

HIGHLIGHTS
2018 FROM THE YEARBOOK
OF THE MAX PLANCK SOCIETY



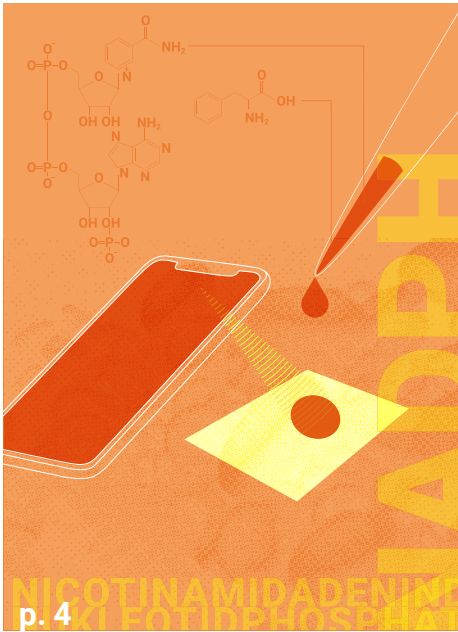
Editorial

Each year, the Max Planck Society submits a scientific research report in the form of a yearbook to render account of the scientific research performed at its Institutes to the public and its funding providers. The central questions addressed are: Where do we stand, and where do we want to go? The Max Planck Institutes are asked to select a work or project from their scientific activities in 2018, which are suitable for publication in the yearbook, and outline the relevant findings and conclusions. The yearbook contributions of all Max Planck Institutes are published on the Internet at www.mpg.de/jahrbuecher.

For this printed yearbook collection, 15 articles were selected and edited in a journalistic manner, which seemed particularly suited for publication from a science communication perspective and especially interesting for non-experts. Among the highlights of the yearbook 2018 are research results, for example, in the field of protein engineering, which should lead to the development of artificial biosensors for a rapid and self-determined control of blood values and could bring great relief for many patients with metabolic diseases. Or the idea of developing carbon dioxide as an alternative carbon source for the production of fuels to high-quality fine chemicals, so-called “Power-to-X” concepts. And finally, the efforts of a team of legal experts to unravel the web of EU directives, national law and scientific regulations that have led to the “Commentaries on European Contract Laws”, which can now serve as the scientific basis for modern European contract law.

A look into the yearbook is definitely worth it!

Content



p. 4

1 Biosensor for blood testing at home p. 4



p. 9

4 A glimpse into the machinery of a gravitational monster p. 13



p. 16

7 Appetite stimulant in the brain p. 23

2 Plants with a memory p. 7

3 Acoustic invisibility cloaks and pricked-up ears p. 9

5 Ways out of terrorism p. 16

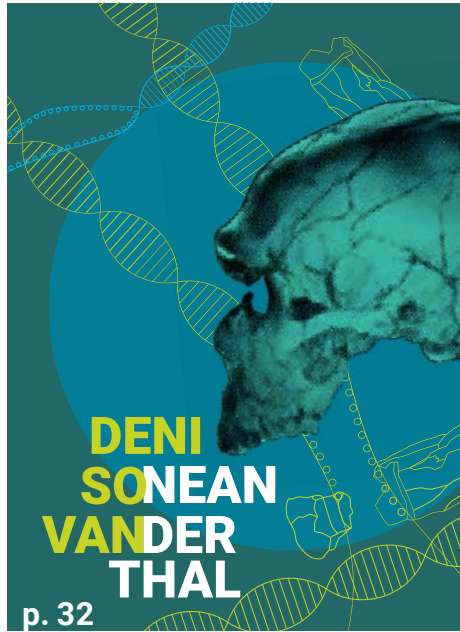
6 CO₂ – a raw material for chemical production p. 20

8 A psychological trick for greater equality of opportunities p. 26

9 3D metal printing – powder bed to part p. 29



p. 26



p. 32



p. 40

10 Rendezvous in the Stone Age p.32

13 Negotiating the labyrinth of European contract laws p.40

11 Wild west on the web p.35

14 Water, ice and snow are determining factors for Arctic climate change p.43

12 Hope for hereditary neuropathy patients p.37

15 In a planetary nursery p.47

1 Biosensor for blood testing at home

KAI JOHANSSON
➤ *Max Planck Institute
for Medical Research,
Heidelberg*

Just eat what tastes good? This is absolutely taboo for many metabolic diseases. A strict diet and regular laboratory tests are part of everyday life – a psychological and social burden. Our latest research results could soon bring great relief to these and many other patients: “protein engineering” enables the design of artificial biosensors for rapid and autonomous blood value checks.

Doctors usually diagnose the metabolic disease phenylketonuria within the first few days of a baby’s life. Research into this hereditary disease, which affects one in every 10,000 children, has been ongoing since the 1970s. The amino acid phenylalanine accumulates in the blood due to a non- or only partially functional phenylalanine hydroxylase enzyme and can damage the growing brain. In everyday life, the disease means not eating most natural foods. Instead, those affected have to take special protein substitutes, because the amino acid tyrosine, which the body produces from phenylalanine, is vital for us.

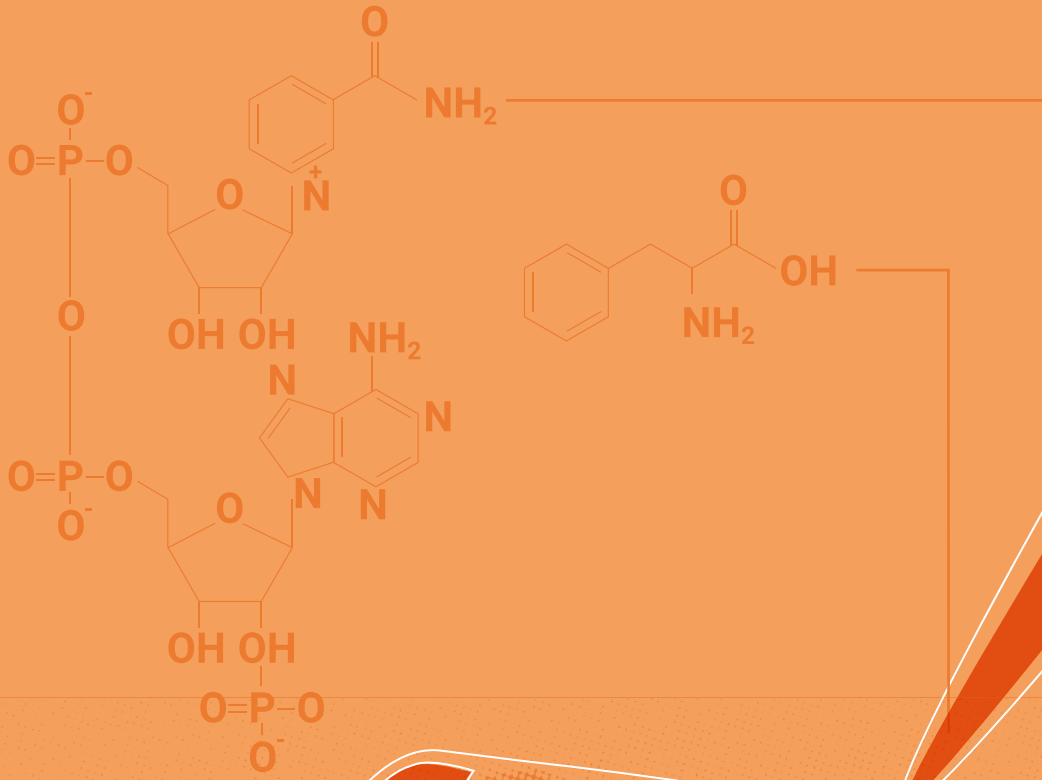
It is important for the parents of sick children to know their children’s phenylalanine levels, as this is the only way for them to assess the leeway for a normal life. Did the kid “sin” on the school trip? In the morning, a muesli bar was eaten in the kindergarten without permission: could that have consequences? How much restriction must there be after that? However, getting a phenylalanine blood value means visiting the doctor

for a blood test, then waiting two to three days for the result, by which time the school trip and muesli bar are long forgotten.

Blood value for dosage of drugs

Drugs that can improve tolerance to phenylalanine in about 30 percent of patients have been approved for adults. In this context too, the laboratory test result is an important tool for setting the correct dosage and checking the efficacy of the medication. And for pregnant women who suffer from phenylketonuria, the strict avoidance of phenylalanine is particularly important to avoid placing the unborn child at risk.

Being able to monitor the blood concentrations of phenylalanine in a timely and patient-friendly manner would significantly improve the everyday life and quality of life of patients. But for such a project, we researchers have to dig deep into our biochemical bag of tricks: the



NICOTINAMIDADENINDI
NUKLEOTIDPHOSPHAT

technology we used to bring such an analysis within reach is known as “molecular engineering”.

Blood values from the lab

Currently, metabolic products or other biomarkers in blood samples are mostly detected using conventional laboratory methods. Most attempts to achieve a prompt diagnosis at the patient’s bedside or in the patient’s home environment aim to reduce the size of existing analysis technology.

Our method, on the other hand, is based on a fundamentally different approach. It is based on a novel molecular tool, a so-called semisynthetic biosensor, which consists of a multifunctional protein and an artificial dye that is covalently linked to the protein. The protein itself consists of two components: a luciferase – an enzyme that emits blue light, and is responsible, for example, for the glow of fireflies; and a receptor for the dye. The special trick: this receptor can only bind the dye in the presence of the co-factor nicotinamide adenine dinucleotide (short: NADPH). If the dye now binds to the receptor and thus comes close to the luciferase, the colour of the light emitted by the luciferase changes from blue to red. This colour change is even visible to the naked eye.

Molecular engineering thus produces a luminous biosensor that changes its colour in the presence of the NADPH cofactor. One molecule of NADPH is formed for each molecule of phenylalanine in an enzymatic reaction. This couples the NADPH concentration to the colour of the biosensor and the amount of phenylalanine. The amount of NADPH produced is therefore directly proportional to the phenylalanine concentration. The colour change from blue to red can be measured with a simple camera and the phenylalanine concentration can be calculated from this value.

However, the same biosensor can also be used for the detection of other metabolites by forming an NADPH molecule for each molecule of the metabolites in a specific enzymatic reaction. We have already shown that our sensor can not only be used in the laboratory for determining the blood concentrations of phenylalanine but also of glutamate and glucose – and there are many other possible applications.

How is the test done? First, a small drop of blood is obtained with a simple lancet of the type familiar to diabetics from the sugar test. A small portion of this

sample is then diluted with enzymes that convert the phenylalanine contained in the sample into the corresponding amount of NADPH. The sample is then applied to a test strip with the dried biosensor. The biosensor begins to emit light, which is recorded by a digital camera or smartphone. The ratio of blue to red, i.e. the colour of the light, directly reflects the phenylalanine concentration. The entire procedure takes only about ten minutes and could be carried out directly at the patient’s home using simple equipment. The accuracy of the results is comparable to the accuracy of modern standard methods in clinical laboratories.

Successful tests on patients

Our new analytical method has already been successfully tested on patients in collaboration with scientists from the University Hospitals of Heidelberg and Lausanne. Currently, these initial promising results are waiting to be confirmed in further studies in Heidelberg. The fast and easy handling as well as the accuracy of the method predestines it for future applications in diagnostics at the bedside or at home. Of course, it will have to be further simplified, automated and tested for this.

The prospect of providing affected patients with an innovative tool for a more autonomous life is a particular motivation for us to master these challenges. From a scientific point of view, our work is also an example of how the synergy between synthetic chemistry and protein engineering can be used to produce semisynthetic biomolecules with completely new properties. ◦

2 Plants with a memory

SALMA BALAZADEH

↳ Max Planck Institute
of Molecular
Plant Physiology,
Potsdam-Golm

Unlike most animals, plants cannot run away or seek shelter. Once a plant has taken root, it is at the mercy of all prevailing adverse conditions of its location, which is why plants need sophisticated survival strategies. My colleagues and I at the Max Planck Institute of Molecular Plant Physiology are investigating how these strategies work.

Pests, diseases, frost, heat, drought, lack of light or storm damage – plants have to master many challenges. How do they do it? And can they better withstand new threats based on their previous experiences?

Memories of unfavourable environmental conditions

Plants do actually have a kind of cellular memory that prepares them for future environmental stress. So far, however, the molecular basis of this plant memory has only been known to a limited extent. Our research, therefore, focuses on two questions: which molecular mechanisms do plants use to regulate the difficult but vital balance between growth and stress tolerance, and how can plants react to rapidly changing environmental conditions? These questions are of enormous relevance, particularly for agriculture as well as for the preserva-

tion and understanding of ecosystems. Knowing the answers could, for example, lead to a reduction in the use of pesticides.

We have already identified several molecular networks that control plant stress tolerance in both model and cultivated plants. In the coming years, we intend to expand our research to crops that have been little studied to date, such as quinoa, which was originally cultivated in South America, because the differences between individual plant species are significant. If we knew the reasons for this, it would be easier to breed new plant varieties adapted to specific locations.

A few years ago, we identified a regulator gene in the model plant *Arabidopsis thaliana*, which on the one hand enables it to tolerate various stress factors and, on the other, controls its growth. Because of its ability to inhibit stress-related aging processes, we call this regulator JUNGBRUNNEN 1 (German: fountain of youth) or JUB1.

We have already partially decoded the gene networks controlled by JUB1, whereby we found that JUB1 influences the balance of growth-influencing plant hormones, such as gibberellic acid and brassinosteroids. Similar genes to JUB1 are also present in other plants, such as tomato plants in which JUB1 plays a central role in environmental stress tolerance. Further experiments have shown that a slight increase in the activity of JUB1 makes a plant more resistant to drought without significantly affecting its growth. We are currently analysing the relevant underlying processes in more detail.

Heat stress protein protects against heat stress

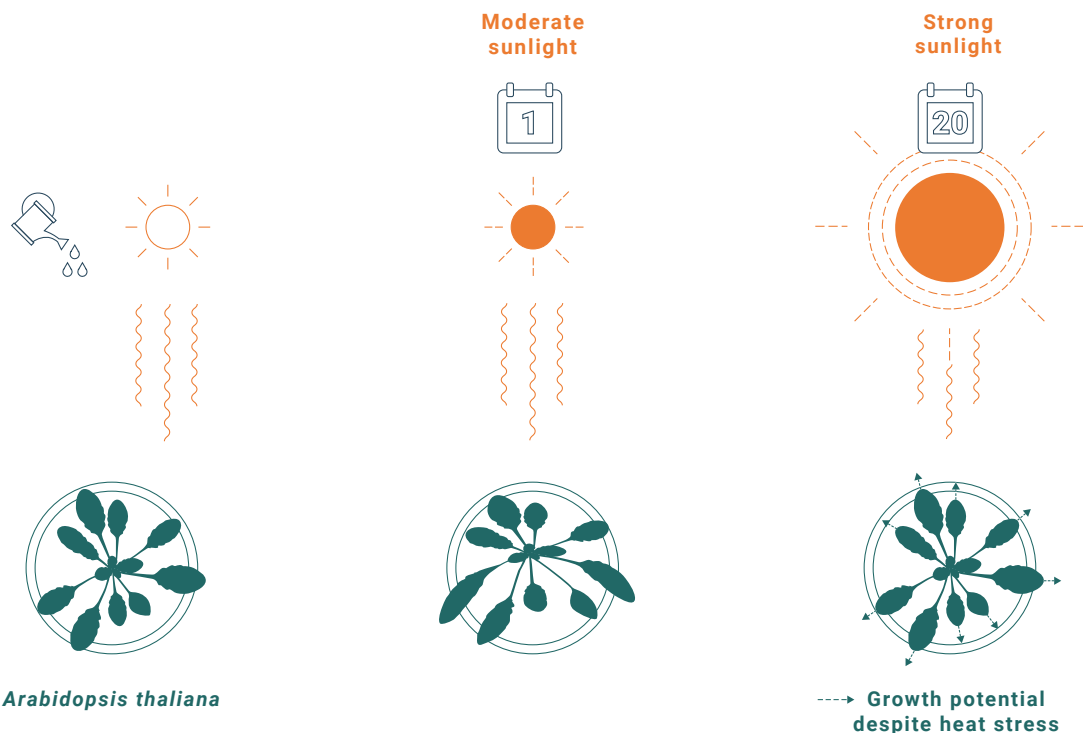
Recently, we have discovered how plants can survive dangerously high temperatures following earlier exposure to a slight temperature increase. The heat stress protein HSP21, which is found in chloroplasts and protects other proteins from excessive temperatures, plays a role in this "molecular memory". The HSP21 protein is initially formed in plant tissue following a slight rise in temperature, but then decomposes as soon as the temperature drops. The rate at which HSP21 disappears from the cells correlates to how long after the first weak heat stress the plant will survive another stronger heat stress.

A protein digesting enzyme, called FtsH6, in turn, plays an important role in the decomposition of the HSP21 protein. Both proteins clearly influence each other and could be important elements in the molecular heat stress memory of plants.

A biological recycling process that decomposes and recycles unusable proteins or cell components also seems to play a role in cellular memory, as mutants with defective cell recycling systems have a better temperature memory than plants in which this mechanism is active. This is because the recycling process is also involved in the decomposition of certain heat shock proteins. In mutants in which the recycling mechanism no longer works, the heat shock proteins are retained longer, which could enhance thermal memory.

Every year, thousands of hectares of agricultural land are lost. We must, therefore, breed and cultivate high-yield crop varieties on the remaining land that are adapted to the prevailing climate. In the light of the expected climate change and the constantly expanding global population, gaining insights into the cellular processes that control plant stress tolerance is enormously important for crop breeding. This is why we want to further decipher the molecular networks of heat and drought stress reactions in plants, in the coming years, and to gain a gradual understanding of the unique survival formulas of plants and make them usable for humans and our environment. ◦

Thanks to its cellular memory of slightly unfavourable environmental conditions such as drought and heat (centre), a plant can survive subsequent, stronger stress (right).



3 Acoustic invisibility cloaks and pricked-up ears

HOLGER GOERLITZ
➤ *Max Planck Institute
for Ornithology, Seewiesen*

A balmy summer evening: a light breeze is blowing, a heady bouquet of flowery scent fills the night. All is dark. Suddenly, the silence is shattered by a shrill cry, quiet at first, then ever louder, faster, getting closer. A moth drops to the ground. A second banks sharply. A third reacts too late and falls prey to a dark shadow, which is soon joined by another: a bat attracted by the calls of the first one.

Finding food and avoiding predators are vital skills for all animals. Predators and prey are continuously evolving adaptations to optimize their hunting and evasion strategies in an evolutionary arms race in which sensory systems play a key role: before they can react with appropriate behaviour, both predators and prey must first detect, recognize and locate each other. At the same time, both use strategies, including different types of camouflage, to avoid detection.

Most people think of “camouflage” in terms of the visual appearance: a green frog on a tropical plant leaf, a brown snake on the similarly coloured bark of a tree. But for some animals, such as nocturnal insects and their predators, the bats, acoustic stimuli are much more important. They use sound for camouflage and deception.

Echolocation – hunting with sound

Acoustic communication is omnipresent in the animal kingdom, for example in the song of birds and insects used for partner selection and territorial defence. Owls, insectivorous monkeys and many other predators take

advantage of these sounds to track down their prey. Since sound is also detectable in the dark, nocturnal animals in particular rely on their sense of hearing.

Echolocation is a special adaptation to orient at night, used by bats and toothed whales. These animals regularly emit high-frequency, stroboscopic “sound flashes” into their surrounding environment and listen for the returning echoes. These calls are as loud as a pneumatic hammer. Luckily, they are inaudible to us humans as they are emitted in the ultrasonic frequency range, otherwise our ears could be damaged in the long run.

For nocturnal animals, it is worth the effort: the sound reflected by their surroundings provides echolocating predators with an acoustic image of their environment including any nearby prey. Bats measure the distance to obstacles and prey from the delay between the emission of the call and the return of the echo. They calculate the direction of an arriving sound based on time and frequency differences between their ears – as we humans do. The properties of a given object, such as its size and surface structure, are encoded in the volume, duration and “tone quality” of its echo.

In response to the predation threat by echolocation bats, hearing organs evolved several times independently



in many different insect groups, enabling them to detect the echolocation calls of predatory bats from a distance and to respond with rapid evasive manoeuvres. Consequently, only few of these eared insects, such as many of the large moth species, are usually found in the diet of bats. Therefore, it was all the more surprising to discover that the western barbastelle feeds almost exclusively on eared moths. This led us to suspect that the western barbastelle is able to camouflage itself acoustically. But how exactly does it do that?

Whispering bats

We were convinced that the key to the western barbastelle's success lies in the volume of its calls. To check this, my colleagues and I launched our own "eavesdropping operation": We fitted moths with miniature microphones and left them to the mercy of western

Western barbastelle bats sneak up on their prey under an acoustic invisibility cloak

barbastelles in their natural habitat. An additional array of four microphones allowed us to measure the three-dimensional flight trajectory, the distance to their prey as well as the call volume of attacking barbastelles.

It turned out that the call volume of the western barbastelle is only a tenth of that of other bats. And that's not all: when the bats first discovered the insects, which was at a distance of about 1.6 metres, their calls become quieter and quieter as they approach their prey. If they did not do so, the call volume received by the moth would increase as they approached, eventually

giving their attack away. But in this way, the moths remain oblivious to the attacking bat, receiving only faint echolocation calls, whose volume does not increase. This low volume is usually not sufficient to trigger an evasive response; and in the rare case it is sufficient, the response comes too late, making the moth an easy prey.

The low sound volume of western barbastelles is astonishing, as they hunt in fast flight within forests and along vegetation edges. Their low call volumes prevent them from detecting obstacles until the last second – they use a candle instead of a torch for orientation, so to speak. In consequence, western barbastelles also only detect their prey at short distances. On the upside, however, these quiet calls are a kind of acoustic invisibility cloak, which enables western barbastelles to sneak up on prey that is otherwise unavailable to other, louder bats. Similarly quiet calls are also known from other bats hunting in forests, yet locating their prey by listening for the quiet rustling sounds of insects and, therefore, need to minimize the interfering "background echoes" of leaves.

Echo of wingbeats

Horseshoe bats also hunt in forests, but they use a special hunting strategy and possess matching highly specialized adaptations. Horseshoe bats emit long whistling sounds at a constant frequency. Similar to the radio frequency of a radio station, the returning echo of these tones carries information generated by the flapping wings of their prey. Using this information, horseshoe bats can detect flying, fluttering insects within the dense and stationary tangle of leaves.

The trade-off for this high echolocation precision, however, is a comparatively small detection space: any prey not directly inside the sonic beam is "invisible" to the bats. Yet, horseshoe bats have found a way to compensate for this deficiency: in addition to their highly developed flutter echo perception, they also hear in the conventional way of the evolutionary older passive hearing. We were able to show that horseshoe bats are

Horseshoe bats combine different modes of hearing to maximize their hunting success

extremely sensitive to the rustling sounds produced by their moving prey. Just as we look towards the crackle made by a bag of crisps, horseshoe bats swing their sonar beam towards the sounds of prey, combining different modes of hearing to maximize their hunting success.

Other species are also spied upon

Echolocation sounds emitted by other bats are also used as a source of information. Since bats emit special attack calls when closing in on an insect and increase the number of calls per unit of time, other bats can hear where to find profitable feeding grounds. In fact, many species exploit this social information. Bats even eavesdrop on the echolocation of other bats across species boundaries, and can often distinguish their own calls from those of other species. The bats react differently depending on which species is calling, how many other members of the same species are there, and how much prey is available. If, for example, the activity of other bats of the same species is too high, the attack calls do not attract further individuals. In addition, species identity affects the reactions: bats react particularly to other species that are acoustically and ecologically similar, i.e. have similar calls and hunt for similar prey. The species that react most strongly are those whose food is only available locally and for a short time, which makes group hunting worthwhile.

How do the insects react?

We are currently investigating how insects react to the attacks of highly specialized predators. It seems that the evasive behaviour of moths differs from species to species. This unpredictability for predators would in turn increase each moth's individual protection from predators. Even the chirping of some locusts, which attracts bats as well as receptive females, seems to be acoustically adapted in such a way that it interferes with the echolocation and thus the orientation of the bats. The next exciting question in this sensory arms race between predator and prey will be which "tricks" are employed by the bats to counter these prey defences. ○

4 A glimpse into the machinery of a gravitational monster

**FRANK EISENHAUER,
REINHARD GENZEL**

↳ *Max Planck Institute
for Extraterrestrial Physics,
Garching*

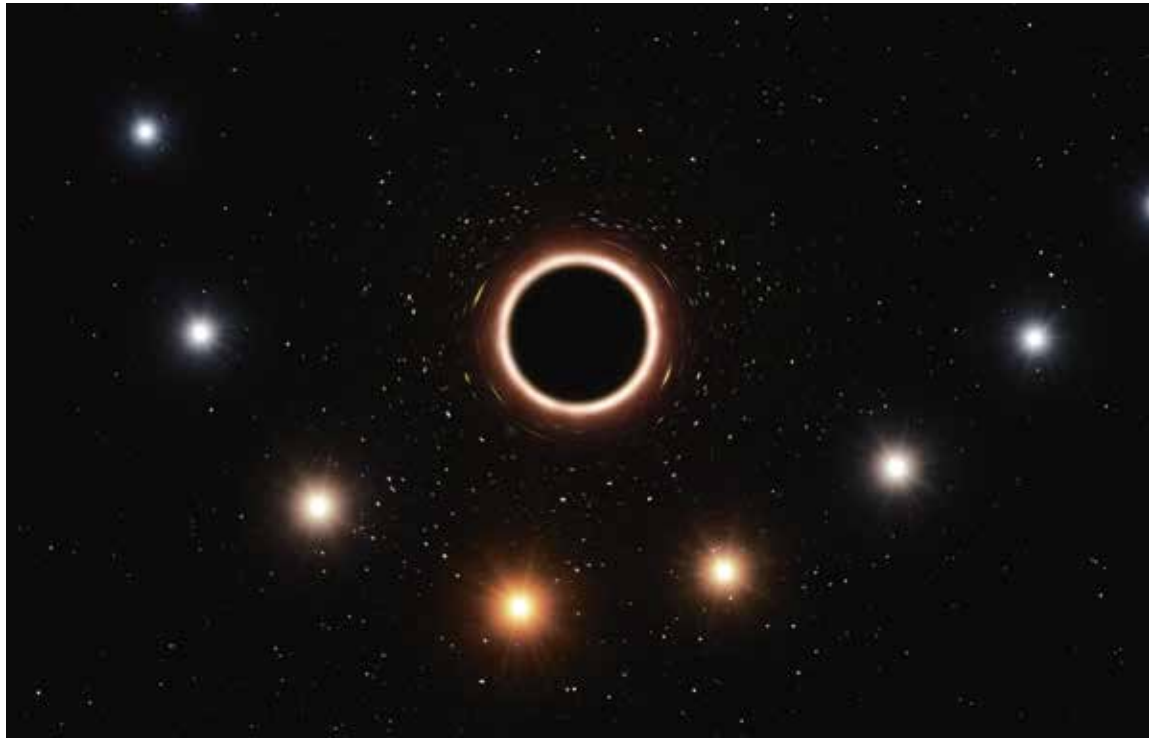
More than a century ago, Albert Einstein completed his general theory of relativity. The predictions of this theory can be tested in the universe – for example in the centre of our Milky Way, where a black hole with enormous gravitational force presents fantastic opportunities for such measurements. In 2018, we succeeded in three ground-breaking experiments with the Gravity instrument that was developed at our Institute. For the first time, we were able to prove the gravitational redshift around a massive black hole, we tracked orbital motions very close to the point of no return, and we determined the mass of cosmic gravitational traps more than a billion light years away. Gravity, with its unique image sharpness and sensitivity, is revolutionizing astronomy.

With the description of gravity in his general theory of relativity, Albert Einstein laid the foundations for our understanding of space and time. Numerous experiments in the weak gravitational fields of our sun and earth have impressively confirmed this theory. We all profit from its practical applications, for example with our worldwide navigation systems. In the extreme environment of a black hole, gravity shows utterly amazing effects: time slows down, space is curved, and entire worlds are irrevocably separated from their surroundings. For those who want to decode the universe, a black hole is like the “Rosetta Stone”.

With the Gravity instrument, developed under the leadership of our Institute, we are now able for the first time to make precise observations of the characteristics of black holes. By combining the four largest telescopes in the European Southern Observatory (ESO), we have created a virtual 130-metre telescope. This

technique, called interferometry, dates back to Albert Michelson (1852-1931), the first person to succeed in measuring the diameter of a star. The light waves received by the individual telescopes are superimposed, resulting in a sharper image of the object. This means that Gravity, in combination with the four 8-metre mirrors of the above-mentioned Very Large Telescope (VLT), can measure the distance between two cars on the moon with an error of only 2 centimetres. After decades of intensive observations of the Galactic Center Black Hole with single telescopes, Gravity represents a technical breakthrough. We are now truly ready to explore the mysteries of black holes.

The black hole in the centre of the Milky Way is an ideal laboratory for our research. After all, there exists no other black hole with a similar mass (about 4 million times the mass of our sun) in closer proximity. Yet even the diameter of this black hole appears no larger than a 1-euro coin on the moon. Using Gravity, we have



Colour change: this illustration shows the star S2 passing the black hole in the galactic centre. The gravitational red shift caused by the extremely strong gravitational field is clearly visible.

been able to track precisely the movements of stars and hot gas orbiting around the black hole. Gravity's accuracy and sensitivity outperforms its predecessors by hundreds to thousands of times, and is unrivalled in the world.

A star accelerates up to 27 million kilometres per hour

The galactic black hole reveals itself primarily by its enormous gravitational force. Just like planets in the sun's gravitational field, stars in the centre of the Milky Way orbit around this gravitational monster. Our group has been tracking the movements of these stars for over 25 years. One star in particular, known as S2, approaches the black hole like a comet every 16 years, down to a distance of no more than 17 light hours or 120 times the distance between sun and earth. The black hole's gravitational pull accelerates the star to a speed of ca. 27 million km/h, or 2.5 % of the speed of light.

Due to this close distance between star and black hole, we are supposed to see a gravitational redshift in the light of the star, according to the general theory of relativity. It is important to note here that this redshift is not caused solely by the Doppler Effect. We are familiar with the Doppler Effect in our daily lives: for example, the pitch of an ambulance siren appears to change as the vehicle rushes past us, because the frequency of the soundwaves reaching us changes as the sound source approaches and recedes. The same effect occurs with

light waves, but here we talk about blueshift or redshift. However, redshift also occurs when light is moving within and, to some extent, fighting against a gravitational field. Thanks to Gravity's spectacular precision and sensitivity and in combination with the Sinfoni spectrometer (also developed at our Institute), we have been able to measure this effect for the first time in the gravity field of a supermassive black hole: an impressive confirmation of Einstein's prediction.

Although the black hole itself is invisible, the effects of gravity renders it visible – specifically, when infalling gas is heated up to temperatures of billions of degrees, causing it to glow. Strong magnetic fields form in this orbiting gas, which then erupt into bursts of radiation similar to solar flares. In summer 2018, we were able to observe three flares from the Galactic Center Black Hole with Gravity.

Flares near the event horizon

The results are spectacular: the radiation bursts appear to come from the so-called "accretion disc" – a gas ring with a diameter of no more than about 10 light minutes, which rotates at extremely high speed around the galactic centre. Matter can orbit safely, as long as it does not get too close to the black hole. However, once matter crosses the event horizon (the point of no return), it is no longer able to escape the tremendous gravitational pull. The flares therefore occur in an orbit close to this event horizon.

In all three cases, we observed the hot gas swirling around the black hole at 30 percent speed of light, orbiting just above the event horizon. A single orbit takes only 45 minutes. This observation allows us to conclude that an enormous mass – more than four million solar masses – must be concentrated in a tiny space. This is exactly what the theory of black holes has predicted, and this result is an overwhelming confirmation of the paradigm of the supermassive black hole at the centre of our Milky Way.

In addition, we were able to use the Very Large Telescope and Gravity to look deep into the universe, far beyond the centre of the galaxy 26,000 light years away. After all, supermassive black holes do not only exist in our own local galaxy: they are at the heart of every large galactic system, and can contain several billion solar

Turbulent gravity trap: this visualization is based on simulations of the motion of gas swirling at about 30 percent of the speed of light in a circular orbit around the black hole in the galactic center.



masses. When matter falls into these black holes, the heated gas glows so brightly that it outshines the whole galaxy and is visible even billions of light years away. However, this very effect also makes it more difficult to measure the mass of such active black holes, as it is no longer possible to see the orbits of the stars.

Up to now, it was only possible to calculate the mass of those objects from the light echo from gas clouds surrounding the black hole, but this means one has to make assumptions about the unknown distribution and movement of these clouds. With Gravity, we have been able to prove that these gas clouds also move in ordered orbits around the cosmic gravitational trap. For this purpose we focused our observations on a quasar named 3C 273 – the first “quasi-stellar

object” identified by astronomer Maarten Schmidt, over 50 years ago. This quasar appears as an extremely bright but distant star. It emits much more energy than a normal galaxy such as our Milky Way, and cannot be explained by fusion processes inside stars. Instead, astronomers believe that gravitational energy is converted into heat when matter swirls into an extremely massive black hole.

Spacetime in rotation

Our team looked deep into the heart of quasar 3C 273 and closely observed the structure of the gases moving rapidly around the central black hole. Until now, such a detailed observation was impossible, because the quasar’s inner region is tiny when observed from earth – the quasar’s size is similar to that of our own solar system, but it is 2.5 billion light years away. With a measured distance of 150 light days between clouds and centre, and the orbital velocity of the clouds, we were able for the first time to determine the mass of an active black hole: 300 million solar masses.

In the future, we plan to measure yet another effect of Einstein’s theory, which is linked to an unusual characteristic of black holes: when they rotate, they are supposed to drag space and time with them, like a spoon, which is dipped in honey and then starts rotating. One highly astounding prediction of the general theory of relativity states that, independent of its complex formation history and internal structure, all observable characteristics of a black hole depend only on two properties: mass and rotation.

Within the next few years, by using Gravity and other instruments being currently developed at the Max Planck Institute for Extraterrestrial Physics, we are going to measure this rotation of space-time from the motion of stars and infalling matter. This will represent another large step towards understanding the general theory of relativity. ◦

5 Ways out of terrorism

CAROLIN GÖRZIG

↳ *Max Planck Institute
for Social Anthropology,
Halle (Saale)*

According to a survey, three out of five German citizens fear terrorist violence. Their fear is fed not only by the perceived unscrupulousness of the perpetrators of violence, but also by the fact that terrorists appear to be barely predictable in their actions. Yet even radical groups act in accordance with a certain logic that can be studied. Our research focuses on understanding the patterns, which cause terrorists either to become radicalized or else to renounce violence.

Do you think we should negotiate with terrorists? Political and public debate often questions whether this would be feasible at all, but the question of how this might be achieved is often overlooked. To make well-founded statements about how to negotiate with terrorists, it makes sense to examine the learning processes of terrorist groups with regard to how a reflection on the meaningfulness of violence is set in motion.

In our research group, we compare the learning processes of terrorist groups that can result either in their deradicalization, i.e. to a renunciation of violence, or radicalization. We collect empirical data in interviews with former and current members of various terrorist groups and have conducted field research in Egypt, Colombia, Palestine, Syria, Niger, Kyrgyzstan, Northern Ireland, and Turkey.

As a result, we have identified a rationale of deradicalization: in the initial stages at least, rather than simply changing their objectives, radical groups tend

to question the means and values that define them. Such considerations may arise due the discrepancy between objectives set and objectives achieved. It is also possible, however, that their objectives contradict each other and that the groups in question attempt to resolve the conflict.

To set the mechanism of deradicalization in motion, the groups themselves must problematize such contradictions. As the organizational scientists Chris Argyris and Donald A. Schön describe it, the aim is to make so-called double binds discussable. These are situations in which conflicting demands result in no-win situations and the paradoxicality of the situation is moreover difficult to define.

The militant Egyptian "Al-Gama'a al-Islamiyya" movement, for example, recognized for itself that jihad – which had become an end in itself – was not compatible with their objective of leading people, and ultimately found it counterproductive. The group solved the double bind by prioritising their objectives and concluding



Dialogue can help terrorist groups to understand the contradictory nature of their objectives

that jihad is merely a means to an end. It is important that the leaders of such groups become aware of the irreconcilability of their objectives.

Negotiations can also help. For contrary to the assumption that willingness and success in negotiations are based only on the rational cost-benefit calculation of the participants in the negotiations, a dialogue in itself can help terror groups to recognize the irreconcilability of their objectives. The Provisional Irish Republican Army (IRA) also adopted new means to achieve their objectives. They had learned from the South African ANC, among others, to renounce violence while remaining true to their own objectives.

Instead of approaching terrorist groups with the demand that they completely abandon their objectives, which is perceived as capitulation and tends to reinforce double binds, negotiations should be aimed at changing the means. In this way, the talks can also provide the leaders with the arguments they will need to convince their supporters. Negotiations can be based on the fact that the actual learning lies in questioning the means and values that define the objectives.

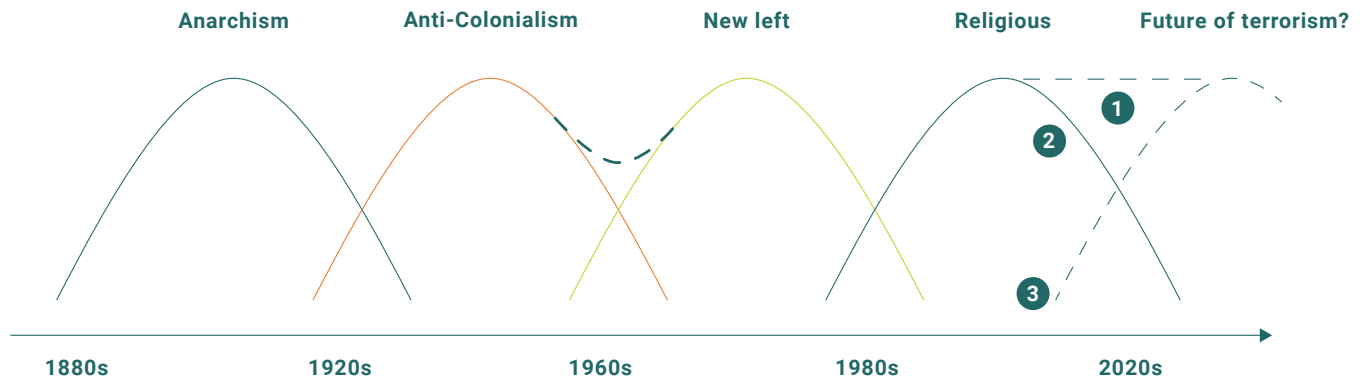
However, the mechanism of deradicalization can also be associated with radicalization. When groups turn away from violence, more radical factions often split off. When the Al-Gama'a al-Islamiyya movement deradicalized, some members migrated to Al-Qaeda, which viewed the moderation of the Al-Gama'a al-Islamiyya movement as a defeat and responded by escalating violence against the "distant enemy", culminating in the 9/11 attacks. This created a new conflict of objectives between global jihad and the local agendas of Islamist groups that were focused on overthrowing their home governments rather than provoking the West too much.

The drone war produces more terrorists than it kills

The globalization of jihad in turn leads to more radical state countermeasures, such as the U.S. drone war. Such measures, however, are often counterproductive because they strengthen the arguments of radical factions against moderating groups. Numerous civilians repeatedly fall victim to drones, which even leads high-ranking US military personnel to conclude that the drone war produces more terrorists than it kills. The victims of the anti-terror struggle often serve more radical groups as arguments against moderate organizations. Al-Qaida leader Ayman Al-Zawahiri, for example, accused Al-Gama'a al-Islamiyya of betraying its ideals to the Egyptian state when it became more moderate. The accusation was that the movement was buying itself out of prison and abandoning its aims, while many other Islamists are being tortured in Egyptian prisons. Such arguments can be defused if state actors act less brutally in the fight against terror and renounce maximum demands such as the abandonment of objectives in negotiations.

The next wave of terror could come from right-wing extremists

Political scientist and pioneer of terrorism research David Rapoport divided development of terrorism since the 1880s into four overlapping historical waves, each lasting about 40 years: the anarchist wave (ca. 1880s-1920s), the anti-colonial wave (ca. 1920s-1960s),



- 1 Continuation/ Renewal of religious wave
 - 2 Declining religious wave
 - 3 New wave (right-wing extremism)?
- — Organisations across waves (e.g. IRA, PLO)

According to political scientist David Rapoport, terrorism is developing in waves, with changing objectives.

the wave of the New Left (ca. 1960s-1990s), and the current religious wave that began around the 1970s and 1980s. The logic of radicalization and deradicalization described above affects both groups of the current religious wave and groups of previous waves, as the examples of the ANC, the IRA or the Palestinian organization the PLO show.

The radicalization of groups in one wave and the overreaction of states could already be preparing the way for the emergence of another wave. Even if military force can contain terrorism in the short term, it contains the roots of long-term developments of violence and terror. Negotiations can provide an alternative that breaks the spiral of violence and the waves of terrorism and counterterrorism.

In any case, the parallel radicalization of the state and non-state groups raises the question of the future of terrorism. Assuming that the current religious wave is coming to an end according to Rapoport's historical pattern, the question of the next wave remains. Recent developments suggest that right-wing extremism could play a role in this context. But the jihadist movement

could also manage to preserve the energy of its wave or transfer it to a second religious wave. Furthermore, it can be observed that right-wing extremists adopt elements of religious groups and, for example, tie in with Christian fundamentalism or Germanic neo-paganism. A future wave could also be of mixed form.

Can the spiral of violence between the state and terrorists be broken? The leaders of the Al-Gama'a al-Islamiyya came to their new positions when they exchanged views with other political prisoners, for example secular liberals. Not only can internal processes and new lines of argumentation be triggered from outside, but arguments for radicalization can also be defused from outside. The learning processes of terrorist groups provide information about the logic behind the mechanisms of radicalization and deradicalization. Our goal is to get to the bottom of these patterns. Our insights into the logic of escalation and deescalation can provide answers as to how such processes are reversed. It is about finding ways out of violence and developing alternatives to repeating counterproductive measures. Do you think we should negotiate with terrorists? o

6 CO₂ – a raw material for chemical production

WALTER LEITNER

➤ *Max Planck Institute
for Chemical
Energy Conversion,
Mülheim an der Ruhr*

Crude oil is currently the most important source of energy and the main raw material for chemical production. However, the increasing availability of renewable energies opens up the possibility of utilizing alternative carbon sources such as carbon dioxide (CO₂) for chemical production. Using hydrogen produced with electricity from renewable energy sources (and possibly with other high-energy reactants), we convert the inert CO₂ into chemical products – from fuels to high-quality fine chemicals. Efficient catalysts are the decisive tool for such “Power-to-X” concepts.

Like the production of energy, the manufacture of chemical products has been dependent on fossil carbon-based raw materials since the beginning of industrialization. The growth of human welfare through petrochemistry in the 20th century was literally fuelled by the interlocking of refinery processes for the production of fuels and base chemicals. However, both the energy and chemical industry sectors will have to rely increasingly on renewable energy and raw materials in the future. This is because the fossil carbon sources are energy carriers – but not energy sources! They were created over millions of years from natural biomass produced through the photosynthetic conversion of carbon dioxide and water with the help of solar energy. Mankind currently exploits fossil resources at such a rate and scale that it profoundly affects the ecosystem of our planet through local environmental pollution and global climate change.

The necessary transition of the electricity sector has already started. The technologies used to generate electricity from photovoltaics as well as wind, hydro, and geothermal power are becoming economically competitive worldwide. Electricity generation will thus become increasingly independent of carbon-based fossil raw materials: it can be decarbonized. This offers the opportunity to redesign also the interface between energy and chemistry. Creating a chemical value chain without carbon is impossible and carbon-based liquid energy carriers remain indispensable in the overall system. However, they could be produced using carbon-free primary energy and alternative carbon sources such as CO₂ and become thus defossilized. But how can this be achieved? The CO₂ molecule is extremely inert, which is why the gas is used for example in fire extinguishers.

Catalysts for important basic chemicals, but also for higher-value products

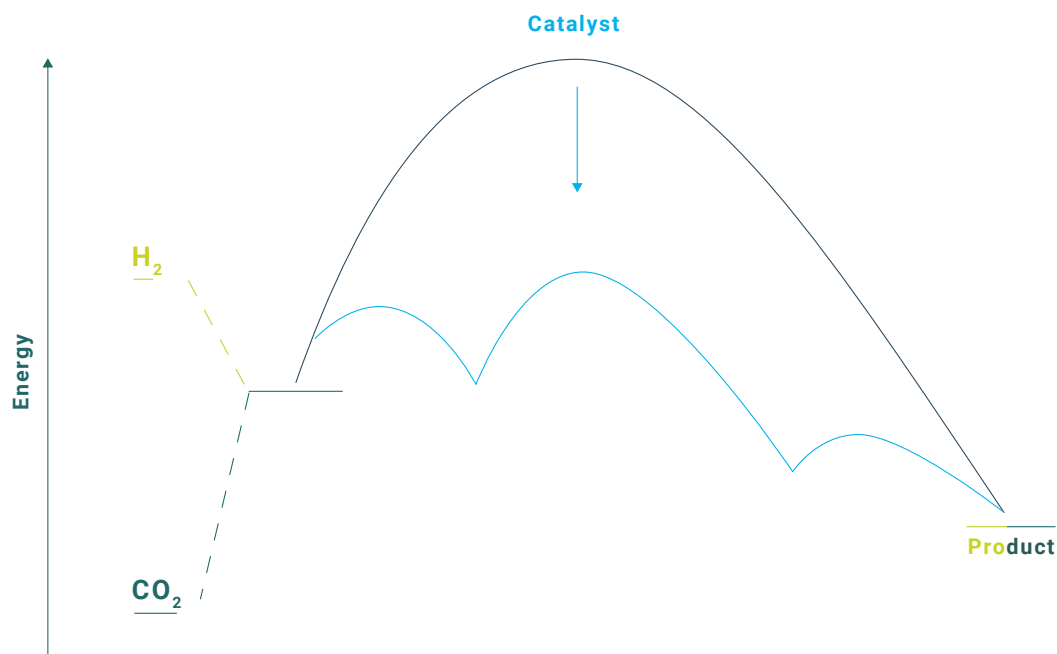
The energy to convert the thermodynamically stable CO₂ molecule can come either directly from regenerative power sources or from electrolytically produced hydrogen. The energy from renewable sources can thus be harvested in the form of useful products. Additional high-energy reaction partners can be drivers for such reactions as well. Highly efficient catalysts must be developed to enable the reaction process or direct it to the desired products.

This approach is pursued in the "Fuel Science Center" cluster of excellence, where scientists from RWTH Aachen University, Forschungszentrum Jülich, and the Max Planck Institutes in Mülheim are working on synthetic fuels for innovative engine concepts with reduced emissions and increased efficiency. In order to convert CO₂ and H₂ directly into relevant substances for chemical production, we at the Max Planck Institute for

Chemical Energy Conversion, together with our team at RWTH Aachen University, are researching organometallic catalysts consisting of one or more metal atoms coordinated with organic molecules, so-called ligands.

Target products are important basic chemicals such as methanol, formaldehyde, or formic acid. Through suitable coupling with further energy-rich reactants, the corresponding building blocks or functionalities can also be integrated into more complex structures for higher-value products. Organometallic catalysts based on precious metals such as platinum, rhodium, and ruthenium are already enabling a growing number of such reactions – some of which we have demonstrated for the first time. In contrast, this is possible in only a few cases with transition metals such as manganese or iron, which are naturally abundant and inexpensive. Our team and two other groups recently discovered organometallic manganese catalysts that hydrogenate organic carbonates (i.e. esters of carbonic acid) to form methanol. The hydrogenation of free CO₂ is not yet possible. However, we were able to achieve the analogous reaction with a more reactive boron-hydrogen compound.

Chemical starting aid: If low-energy CO₂ and high-energy hydrogen (H₂) are to react with each other, an extremely high activation energy is required (upper blue-green line). A catalyst considerably reduces the energy required (light blue line) and leads to the desired product via intermediate products.



Energy and CO₂ balances throughout the entire process

In order to better understand the catalytic transformations, we use an extensive arsenal of experimental and computational chemistry methods. Chemists have long assumed that inert CO₂ must be activated during its catalytic conversion. We now know, however, that the catalyst often renders the already highly reactive agent (e.g. hydrogen or the corresponding boron-hydrogen compound) chemically even more aggressive, thus “capturing” the CO₂. We gain such fundamental mechanistic insights by combination of spectroscopic analyses of intermediates formed from the catalyst and the starting materials together with computational methods and other techniques. This helps us to make chemical transformations more efficient or even to open up reaction pathways that were previously not available.

In addition to the metal as the catalytically active centre, the ligands are decisive for the course of the reactions. These are organic molecules bound to the metal via nitrogen or phosphorus atoms. Their electronic properties and geometrical arrangement critically determine which intermediate products are preferentially formed and which substances are produced from them. By optimally combining the metals with suitable ligands, we define whether CO₂ is hydrogenated to formic acid, formaldehyde, or methanol. When coupled with other reactants, not only the preferred chemical functionality but also its position within the target molecule can be controlled. This is of crucial importance for the application of high-quality products such as performance plastics or biologically active substances.

However, a suitable catalyst for the hydrogenation of CO₂ and a precise understanding of the chemical reaction are not yet sufficient to implement such syntheses in process technology. In addition to the actual chemical conversion, the extraction of the pure product and the recovery of the catalyst are decisive factors. We are therefore developing methods to separate our

catalysts, which are either dissolved in the reaction medium or homogeneously dispersed in the form of nanoparticles, via integrated processes from the products.

A closed carbon cycle as ideal

Apart from the central research questions that we are addressing through basic chemical research and reaction engineering, there are, of course, other aspects to consider for the transfer of “Power-to-X” concepts into application. For the identification of promising target products and reaction paths, the decisive criterion is whether a CO₂-based process conserves resources and significantly reduces greenhouse gas emissions relative to a corresponding production process based on fossil raw materials. We therefore work closely with life cycle assessment experts to analyse energy and CO₂ balances as well as environmental impact throughout the process. We discuss questions of socio-economic framework conditions intensively with partners from science, industry, and society, for example within the framework of the Kopernikus Project “P2X”.

The vision of a completely closed anthropogenic carbon cycle modelled on nature was vividly formulated by Italian chemist and writer Primo Levi in his book “The Periodic System (Il Sistema Periodico)”. To come closer to this ideal through a sustainable design of the interface between energy and chemistry is the motivation and incentive for our catalysis research at the MPI for Chemical Energy Conversion. ◦

7 Appetite stimulant in the brain

RÜDIGER KLEIN

↳ Max Planck Institute
of Neurobiology,
Martinsried

You cast an eye over the menu at your favourite restaurant: pasta with a cream sauce, or just a small salad? What you finally tell the waiter is the result of a complex decision-making process in the brain that involves more than just hunger. We have identified “pleasure neurons” in the mouse brain, which play a major role in this process. By investigating their activity, we also hope to identify the causes of human eating disorders.

What gives us an appetite? And, why are some people obsessed with every calorie, while others starve themselves? To the chagrin of many people, eating habits are not an easy thing to tackle: too many factors seem to be involved. In fact, our eating habits are determined by several distinct areas of the brain. For scientists, appetite regulation is a major puzzle. However, neurons have now been discovered whose activity and control function are apparently crucial for our eating behaviour.

Starvation neurons and “feel-good” neuromodulators

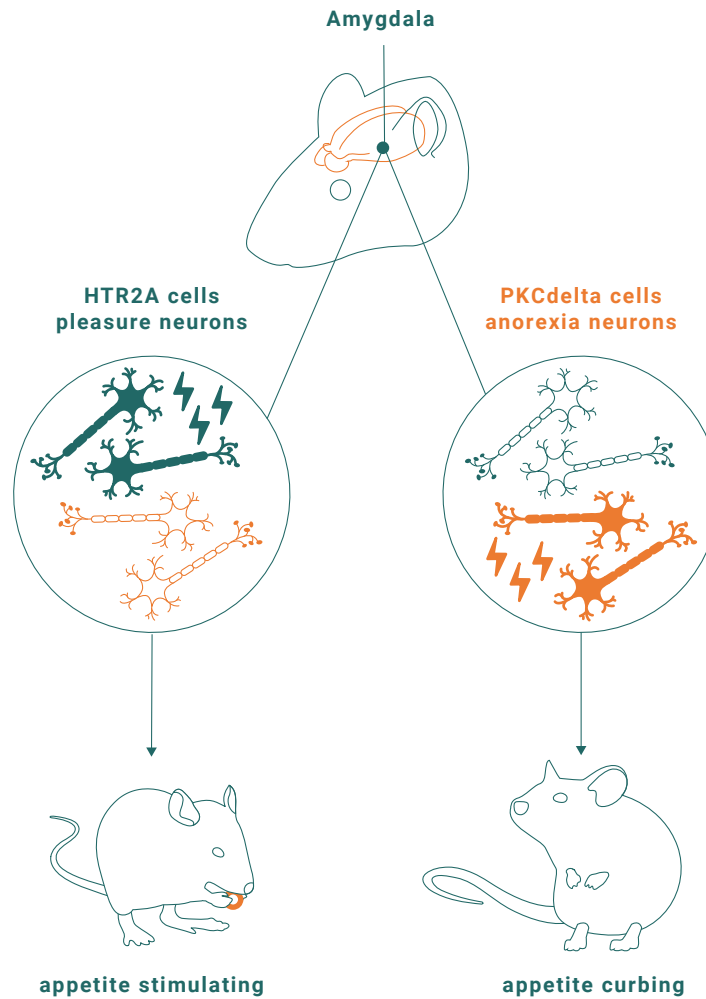
First, there is the basic need for energy, which is regulated by the brain. Signals from the sensory organs, intestines, pancreas, muscle and fat tissue provide information about the actual state of the body, which are processed within the control centre of the vegetative nervous system, the so-called hypothalamus where,

specialized nerve cells regulate food intake, digestion and storage. The hypothalamus is known to contain the so-called “hunger neurons”, which are highly active during the search for food. As soon as food is ingested, however, they rapidly cease their activity.

And yet, we often eat despite not feeling hungry for, rather than being regulated by our energy balance alone, our appetites are also influenced by our emotions. Food intake is influenced by internal stimuli, such as stress, as well as external stimuli, such as taste. When food is ingested, the Nucleus accumbens of the basal forebrain mediates a reward effect by releasing the “feel-good” neuromodulators dopamine, endorphin and endogenous opiates.

The importance of another brain centre for appetite control – the so-called amygdala – was long underestimated. The fact that it plays an important role not only in connection with emotions such as fear and joy, but also in the consumption of food only came to light a few years ago. The amygdala creates and records links between events and emotions and initiates the corre-

Networks of nerve cells in the amygdala of the brain determine eating habits: a mouse with active pleasure neurons continues to eat, even when it is full (left). If the anorexic neurons are active, it stops eating despite being hungry (right).



sponding patterns of behaviour. If, for example, a given incident was associated with unpleasant feelings, the amygdala can trigger a strong reaction such as nausea: an important protective mechanism, which enables us to recognize and avoid spoiled food in the future, for example.

Opponent wanted

Some years ago, researchers discovered a special type of nerve cell in the central nucleus of the amygdala of mice: “anorexic neurons”, scientifically known as PKCdelta cells, cause mice to stop eating when they feel nauseous. Whenever these nerve cells are activated, even in hungry mice, they stop eating immediately. Anorexia neurons also react in the same way to other

stimuli such as satiety, a bitter taste or nausea, apparently acting as central appetite circuit breakers.

Fascinated by these amazingly clear results, we asked ourselves the question: could the amygdala also contain neurons, which have a positive influence on food intake – i.e., which activate the appetite?

HTR2A cells promote food intake

We focused our search for pleasure neurons in mice on a nerve cell type that produces the serotonin receptor HTR2A. These HTR2A cells may work as opponents of anorexia neurons. Just like anorexia neurons, HTR2A neurons are inhibitory neurons – they can suppress the activity of anorexia neurons or are themselves inhibited by anorexia neurons.

To activate the HTR2A cells, we inserted a light-sensitive ion channel into the cells and stimulated them via two optical fibres, which we had previously implanted on both sides of the brain, just above the right and left amygdalae.

This artificial activation of the HTR2A cells actually caused the animals to eat for a longer period – the more satiated the animals already were, the greater the effect. In another experiment, the mice were able to activate HTR2A cells themselves via an optical fibre by activating

Pleasure neurons increase food intake and produce a reward effect

a light switch with their muzzles. The result: the animals preferred active HTR2A cells.

In another experimental setup, the mice were given the choice of staying in one of two different rooms, but the HTR2A cells were only activated in one of them. The fact that the mice stayed significantly longer in the “activated” room confirms that they preferred active HTR2A cells. Our most important finding, however, was that the activity of the HTR2A cells was required for normal food intake. If the HTR2A cells were switched off or inactivated, the animals’ feeding times were significantly shorter, even when they were hungry or were offered particularly tasty food.

Food activates the pleasure neurons

The activity of nerve cells can be measured by the influx of calcium into the cell, a fact we were able to use to demonstrate that the HTR2A cells are only activated when the animals start eating and not when they are about to be fed.

These results suggest that the HTR2A cells of the amygdala promote sustained food intake regardless of hunger by positively enhancing perceived food properties such as taste and attractiveness. Another experiment shows the importance of HTR2A cells for the positive evaluation of nutritional properties: we can

make animals prefer a taste that was previously less popular simply by activating the HTR2A cells.

Pleasure neurons are part of a neuronal network

Precisely how the HTR2A cells influence food intake within the brain has not yet been conclusively investigated. The mechanism is probably partially based on the mutual inhibition of HTR2A cells and anorexia neurons within the amygdala. If the animal ingests spoiled food, the anorexia neurons are activated, which inhibits the HTR2A cells and stops food intake. Eating something tasty activates the HTR2A cells and inhibits the anorexia neurons. The HTR2A cells also regulate cell activity in other brain areas, for example those responsible for processing information about the value and quality of food.

Conversely, the HTR2A cells receive signals from other brain regions, such as the insula cortex, the gustatory thalamus and hypothalamus, which provide information on physiological states, such as hunger or thirst, but also on emotional states such as anxiety.

At the interface between hunger and reward

Research into HTR2A cells extends our knowledge of the role of the amygdala in the regulation of food intake, but our findings also raise other exciting questions: do these cells function as food-intake specialists or rather as generalists in other consumption-related behaviours such as drinking and mating, or even in general reward behaviours such as raising babies or altruism towards other members of the same species? What role does the neurotransmitter serotonin, for which the HTR2A cells have a specific receptor, play in all these functions? Could extreme eating behaviours be the result of malfunctions in the amygdala’s circuits? And finally, could the manipulation of HTR2A cells and anorexic neurons be a science-based approach to help people with abnormal eating behaviour?

More recently, we have begun analysing the connection between appetite-increasing HTR2A cells and appetite-inhibiting PKCdelta cells. For example, we hope to gain insights into the role of the amygdala in learning processes in which external stimuli are linked to the availability and quality of food. ○

8 A psychological trick for greater equality of opportunities

MATTHIAS SUTTER

↳ Max Planck Institute
for Research on
Collective Goods, Bonn

To this day, management positions tend to be men's business. One of the reasons for this is the fact that women are more likely to avoid competition. Fewer women apply for senior positions as a result, even when they are qualified for these posts. Men on the other hand, are prone to overestimating themselves, striving for leadership positions that are beyond their abilities. We were able to demonstrate in an experiment that this difference can be bridged by means of a simple tool.

“Forty more years to achieve gender equality.” This was found to be the case by the news magazine *Spiegel* in December 2018. According to calculations made by the Boston Consulting Group and the Technical University of Munich, this is how long it is going to take before the management boards of German companies are made up of equal numbers of men and women – provided that the situation continues to change at the current rate.

It has been studied for decades, why so few women rise to the top of companies and public institutions. Explanations traditionally focus on aspects such as discrimination against women, and the issue of reconciling family and professional life. However, this explanation does not go far enough.

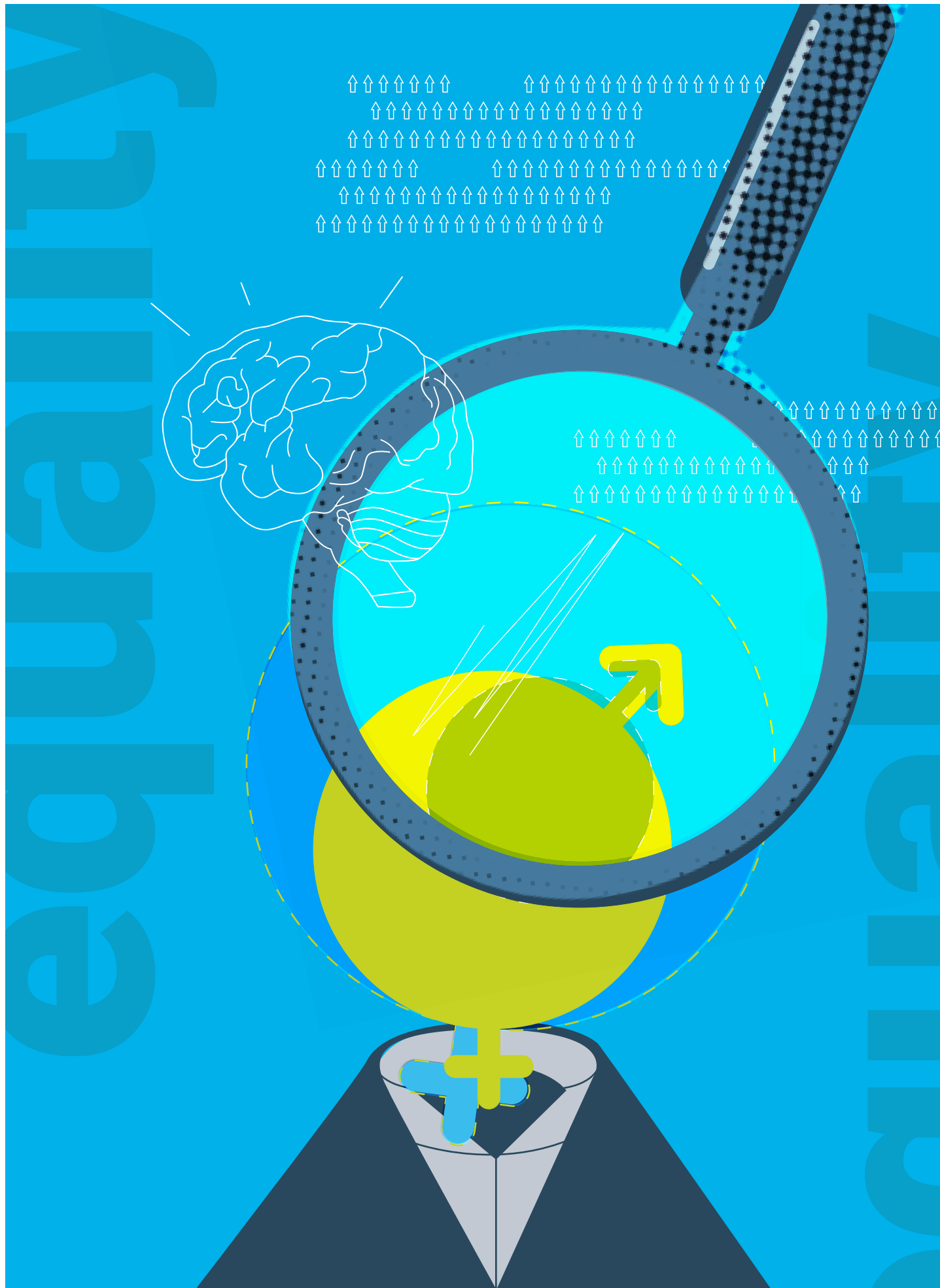
For a number of years now, behavioural economists have been examining the question, whether gender differences in competitive behaviour might be a major cause of the lack of equal opportunities of men and women in the professional sphere. The question is,

whether women are less willing to face competitive situations than men.

And the results are very clear: women avoid competition much more than men do. This is not least due to the fact that men on the one hand tend to be more likely to overestimate themselves, and women on the other hand tend to be less prepared to accept the risks associated with competitive situations. For companies, but also for the entire society, it would be wiser, however, if leadership positions were taken on by the best qualified individuals, regardless of their gender.

Quotas can help women in competition, but can also be counter-productive

If women are more likely to avoid competitive situations, this gives rise to the question how gender differences can be overcome or at least reduced in this respect. A few years ago, my colleague Loukas Balafoutas from



It is about a realistic assessment of one's own abilities

Innsbruck and I published a study in *Science*, which demonstrated that political measures such as quota arrangements can encourage women to face competition more frequently. Such arrangements however, are very controversial and usually difficult to introduce. Another aspect is the fact that such quotas can also be counter-productive: women benefiting from them are often exposed to accusations of having achieved their position due to their sex, rather than their qualifications.

Men significantly decreased their willingness to compete

In my joint research project with Loukas Balafoutas and Helena Fornwagner from the University of Innsbruck, I therefore set out to look for an alternative approach. Our target was to avoid the disadvantages related to political interventions, while balancing out the willingness of men and women to enter into competition as far as possible. We found a suitable approach in the well-known psychological technique of *priming*.

We asked the women and men who participated in our study to write a short text, describing a situation from their past, in which they successfully influenced other people. By means of this technique called *power priming*, we created an influential mindset in a group of the participants. The other test subjects were either not primed at all, or put in a situation in which they felt powerless and dependent. Our expectation was that *power priming* would remove gender-specific differences in competitive behaviour, and that equal numbers of women and men would thus enter into competition.

The results proved us right. In the neutral group, the following gender-typical pattern emerged: 40 percent of men, but only 14 percent of women decided to enter into competition with others. When primed for a situation of dependence, the test subjects also behaved largely in line with this pattern.

Reminiscence of an influential situation, on the other hand, did cause behaviour to converge between the sexes. Interestingly, there were significant differences between the responses of men and women. The result was due less to the reaction of the women than it was to the behaviour of the men. 20 percent of the female test subjects, and therefore slightly more than

in the neutral group, decided to enter into competition with others. From a statistical point of view, this corresponds to an insignificant increase of their willingness to compete. The men's willingness to compete, on the other hand, was reduced by a statistically significant amount: only 28 percent of the male test subjects chose to enter into competition with others.

Power priming apparently enables all individuals to assess their abilities realistically. While it strengthens confidence in women to a certain extent, men are more likely to become reluctant to take higher risks. We consider this finding to be particularly important: past studies about competitive behaviour showed that men often overestimate themselves, causing them to take part in competitions unsuccessfully. This is not only a waste of time and effort, it also leads to frustration. *Power priming* meanwhile causes men to assess themselves more realistically – as women do – and as a result, it is almost exclusively the best who are prepared to enter into competition.

The fact that *power priming* reduces readiness to take risks, especially in men, is also significant in another context. After all, companies often face the problem that their staff members take risks that are too high, as was demonstrated clearly by the most recent financial crisis. Our intervention approach that prevents people from taking excessive risks could therefore also be interesting for companies.

The method is relevant in schools as well as on management levels

Priming based tools can be useful in many areas, such as the education system – in particular considering the fact that gender-specific differences in willingness to compete occur from an early age – or as part of active employment market policy, in professional training programmes. The findings made by Loukas Balafoutas, Helena Fornwagner, and myself indicate that the feasibility and impact assessment of *priming* based intervention should be studied in greater depth in these areas of practical use.

In fact, it has already been shown that the technique of *power priming* used in our study, improves the performance of applicants in job or college interviews. Last but not least, *power priming* is also relevant for the management levels of corporations and public institutions. The share of women in leadership positions in such organizations can only be increased if both sexes compete for these positions to the same extent. ○

9 3D metal printing – powder bed to part

ERIC A. JÄGLE
↳ Max-Planck-Institut
für Eisenforschung GmbH,
Düsseldorf

3D printing of plastic parts is a standard procedure in many fields, but a lot of research work is still needed when it comes to metals. However, it is obvious that additive manufacturing, the specialist term for this technology, could potentially revolutionize metalworking and open up new fields of application. Our group at the Max-Planck-Institut für Eisenforschung develops procedures to improve the design of metal alloys for and through 3D printing.

Long-life turbine blades, customized implants for patients and ultralight but sturdy car bodies – these are just some of the potential fields of application for components that can be produced by additive manufacturing, in other words 3D printing. Additive manufacturing is the term used to describe all methods in which material is applied by a computer layer-by-layer to create a three-dimensional object.

One special additive manufacturing method is selective laser melting. With this method, a several hundred watt laser beam scans a thin layer of metal powder in a matter of seconds. This powder melts and cools down within thousandths of a second. A brush applies a new layer of metal powder and the laser once again scans the metal trace that has just solidified. This procedure is repeated until the desired workpiece is finished. You could say it arises from the powder bed like a phoenix from the ashes.

3D metal printing has a number of advantages over conventional production methods. Bodies with complex

shapes can be manufactured “in one piece” without any welding, milling or bonding of individual components. At the same time, shapes can be adapted individually and so-called art-to-part concepts realized, i.e. designs with no prior adjustment of the production line. It is often impossible to manufacture creatively designed components using conventional methods on account of the technical limitations, but with additive manufacturing, any design, no matter how complicated, is in principle possible. For example, turbine blades with complexly shaped and therefore very efficient cooling ducts can be printed for power stations and aircraft that are exposed to extremely high temperatures. Constant cooling during operation protects the material, allowing higher operating temperatures and saving fuel. Parts with cavities can also be printed in automotive engineering, thus saving material as well as weight whilst still guaranteeing a high stability thanks to the correct statics.

One of the limiting factors for 3D metal printing at present is not the production method but the alloy, in

Group leader Eric Jäggle (left) and his PhD student Priyanshu Bajaj fill the chamber of the 3D printer with metal powder. This is so fine it could easily be inhaled. Which is why they are both wearing protective clothing.



One example of the complexity of components that can be produced by additive manufacturing: the logo of the Max-Planck-Institut für Eisenforschung as a relief on 3D printed coins of stainless steel.

other words the material from which the component is to be made. Although numerous alloys are known for every field of application from the classic metalworking methods such as forging, casting or sintering, and some of these are even suitable for additive manufacturing, they do not exploit the full potential of this method because they have been adapted to conditions that have become irrelevant thanks to additive manufacturing. This is why the feedstocks for 3D printing still have to be developed. And this is the research focus of our group at the Max-Planck-Institut für Eisenforschung.

The speed, strength, and diameter of the laser beam influence the microstructure

One approach being pursued by our team is of particular significance for us because it holds out the promise of

a more flexible use of 3D metal printing. Those metal powders that are commercially available consist of alloys with a fixed mixing ratio for the individual constituents. Every single powder particle consists of this metal mixture. Classic alloys are often unsuitable for additive manufacturing. However, ordering special alloys from a company is expensive and complicated, and what's more not every alloy composition is accessible this way. It would thus be ideal if powder from pure elements could be used in the desired mixing ratio. In this case, the different powder particles would only melt to form an alloy during printing.

To investigate this possibility, we used metal powders of iron, chromium and nickel and tested the influence of various parameters on the alloy's properties both before and during the printing process. We investigated the printed components in detail, cubes for simplicity's sake, by means of light and scanning electron microscopy as well as x-ray spectroscopy and

In-situ alloy design opens up further production paths for composite materials

chemical analysis methods. The result: the speed at which the laser moves over the powder bed, the intensity of the laser beam and its diameter as well as the thickness of the powder layer affect the microstructure, which primarily determines the properties of the component. But the really crucial factor is the period of time in which the individual powders exist in a molten form in the melt pool before they solidify and form a chemically homogeneous component. Because to ensure that the various elements, which originate from different powder particles, mix well, the melt pool has to be kept alive for a while. We have been able to confirm this with model calculations too.

This in-situ alloy design enables some huge time savings and great flexibility in research work. One only has to buy the pure metal powders, mix them to the desired ratio oneself to carry out experiments quickly and easily. What's more, it is possible to combine materials that are very hard to mix using classical methods, for example metal matrix composite materials. These consist of a metal matrix to which ceramic components have been added, for example, as a reinforcement. They are used in a number of different fields, such as power electronics as well as automotive engineering and the aviation industry.

The result: a material for application at very high temperatures

At the same time, in-situ alloy design opens up further manufacturing routes for composite materials, for example for oxide dispersion-strengthened alloys. These kinds of steel, ODS for short, are of interest for applications at very high temperatures. They would normally have to be produced by a very complicated mechanical alloying process in which oxide particles are introduced into the steel. We managed to do this directly with the in-situ alloy design. To this end, we mixed the inert gas otherwise used in the process (nitrogen or a noble gas such as argon) with carbon dioxide (CO₂). This is normally very inert in itself, but under the laser beam it is split into carbon monoxide (CO) and oxygen, which then react with and penetrate the material. Under these conditions, finely distributed oxide particles formed by themselves in the material. The result: a material that

can be manufactured relatively easily, without mechanical alloying, and that is roughly 25 percent stronger at high operating temperatures up to 800°C than the base material without the strengthening oxide particles.

The industry's interest is aroused

The results to date are very promising and have already aroused interest in industry, which was very hesitant when it came to new alloys for 3D metal printing only a few years ago. This also holds true for another hopeful branch of research into so-called high-entropy alloys. This class of material is very interesting because it displays a high strength and is also resistant to temperature and corrosion. High-entropy alloys usually consist of five metallic elements, each of which occur in similar amounts in the alloy. We are currently involved in developing such alloys especially for additive manufacturing. This would clear the way for long-life turbine blades, customized implants, lighter car bodies and much more. o

10 Rendezvous in the stone age

**VIVIANE SLON,
SVANTE PÄÄBO**

Max Planck Institute
for Evolutionary
Anthropology, Leipzig

Two distinct groups of ancient humans coexisted in Eurasia between 400,000 and 40,000 years ago: the Neanderthals in the west and the Denisovans in the east. During the genetic analysis of prehistoric bones, we came across an individual woman whose mother was a Neanderthal but whose father was a Denisovan. This suggests that throughout history, different human groups have always mixed.

Neanderthal remains were first discovered near Düsseldorf in 1856, and by now, hundreds of Neanderthal sites are known in Europe, the Middle East and Central Asia. In contrast, the existence of Denisovans was unknown until a few years ago. In 2010, a research team led by Svante Pääbo of the Max Planck Institute for Evolutionary Anthropology analysed a tiny finger bone from the Denisova Cave in the Altai Mountains in Russia. The genetic analyses showed that the bone belonged to a group of prehistoric humans that differed genetically from Neanderthals.

So far, remains of this group are only known from Denisova Cave. However, people living today in Oceania and South East Asia still carry traces of Denisovan DNA in their genomes, which suggests that the Denisovans were once widespread in Asia. We wanted to know whether Neanderthals and Denisovans interacted, and if so – when and how often did that happen.

How can we examine the relationships between different human groups who lived tens of thousands

of years ago? The answer to such a question may be found in the genomes of these ancient people, which is why we teamed up with scientists from the Russian Academy of Sciences to analyse the DNA of a small piece of bone discovered in Denisova Cave in 2014. The fragment, known as “Denisova 11”, was part of an arm or a leg bone of an individual who was at least 13 years old and who lived around 90,000 years ago.

Half Neanderthal, half Denisovan

To find out whether Denisova 11 was the remains of a Neanderthal or a Denisovan, we checked whether her genome had more Neanderthal-like or more Denisovan-like genetic variants. To our surprise, both types of variants occur in almost equal proportions, meaning that Denisova 11 had both Neanderthal and Denisovan ancestors.



**DENI
SONEAN
VANDER
THAL**

There could be two possible ways to explain this result: either the parents of Denisova 11 were themselves from a mixed Neanderthal-Denisovan population, or each parent belonged to a different group. We then analysed how often the chromosomes inherited from the mother differed from those inherited from the father. The results show that Denisova 11 had one Neanderthal parent and one Denisovan parent.

Different human groups have mixed in the past

According to our analyses, the bone fragment belonged to a female, as the genome contained two copies of the X-chromosome. Since her mitochondrial DNA – the small part of the genome that is inherited only from the mother – comes from a Neanderthal, Denisova 11 must have been the daughter of a Neanderthal mother and a Denisovan father. This is clear evidence that the two groups were in contact in the region of the Altai Mountains some 90,000 years ago.

The mixed origin of Denisova 11 gave us the unique opportunity to study two groups of ancient humans from a single genome. First, we compared the Neanderthal DNA from the maternal side to Neanderthal genomes that have already been sequenced. We discovered that the mother of Denisova 11 was more closely related to a Neanderthal from Southern Europe than to one from Denisova Cave. This suggests that

Neanderthals migrated between eastern and western Eurasia at least at one point in their history. We also found small traces of Neanderthal DNA in the parts of the genome that Denisova 11 inherited from her Denisovan father. From this we can conclude that the father had at least one distant Neanderthal ancestor in the previous 300 to 600 generations.

The genome of Denisova 11 testifies to the fact that her Neanderthal and Denisovan ancestors had mixed several times in the past: once in the case of her own parents, and at least once somewhere along her paternal lineage. It is therefore possible that the two ancient human groups mixed whenever they had the opportunity to meet – but encounters between the few members of the Neanderthal and Denisovan groups were probably very rare. This may explain how the two groups remained genetically distinct despite occasionally mixing.

Our study provides further evidence in support of the notion that different human groups have mixed in the past. From earlier genetic analyses carried out at our Institute, we know that Neanderthals mixed with the ancestors of present-day non-Africans, and that Denisovans did so with the ancestors of present-day Asians and Oceanians as well as with another yet unknown group of prehistoric humans. We also know of an ancient modern human who lived 40,000 years ago in what is today Romania, who had a Neanderthal ancestor only four to six generations before him. Taken together, these studies suggest that throughout our history, different groups of humans have always mixed. ○

11 Wild west on the web

ANJA FELDMANN
➤ Max Planck Institute
for Informatics, Saarbrücken

Internet routing protocols such as the Border Gateway Protocol (BGP) control the flow of data in cyberspace using special attributes, BGP communities. They control the distribution of data and can trigger other actions – for example to protect against hacker attacks. However, they can easily be misused too. Moreover, there is not even a binding specification for the way they work. Everyone can do whatever they want: Wild West on the Web. Here at the Max Planck Institute for Informatics, we show you what's possible.

Two weeks before Christmas. The run on presents is reaching its climax, on the Internet too. The owner of an online shop is celebrating his record sales – when suddenly his heart misses a beat: he can no longer access his website. An analysis of the data traffic shows that thousands of attackers – for example a “BotNet” made up of several computers – has bombarded his online shop with a flood of nonsensical inquiries and thus brought it to its knees. This is what experts call distributed Denial-of-Service attacks (DDoS). Everything grinds to a halt. The collapse is an economic catastrophe for the retailer.

The 64,000 dollar question is: what should he do to remove the damaged online shop from the line of fire? The radical solution would be to “hide” the entire computing centre where the retailer's server is located. This means simply removing it from the “map of the Internet” for a while until peace can be restored. The malicious data packages can then no longer find their way to their victim. But this means that none of the other computers in the computing centre can be accessed for

a certain length of time too. These could be other online shops or servers for various media and authorities, for example. This solution is obviously anything but ideal because it entails high collateral damage.

A new way to fend off DDoS attacks

We at the Max Planck Institute for Informatics have thus developed a method to fend off such attacks together with partners at the Technical University Berlin and the German Internet hub DE-CIX. It is a kind of extension to the “BGP messages” that are used to control data traffic on the Internet. These are exchanged regularly between the Internet routers – those relays at which every data package pauses for a fraction of a second on its way from the sender to the recipient. The routers determine each data package's destination during the brief pause and then send it on to the next router that is a little closer to the final destination on its journey through cyberspace.

In the event of the DDoS attacks on the online shop, the protocol attributes, called “BGP communities”, can become a crucial line of defence, as we have been able to prove. The approach is called “Advanced Blackholing” and allows much more precise defensive measures than temporarily hiding an entire computing centre along with the numerous websites that it hosts. Instead, the computing centre could send a BGP message with special BGP communities to routers from which it receives DDoS data packages.

It has already been possible to request a simple “Blackholing”: to simply forward nothing more to the network area of the victim. The Advanced Blackholing in whose development we were involved allows much more complex “help requests” to be sent that can then be handled automatically by an Internet exchange point (IXP). For example, it is now possible to specify exactly which data packages are to be processed from which senders to which recipients; these can be easily deleted, rerouted or a few of them “let through”. This prevents the victim from being cut off from desired Internet traffic.

The attack has been averted as soon as the BGP community with the request for Advanced Blackholing has spread from router to router: the unwanted data traffic does not get anywhere near the victim, but there are no negative effects on the other connections as well as the data traffic in the computing centre via all of the other ports. The computing centre can continue to operate undisturbed; websites that are not involved don't even notice the attack.

But BGP Communities can be used not only to thwart cybercriminals. They can also be used to enforce applicable laws on the Internet: for example, a router in New York could inform other routers of its whereabouts. These would then know whether they could send it certain data or not – for instance, because this is forbidden by the General Data Protection Regulation (GDPR).

BGP Communities can also inflict damage

Unfortunately, BGP communities have a drawback too. One of their main problems is that their sender cannot be verified – and as we all know, wherever anonymity prevails, abuse is never far away. This could lead to the following situation, for example: an attacker A wants to cut his victim O off completely from all data traffic. To this end, he sends a blackhole community to those routers from which O is normally supplied with data packages. If A manages to broadcast this message as widely as possible, O will receive hardly anything.

This means that BGP Communities can also be a very effective method of inflicting great damage: the attacker only has to send a small routing package to isolate their victim almost completely. What acts as pro-

tection against hackers in the event of a DDoS attack in this case becomes their weapon. The manipulation will of course be noticed – at some point in time. And it may then even be possible to identify the offender and the victim may be able to bring them to justice in court.

Weaknesses in defence and ways to eliminate them

BGP Communities are a powerful tool to influence the routing of data packages on the Internet. However, they have three serious weaknesses – at least at the moment – that we are investigating. Weakness number one: any BGP router can send communities and there is no way of determining the authenticity of the sender. Has a community been sent by someone authorized to do so? This can only be established in retrospect. We will continue to look into how this kind of authenticity check could be carried out.

Weakness number two: there are no accepted and binding rules. Every router can decide what to do with the communities it receives. Nowadays, routers usually accept BGP communities from any number of other routers, which obviously makes their misuse much easier – this is the only way the attacker A could exclude their victim O from Internet traffic with no great effort. This could easily be changed: for example, you could specify that communities will only be accepted if they come from the affected router itself. O could thus have requested blackholing themselves – as is the case in DDoS attacks. But no other router would have been authorized to block data packages for O. Unfortunately, things aren't quite as simple as this: there are by all means cases in which this kind of external control is desired – for example when outsourcing the network control or during telephone tapping by law enforcement authorities.

Weakness number three: there is no binding definition of a certain BGP community. This means that although “666” is known as a “BGP blackhole” – nobody could prevent a router, for example, from flagging all of the data traffic from and to a website with supposedly criminal content as 666.

The last two weaknesses may be able to be eliminated by binding rules in the “Requests for Comments” (RFC) – the documents which define a number of technical principles for the Internet. On the other hand, there is still no satisfactory solution to the question of a reliable authentication of BGP communities. As you can see, we have our work cut out for us. And when it comes to routing, Wild West conditions are likely to prevail for some time yet. o

12 Hope for hereditary neuropathy patients

**MICHAEL SEREDA,
LISA REINECKE,
ROBERT FLEDRICH,
THOMAS PRUKUP,
RUTH STASSART,
KLAUS-ARMIN NAVE**

↳ *Max Planck Institute
of Experimental Medicine,
Dept. of Neurogenetics,
Göttingen*

It may start with just a tingling sensation or numbness. Feet can no longer be lifted and feel increasingly heavy. Coordination problems, weakness, muscle loss: the course of Charcot-Marie-Tooth disease (CMT) is inexorable – so it was believed so far. But now there is some prospect of a therapy: a simple dietary supplement could alleviate the symptoms.

The somewhat unwieldy name of this hereditary peripheral neuropathy goes back to its three discoverers, the neurologists French Jean-Martin Charcot and Pierre Marie from France and Henry Tooth from Britain. With an incidence of just 1: 2,500, Charcot-Marie-Tooth disease falls into the category of rare diseases. But rare is often not that rare at all: some 30,000 people are affected in Germany alone. The prevalence is rising as modern genetic testing methods have facilitated diagnosis. However, the disease still often remains unrecognized.

Together with other physicians and scientists from Göttingen, Munich, Münster, Würzburg and Aachen, we have founded a network (www.CMT-NET.de), which is coordinated from Göttingen, in order to analyze the causes and develop treatment options as efficiently as possible. Here, patients, scientists and physicians can inform themselves on the newest findings in CMT.

The most common form of the disease is a disorder affecting myelin production. Myelin is a fat-rich substance that is mainly produced by the so-called

Schwann cells. Similar to an insulating cable sheath, it surrounds and protects the extensions of many nerve cells. Thanks to this insulating layer, the electrical nerve impulses are conducted more quickly. In the mentioned form of the disease, myelin production is apparently disrupted: the electrical signals of the nerve cells are transmitted more slowly and the entire peripheral nerve cell is damaged. Finally, the muscles degenerate due to the lack of input by nerve signals.

Early symptoms

The first symptoms often appear early during development in childhood or adolescence, but can also first appear in adulthood. In some patients, the disease is so mild that it remains undetected throughout their lives. Yet, for others it eventually leads to a life on crutches or in a wheelchair. Children of an affected parent have a 50 percent probability of inheriting the disease.

The PMP22 protein (peripheral myelin protein 22) is a component of myelin in the peripheral nervous system and plays a central role in the myelin production of Schwann cells. Between 70 and 80 percent of all patients have mutations of the *pmp22* gene on chromosome 17; in most cases the gene is doubled (CMT1A). How exactly the disease develops is still unclear.

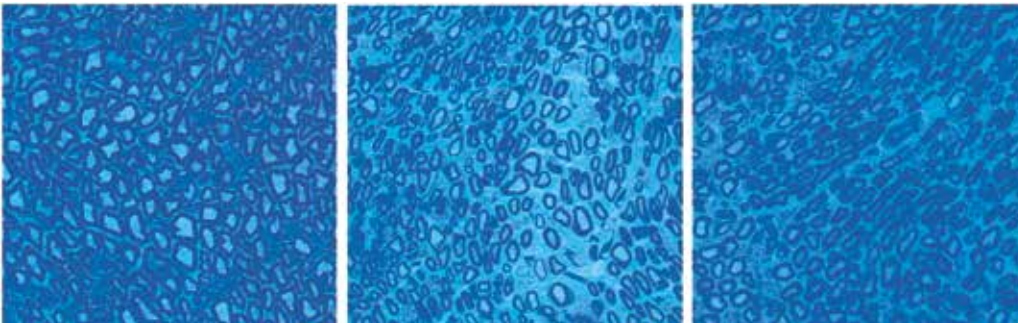
Genetically modified rats as models

In order to find new drugs and test treatment options, we first attempted to gain a better understanding of the disease mechanisms. We therefore generated genetically modified rats that also possess an additional copy of the *pmp22* gene and that develop symptoms similar to those of humans.

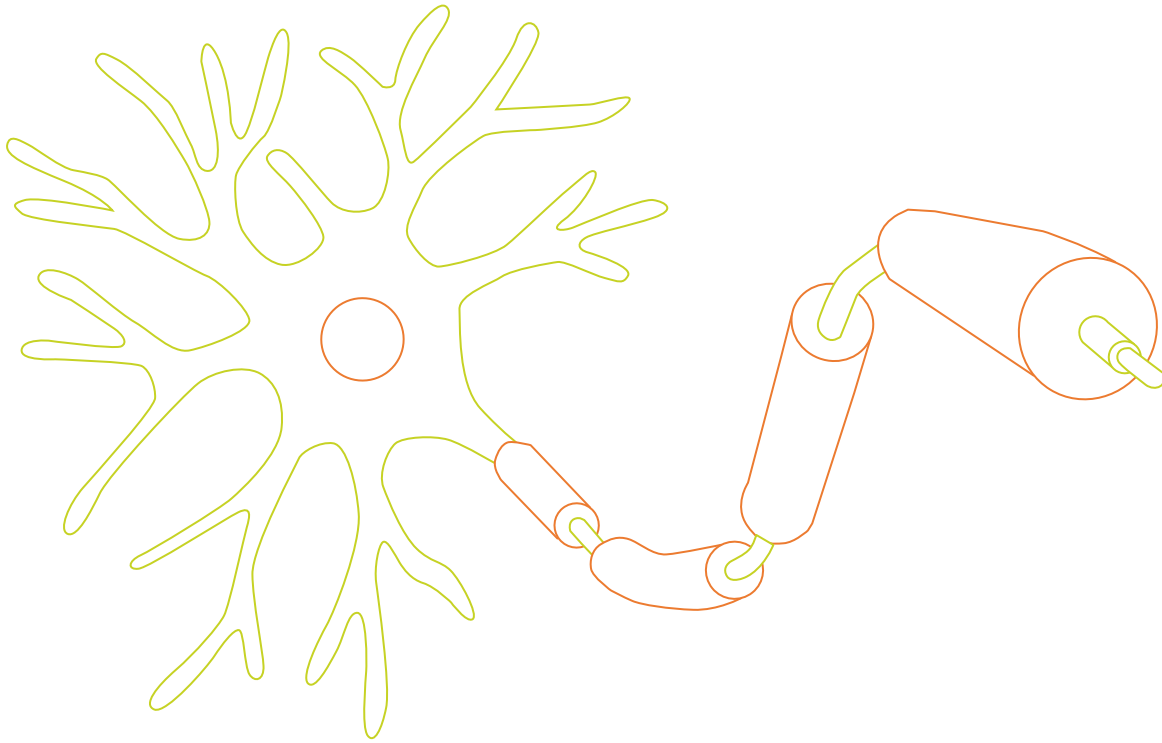
To enable cells to form fat-rich myelin in the first three weeks after birth, the genes involved in fatty acid metabolism in healthy rats are increasingly switched on. In earlier studies, we found that the additional copy of the *pmp22* gene disrupts the activation of genes responsible for the production of fat in the peripheral nervous system in rats. The lack of fat formation could therefore be partially responsible for the disturbed myelination in patients with Charcot-Marie-Tooth.

Next, we investigated whether we could compensate for the impaired fatty acid synthesis. An obvious candidate for the supply of fats is the fat-like lecithin. From a chemical perspective, lecithin is a mixture of phospholipids and is found in particularly concentrated form in egg yolks and plant seeds, such as soy.

In preliminary experiments, we discovered that Schwann cells incorporate externally added fats into their myelin both in cell cultures and in experimental animals. A so-called proof-of-principal study with the genetically modified rats then proved that the diseased animals develop more muscle strength at the end of the study if they receive lecithin as a dietary supplement for 16 weeks from the second day after birth. The reason for this can also be seen under the microscope: an increased number of myelinated nerve cell processes.



In healthy rats, the myelin sheaths of the nerve cells appear as blue rings in the nerve cross section. In comparison (left-hand image), the number of nerve fibres coated with myelin in the nerve cross section is significantly lower in CMT1A rats (centre image). Treating CMT1A rats with lecithin increases the number of myelinated nerve cells (right-hand image).



PXT3003 is expected to be brought on market in 2020

In addition to PMP22, certain hormones are also involved in myelin formation. In particular, the hormone progesterone influences myelination in Schwann cells and boosts the formation of PMP22. We were able to show that the excessive formation of PMP22 can be corrected by blocking the progesterone receptor in transgenic rats thus influencing the course of the disease.

However, since such progesterone blockers are not suitable as active substances due to their importance as hormones for metabolism and fertility, we have examined a combinational drug with the working title PXT3003, which consists of Baclofen, Naltrexone and Sorbitol. These three components have a combined effect on the overproduction of PMP22, but also on other disease-relevant signalling pathways. The consisting active substances have already been approved and are therefore safe for patients.

We administered the PXT3003 combination drug to young rats from the sixth to the 18th day of their lives. The result was surprisingly good: the Schwann cells actually did produce less PMP22 protein and developed

more normally. Just this brief treatment within the first two weeks of life improved the motor abilities of the animals to such an extent that the onset of the disease could be significantly delayed.

Study confirms effectiveness

Following some promising results in preclinical studies and a subsequent Phase 2 trial, PXT3003 has already undergone an international, multicenter Phase 3 clinical registration trial with approximately 300 patients. The effect of PXT3003 was surprisingly positive. PXT3003 is the first hereditary neuropathy drug successfully developed from preclinical research. It is expected to be available in the USA and Europe within the next two years.

Thus, with the help of the PXT3003 therapy, the development of symptoms can be prevented to some extent, and the onset of the disease delayed into adulthood. We hope that early treatment and replacement of the missing fats with lecithin will also have a decisive influence on the course of the disease in humans. Since the disease can now be diagnosed at an early stage using genetic tests, children of affected parents can be genetically screened before the first symptoms appear. In particular, young Charcot-Marie-Tooth patients could benefit enormously from early treatment, as the disease initially usually only causes mild symptoms. ○

13 Negotiating the labyrinth of European contract laws

**REINHARD
ZIMMERMANN**

↳ *Max Planck Institute
for Comparative and
International Private Law,
Hamburg*

Creating a uniform contract law within the European Union is one of the most important projects in the development of European private law. For seven years, we have worked as part of a team of 21 legal experts to disentangle the complex web of EU directives, national legislation and academic model rules. The result, the Commentaries on European Contract Laws, can serve as an academic basis for a modern European contract law – just as successful acts of legislation have in the past been based on theoretical preparation.

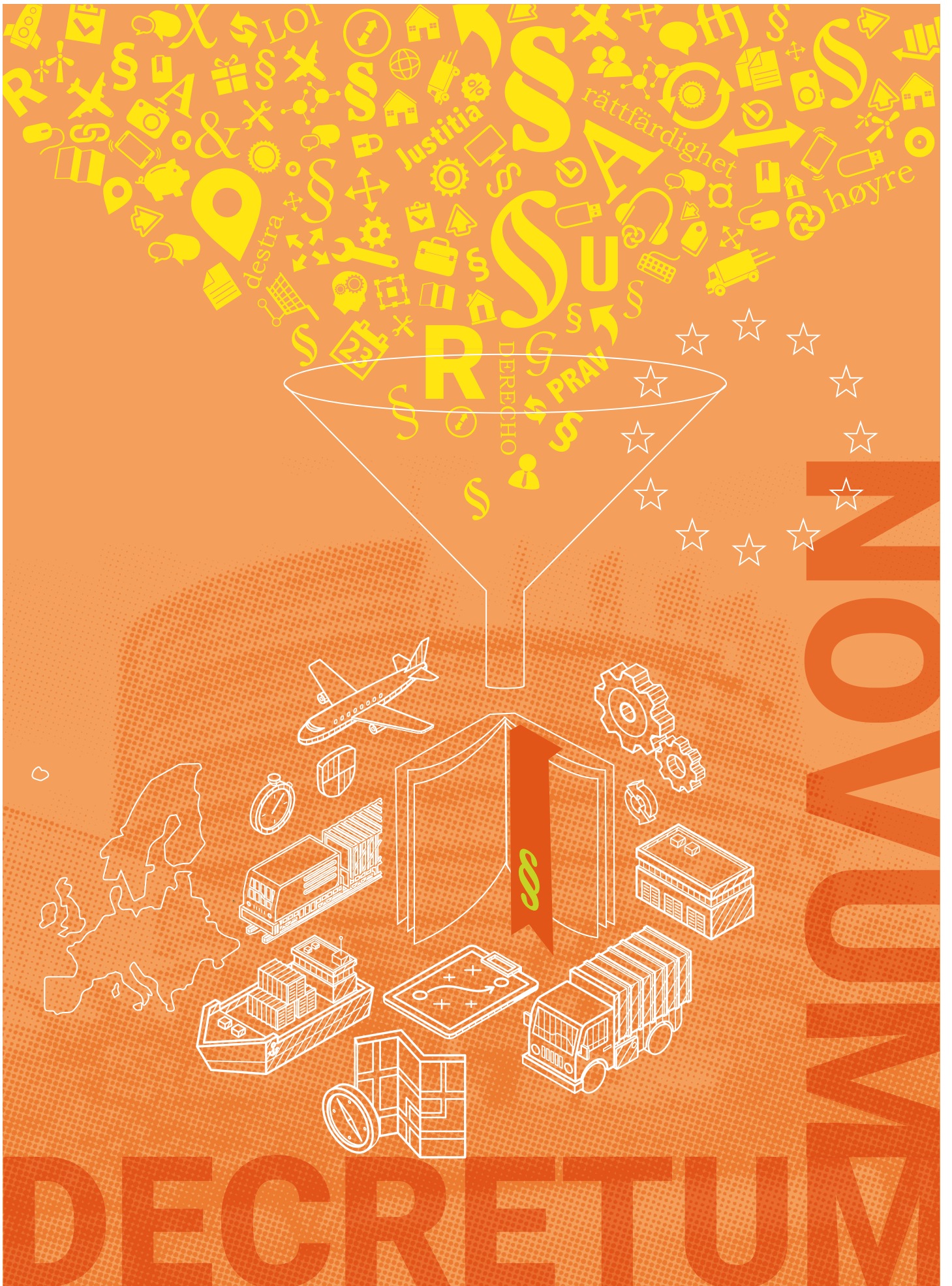
When Gratian, a learned monk in Bologna, completed his “Concordia Discordantium Canonum” in 1140, no one would have guessed how important his compilation of legal church documents would soon become. The sheer number of legal sources available in the High Middle Ages was almost impossible to organize, let alone to understand: the law, at that time, was influenced by Roman law, the Bible, papal letters, council and synodal acts, as well as older collections of laws. Gratian gathered and sorted nearly 4,000 excerpts in his work, including council resolutions (canones) and papal decrees (decretales). He added his own comments (dicta) which could be used as a key for resolving apparent contradictions. The “Decretum”, as Gratian’s main work later became known, is regarded as a masterpiece and is one of the most important sources not only of Roman Catholic church law, but also of private law during the medieval and early modern period.

From an outsider’s perspective, European contract law sometimes also appears to be a highly complex

mesh of EU directives, national laws, and academic model rules, constituting a labyrinth of textual layers, partly hermeneutically related to, and partly independent of, each other. When are contracts considered to have been concluded? What period of limitation applies, and when does it start to run? – These are questions that elicit different answers, depending on which of the now 27 legal orders of the member states you consult.

Politically independent and scientifically thoroughly prepared

When in the autumn of 2010 Nils Jansen, professor at the University of Muenster, and I discussed what needs to be done in European contract law, we both immediately came up with the “Decretum Gratiani” as an inspiration. A few weeks previously, the EU Commission under José Manuel Barroso had published its green paper “on policy options for progress towards a European Contract Law for consumers and businesses” and had,



against the background of higher transaction costs for cross-border trade, a large number of obstacles to trade for small and medium-sized businesses, and a decline in trust among citizens with regard to the single market, presented seven recommendations for consultation. Alongside the creation of facultative EU contract law, the idea of enacting a European Civil Code was part of this set of recommendations.

We discussed the Commission's proposals in a working group. The result was the creation of the project that soon became known internally as "Decretum novum". Would it be possible to create a common contract law bringing together the legislation of all EU member states in a way that would take account of the underlying policies and value judgments and gain acceptance in the business world and in society in general? We were aware that projects in the field of international legal harmonization can only be successful when they are thoroughly prepared in a politically independent and impartial way, and on an academic basis.

With a team of 21 academics, we began a comparative evaluation of the many relevant different legal sources. Thus, over the past 40 years, a whole series of drafts have been presented for a common contract law. Starting with the Principles of European Contract Law, the first fundamental attempt of restating European contract law, on which national judges and legislators have already begun to base their decisions today, the aim was to examine both subsequent restatements and model rules and the European legislation that had already been passed, also taking account of legal sources extending beyond Europe, particularly the UN Sales Law.

A panorama of legal diversity with great depth of focus

In order to do justice to the complexity and innovative nature of the project, we developed a uniform approach based on a historical and comparative perspective and the analysis of textual layers. The purpose was to determine to what extent the sources really reflect a common core of contract laws in Europe which can form the basis for a future comprehensive legislation. What do they have in common? What sets them apart from each other? How can the differences be explained, and how are they to be assessed?

What made this project particularly interesting was the challenge of presenting in an appropriate manner the law prevailing in Europe today in its sometimes dissonant and sometimes harmonious polyphony. Our team reconstructed the development of all the drafts that have been submitted to date, compared them with each other, and

evaluated them against their historical and comparative background. A broad and comprehensive panorama of contract law was thus created, with an unusual depth of focus: ranging from the rules on contract formation and agency through to assignment, compensation, multiple debtors, and extinctive prescription.

Our team conducted research over a period of seven years, in the course of which we attempted to create a basis for the establishment of a uniform contract law. The findings are documented in the Commentaries on European Contract Laws, which were published in 2018 by Oxford University Press.

Calls for a uniform European contract law will become louder again

On a political level it became clear, while the project was still ongoing, that creating a comprehensive contract law for Europe is an enormously ambitious project. The Commission of the European Union thus, for the time being, abandoned its plans to enact a contract code. A number of reasons was responsible for that decision. One of the most important ones was, without a doubt, the fact that the draft submitted by the European Commission in 2011 had not been prepared sufficiently carefully and that there had been unreasonable political pressure to deliver by a certain deadline. There was resistance among the member states, and large sections of German industry and trade, consumer protection organizations, and the Federal Chamber of Notaries also rejected the proposal.

For us, as editors of the Commentaries, that development was not unexpected. Rather, it is commendable that this European legislative project – meaningful as it is as such – was not implemented straight away. After all, a poorly prepared European contract code would have discredited the European idea even more than it is the case already in the eyes of many citizens of the European member states. At present, the European legislator will primarily focus on implementing its strategy for digitalising the single market.

However, at some point, the calls for a uniform European contract law will become louder again. We have taken up the challenge from an academic perspective, to disentangle the highly complex web that characterizes contract law in Europe today – without political pressure to complete our research by a specific deadline. On that basis, the Commentaries provide a comprehensive account of the development to date and, at the same time, offer orientation for the future. ○

14 Water, ice and snow are determining factors for Arctic climate change

MATHIAS GÖCKEDE

↳ Max Planck Institute
for Biogeochemistry, Jena

The extent to which carbon remains stably stored in Arctic permafrost in the future, rather than escaping into the atmosphere as a greenhouse gas, has huge significance for global climate. In our field research in Siberia, we have used new data and models to explain how redistribution of water and increased snow cover – two well-known consequences of current climate change – can further destabilize carbon stores in the Arctic. Our results help to more reliably assess the role that the Arctic plays in global climate change.

About half of the global soil carbon pool is stored in the Arctic. Even if only a part of these vast reservoirs were released, the CO₂ content in the atmosphere could increase noticeably. The Arctic, with its permafrost soils, therefore plays a central role in climate change. In the past few decades, a critical trend has already begun to emerge: the average temperature in the Arctic has risen far more than the global average. According to forecasts, this development may well continue, or even accelerate. This threatens to thaw parts of the soil layers that are currently still frozen, and to release more carbon in the form of greenhouse gases and further stimulating climate change. However, how much carbon will ultimately escape from the Arctic into the atmosphere, and further contribute to global warming, does not depend solely on the air temperature trends in these regions.

The hydrologic conditions and, above all, the form in which the water is present in these regions, plays a decisive role. Since water is particularly efficient at not

only storing, but also conducting heat, it contributes significantly to the energy balance of an area and can slow down or accelerate warming at a local level. In addition, it forms the basis of life for micro-organisms and vegetation, which first convert soil-bound carbon into metabolic processes and then release it into – or conversely, bind it from – the atmosphere.

A deeper snow cover threatens the permafrost stability

So far, many Arctic landforms have been stable simply because only the top decimetres to metres of the soil thaw during summer. Deeper layers remained permanently frozen. The hypothesis is that, paradoxically, greater quantities of winter snow could threaten the stability of the Arctic permafrost soil.

The thicker the snow cover, the better it insulates the soil from the extremely low temperatures of the

A few years of high snowfall are sufficient to destabilize permafrost soils

winter Arctic atmosphere, which can remain at -30°C to -50°C for long periods. Soil temperatures therefore often stay comparatively mild, so that the surface thaws more easily in the summer.

Our long-term measurement data from north-eastern Siberia confirm this relationship: over the course of five winters, from 2013/14 to 2017/18, the average snow cover doubled in total, while soil temperatures rose by up to 6°C during the same time period. In addition, due to increased micro-organism activity, over 50 percent more carbon escaped from the soil. During the following winter of 2018/19, which had relatively little snowfall, temperatures then experienced a sharp drop; initial analyses indicate that carbon emissions also decreased. Our investigations prove that just a few years of high snowfall are sufficient to at least temporarily destabilize permafrost soils even in very cold Arctic regions. As

much of the Arctic is predicted to experience increased rainfall due to climate change, this process is extremely important for the future development of the permafrost landscape and its carbon balance.

Field experiments show: water redistribution can intensify climate change

The increased thawing of Arctic permafrost soils – itself a direct result of ongoing climate change – can change the geo-ecological structure of the landscape even more drastically: permafrost cliffs along river banks and Arctic Ocean coastlines are being worn away by erosion, a process that could be significantly accelerated by soil warming; elsewhere, thermokarst lakes are being created by the thawing of underground ice lenses. And when ice wedges within the ground thaw, interconnected ditch systems may form, which redistribute the available water over a large area.

But how do such changes affect the Arctic ecosystem and its local energy and carbon cycles? To investigate this question, our working group has been undertaking a unique 14-year field experiment in a permafrost wetland area in Siberia. We drained part of

When permafrost soils thaw, such as the Kenai Peninsula in Alaska depicted here, more carbon will be flushed into the rivers.



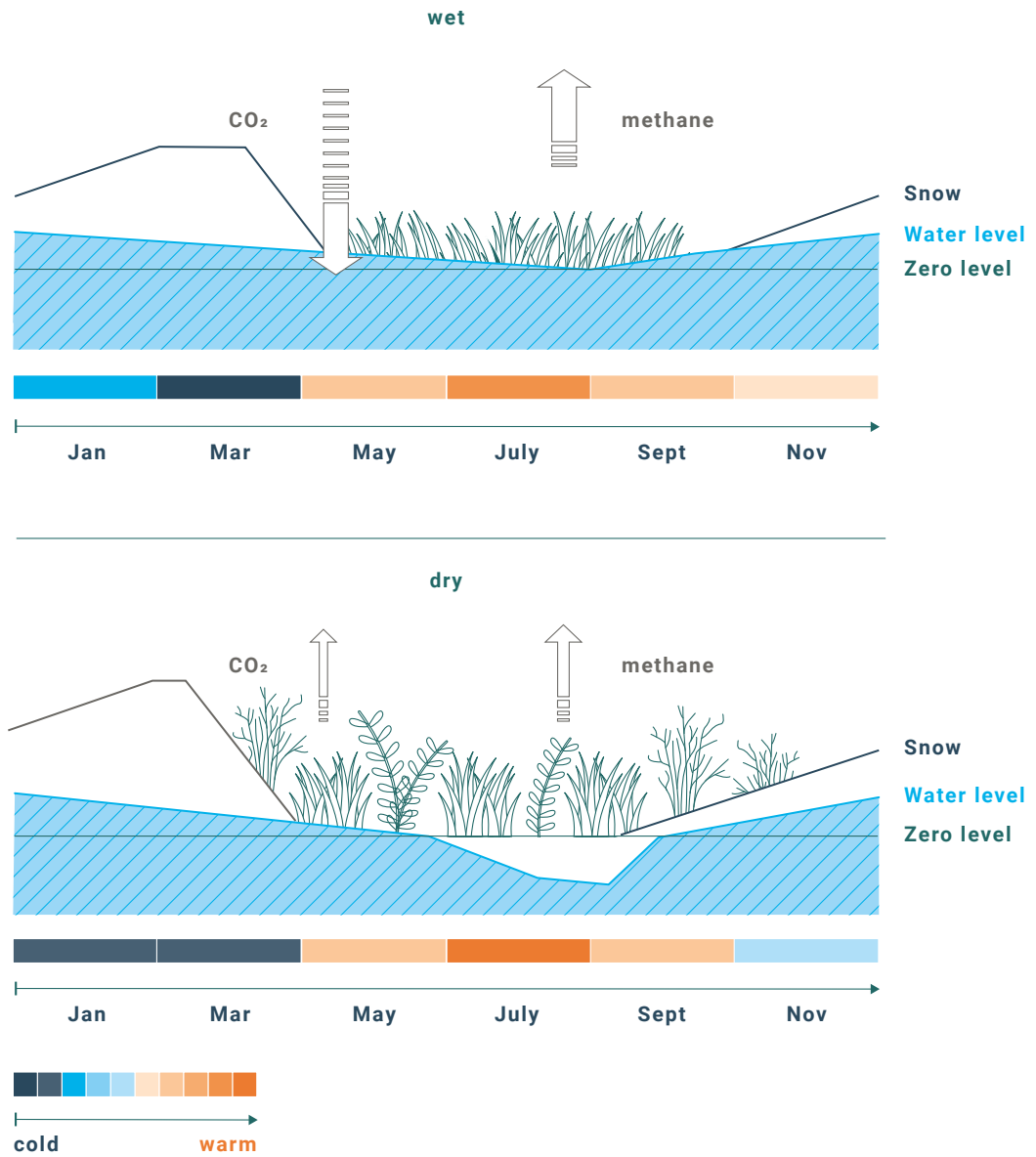


Diagram showing how the permafrost ecosystem under investigation has changed as a result of long-term drainage. Compared to the original wet conditions (above), after drainage (dry, below) a significantly lower summer water level (blue line) can be seen. As a result, a gradual increase in plant growth occurred. The course of the soil temperature, represented as colour-coded average values of two-month periods, was also changed.

the area with artificial ditches and compared it with an undisturbed natural area. It emerged that this long-term redistribution of water not only caused a sustained change in the composition of the flora and soil organisms, but also in the energy cycle.

As expected, since soil dryness particularly limits the activity of methane-forming micro-organisms which are prevalent in natural wetland areas, only small amounts of the highly climate-impacting greenhouse gas methane were released in the field experiment compared to the wetter areas left in their natural state. In contrast, micro-organisms that convert carbon into carbon dioxide positively thrive in dry conditions. Higher plants, which also colonize the drier areas in increased numbers, absorbing CO₂ from their environment for

Changes in the water balance mostly reinforce greenhouse gas emissions

photosynthesis, could not offset the increased carbon emissions in the field experiment. Accordingly, CO₂ emissions increased by a significant amount in the drained areas. Our case study shows that if the structure of the landscape were to change, resulting in drainage of large parts of the Arctic tundra, associated increases in carbon emissions may constitute a positive feedback to climate change. If we consider the entire Arctic permafrost landscape, such soil processes could result in a mosaic of smaller, dry plots with significantly lower methane emissions, even in an increasingly wetter Arctic. However, whether the CO₂ balance on these increasingly dry plots will simultaneously change from a moderate carbon sink to a carbon source, as in our case study areas, is a question that remains unanswered yet.

Improved models based on our measurement data

Modern computer simulations could help to clarify this question in the future. In order to estimate the further course of climate change, and in particular to determine the effects of hydrology on methane emissions in Arctic permafrost areas, we have created an extended version of a suitable computer model: the land surface model from the Max Planck Earth System Model, JSBACH. In contrast to earlier simulations, it is now possible to use this model to precisely simulate the emergence of dry areas on the one hand and flooded regions on the other, based on the prevailing topography and taking into account the current measurement data. Our improved model represents a significant advance in the process-based simulation of future Arctic methane emissions as it can very accurately depict the effects of drier or wetter conditions on the carbon cycle.

With the research results from the Siberian permafrost areas, we can better identify the key factors and mechanisms that sustain the stability of these ecosystems and their enormous carbon stores. The availability and distribution of water plays an important role here: It affects almost every feature of the Arctic ecosystems. Changes in hydrology, which we have been studying for many years, have usually been associated with an increase in greenhouse gas emissions. These findings need to be fed into improved models to extrapolate these findings into larger areas, in order to properly classify the role of permafrost carbon emissions in future climate change predictions. The stability of Arctic permafrost areas will be crucial for future living conditions in many regions of the world. In order to effectively protect them, it is essential to research the underlying processes. ○

15 In a planetary nursery

**MIRIAM KEPPLER,
ANDRÉ MÜLLER**

↳ *Max Planck Institute
for Astronomy,
Heidelberg*

Astronomers have so far identified about 4,000 planets orbiting alien suns. Our team has recently discovered an extremely young exoplanet. The gas giant with the designation PDS 70b is located within a gap of the dust and gas disc around its mother star – and thus in the vicinity of its birth. It is apparently still drawing new matter and growing. PDS 70b therefore offers a unique opportunity to test models of planet formation and learn about the early history of our own solar system.

The search for exoplanets – celestial bodies orbiting alien suns – has already brought to light about 4,000 examples of different sizes, masses, and distances from their mother stars. However, it is not known exactly how they are created. Researchers do have theories and models of possible scenarios. However, until now it has hardly been possible to detect planets in their formation state, to investigate this process directly, and to compare their properties with the calculations of the models. Our group at the Max Planck Institute for Astronomy and our colleagues from the consortium of the SPHERE instrument at the Very Large Telescope of the European Southern Observatory (ESO) have achieved exactly that.

We tracked the planet called PDS 70b at a distance of 22 Astronomical Units (AU) from its central star PDS 70. The planet is thus 22 times as far away from its mother sun as the Earth is from its sun. The discovery did not come by chance. For our investigation with PDS 70, we chose a star on which we suspected that a young planet was circling.

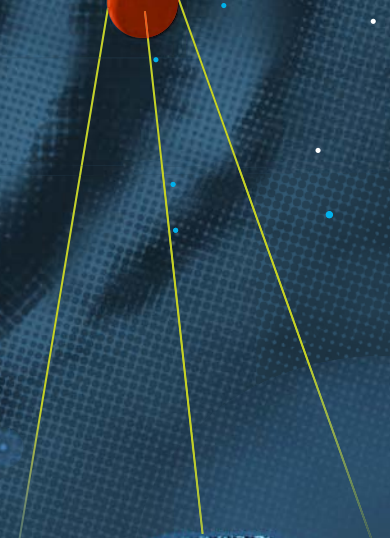
A large gap in the circumstellar disc

PDS 70, which is 370 light years away, is only about 5.4 million years old and belongs to the class of T Tauri stars. It is surrounded by a protoplanetary disc of gas and dust with a diameter of about 130 astronomical units (for comparison: the outer edge of the sun system, the Kuiper belt, reaches only up to about 50 AU into space). Such discs consist of material that remain after the formation of a star. The circumstellar disc around PDS 70 has a large gap. We assume that this gap can be explained by the fact that a young giant planet collects matter from the disc during its orbit. Because of the interaction with the disc, it slowly changes its distance to the central star. Thus it gradually clears a larger zone within the disc.

In a subsequent investigation, our group managed to obtain a spectacular image of the PDS 70 system. In this image, the planet can be clearly seen at the inner edge of the disc gap. Around once every 120 years, it

370 LIGHT-YEARS

PDS 70 b



A spectrum allowed us to determine atmospheric and physical properties

circles around its mother star. A spectrum of PDS 70b allowed us to determine its atmospheric and physical properties. This discovery offers an unprecedented opportunity to test theoretical models of planet formation.

The celestial body is surrounded by clouds with a temperature of 1,000 degrees

By combining our own measurements with archive data, we conclude that PDS 70b is a huge gas planet with several Jupiter masses and a surface temperature of about 1,000°C. It is therefore much hotter than any planet in our solar system. PDS 70b is younger than the central star and is still growing as the observations of a US research team have shown since our discovery. Our data also show that the planet is surrounded by clouds. PDS 70b also confirms the idea that gas planets like Jupiter should form at a greater distance from their central star.

In order to make protoplanetary discs visible, we must use sophisticated observation and evaluation methods: In normal images, the star outshines all objects in its immediate vicinity – including its own planets. With the SPHERE instrument, however, the light that reaches us directly from the star can be largely eliminated. SPHERE is a special camera developed and built by an international consortium led by our Max Planck Institute for Astronomy and the Institut de Planétologie et d'Astrophysique de Grenoble (IPAG). It is used on one of the eight-metre telescopes of the European Southern Observatory in Chile.

SPHERE uses the property of the polarization of light. Explanation: light waves are electromagnetic waves that propagate in space. With the individual waves, the direction of oscillation is different and randomly distributed in space; the light is unpolarized. Linearly polarized light waves, on the other hand, oscillate in only one plane. The light of a star is predominantly unpolarized (i.e. it oscillates in all directions). If

it hits a disc of matter surrounding the star, it is linearly polarized during the scattering of the dust particles. If a polarization filter that allows light waves to pass through in only one plane of oscillation is used, the light coming from different areas of the disc is detected or blocked depending on the orientation of the filter. Photographers use a similar effect when they want to fade out reflections from a smooth surface (e.g. a reflective window pane). On the other hand, the light of the star always produces a signal regardless of the filter configuration. This difference allows us to calculate the direct starlight from the data. The operation is supported by another method: we cover the star with an aperture. An image of the disc remains.

A powerful instrument makes a dream come true

After ten years of developing new, powerful astronomical instruments such as SPHERE, we are finally able to find and study planets directly during their formation. This helped us to realize a long-held dream. We are sure that more exciting discoveries await us. ◦

The Max Planck Society

The Max Planck Society (www.mpg.de/en) is one of the world's leading research institutions with a workforce of more than 23,000 professionals. In 84 Max Planck Institutions about 6,900 scientists and more than 7,000 early career researchers and visiting scientists conduct basic research in the natural sciences, life sciences, and the humanities.

Max Planck Institutes work in research areas, which are particularly innovative and require a special commitment in terms of funding or time. Their research spectrum is constantly growing. New Institutes or departments are set up and existing ones rededicated in order to find answers to seminal scientific questions. This process of constant renewal preserves the Max Planck Society's leeway to pick up quickly on new scientific developments.

It was set up in 1948 as the successor organisation to the Kaiser Wilhelm Society, which had been in existence since 1911. Since then, 17 male Nobel Prize winners and one female Nobel Prize winner have been produced from its ranks. As well as five Institutes abroad, the MPG runs a further 20 Max Planck Centers with research facilities such as Princeton in the USA, Harvard University, Science Po in France, University College London / UK or the University of Tokyo in Japan. Funded in equal measure by the Federal and State Governments, the Max Planck Society enjoys a total annual budget of 1.8 billion euros.



Imprint

Publisher

Max Planck Society
for the Advancement of Science
Department Communication
Hofgartenstr. 8, D-80539 München
Tel: +49 (0)89 2108-1276
Fax: +49 (0)89 2108-1207
E-Mail: presse@gv.mpg.de
Internet: www.mpg.de

Editorial staff

Christian Buck, Dr. Thomas Bürke,
Dr. Virginia Geisel, Peter Hergersberg, Helmut Hornung,
Dr. Jan-Wolfhard Kellmann, Dr. Felicitas Mokler,
Mechthild Zimmermann

Design

mattweis, Munich

Printing

F&W Druck- und Mediencenter GmbH, Kienberg

June 2019

Picture credits

Biosensor for blood testing at home:

p. 5: Illustration: mattweis

Plants with a memory:

p. 8: Infographic: mattweis

Acoustic invisibility cloaks and pricked-up ears:

p. 10: Illustration: mattweis; using an image by freepik (moth); Wikimedia Commons (western barbastelle); istock photo (bats)

A glimpse into the machinery of a gravitational monster:

p. 14: ESO / M. Kornmesser

p. 15: ESO / Gravity Consortium / L. Calçada

Ways out of terrorism:

p. 17: Illustration: mattweis; using an image by Wikimedia Commons (Map World)

p. 19: Infographic: mattweis, based on an image by David Rapoport

CO₂ – a raw material for chemical production:

p. 21: Infographic: mattweis, based on an MPG image

Appetite stimulant in the brain:

p. 24: Infographic: mattweis; using a freepik image (mice), based on MPG

A psychological trick for greater equality of opportunities:

p. 27: Illustration: mattweis

3D metal printing - powder bed to part:

p. 30, top: Max-Planck-Institut für Eisenforschung / Working group Jäggle

p. 30, below: Max-Planck-Institut für Eisenforschung / Working group Jäggle

Rendezvous in the Stone Age:

p. 33: Illustration: mattweis; MPG (photo: skull)

Hope for hereditary neuropathy patients:

p. 38: MPI for Experimental Medicine

p. 39: Infographic: mattweis

Negotiating the labyrinth of European contract laws:

p. 41: Illustration: mattweis;
istockphoto (Parliament; icons)

Water, ice and snow are determining factors for Arctic climate change:

p. 44: NOAA

p. 45: Infographic: mattweis; using an image by Vecteezy.com (grass), based on MPG

In a planetary nursery:

p. 48: Illustration: mattweis;
MPG (telescope and planet)

Tear here
and use
as bookmark

