity. But even though there is indeed a trend toward ever larger networks, in reality these are of course still finite. “Such simplifications can cause big problems,” Montúfar says. The reason for this, he explains, is that unforeseen effects then occur in the networks, which are huge but still finite, and these effects can be very significant. “If we could understand and explain these effects, we could train these AI systems much faster in practice,” Montúfar estimates. And this would not only save a lot of electricity

with which it works, begins its search at a starting point chosen more or less arbitrarily by the developer. Because of this, it tends to seek out solutions that are close to this point. In a sense, the neural network is trapped in the immediate vicinity of the nearby solution. “We now want to understand what the neighborhood around this solution looks like and why the neural network can’t get out of it,” Montúfar explains.

Artificial intelligence could be tasked, for example, with establishing a connection between data on living space

and rental prices and finding a suitable mathematical function for this purpose. A reasonable solution would not simply consist of a line or, more precisely, a mathematical function that provides the best possible connection between the individual data points. In order to show a plausible dependence of continuously increasing rent with increasing apartment size, this line should also be as smooth as possible, i.e., it should not have any kinks. “Hence, a suitable area to start searching the landscape of solutions would be around functions that are very smooth,” Montúfar explains.



and money, but also time. After all, the supercomputers that run these algorithms often operate for weeks or even months at a time.

Another important focus for Montúfar's team is the data itself, which is used to train the machines. In a similar manner to living brains, its quality has significant influence on the development of an artificial neural network. One example of this is provided by research conducted in the 1960s. It studied animals with early vision impairments and discovered that the impairment was irreversible. Even after the eye problem was corrected, the animals were unable to see sharply. "If you've learned to see with blurry images, your brain can't do much with sharp images later on," Montúfar summarizes. And in computer science, the way training data is designed also affects the learning process. "We

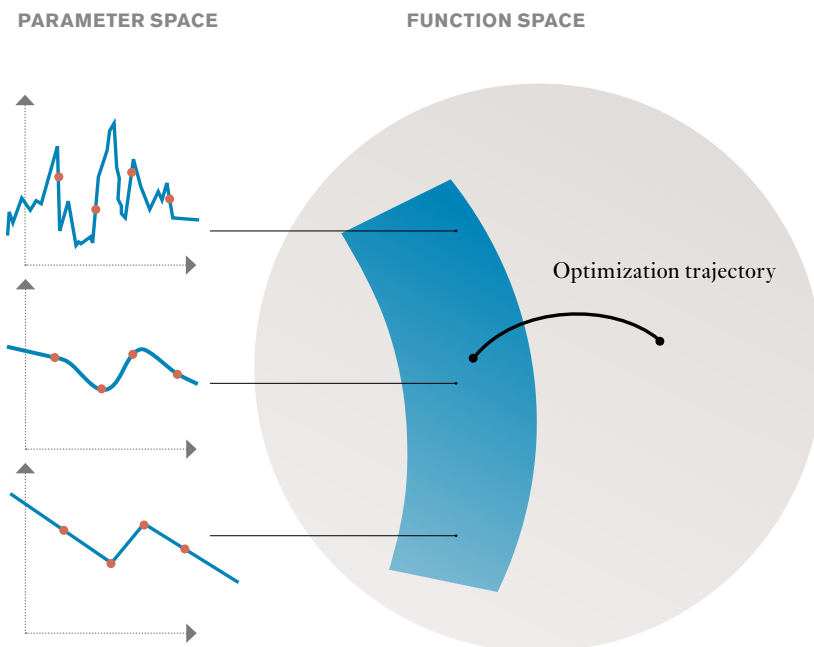
want to know what those effects are," says the researcher, "that is, what influence the selection of training data has on the development and then later the performance of a network." If artificial intelligence development continues on its current trajectory, then the issue of artificial consciousness may arise at some point. "If we assume that consciousness exists, I see no reason why it shouldn't also exist in artificial neural networks," Montúfar says pragmatically. Many researchers are already dreaming of developing artificial intelligence to the point where it is no longer limited to doing single, specialized tasks but instead gains a thorough understanding of the world. An artificial general intelligence such as this would then be able to perform a multitude of different intellectual tasks and would probably outperform humans in each of them sooner or later.

**ARTIFICIAL NEURAL NETWORK** is the name given to a computer-simulated system in which numerous artificial neurons are networked in a similar way to the nerve cells of the brain. Artificial neurons generate an output value from an input value and pass this on to another neuron. In neural network training, the connections between neurons are made and strengthened to optimally solve a task. These connections correspond to the criteria specified in the search for solutions to a problem and are weighted according to their relevance.

However, the question remains as to when and how we will decide whether AGI has been achieved. "In the past, you might have called a spam filter intelligent, but no one is impressed by this anymore," Montúfar says. So the boundary is constantly shifting, and AGI is in fact hard to define. How many tasks should this system be able to solve in order to be called "artificial general intelligence?" "Some people have already formulated tests and defined benchmarks on how to decide this," Montúfar says. "But, I think it's ultimately going to come down to practice whether people perceive a system as general intelligence or not."

"It's possible, however, that a computer intelligence will be created in a similar manner to birthing a child," Montúfar says. "Children are also intelligent beings and we don't actually have to understand anything to create them." So we might eventually create AGI without knowing exactly what we're doing. "The question is what kind of being this will be," Montúfar muses. "And if it is somehow supposed to be compatible with our society and our concepts of civilization, it would be very useful if we could understand it." But to be able to do this, he says, we must first become acquainted with the theoretical foundations of AI.

65



During learning, an artificial neural network adjusts its parameters, effectively its synaptic connections, along the optimization trajectory and seeks the blue-colored region of functions that fit all data points (red). The task is considered to have been solved very well by the function in the mid panel with as few maxima and minima as possible and without any kinks.

# HOW THE MILKY WAY WAS BORN

TEXT: MARKUS PÖSSEL

66

The galaxies we see around us have had a turbulent past, full of collisions, plentiful gas flows, and bursts of increased star formation. Our home galaxy is no exception. A team led by Hans-Walter Rix at the Max Planck Institute for Astronomy is reconstructing the Milky Way's history in a process that resembles archaeological research.

IMAGE: S. PAYNE-WARDENAAR, K. MALHAN / MPI FOR ASTRONOMY





Witnesses to past collisions: in the artistic representation of our Milky Way, streams of stars can be seen rising in wide arcs from the disc-shaped spiral galaxy, representing relics of mergers with other galaxies.

67

Our Milky Way is almost as old as the universe itself, and can look back on a rich history. Like most galaxies, it was formed within the first billion years after the Big Bang, making our home galaxy roughly 13 billion years old.

Astronomers can now reconstruct details of its history quite accurately using observational data. “By doing so, we not only learn something about the beginning and early stages of our home galaxy, but also about the evolu-

tion of distant galaxies that we cannot observe in such detail,” explains Hans-Walter Rix, Director at the Max Planck Institute for Astronomy. His team is working on a comprehensive chronicle of the Milky Way, em-



ploying methods similar to those used by historians or archaeologists when reconstructing the history of a city. In the case of a city, some buildings come with definite construction dates. For others, the clues are more indirect – the use of primitive building materials, or the characteristics of older architectural styles, can serve to indicate the relative age of a building. Finding remains of older buildings under newer structures also serves to establish relative age. And, last but not least, spatial patterns are important: in many cities, a central old town is surrounded by much newer neighborhoods.

For the Milky Way and similar galaxies, the situation is much the same. Here, the “buildings” are the stars. It is possible to deduce the age of certain types of stars through observation. In cases where this is not possible, the chemical composition of stars is analogous to the role of architectural styles, allowing for conclusions about the relative ages of the star in question. Cities undergo radical remodeling, with construction booms and re-districting, but can also experience gradual growth. Similarly, galaxies undergo collisions and mergers, but can also form stars more slowly, as fresh hydrogen gas – the raw material from which new stars are formed – flows into a galaxy from the surrounding regions over billions of years. A galaxy’s history begins with smaller protogalaxies: regions where stars were already formed in the first billion years after the Big Bang. These are the seeds of the galaxies we know today. The Milky Way is likely to have come into being as three or four such protogalaxies, which, having formed in close proximity to one other, subsequently merged.

Reconstructing the evolution of a galaxy like our own requires the interplay of observation and simulation. “Modern large-scale surveys have helped us a lot in this regard,” says Hans-Walter Rix. “They’ve given us dramatically improved and more comprehensive data than was previously available.” In

these surveys, telescopes scan substantial parts of the night sky to gather information such as the position and brightness of stars, but also spectra – the rainbow-like decomposition of starlight. Our Milky Way is special in that we have an inside view, and are able to observe many of its stars in detail.

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## SUMMARY

Using data from the Gaia space telescope, which determines the positions and motions of stars and provides information about their ages, a team from the Max Planck Institute for Astronomy is reconstructing the early history of the Milky Way.

When it was just a few billion years old, the Milky Way merged with the Gaia Enceladus/Gaia Sausage galaxy and subsequently went through a phase of intense star formation.

The core of the Milky Way contains stars that are more than 12.5 billion years old; these formed shortly after the merger of the protogalaxies – the precursors of our galaxy.

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To carry out the archaeological work in the Milky Way, Hans-Walter Rix’s team used surveys from ESA’s Gaia satellite, the Sloan Digital Sky Survey, and China’s Lamost telescope. To date, Gaia has determined the positions, orbits, and magnitudes of nearly two billion stars in the Milky Way – equivalent to about one percent of the total stellar population of our home galaxy. Lamost, in turn, measures the spectra of about ten million stars. Using this data, Hans-Walter Rix and Maosheng Xiang, a fellow researcher at the Max Planck Institute for Astronomy, first determined the surface temperature, luminosity, and chemical composition of 250,000 stars known as ‘subgiants’. This is the term

for a relatively short phase of stellar evolution, which has one key advantage: during this phase, it is possible to deduce the age of a star very accurately on the basis of its observable properties. By looking more closely at the Gaia and Lamost data, the researchers were able to obtain a clear picture of the history of the Milky Way between 11 and 8 billion years ago. In particular, they were able to discern the consequences of the Milky Way’s most recent turbulent merger with another galaxy, which is known as either Gaia Enceladus or the Gaia Sausage.

The enormous amounts of gas carried by the two galaxies condensed during the merger, resulting in the rapid formation of large numbers of new stars. These accumulated in a region of the galaxy referred to in astronomy as the ‘thick disk’ of the Milky Way. Eventually, things calmed down with regard to star formation: “After the turbulent early period, there was much less hydrogen gas in the galaxy,” explains Maosheng Xiang. “Further, steady inflow from the outside resulted in the structure we now call our galaxy’s ‘thin disk.’”

The reconstruction of the stellar aftermath of the Gaia Enceladus/Gaia Sausage merger was based on the special properties of sub-giants. But it contains hints of an even earlier history – involving the galactic analogue of architectural styles: the metallicity of stars, in other words the quantity of chemical elements in the stellar atmosphere that are heavier than helium. These types of elements, which astronomers (somewhat incongruously) call metals, are formed in the interior of stars by nuclear fusion. Massive stars blast those elements into space when they end their lives in supernova explosions. This enriches the interstellar gas with heavier elements. It is from this gas that the next generation of stars is formed, now with a higher initial metallicity. Stars with a higher metallicity therefore tend to be younger than those with a lower metallicity. The metallicities of the old-

est sub-giants that Rix and Xiang had examined were already quite considerable, a clear indication that they were formed from the remnants of an earlier generation of stars.

“The existence of these earlier generations of stars is anything but surprising,” says Hans-Walter Rix. “This has long been shown by simulations of cosmic history.” Interestingly, those simulations also predict where representatives of the earlier generations of stars should still be found today: in the relatively compact core region of the Milky Way, just a few thousand light-years in diameter. This core region should incorporate stars from the first mergers of proto-galaxies that formed the Milky Way.

“We then wanted to know how we could detect these stars from the old core of our galaxy,” says Rix, who teamed up for this project with René Andrae, a researcher at the Max Planck Institute for Astronomy, and Vedant Chandra, a visiting doctoral student from Harvard University. “It was clear that we wouldn’t get anywhere with subgiant data here.” Subgiants are too faint to be observed beyond

distances of about 7,000 light-years. Consequently, the researchers focused on a different type of star – red giant stars. Typical red giants are about a hundred times brighter than subgiants. It is, therefore, easy to observe them, even at the distance of the galactic center and its surrounding neighborhood. The Gaia measurements contain information about numerous red giants, and since the most recent data release in the summer of 2022, even the associated spectra. The red giants cannot be precisely dated in the same way as the subgiants, but using their metallicity, which can be determined based on the spectra, it is at least possible to estimate their approximate age.

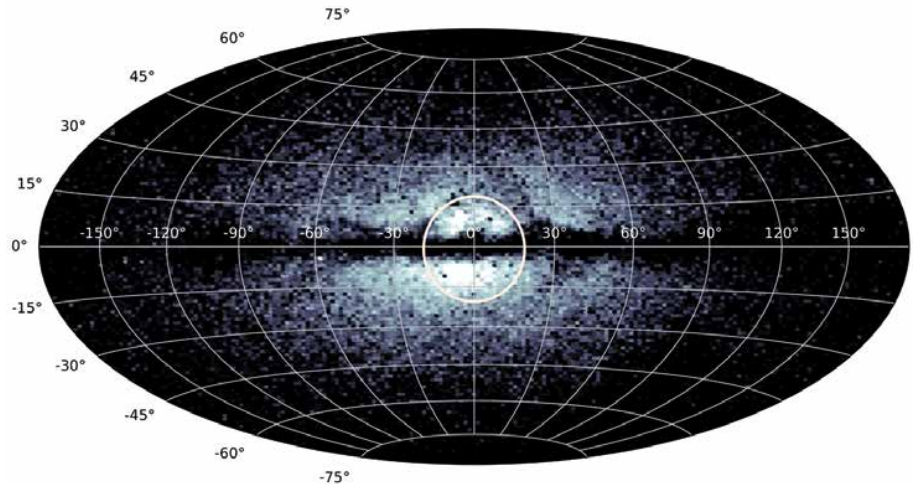
## Spectra analyzed by artificial intelligence

Gaia’s spectra are, however, too poorly resolved for traditional analysis techniques that use a plethora of fine spectral lines associated with various chemical elements. Rix’s team had to find a new way of analyzing these spectra, and they decided to employ

**METALLICITY**  
in astronomy refers to the abundance of chemical elements that are heavier than hydrogen and helium. It can be determined from the spectrum of a star and provides a rough measurement of its age.

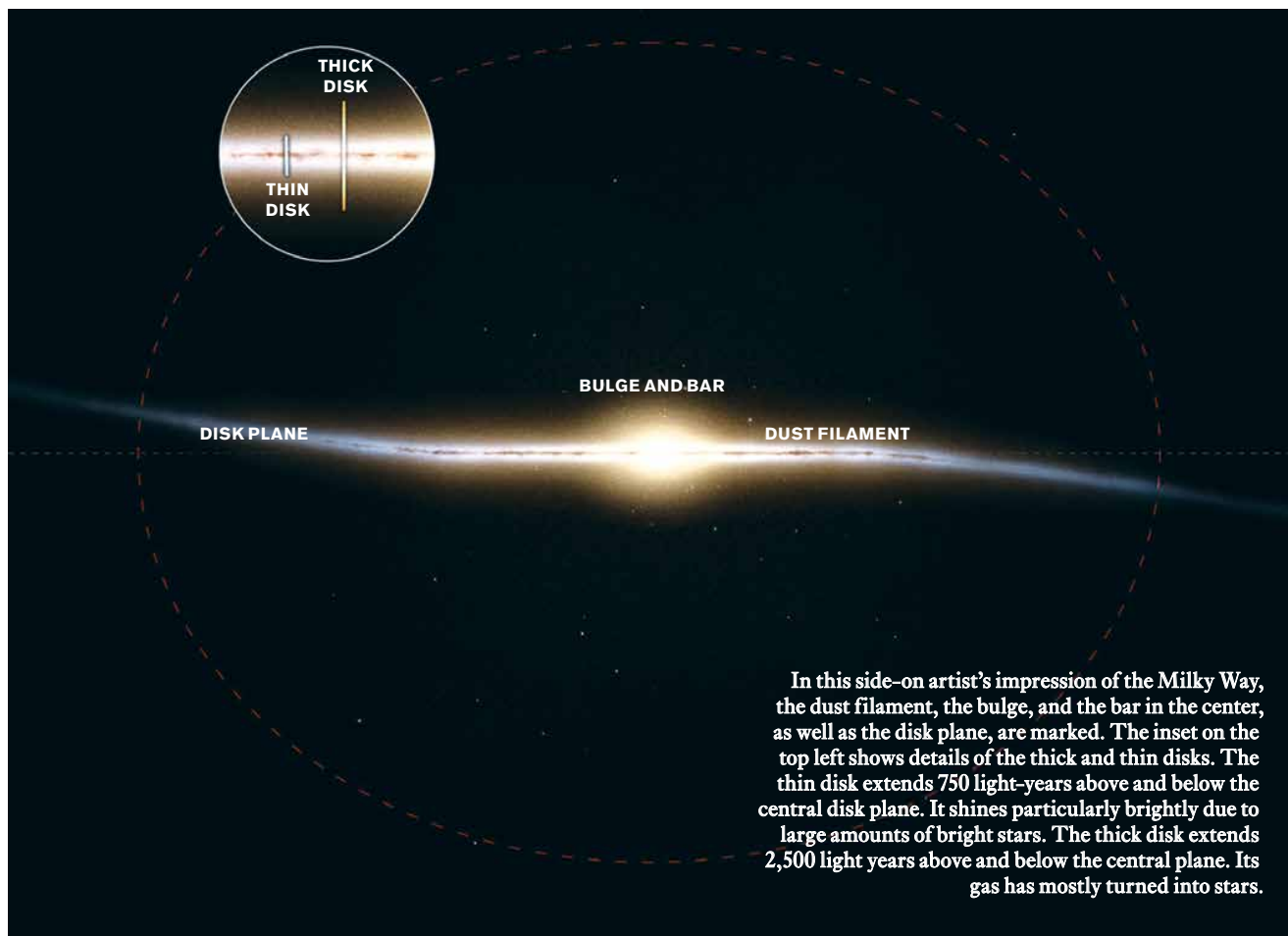
**GIANT STARS**  
are stars that have exhausted their hydrogen fuel supply and, as a result, have undergone significant expansion. Astronomy makes a distinction between subgiants and red giants. Subgiants are in a relatively short stage of development, which allows for a precise determination of their age. Red giants are up to 100 times larger and up to 1000 times more luminous than our Sun, but they are relatively cool and therefore, appear reddish.

**SPECTRUM**  
describes the distribution intensity, for example, of light with respect to wavelength. Lines in the spectrum of a star are characteristic of chemical elements in its atmosphere.



The ancient heart of our galaxy: the map shows the distribution of red giant stars in the Milky Way in much the same way that certain world maps show the surface of the Earth. The galaxy’s disk, where gas and dust obscure the view of the stars, bisects the map from left to right. In the center (white circle) are stars that are already more than 12.5 billion years old.

IMAGE: STEFAN PAYNE-WARDENAR / MPI FOR ASTRONOMY



In this side-on artist's impression of the Milky Way, the dust filament, the bulge, and the bar in the center, as well as the disk plane, are marked. The inset on the top left shows details of the thick and thin disks. The thin disk extends 750 light-years above and below the central disk plane. It shines particularly brightly due to large amounts of bright stars. The thick disk extends 2,500 light years above and below the central plane. Its gas has mostly turned into stars.

70

machine-learning methods. This AI-based approach requires an algorithm to be trained for the specific task in question. For a number of the stars studied by Gaia, suitable training data is available in the form of more detailed spectra recorded by ground-based telescopes. Using this training data, the algorithm learned to deduce metallicity from Gaia spectra. To check whether the artificial intelligence was up to the task after training, the researchers used spectra of stars whose metallicity was also known, but which had not been used for training. The tests indicated that the algorithm was able to determine the metallicity from the Gaia spectra with impressive accuracy. This was convincing evidence that the AI would be able to provide reliable metallicity values for the two million Gaia spectra of red giants in the inner regions of the Milky Way. From the results, the team was

able to identify a population of stars with appropriately low metallicities that form the ancient heart of the Milky Way galaxy. A comparison with the subgiants, whose ages Rix and Xiang had determined in the prior study, indicates that this core of the Milky Way must be older than roughly 12.5 billion years. The stars are all located at a maximum distance of about 15,000 light-years from the center – for comparison: the entire Milky Way stretches over almost 200,000 light-years.

## The hunt for protogalactic stars

Further examination of the chemical makeup of some of the stars, where more detailed data was available, revealed that they most likely formed in

the Milky Way not long after the protogalaxies had merged. “We have now validated what cosmological simulations had suggested about the early development of our galaxy,” says Hans-Walter Rix. Next, the researchers hope to use high-resolution spectra from additional sky surveys to pinpoint the positions and even the movement patterns of stars in the Milky Way’s core. If the stars can be assigned to distinguishable groups, each with a characteristic motion pattern, these groups might well correspond to the protogalaxies from which the Milky Way was formed. The archaeological reconstruction by Hans-Walter Rix and his team would then truly have arrived at the origin of the Milky Way.





# My neighborhood, the prime numbers

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On course for the Caribbean: Lena Heins sailed across the Atlantic aboard the S/Y Eugen Seibold. The 22-meter ocean-going yacht was designed in 2018 for the purpose of conducting marine and climate research.

72 Max Planck researchers cooperate with partners in more than 120 countries. In these articles, they talk about their personal experiences and impressions. Lena Heins from the Max Planck Institute for Chemistry in Mainz crossed the Atlantic aboard the research sailing yacht S/Y Eugen Seibold. During the voyage from Cape Verde to the Caribbean Island of Grenada, she collected samples for various climate projects. Here, the scientist offers an insight into her work on the ship and tells us about dolphins, flying fish, and a climate archive on the ocean floor.

The S/Y Eugen Seibold is a 22-meter ocean-going research yacht designed for the collection and analysis of seawater, plankton, and air samples. Its

propulsion by sail is not only environmentally friendly, but also makes it possible to collect samples that are free from contamination by the ship's exhaust. The yacht boasts a water lab and an air lab, so some of the samples can be processed on location. At the end of November, I boarded the yacht on the Canary Island of Lanzarote to head first to Cape Verde and then across the Atlantic.

For my doctoral thesis, I am studying planktonic foraminifera – a group of single-celled organisms that float freely in the ocean. Most species are microscopic and live in chambered calcareous shells. When they die, the shells sink to the seafloor, where over time they form a natural climate archive that can be accessed using sediment cores. Since calcification takes place in interaction with ambient seawater, the temperature, salinity, oxygen concentration, and pH value are all preserved in the shells. Because of this, foraminifera serve as

archives for reconstructing the climate of earlier epochs. I analyze the calcareous shells of present-day species and compare their composition with that of the marine environment. This is important, as it enables us to know how accurately the data represent the state of the modern ocean and climate, and thus to calibrate the paleoclimate data.

On our voyage, we followed a classic blue-water route – a sea route favored by sailors because ideal wind, weather, and currents can be expected at a certain time of year. The weather was a mix of sun, clouds, and scattered showers. The trade winds blew from easterly directions at an average of 20 knots, and we were able to cover most of the total of about 2200 nautical miles under sail. What really struck me was how alone you are in the Atlantic. In two weeks, we encountered only three other ships. But that didn't make me feel uneasy; in fact, I was fascinated by the little microcosm of our



## GRENADA, CARIBBEAN

ship contrasted against the boundless expanse of the ocean. Sometimes we were accompanied by dolphins, or flying fish would glide over the water. Time and again we sailed through large carpets of Sargassum algae, which are currently spreading rapidly in the Atlantic. At night we enjoyed a magnificent starry sky.

Our team consisted of four crew members and two scientists. My colleague Isabella Hrabec de Angelis was responsible for atmospheric chemistry, and I took care of the water and plankton samples. The two-person cabin I shared with Isabella was small but comfortable, with two closets and bunk beds. It featured an ingenious invention: a pulley that adjusts the angle of the upper bed, which allows you to kind of wedge yourself in so that you don't roll around, even in heavy seas. Accompanied by the lapping of the water against the ship's hull, I slept very well in the middle of the Atlantic. During the voyage, the on-

board instruments were continuously recording data, and on top of that we took water and air samples at 12-hour intervals. We worked in shifts, ensuring that someone always had an eye on the instruments. Where there were technical problems that could not be solved with the help of the instrument manual, we were assisted by colleagues whom we could contact via the Internet. Fortunately, though, everything went according to plan, and we are very satisfied with our yield of samples and data.

After 14 days on the open sea, we finally entered a port on the Caribbean Island of Grenada. For me, that was almost the end of the journey, and five days later I flew back from there to Frankfurt – quite a temperature shock in the middle of winter! The S/Y Eugen Seibold, meanwhile, was sailing on to Panama. Over the next three years she will cruise in the tropical eastern Pacific and hopefully deliver more exciting data.



PHOTO: PRIVATE

Lena Heins

29, is fascinated by the diversity of the oceans and is also passionate about art and design. After studying geosciences, she earned a master's degree in integrated design at Bremen University of the Arts. For the past year, she has been working on her doctorate at the Max Planck Institute for Chemistry in Mainz. In the Climate Geochemistry research department under the direction of Gerald Haug, she is working on foraminifera, a group of unicellular marine organisms.

# FIVE QUESTIONS

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## ON CHATGPT AND COPYRIGHT

FOR DARIA KIM



74

**Who owns the rights to texts if they are written by a machine and not a human? Daria Kim, a legal scholar at the Max Planck Institute for Innovation and Competition in Munich, deals with questions like these. In this interview, she tells us what rules apply to AI-generated works and discusses the protection of intellectual property in this context.**

**Ms. Kim, if ChatGPT writes a text, can I simply use it?**

DARIA KIM That depends on whether such texts are protected by intellectual property rights. This varies from one country to the next. In Germany, a convention known as the continental European copyright tradition applies. A certain level of human creativity is always necessary to justify copyright protection. This applies to texts as well as to images and musical compositions. In Germany, the raw output generated by AI cannot be regarded as a work of authorship of the person who merely presses the button to create it.

**If the raw output is not protected, what if it is modified?**

It depends on how the text is modified. A human must be sufficiently creative in mod-

ifying the raw AI data in order to be entitled to copyright protection. It is interesting to note that in its terms of use, OpenAI, the company behind ChatGPT, prohibits the presentation of output as “human-generated” if this is not the case – something which would be unethical anyway.

**Nevertheless, the discussion about the protection of intellectual property in connection with AI products is far from over.**

This is due to international differences in copyright law. Harmonization of the protectability of AI products would definitely be desirable, especially in terms of legal certainty. However, the key question remains: which legal norms should be used as a basis for this? The World Intellectual Property Organization is currently in the process of identifying problems that AI poses for intellectual property rights. However, legislative harmonization measures cannot keep up with the pace at which artificial intelligence is taking hold.

**There is also the question of the rights of the authors of those works that are used as training data – are they protected from text and data mining, i.e., automated analysis by software?**

If data used as input for machine learning is protected by copyright, the question arises whether the existing exceptions in copyright law are applicable to the development of AI systems. Such exceptions should in principle balance the interests of authors and users – in this case, of AI developers as well. In order to circumvent these possibilities, authors can use technical barriers to protect their works.

**Is the use of works for machine learning actually regarded as text and data mining?**

The EU legislator defines text and data mining broadly enough that machine learning can certainly be regarded as text and data mining. Another question, however, is whether the use of protected works for machine learning falls within the scope of the applicable exceptions in copyright law for text and data mining. This question has not yet been conclusively clarified.

*Interview: Emma Lehmkuhl*

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Daria Kim is a senior research fellow at the Max Planck Institute for Innovation and Competition.

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- Sub-institute / branch
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PUBLISHER'S INFORMATION

*MaxPlanckResearch* is published by the Science and Corporate Communication Office of the Max Planck Society for the Advancement of Science. Legal headquarters of the association: Berlin.  
ISSN 1616-4172

**Publisher's mailing address**

Hofgartenstraße 8  
D - 80539 Munich  
Tel: +49 89 2108-1719 / -1276 (before midday)  
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www.mpg.de/mpresearch  
App for free download: www.mpg.de/mpr-mobile

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**Layout**

GCO Medienagentur  
Schaezlerstraße 17  
86150 Augsburg  
www.gco-agentur.de

**Printing & Distribution**

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Leibnizstraße 5  
97204 HÖchberg

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To improve readability, we have used only the masculine form in some of the texts. However, the chosen formulations address all genders equally.

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