

01 | 2024

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Research

CLIMATE RESEARCH

An Umbrella of Flower Clouds

ASTRONOMY

The Digital Universe

MATERIALS SCIENCE

Packaging in Nature



(UN)FREE



PHOTO: ISTOCK/KARDD

The Basic Law in Germany guarantees extensive rights of freedom and these go further than many people think. But of course, freedom also has its limits. There are limits even on social media, where almost anything goes. Virtually nothing is allowed under repressive regimes. Creating freedom there is an art form.

EDITORIAL

Dear Reader,

“Open-mindedness, respect, and community are values which underpin the quality and nature of life in Germany, while also strengthening its economy. That is why we stand together for an open country that faces difficulties with courage.” With this message, approximately 500 companies and social institutions, as well as over 350 academic facilities, took a stand against right-wing extremism and professed their commitment to freedom and diversity in the campaign #Zusammenland. The Max Planck Society has also joined the campaign. By doing so, it is responding to social developments that threaten our free and democratic form of society. “I am concerned about right-wing radical sentiments and xenophobia,” Max Planck President Patrick Cramer recently said in his video blog, which addresses the research organization’s employees. “We must never forget: democracy is not to be taken for granted. We need to advocate for it and treat our rights with responsibility.”

It is quite fitting that the Federal Ministry of Education and Research (BMBF) has dedicated the Year of Science 2024 to the topic of “freedom.” In the research carried out at Max Planck, we will likewise be illuminating various aspects of freedom this year, beginning with the main topic of this issue, which focuses on the area of tension between freedom and a lack of freedom. In recent years, the importance of support for freedom and democracy has become clear in an alarming number of countries, in which free democracy has been successively subverted. By restricting the balance of power, illiberal democracies like Hungary no longer guarantee liberal freedoms. In Russia, which is now classified as a dictatorship, these rights were completely done away with at the beginning of Russia’s war of aggression against Ukraine. Our infographic shows you which state interventions undermine freedom and jeopardize democracy. But there is hope. What’s more, campaigns like #Zusammenland and protests against right-wing extremism in many German cities are not the only sources of hope. The example of Poland demonstrates that liberal powers can return to the government despite the authoritarian restructuring carried out by the Law and Justice Party. Armin von Bogdandy and Dimitri Spieker at the Max Planck Institute for Comparative Public Law and International Law explain how freedom and the rule of law can be restored in Poland in their essay.

Advocating for freedom and democracy should be important for all of the people and institutions in this country, especially science: it needs more than the freedom to break new ground. The forces that threaten freedom and democracy also deny scientifically acknowledged facts, something that becomes clear time and again in debates about climate change. “Those who disregard and twist the facts harm dialog,” says Patrick Cramer. And it is precisely open, fact-based dialog that characterizes pluralistic societies. We want to do our part to make sure this remains possible in Germany.

Your Editorial Team



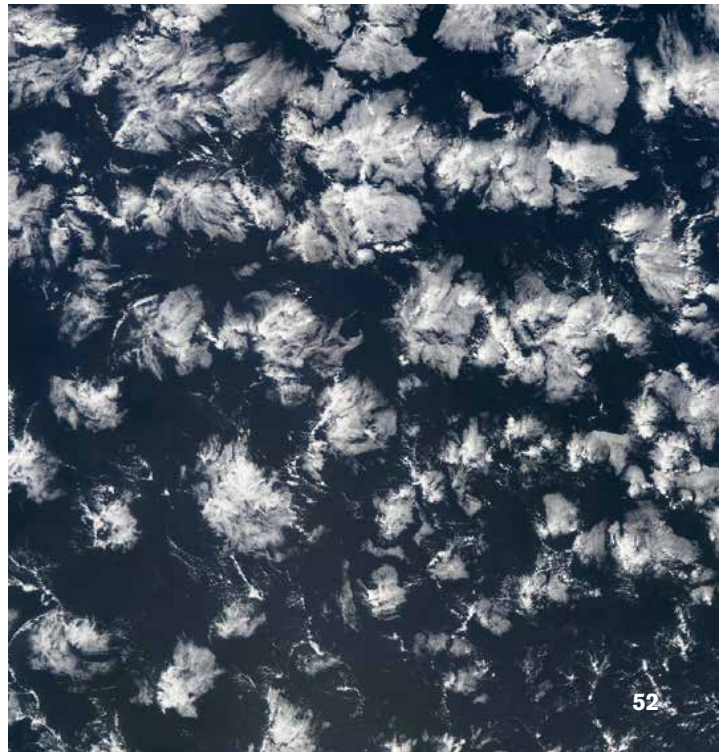
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IMAGES: ALEXANDRA ARKHIPOVA, YURI LAPSHIN (2023); NO WOBBLE, V. 1.0, DISCUSS DATA (TOP LEFT), KATRIN BINNER FOR THE MPG (TOP RIGHT), DR. SUSANA COELHO / MPI FOR BIOLOGY TUBINGEN (BOTTOM LEFT), MPI FOR METEOROLOGY / NASA WORLDVIEW (BOTTOM RIGHT)

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*SUMMER IN
THE FAR NORTH*

6 **T**he Arctic tundra is an extreme habitat. Even in summer, when the sun does not set, temperatures rarely rise above 5 to 10 degrees Celsius. And yet thousands of migratory birds breed in this largely treeless landscape. Ideal conditions for ornithologists to study the influence of light on the courtship behavior and the “internal clock” of birds. Bart Kempenaers from the Max Planck Institute for Biological Intelligence chose the surroundings of Utqiagvik in Alaska’s extreme north for this purpose. The northernmost city in the U.S. emerged out of a winter camp established by the indigenous Iñupiat, which had existed here for centuries. In the language of the Iñupiat, the name means “place where we hunt snowy owls.” Over several summers, Kempenaers and his team investigated four migratory bird species with different ways of life: sandpipers, pectoral sandpipers, Lapland buntings, and gray phalaropes. The latter is one of the few bird species in which only the males take care of rearing the young. In contrast, male pectoral sandpipers display and fight intensively and almost non-stop in order to mate with as many females as possible throughout the short Arctic summer. The males who produce the most young are the ones who remain vigorous despite hardly sleeping at all. The predominantly monogamous Lapland buntings, on the other hand, maintain a strict 24-hour daily rhythm despite the lack of day-night changes. The “internal clock” seems to be much more flexible than expected, depending on social and environmental factors. Even though the scientists have solid ground under their feet and look out over the frozen polar sea, most of the tundra is swampy in the polar summer. And so the researchers spend most of their time standing in water at temperatures just above freezing, sometimes up to their thighs. The special boots keep them reliably warm and dry – and some of the team wonder why their winter shoes can’t do the same for them back home.



ON LOCATION



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PHOTO: MPI FOR BIOLOGICAL INTELLIGENCE / SABINE SPEHN

ADDITIONAL FUNDING FOR GERMAN-ISRAELI COLLABORATIONS

The Max Planck Society maintains close and longstanding ties with Israeli research institutes. Its subsidiary, the Minerva Stiftung, promotes many of these collaborative endeavors. The Federal Ministry of Education and Research (BMBF) has now approved additional financing for the Minerva Fellowship Programme and the Minerva Centers Programme.

Additionally, Israelis of Arabic origin are to receive support amounting to half a million euros per annum within the scope of the Minerva Fellowship Programme and the two research fields “Human Rights and Democracy” and “Life under Extreme Conditions.” In the wake of the horrible terror attacks carried out by Hamas on October 7, 2023, the Max Planck

Foundation also wants to strengthen collaboration between Germany and Israel: The Max Planck Israel Programme has a funding volume of approximately 1 million euros and will run for two years. Among other things, it promotes research residencies for Israeli scholars at Max Planck Institutes.

[www.mpg.de/
max-planck-israel-programme](http://www.mpg.de/max-planck-israel-programme)

OUTSTANDING! ★

2023 – AN EXTREME YEAR

In terms of the climate, 2023 was another year of extremes. Throughout 2023, the global average temperature was 1.48 degrees Celsius above the preindustrial average. There were also extraordinary heat waves and droughts, extreme storms, and catastrophic precipitation. Studies performed by the European consortium Xaida, in which a team from the Max Planck Institute for Biogeochemistry is involved, now confirm that such extreme weather and climate events, which are caused by anthropogenic climate change, will become more likely and more severe. Extreme rainfall like that which took place during Storm Daniel, causing two dams

to break in Libya in September, has become 10 times as likely as a result of global warming. The floods cost thousands of people their lives and made Daniel the deadliest storm in Africa to date. Partners at the Xaida consortium also analyzed deadly heat waves, during which temperatures in the USA and China, for example, rose to over 50 degrees Celsius in July. The summer of 2023 was also exceptionally hot in Southern Europe, where temperatures exceeded 40 degrees Celsius. According to a study by ETH Zurich, it is possible that Europe will experience temperatures in excess of 50 degrees in future.

www.mpg.de/21506133



DIRK GÖRLICH

The Louis-Jeantet Foundation is honoring the Director at the Max Planck Institute for Multidisciplinary Sciences for discovering a special form of biological material. It is a highly selective barrier that plays a decisive role in controlling central transport paths in cells, such as between the cell nucleus and cytoplasm. According to the foundation, Dirk Görlich has made pioneering contributions to our understanding of the processes through which macromolecules are transported into and out of the cell nucleus. The Louis-Jeantet Prize for Medicine is awarded with 500,000 Swiss francs (approximately 537,000 euros) in prize money.

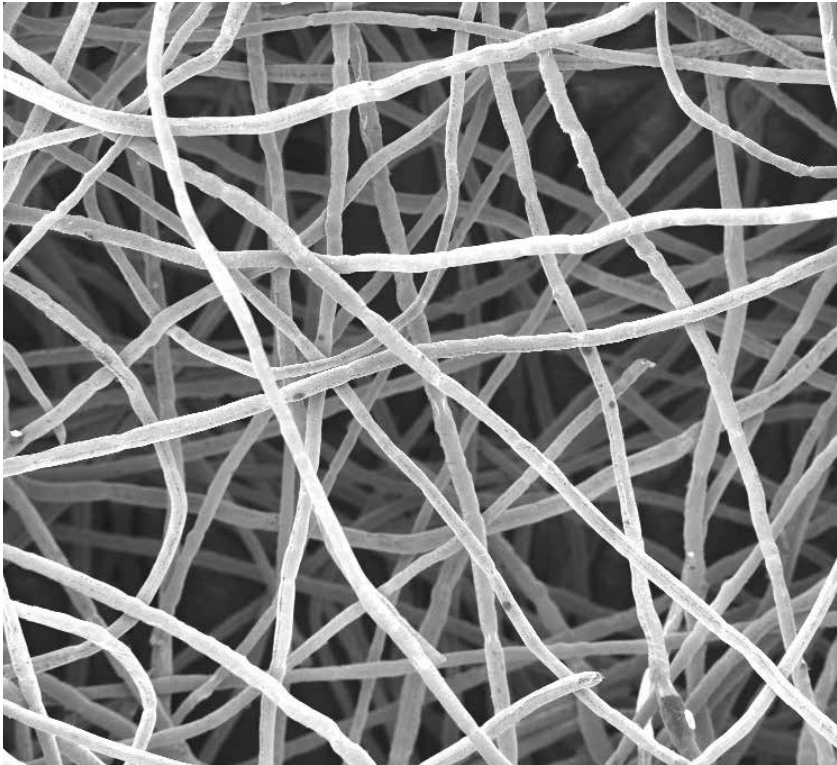
PHOTO: MPFNAT; IRENE BÖTTCHER-GAJEWSKI



PHOTO: HALLIL FIDAN/ANADOLU/PICTURE ALLIANCE

The rain during Storm Daniel made two dams in Libya burst. The flood triggered by this destroyed parts of the city Darna.

IMAGE: MPI FOR MEDICAL RESEARCH



Fleeces made of fine metal wires developed by Batene make batteries considerably more efficient and inexpensive.

A PUSH FOR NEW BATTERY TECHNOLOGY

Batteries can store up to 80 percent more energy if they use the technology from Batene GmbH. The start-up, which was founded from within the Max Planck Institute for Medical Research, is now receiving the Max-Planck-Startup Award along with 30,000 euros in prize money from the Donor's Association for its innovation. Batene replaces the thin contact foil used in conventional batteries with fleeces made of

fine metal wires called batene fleece™. That significantly accelerates the charge transport through the batteries' storage material. The metal fleece makes energy storage considerably more efficient. In addition, it drastically simplifies battery production and, as a result, can reduce manufacturing costs by up to 50 percent. Batene's technology can also increase the range of electric cars and reduce their price.

www.mpg.de/21572651

AFTER THE QUAKE

A powerful earthquake shook Turkey and Syria on February 6, 2023. Max Planck scholars and their families were also impacted by the catastrophe. Members of the Max Planck Society founded a support initiative in the wake of the event: Maxminds. The online mentoring program fosters the academic and professional development of bachelor's and master's students at universities in the region struck by the earthquake. The program has over 60 mentors who are all current or former employees of the Max Planck Society and come from various professions and different scientific institutions. More than 50 Max Planck Institutes and facilities are participating in the mentoring program. The initiative is being supported by the Diversity Excellence Fund of the Max Planck Society and the Turkish Association for Supporting Contemporary Life (CYDD), among others.

www.mpg.de/21508299

ISN'T THAT FUNNY?

“Have you heard about the...?” Jokes are not simply funny, they also strengthen social ties. To have a sense of humor, people need to have social intelligence, be able to understand the actions of others, and be able to assess their expectations. A precursor of joking is playful teasing. From as early as eight months, babies tease their parents by holding out objects for them and then, all of a sudden, taking them back. A team

involving researchers from the Max Planck Institute of Animal Behavior has now proven that chimpanzees, bonobos, gorillas, and orangutans also tease each other and try to get attention by provoking others in a targeted manner. For example, they repeatedly wave objects right in front of others, poke them, or pull their hair. Much like people, apes tease each other most often when they are relaxed. In contrast to pure

play, playful teasing is usually initiated by only one individual and is seldom reciprocated. After the provocation, the animal looks at the one it has teased, waits for a reaction, and then either repeats the action or tries something new. The fact that all four species of great ape have the ability to playfully tease indicates that our last common ancestor set about annoying its fellows 13 million years ago. www.mpg.de/21524011

Multiple-star systems containing protostars (black star symbols in the enlarged details) can be seen in the pseudocolor image of star formation region G333.23–0.06.

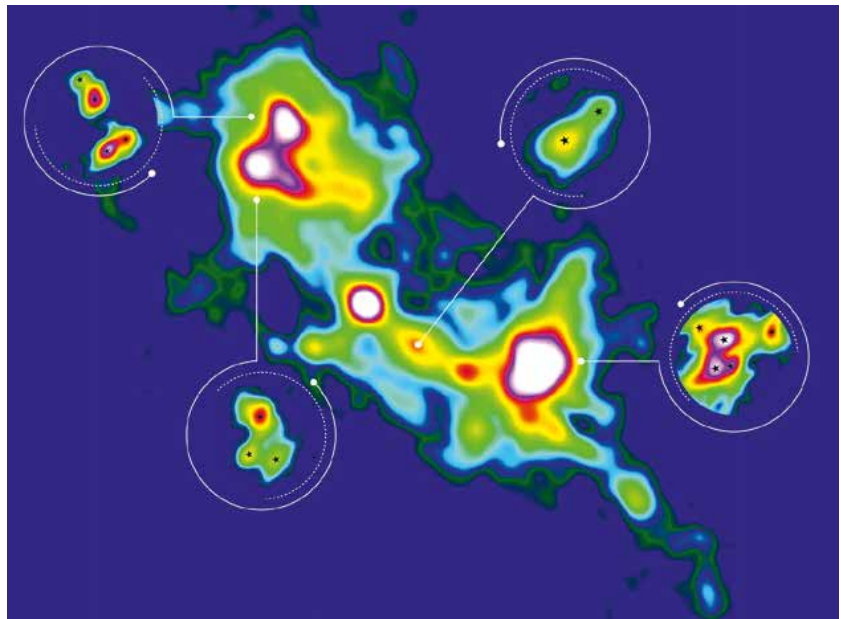


PHOTO: S. LI, MPIA/J. NEIDEL, MPIA GRAPHICS DEPARTMENT/ALMA

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PLASTICS ARE EVERYWHERE

Microplastics have made their way to even the most remote corners of our planet. The plastic particles can only have reached some places, such as Arctic and Antarctic glaciers and ice sheets, through the atmosphere. The distance microplastics can travel through the air depends largely upon the form of the microplastic particle in question. Researchers at the University of Vienna and the Max Planck Institute for Dynamics and Self-Organization in Göttingen reached this conclusion with the help of laboratory experiments and model simulations: while spherical particles are quickly deposited, microplastic fibers can cover large distances, such as those required to reach the Arctic or Antarctic from Germany, and can even reach the stratosphere. Now additional studies aim to clarify the extent to which high-flying microplastics can also influence the climate and the ozone layer.

www.mpg.de/21360687

STARS ARE SELDOM SOLITARY

Unlike the sun, about half of the stars in the Milky Way that are similar to our sun are not alone in their respective systems. In fact, 90 percent of the especially massive and thus bright stars have more than one star per star system. Until now, it was unclear whether these multiple-star systems were born in that form or whether the stars find each other during their development in star formation regions. Researchers at the Max Planck Institute for Astronomy have now observed, for the first time how double-, triple-, and multiple-star systems form from cold molecular gas in region G333.23–0.06 of our

Milky Way. Every one of the node structures observed corresponds to a package of gas that will develop into a star when the density is high enough that atomic fusion ignites. To make their observations, the researchers interconnected several dozen radio antennas at the Alma Observatory in Chile with a telescope network that is several kilometers in diameter. This allowed them to observe relatively small structures the size of our solar system at a distance of 16,000 light years. A telescope with this resolution could be used to observe a euro coin at a distance of 100 kilometers. www.mpg.de/21352437



Aerial photo of the 3000-year-old settlement Alto de la Cruz in Navarre during excavation work in 1989. Researchers discovered the burial sites of two children with Down syndrome and one with Edwards' syndrome in the settlement.

DOWN SYNDROME IN PREHISTORY

People with Down syndrome have often been discriminated against in recent history. During the Bronze Age and the Iron Age, however, this does not appear to have been the case. Genetic material analyses of people who were buried between 5000 and 2500 years ago in Greece, Bulgaria, and Spain indicate this. Researchers at the Max Planck Institute for Evolutionary Anthropology in Leipzig found so many DNA sequences of chromosome 21 in the genetic material of five children from that time that they concluded the children clearly had an additional copy of this chromosome, and thus had Down syndrome. Nonetheless, they appear to have been acknowledged and cared-for members of their re-

spective societies since they were granted the privilege of being buried within their settlements. Furthermore, they were given special gifts like pearl necklaces, bronze rings, or muskels that accompanied them to their graves. Among the approximately 10,000 DNA samples analyzed, the researchers also discovered one belonging to a baby with three copies of chromosome 18. Accordingly, this baby must have suffered from what is known as Edwards' syndrome, a condition that is rarer than Down syndrome and entails more severe health problems. Without the help of modern medicine, all of these children died before they reached the age of one.

www.mpg.de/21538858

DIAGNOSIS BY PUPIL DILATION

Many individuals with depression experience symptoms such as listlessness and an inability to feel joy. This can often be seen in the eyes of those affected. In healthy people, pupils dilate in anticipation of a reward for an achievement. In an earlier study, researchers at the Max Planck Institute of Psychiatry found that the pupils of individuals with depression dilate less compared to those of their healthy counterparts. Recent findings suggest that pupil dilation is particularly low in patients who report feelings of joylessness and low energy levels. As pupil dilation is also a sign of an active locus coeruleus, it appears that this region is not adequately active in individuals with depression. The nerve cells of the locus coeruleus play a crucial role in activating the nervous system via the neurotransmitter noradrenaline. In future, measuring pupil dilation could enhance depression diagnosis and aid in tailoring treatments to patients' individual needs. For example, antidepressants that act on nerve cells with the neurotransmitter noradrenaline may be more effective for patients with a weak pupillary response than other drugs. Moreover, utilizing pupillary response could facilitate more precise dosing of antidepressants.

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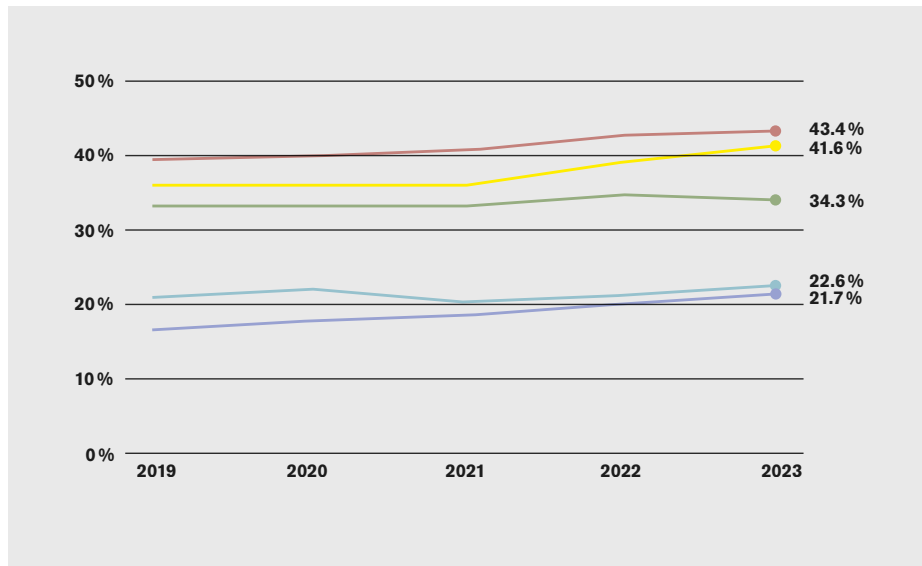
PHOTO: ISTOCK.COM/PETER SCHAEFER

The neighborhood has a measurable influence on people's fear of crime.

FEAR AFTER THE CRIME

People process acts of violence differently, and this also depends on the social structure of their neighborhood, as a team from the Max Planck Institute for the Study of Crime, Security and Law has discovered. The researchers surveyed more than 3,300 people from 140 different residential areas in Cologne and Essen at intervals of around one and a half years. They collected data on experiences of violence, such as assault or sexual harassment, as well as on the fear of becoming a victim of crime again after experiencing an attack. According to the results, this fear grows more strongly among residents of neighborhoods where more than 30 percent of people receive social benefits compared to those from more privileged residential areas. In contrast, a high crime rate or signs of disorder in public spaces do not increase the fear of crime.

www.mpg.de/21584605



GRAPHIC: MPG

- Directors
- Independent Research Group Leaders
- Group Leaders
- PostDocs
- PhDs

This chart shows how the proportion of women in management positions in the Max Planck Society has been changing.

BOOSTING FEMALE REPRESENTATION

The Max Planck Society has been steadily increasing the representation of women in leadership positions for years, and in 2023, it made significant progress. This year, it appointed female scientists to six out of eleven new directorial position, raising the percentage of female directors by two percent compared to the previous year. For the 27 research group leadership positions that needed to be filled, the MPG recruited 18 women, which corresponds to a 2.7 percent in-

crease. The Max Planck Society has thus exceeded its self-imposed target of increasing the share of female scientists in management positions by one percentage point per year. Nevertheless, it intends to intensify its efforts to further boost female representation, as the proportion of women heading research groups was 22.6 percent at the end of 2023, and only 21.7 percent of institute directors were women.

www.mpg.de/21664905

KAMIKAZE BACTERIA

The bacterium *Yersinia entomophaga* attacks and kills insects. According to researchers at the Max Planck Institute of Molecular Physiology, it uses an unusual trick: in a kind of kamikaze-style attack, a select group of the pathogen sacrifices its life for the good of the others. The researchers observed that these bacteria undergo transformations at temperatures, nutrient ratios and cell densities that are typical of their host's internal environment. They grow larger and produce copious amounts of a deadly toxin cocktail. Upon reaching their destination—the rear midgut of the insect—

special proteins tear holes in the bacterial cell membranes, leading to their demise, but also releasing the potent toxins contained within. The toxins are then injected into the host's cells using a cannula-shaped protein complex, effectively killing them. The specialization of these cells, dubbed “soldier” bacteria by the researchers ensures that only a few individuals need to be sacrificed for the collective good of the bacterial population. Such altruistic behavior is reminiscent of the division of labor observed in bees, ants, and termites.

www.mpg.de/21414471

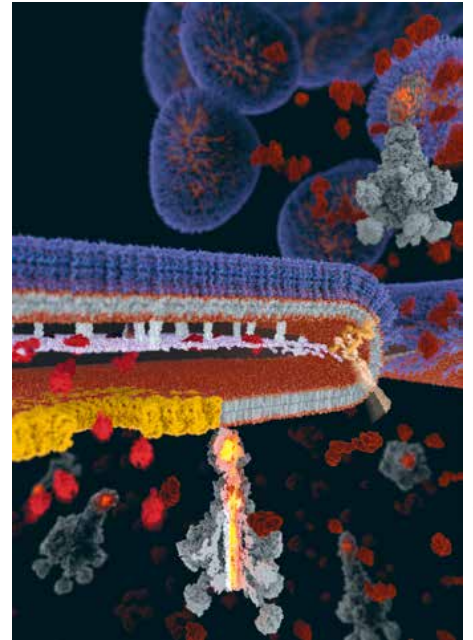


IMAGE: MAX PLANCK INSTITUTE OF MOLECULAR PHYSIOLOGY

Membrane of a bacterial cell with the injection apparatus for the toxin (gray with a yellow core)

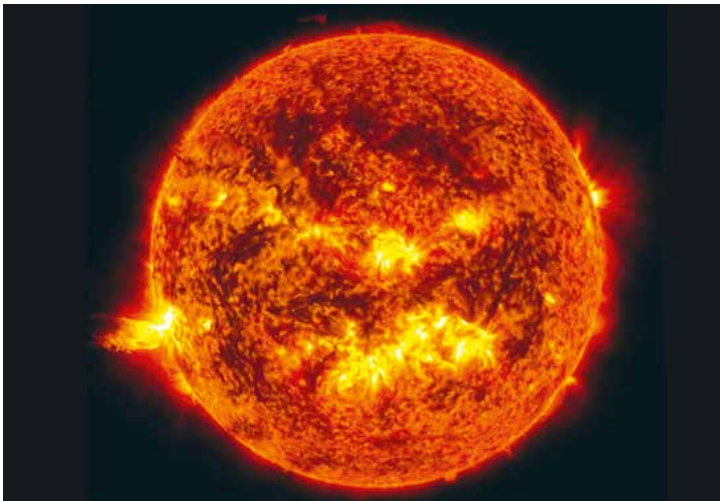


IMAGE: NASA/GODDARD/SDO

There could be a black hole inside the sun without it being visible from the outside.

BLACK HOLE AS AN ANTI-AGEING CURE FOR STARS

Black holes are typically seen as dangerous and destructive, as anything that ventures too close to them can no longer escape. The universe could harbor many of these cosmic phenomena, including tiny versions barely larger than an atom and yet as heavy as a skyscraper. However, most black holes would go unnoticed due to the vast emptiness of space and the low probability of matter coming close enough to them. It would be different if a miniature version of a black hole were to settle in the center of a star like our Sun. Researchers at the

Max Planck Institute for Astrophysics have now simulated the potential development of our Sun under these circumstances in a computer model. First of all, their models provide some reassurance. A miniature black hole would not devour the Sun abruptly. In fact, we would likely not even have noticed anything about the intruder yet. Instead, matter would gradually fall in its direction over billions of years, so that the black hole would have accumulated about 0.1 percent of the Sun's mass by the time the Sun's fuel is exhausted in a few

billion years. This mass accumulation could be significant enough to replace nuclear fusion as the Sun's energy source, thereby extending its by several billion years. Because when matter falls into a black hole, it releases gravitational energy. We do not know whether our Sun is one of these hypothetical so-called “Hawking stars”. However, it is theoretically possible to test this with the help of astroseismology, a method using acoustic vibrations to explore the Sun's interior.

www.mpg.de/21396491

“DEMOCRACY CAN BE DISMANTLED MORE QUICKLY THAN IT CAN BE RESTORED”

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Polish voters have spoken: after eight years of government by the Law and Justice party (PiS), Poland wants to stop the dismantling of its constitutional democracy. But how can democracy be restored if the nation’s president and its constitutional court are pursuing a different agenda? Armin von Bogdandy and Dimitri Spieker believe prudence, strategy, and ideas from the people are crucial.

The past years have seen a remarkable decline in constitutional democracy in several EU Member States. The recent Polish elections in October 2023 demonstrate that such illiberal developments are not a one-way street. A majority of the Polish people has tasked the new government with reversing the overhaul pursued by the PiS-led government.

This overhaul has many facets. It affects rights for women and members of the LGBTIQ+ community, free speech, media pluralism, and freedom of the press and academia. To remove possible checks and balances in this process, PiS focused in particular on dismantling the Polish judiciary. In a large-scale upheaval, the government lowered the retirement ages for judges, brought the appointment processes under its control, and sought to fill the vacant positions with loyal supporters. Remaining judges were brought into line through disciplinary measures. The conflict over the highest courts was especially dramatic. While a strong opposition of independent judges formed at some courts, the Polish constitutional tribunal was quickly captured. Today, it is hardly more than a puppet of PiS.

→

VIEW POINT

ARMIN VON BOGDANDY AND DIMITRI SPIEKER



Armin von Bogdandy is Director at the Max Planck Institute for Comparative Public Law and International Law in Heidelberg. His research concerns the foundations of public law, including the rule of law in the European Union.

ILLUSTRATIONS: SOPHIE KETTERER FOR MPG



Dimitri Spieker is a senior research fellow at the Max Planck Institute for Comparative Public Law and International Law. His research concentrates, among other things, on the basic values of the European Union.

**A MERE STROKE
OF THE LEGISLA-
TURE’S PEN WILL
NOT SUFFICE:
POLAND NEEDS A
TRANSITION 2.0.**

These measures disregarded not only the Polish constitution, but also European law. In a series of pioneering judgments, both the Court of Justice of the European Union and the European Court of Human Rights ruled that the respective measures violated the rule of law and judicial independence. Still, the Polish government stayed its course. By 2023, thousands of judges had been appointed through procedures that do not comply with European law.

The erosion of democracy and the rule of law run deep. A mere stroke of the legislator’s pen will hardly suffice to restore constitutional democracy and the rule of law in Poland. After eight years of PiS rule, a kind of transition is required that builds on the transformations of the 1990s: a Transition 2.0.

After the fall of the Communist rule, a large-scale political, social, economic, and legal transformation took place that led towards constitutional democracy in many Central and Eastern European countries, culminating in those countries joining the European Union. To become EU members, these states had several conditions to fulfil. These included the “Copenhagen criteria,” meaning democracy, the rule of law, and fundamental rights.

Later they were codified as common values of the Union and its Member States in Article 2 of the Treaty on European Union. Despite those requirements, however, the transitions of the early 1990s remained relatively unconstrained by international or EU law: even if naturally seeking inspiration and assistance from abroad, each country had considerable latitude in deciding how to deal with its past and how to shape its constitutional and legal future.

Unlike these processes, a Transition 2.0 will be embedded in a much stronger European context. The respective states are members of the European Union and the Council of Europe. The Member States are part of one European society, one that is characterized by the common values enshrined in Article 2 TEU: democracy, the rule of law, and fundamental rights. If these principles come under pressure in one Member State, the entire European society is affected. Accordingly, the Union’s law and institutions have a central role to play.

In this spirit, the EU institutions sought to counter illiberal developments in the Member States. In response to these challenges, the EU’s legal toolbox has considerably evolved. Freezing EU funds – unthinkable a few years ago – is now an accepted form of leverage to force national governments to comply with European values. The same is true for the protection of these values before the European Court of Justice.

EUROPEAN LAW PLAYS A TWO- FOLD ROLE: IT SUPPORTS AND CONSTRAINS A TRANSITION

However, the EU's mandate is not limited to taking action against a Member States' disregard for common values. It also has a role to play when a Member State decides to change course and restore compliance with these values. This role is twofold: first, EU law limits the new government's room to maneuver. Second, it can support a democratic transition, for instance by weakening the power of the PiS-controlled constitutional tribunal. This uncharted legal territory was explored by the Max Planck Institute for Comparative Public Law and International Law together with a group of predominately Central and Eastern European lawyers, among them Poland's new minister of justice, Adam Bodnar.

To start with, European law places constraints on reform processes. The procedures in which the new majority take action against laws, appointments, and measures that violate European values must themselves respect these values. This requires adherence to the principles of legal

certainty and legality, which are also an inherent part of the rule of law guaranteed as a common value under Article 2 TEU.

Particularly grave or intentional breaches of national law can amount to systemic deficiencies in the rule of law which, in turn, can violate the Union's common values. When assessing the overhaul of the Polish judiciary, for instance, the EU institutions took into account that these measures were adopted in open violation of the Polish constitution. In consequence, they constituted an infringement of the rule of law protected by Article 2 TEU.

For the new Polish government this means that the restoration of democracy and the rule of law must take place in a legitimate manner, namely in compliance with national law. As such, the current situation calls for nuanced solutions, which are not only politically and practically feasible, but which also respect national and European requirements. Put differently: Democracies can be dismantled more quickly than they can be restored.

Against this backdrop, it would appear highly problematic if the new majority simply dismissed all judges who were appointed or promoted under the former government. Even if these persons were appointed through unlawful proceedings, this does not automatically mean, as some Polish voices maintain, that they are not judges. It is also necessary to consider that these judges have made thousands of rulings whose validity could then be questioned. Such a radical move is hardly compatible with the principle of legal certainty.



This leads to a further challenge. The new Polish government does not have the necessary majority to amend the constitution. Therefore, any restoration of the democratic rule of law must take place through ordinary laws. These laws require the president's cooperation, who is a supporter of PiS, and could fail before the constitutional tribunal, which is dominated by PiS-friendly judges.

This raises several questions. Can the court not simply be packed with new, independent judges? Unlikely. The number of judges and the duration of their terms of office are enshrined in the Polish constitution. Without a majority to amend the constitution, these rules cannot be changed. As long as these judges were appointed in compliance with the constitution, they cannot simply be dismissed. Instead, they will remain in office until the end of their terms. Additionally, premature substitutions on the bench would contradict the very value the new government seeks to protect—judicial independence. Finally, court packing, i.e., creating additional positions at the respective court and filling them with new judges, as often discussed in relation to the US Supreme Court, harbors considerable risks too. Such measures can further erode the court's neutrality and authority in the eyes of the public. No matter how much it is striven for, the restoration of constitutional democracy does not justify any violations of Polish law. An essential principle of the rule of law is that the ends do not justify the means. Therefore, the democratic transition must be pursued in legal ways.

If there were to be a breach of law, members or supporters of the previous government forces could initiate proceedings in domestic courts. Should they reach the European Court of Justice, it would be forced to concede that they are right, regardless of the fact that the PiS-led government was responsible for the dismantling of the democratic rule of law. The Court's decisions on the overhaul of the Polish judiciary have led the former government to accuse the Luxembourg judges of ruling according to their liberal sympathies. The Commission could find itself in a similarly difficult situation: if it wants to counter accusations of bias and double standards it cannot remain inactive. The Commission would then have to initiate infringement proceedings against the new Polish government on the grounds of violations of the rule of law.

Nonetheless, EU law does not leave the new government in the grip of the previous one. On the contrary, it can even support the transition. The new majority should focus on particularly grave violations. That is because only especially serious, persistent, or intentional violations of democracy, the rule of law, and human rights constitute an infringement of the Union's common values in Article 2 TEU. However, not all decisions, appointments, and measures adopted by the previous government will meet this requirement.

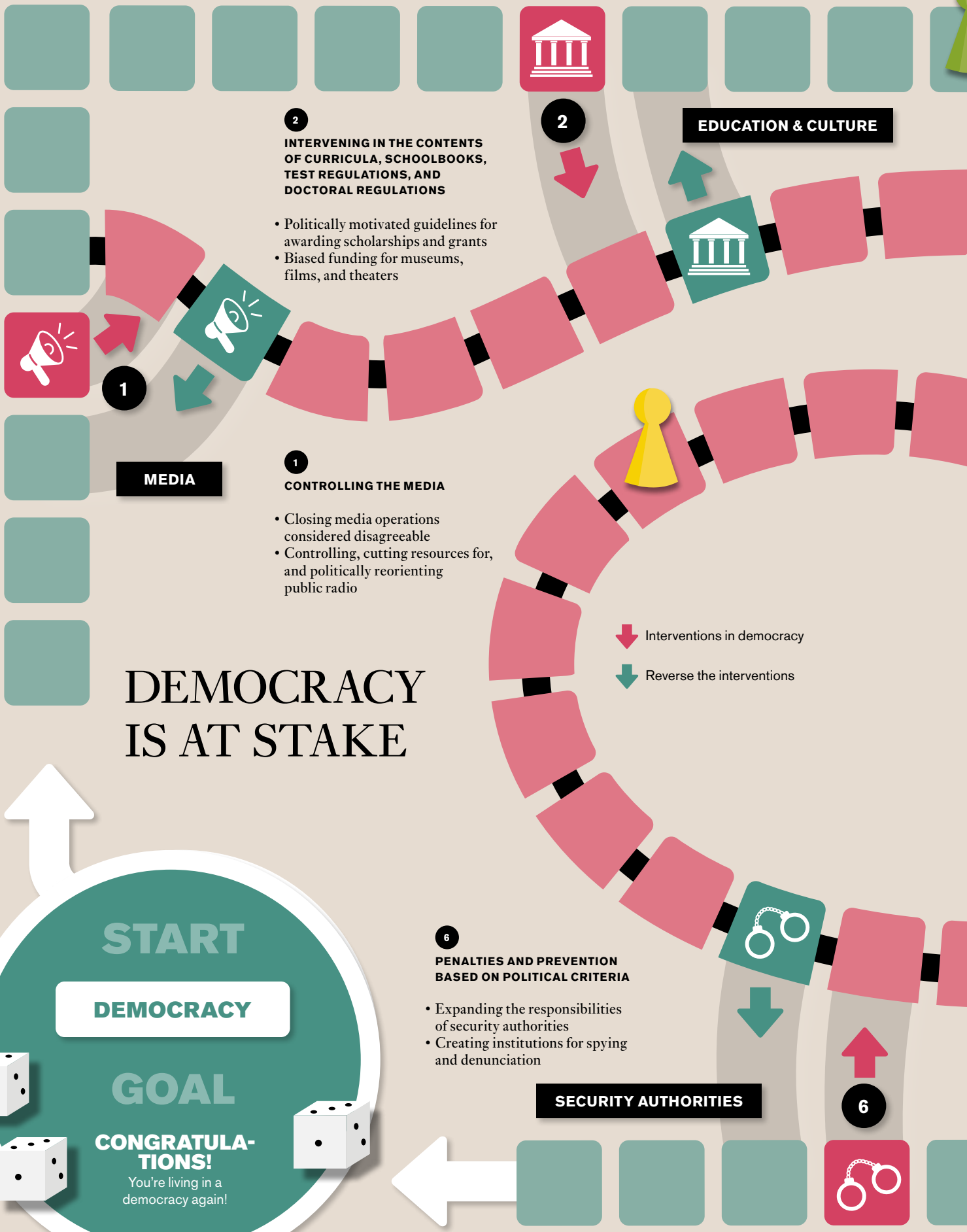
PARTICIPATION OF THE PEOPLE CAN BE A DRIVER OF THE TRANSITION

What is the consequence if the government identifies such breaches? EU law – and thus Article 2 TEU – has primacy over the law of the Member States, including their constitutional law. If national law breaches EU law, the respective national provisions must be disapplied. In other words, all state authorities – courts, the executive and the legislature – must disregard such laws. The same applies to decisions rendered by a constitutional court that are in breach of EU law. They must be disregarded as well. Owing to the primacy of EU law, acts that violate the Union's values in Article 2 TEU would not be applicable and would no longer pose an obstacle for the democratic transition.

Again, a highly prudent application of the relevant legal bases, standards, and procedures is required here. To ensure smooth operation, Poland's new government should coordinate with the European Commission for Democracy through Law. This expert committee, better known as the Venice Commission, advises the Council of Europe on issues concerning constitutional law and has great expertise in supporting democratic transitions. Thus, the committee can foster and legitimize the Polish transition through corresponding evaluations, which it can issue at short notice.

At the same time, it is essential to learn from the past. The Transition 2.0 must not repeat the mistakes of the Transition 1.0. Many lament that the transitions of the 1990s were carried out too technocratically. As such, these processes lost sight of promoting a democratic culture in the respective states. This shortcoming could be countered with stronger public participation. There is an appropriate format for doing so: the Conference on the Future of Europe, which was held between 9 May 2021 and 9 May 2022 with astounding success – including in Poland under the PiS-led government. This format allows the people to get involved in the restoration of an independent judiciary. Importantly, it could generate interesting ideas, counter accusations of technocratic decision-making with little democratic accountability, initiate a non-partisan dialogue, and put PiS in a difficult position: either the party boycotts the conference and, by doing so, demonstrates that it is not interested in improving the judiciary, or it participates, thereby endorsing the legitimacy of this process.

←



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MEDIA

EDUCATION & CULTURE

SECURITY AUTHORITIES

2
INTERVENING IN THE CONTENTS OF CURRICULA, SCHOOLBOOKS, TEST REGULATIONS, AND DOCTORAL REGULATIONS

- Politically motivated guidelines for awarding scholarships and grants
- Biased funding for museums, films, and theaters

1
CONTROLLING THE MEDIA

- Closing media operations considered disagreeable
- Controlling, cutting resources for, and politically reorienting public radio

6
PENALTIES AND PREVENTION BASED ON POLITICAL CRITERIA

- Expanding the responsibilities of security authorities
- Creating institutions for spying and denunciation

DEMOCRACY IS AT STAKE

START

DEMOCRACY

GOAL

CONGRATULATIONS!

You're living in a democracy again!

↓ Interventions in democracy

↑ Reverse the interventions

PARTIES & ELECTIONS

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3

REJECTING CONSTRUCTIVE, NONPARTISAN COOPERATION

- Manipulating elections
- Contesting the results of elections

ADMINISTRATION

4

4

REALIGNING THE ADMINISTRATION

- Restructuring and firing employees found to be disagreeable
- Politically motivated staffing of positions

5

INTERVENING IN THE JUDICIARY

- Discrediting and ignoring rulings that are considered to be disagreeable
- Politically motivated restructuring of the judiciary
- Creating political control mechanisms

JUDICIARY & COURTS

5

DICTATORSHIP/ AUTOCRACY

TOUGH LUCK!

You now live under a dictatorship and have lost many of your freedoms!

FOCUS

(UN)FREE

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34 | PURE FREEDOM



Protest through clay: In Russia, anonymous street artists create clay figures that say forbidden things. The two on a bridge railing in Moscow demand “Stop killing children” (left). And “Stop bloody Vlad.”

PHOTO: ALEXANDRA ARKHIPOVA, YURI LAPSHIN (2023): “NO WOBBLE,” V. 1.0, DISCUSS

THE ART OF QUIET CRITICISM

TEXT: TANJA BEUTHIEN

Repressions and censorship in Russia are having an effect: people need to find new ways to protest. Artists who express criticism are making use of a variety of imaginative aesthetic tactics from the Cold War era. At the Kunsthistorisches Institut in Florenz, Hana Gründler and her team are researching how art in Eastern Europe circumvents authoritarian structures and opens up spaces of freedom – then and now.

It is spring in Saint Petersburg, the end of March 2022, and artist Aleksandra Skochilenko is entering a supermarket. The “military special operation” in Ukraine, as it is referred to by the Kremlin, is in full swing, but nobody can mention war. Skochilenko takes a look around, pulls some price labels from their holders, and replaces them. Instead of a special offer for instant coffee, there is now an entire sentence: “The Russian army bombarded an art school in Mariupol where approximately 400 people had been hiding from the attacks.” And: “Military action causes record inflation.” Or: “Stop the war!” A few days later, the draftsman and musician is arrested. She is charged with “disseminating deliberately false information about the Russian military forces” – a statutory offense in the Russian criminal code designed to silence critical voices.

Russia’s repression of its own population has intensified since the attack on Ukraine. According to Russian non-government organizations, since the new paragraph was introduced, over 250 people have been criminally prosecuted – and over 800 have been persecuted due to anti-war activities. Organized political opposition was defeated long ago, and Kremlin critic Alexei Navalny met his death in a polar penal camp.

The situation is similar in other successor states to the Soviet Union. For example, according to the UN, approximately 1,500 political prisoners are currently imprisoned in neighboring Belarus. But how are resistance and critical art possible when artistic direction action can be sanctioned with drastic punishments? Hana Gründler, Research Group Leader at Kunsthistorisches Institut in Florenz – Max Planck Institute, and her team are researching how art and philosophy can be understood as subversive practices in repressive systems, focusing on Eastern Europe. “When does art have disruptive political power, and how do we define the concept of ‘the political?’” Gründler asks.

“The public sphere has always been an ambivalent intermediate zone in totalitarian countries,” says the image historian and philosopher. Satellite states of the Soviet Union, such as Hungary, Czechoslovakia, and the former GDR, were tightly merged under the Warsaw Pact until 1991. The socialist countries were under Moscow’s rule and forced into line. Their inhabitants were often subjected to spying and political persecution. Soviet troops violently put down attempts at reforms, such as the Hungarian Revolution of 1956 and the Prague Spring of 1968. Protest was extremely difficult.

In the repressive climate of the 1970s, the Czech artist Jiří Kovanda and others began using the rigorously monitored public space for direct action through the medium of art. Much as Aleksandra Skochilenko sought to use the supermarket as a site for her direct actions, Kovanda used the pedestrian zone of the city in his day. With his arms spread out, he positioned himself in Wenceslaus Square in Prague. Passersby were forced to walk around him and turned around to look at him.

In this action and others, he became a disturbing element in the city’s hustle and bustle, an inexplicable obstacle, an irritation. In doing so, Kovanda did not explicitly evoke the invasion of the Soviet troops or the tanks in Prague’s city center. Nor did he reference the suicide of the 20-year-old student Jan Palach, who poured gasoline over himself and set himself on fire in January 1969 to protest the invasion and repressions of the Soviet occupants. Jiří Kovanda’s performance was subtle. And visible only to those who stopped and watched the artist. An act of resistance with his own body.

“In the phase of so-called normalization in the ČSSR, these performances took place under extremely difficult and risky conditions. However, the artists always defended themselves against overly catchy, one-dimensional political interpretations,”

Gründler explains. They resorted to small gestures when big ones were not possible. Afterwards they disseminated them with photos or critical writings via Samizdat (an underground system of copying and distributing self-published, non-conformist texts) – and also in the West. “Many artists emigrated; there were channels that were used to make documentation of these kinds of direct actions and performances known. For instance, exile magazines and art magazines like *Flash Art* or exhibitions in Germany and France. The Iron Curtain was more permeable than people thought.”

Nowadays the Internet serves as a multiplier for direct action. For example, in April 2022 photos were published of a person lying bound and gagged at different locations in Moscow in order to remind people of the cruel acts Russian soldiers committed against civilians in Bucha. But there are more subtle forms of artistic and civil resistance that, consciously or unwittingly, draw on the aesthetic practices of the 1970s. The critical community is increasingly using art and graffiti in public spaces to illustrate the unspeakable and then share it in networks. The website “No wobble!” (<https://nowobble.net>), for example, documents anonymous anti-war street art in Russia. Among other

SUMMARY

Since the ambush on Ukraine in February of 2022, the pressure on the civilian population and art scene in Russia has increased once again.

Image historian and Max Planck researcher Hana Gründler explores art, culture, and philosophy as resistant practices under repressive regimes in Eastern Europe since 1945 together with her team in Florence.

Artists are once again using the subtle forms of protest from the past and re-interpreting them.

IMAGE: RICHARD UUTMAA, PUUSE BAY, OIL ON CANVAS, AROUND 1955, KUMU ART MUSEUM, TALLINN



Provocation through nostalgia: the symbols of Stalinism – progress, work, and order – are absent from Richard Uutmaa’s painting from around 1955. Leisure reigns in their place. An idyll instead of bustle and activity.

IMAGE: ZORKA SÁGLOVÁ, JAN SÁGL, KLADENÍ PLIN U SUDOMĚŘE (LAYING OUT NAPKINS NEAR SUDOMĚŘ), ACTION, 1970



Criticism through fabric: with her land art action of 1970, Zorka Ságlová evoked a legend from Czech history from the year 1420, according to which Hus-site women laid clothing down on the muddy bottom of a pond so that the enemy’s horses would become entangled in the fabrics. Ságlová represents quiet protest by women.

things, it shows Lego figures holding white papers in the air and thus evoking the White Paper Protests. There are also clay figures bearing a sign with the words “Нет Войне” (“No to war”), or simply a carp that has been crossed out: here the word “vobla” (carp) replaces the nearly homonymous word “voina” (war).

It seems playful – and powerless. “They look like harmless gestures. But in an oppressive system, they are extremely potent signs,” says Gründler. “There are aesthetic practices of the unofficial culture of the underground that question everyday processes. Many artistic

approaches motivate spectators to question their own view of reality. Similar to grassroots movements, they transform the beholder’s perception, and this, in the end, could lead to changes in political reality as well.” Hana Gründler does not speak of a lack of freedom of art. Instead, she believes that “art opens up spaces of freedom.”

One example from the past that Hana Gründler mentions is a collage by the Czech artist and poet Jirí Kolář. It shows a cutout of an iconic press photo: a burning streetcar that was photographed near the Czechoslovakian radio station on August 21, 1968 during the invasion of the



Soviet Troops. On top of it, Kolář attached a hand presenting a portrait of Dante Alighieri – a poet who refused to be silenced by authorities and was forced into exile for political reasons – much like Kolář hundreds of years later, who took French citizenship. “This isn’t agitprop or political art,” says Gründler. “During the era of socialist realism, art was expected to represent reality ‘correctly’ and without political ambiguity. In contrast to this, artists like Kolář insisted upon the complexity and ambiguity of their living environment. They turned fantasy, which was tabooed by the state artistic doctrine, into a highly effective instrument for raising awareness.” It is important to be able to “read between the lines.”

Deciphering a painting by the Estonian painter Richard Uutmaa also requires a good deal of imagination. Oliver Aas, doctoral fellow in Gründler’s research group in Florence, mentions it as an example of subtly subverting the dominant narrative. At first glance, the painting of Puise Bay (1955) appears to be nothing more than a “banal” landscape. However, in the cultural context of that period’s Stalinism, it becomes an egregious provocation: a non-political, purely aesthetic depiction of a landscape that could not be more political.

The importance of beginning on a small scale

The artist Zorka Ságlová also questioned common patterns of narration when she laid out 700 white napkins in a field in Bohemian Sodoměř in 1970. Her land art performance evoked one of the most famous battles in Czech history from the year 1420. Legend has it that the leader of the Hussites, Jan Žižka, and Hussite women decided to lay out clothing on the muddy bottom of a pond so the horses of the Catholic nobility would become entangled in the fabrics. “The Communists appropriated this story about the Hussites and perpetuated it as an extremely heroic, masculine narrative. Ságlová instead, reinterpreted it. She showed how women brought down an entire army of knights and thus hints at feminine, supposedly unheroic forms of resistance,” says Gründler.

But how effective are these kinds of artistic practices? How do such actions resonate with the public? “At the time, Ságlová’s performance probably went largely unnoticed outside of a small circle of unofficial culture,” Gründler explains. “However, as Václav Havel has shown, it is significant even if only a couple of people change their opinions in such a repressive system. It’s



Protest through information: instead of naming prices, Aleksandra Skochilenko’s labels in a supermarket in Saint Petersburg address the war in Ukraine, for example: “20 – Putin has used television to lie to us for 20 years. The result of these lies: our willingness to justify a war and senseless deaths.” Or: “4300 – Stop the war. In the first three days, 4300 Russian soldiers fell. Why is this not reported on television?”

important to start on a small scale: like the vegetable merchant from Havel’s essay “Power of the Powerless,” who does not hang a banner in his shop window on May 1 and thus refuses to give space to the official rhetoric. It is bottom-up strategies that help overcome civil society’s passiveness and that can lead to an ethico-political transformation.”

In former Czechoslovakia, history has proven the artists and dissidents right. In 1989, as in other countries of the “Eastern Bloc,” the predominately non-violent Velvet Revolution took place. The dramatist Václav Havel played an important role in it. “This sharp critic of the regime spent several years incarcerated as a political prisoner, where he wrote letters to his wife, Olga, every week. The Letters to Olga are expressions of hope and humanity in dark times and have special relevance again now, at a time in which many artists and oppositionists are imprisoned,” says Hana Gründler. “From our safe vantage point, we need to understand the kinds of dangers artists are currently exposing themselves to in Russia and Belarus.” Artists like Ales Pushkin, who emptied a wheelbarrow full of manure in front of Alexander Lukashenko’s presidential administration in Minsk in 1999 and was briefly imprisoned. He repeated the performance in Kiev in an exhibition in 2021. And, even though he was facing criminal proceedings, he returned to Belarus. Shortly after, he was sent to prison on the grounds of “denigrating state symbols.” He died there in the summer of 2023 under mysterious circumstances, much like Navalny.

Or Aleksandra Skochilenko, who was sentenced to seven years in prison for her supermarket-based direct action in November of last year. “In March of 2022, the war was a ‘special operation’. But Skochilenko called it by its real name,” says Gründler. According to information from Amnesty International, the 33-year-old is still in a detention center in Saint Petersburg awaiting her appeal hearing, despite suffering from several chronic illnesses. The human rights organization says it is unlikely that she will receive a fair trial. She can only hope for humane treatment during her sentence.

According to media reports, during her pretrial detention Skochilenko has meanwhile written in a letter that she embodies everything “that is insupportable for Putin’s regime: creativity, pacifism, LGBT, psychological enlightenment, feminism, humanism, and love for everything that is bright, ambiguous, and unusual.”

In prison for the truth

At this time, it cannot be foreseen whether and how the repressions in Russia will be further intensified after the election in March. Last year, the administrations in art museums across the country were staffed with people close to the state, observes art historian Sandra Frimmel from the University of Zurich. There is currently no reliable artistic state doctrine, “no canon of what is allowed, but rather a canon of what is forbidden.” All institutions and forms of art, whether circuses, theaters, or museums, should represent “state values.” Disparagement of military forces, religious symbols, and “homosexual propaganda” are generally forbidden. Even the rainbow, which could be read as an LGBTQ+ symbol, is on the list. Until recently, the national conservative party Law and Justice in Poland pursued a similar policy during its eight-year term of office from 2015 to 2023. In her research, Magdalena Nieslony, who was a visiting scholar in Hana Grün-

der’s team, shows how “cultural politics became a central battleground of indoctrination” under the right-wing government. That is now changing under the new government of Premier Donald Tusk. At the Biennale in Venice in 2024, the Ukrainian collective “Open Group” will display a performance video in the Polish pavilion. The contribution by a right-wing artist was withdrawn in January.

In Russia, in contrast, it is now important to “create solidarity networks, smaller and trust-forming measures that build up hope and bridge gaps,” says Alexander Borodikhin, journalist and publisher of “Mediazona,” one of the largest Russian oppositional media. “The general demobilization and desensitization of recent decades has induced a certain learned helplessness,” according to Borodikhin. In his view, artistic protest should not be viewed as a practicable means that can be used to question the existing order. “Art can be a way of reinvigorating connectedness – not a battering ram, as some dissidents hope.” It is a tactic involving small steps, one which artists have used for decades. After all, as Hana Gründler puts it: “Art does not have to be unequivocally political. But as micro-ethical practice, it opens up possibilities to think differently.” And, in the end, changes in perspective have inspired revolutions in the past.

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

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Penal camp for messages against the war: even though she was facing ten years of imprisonment on the grounds of “disseminating false information about the Russian military,” Aleksandra Skochilenko replaced price tags with anti-war messages in a supermarket in March of 2022. In November of 2023 she was sentenced to seven years of imprisonment in a camp.

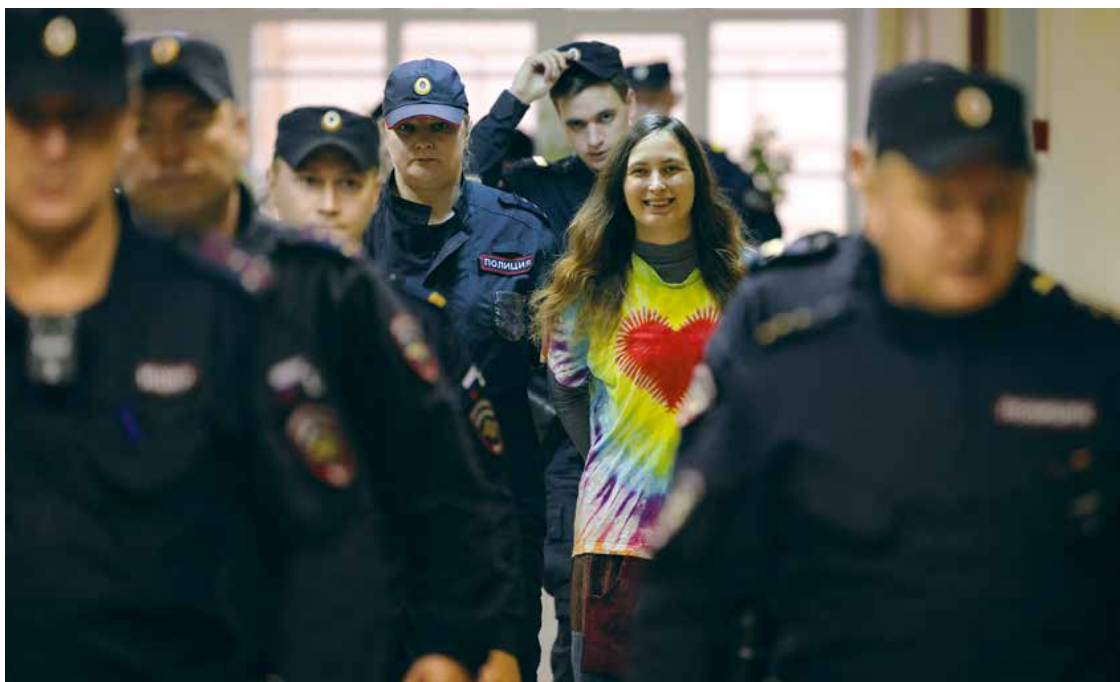


PHOTO: PICTURE ALLIANCE / REUTERS | ANTON

In the echo chamber: Social media benefits from bringing like-minded people together at the expense of diversity of opinion.



IN THE ECHO CHAMBER

TEXT:
SABINE FISCHER

Studies show that the louder political minorities shout on social networks, the quieter the democratic majority becomes. Hate, hate speech, and propaganda thrive in echo chambers and distort perceptions in political discourse. Researchers investigate this phenomenon from the perspective of social science, law, and mathematics.

It's noisy up at the lectern of the German Bundestag. When Beatrix von Storch (Alternative for Germany, AfD) rails against the Green New Deal or her AfD colleague René Springer calls for "mass remigration," hardly a second passes without another shout of opposition echoing through the chamber. These include loud arguments from the ranks of the other parliamentary groups, indignant rebuttals, and requests to hurry up and get the speech over with. In contrast, there are hardly any objections in the comments section of the the AfD Bundestag parliamentary group's TikTok profile. There, where excerpts of these speeches are posted, the community often appears united in the sentiment: finally, someone has the nerve to come out and say it.

Emotional and provocative

These posts are dominated by shrill statements that the party's social media team display prominently in the middle of each video: "We need Fortress Europe!," "Citizens are being ripped off!," "How stupid can you be?!" These loud slogans in black lettering on a white background appear serious at first glance, which is what makes them all the more dangerous.

30 The statements that generate a lot of agreement in the AfD community are in fact extreme exaggerations devoid of context that cannot be verified – a form of propaganda that works particularly well on social media: "The posts by the AfD parliamentary group are a good example of how such content works on social platforms," says Philipp Lorenz-Spreen, who studies self-organized online discourse and its effects on democracy at the Max Planck Institute for Human Development. "TikTok is optimized for short, bombastic content that attracts people's attention in a matter of seconds. The algorithm rewards such provocative, emotional content and displays it frequently."

The AfD seems to have understood the formula: its posts regularly reach hundreds of thousands of people on TikTok – numbers that other parties represented there can only dream of. Many of them have long underestimated TikTok's potential and reach. Posts from the CDU and SPD parliamentary groups only average in the low five-digit range. The consequences are dire: hate speech, populism, and propaganda find their way onto countless users' feeds – and at first glance, they're often hard to see for what they truly are. How do algorithms influence the way we form opinions? Is it even possible to move and make decisions freely on social media? Lorenz-Spreen is very skeptical. He maintains that the idea people can move freely on social media platforms is an illusion: "Everything that you see on your feed or that is brought to your attention is predetermined and constructed by the platform. There is no such thing as a neutral space. The fact that users are

entering a space that limits their freedom of choice when they access their profile on Instagram, Facebook, or TikTok remains invisible to them at first. "There's a massive lack of transparency," Lorenz-Spreen explains. "As users, all we see is a nice, smooth interface. We have no information about how and where the content we see comes from, or why it's shown to us instead of other content. Information about why content is displayed on our feed and where it actually comes from is usually simply unavailable. This is a trap that even the most observant among us can't escape.

But it would be difficult for the platforms to create more transparency, says Lorenz-Spreen. "For example, if we as users were constantly shown how the algorithm

A researcher goes online:
Philipp Lorenz-Spreen explores the roots of
hate and disinformation on the internet.

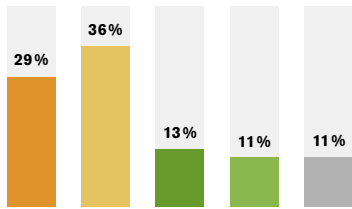


PHOTO: GESINE BORN FOR MPG

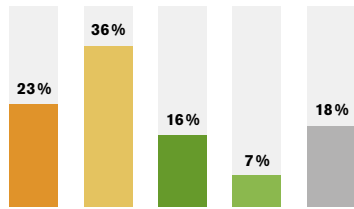
Hate and hate speech on social networks is on the rise and is silencing majorities. This is what the Jena Institute for Democracy and Civil Society found in an online survey of 7,349 people aged 18 and over in Germany.

WHAT DO YOU THINK ABOUT THE FOLLOWING STATEMENTS?

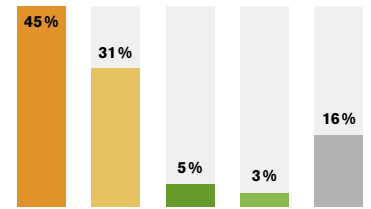
I'm surprised by how many people agree with hateful comments on some topics.



Public online hate has changed what you can and cannot say outside the internet.



Aggressive and derogatory comments have increased online in the last four years.



Agree Somewhat agree Somewhat disagree Disagree No answer

Source: IDZ

GRAPHIC: GCO, ADAPTED FROM THE INSTITUTE FOR DEMOCRACY AND CIVIL SOCIETY (IDZ)

works in the background, it would overwhelm us and disrupt our user experience.” He sees a solution in gamified approaches: “Platforms could allow users to modify the algorithm themselves and experience the consequences. For example, if you could set your preference to show more political content, you would simultaneously develop an awareness of the fact that content is pre-selected.”

However, commercial platforms have their own agendas: to be commercially successful, they need to keep their users engaged for as long as possible. Attention becomes a currency. And to ensure that this currency is spent in the highest possible installments, social media exploits the human need for entertainment and validation. After all, who doesn't like to spend time in a place where they feel comfortable and entertained? Unfortunately, this leads to the creation of social echo chambers on these platforms. “People are social creatures and like to surround themselves with others who share similar views. We are homophilic and strive to maintain a coherent worldview. This is why groups of people with similar views often form around those views,” says Lorenz-Spreen. Social networks act as a catalyst, he continues. “In this way, platforms satisfy their commercial need to engage users for as long as possible, and at the same time promote the formation of social echo chambers.” However, people are more susceptible to phenomena such as propaganda, hate speech, and misinforma-

tion in spaces where their own worldview is confirmed from all sides: “One explanation for this is false consensus, which is the feeling that thousands of people agree with you and you believe yourself to be the majority,” says Lorenz-Spreen. This is also a problem for democracy: “Social echo chambers are not conducive to a culture of debate,” says Lorenz-Spreen.

Visualizing the public sphere online

This finding can even be measured: at the Max Planck Institute for Mathematics in the Sciences in Leipzig, Eckehard Olbrich is researching the influence of social media on democracy and the visualization of the digital public sphere. The Odyceus project, a HORIZON 2020 project coordinated by Olbrich, has developed tools to measure the prevalence of echo chambers on social networks. “One empirical finding was that echo chambers are not closed. There can be an exchange between the individual camps – though this exchange can be quite hostile,” he says. For example, Olbrich and his team used clusters to examine the interaction between left-wing and right-wing networks on X (formerly Twitter) in a case study in Saxony. “We found that right-wing accounts react more actively to left-wing content than vice versa.”



What are the consequences of echo chambers for individuals – and society? According to Germany's Federal Statistical Office, about a quarter of all internet users were exposed to hate speech last year. A study by the Institute for Democracy and Civil Society (IDZ) examined the effects of hate and hate speech on those affected and on public dialog. Their finding: approximately two-thirds of those who have experienced hate speech report negative effects such as emotional stress, fear, anxiety, and depression. People who come into contact with hate speech online are also intimidated and sometimes excluded from public dialog. In a study published in 2024 by the Kompetenzzentrum gegen Hass im Netz (Competence Center against Hate on the Internet), about half of those surveyed said they were less likely to participate in online discussions and more likely to hide their political opinions as a result of hate speech.

This has serious implications for society as a whole. Together with Lisa Oswald, Stephan Lewandowsky, and Ralph Hertwig, Philipp Lorenz-Spreen investigated how the use of social media affects democracy. The research team analyzed around 500 scientific articles that show correlative and causal relationships between social media use and political behavior. Their finding: social media has both positive and negative effects on democracy. It increases political participation, motivates more people to take part in protests and civic engagement, and makes it easier compared to other media for people to receive information on par with their level of education. But there are drawbacks as well. "We see a lot of negative correlations between trust in democratic institutions and the use of social media. The more people use social media, the less trust they have." The exact cause, they say, needs to be the subject of further research, but it is clear that trust in institutions is a cornerstone of a functioning democracy.

The study also shows that social media encourages propaganda and populism: "Populist parties are particularly successful on social media platforms, and this carries over into the offline world. This is linked to trust in state institutions themselves. The lower the level of trust, the easier it is for populism to create enemy stereotypes." On social media, this works particularly well through short-form content and the feeling of group cohesion in social echo chambers. All in all, Lorenz-Spreen sees cause for concern: "When we look at these results, especially knowing that democracies

around the world are in crisis right now, I see a big question: how do we deal with this?" How do we tame the beast that is commercial social media platforms? Can negative effects such as propaganda, misinformation and hate speech be contained?

According to Johanna Rinceanu, Senior Researcher at the Max Planck Institute for the Study of Crime, Security and Law, these efforts have not been all that successful so far: "An aggressive tone often characterizes the new debate culture taking place online (Verrohung der Debattenkultur) that has yet to be contained," says Rinceanu. There are problems in many areas. For example, the speed of technological development makes legal regulation difficult. "The internet develops at the speed of light, while legislation moves at a snail's pace and can't keep up," explains Rinceanu. Moreover, attempts at regulation are always caught up in the conflict between freedom of expression and protection against hate speech and incitement to hatred. Legal interpretation is difficult. Since hate speech, for example, has no legal definition, it has to be decided on a case-by-case basis whether statements constitute incitement to hatred (Volksverhetzung) and are therefore subject to criminal law, or whether they fall under free speech.

It is hard to find a legal framework for this dilemma. The latest attempt is the Digital Services Act (DSA), which since February has regulated how online platforms within the European Union are required to handle hate speech, fake news and the like. The "notice and action" model is used to determine which posts might actually be punishable: users can report potentially criminal content to platforms, who are then obliged to review it and remove it if necessary. The

SUMMARY

Freedom on social media is an illusion: the algorithms used by commercial platforms create an artificial space. This space dictates what content appears on users' feeds – in a way that usually goes unnoticed.

The creation of social echo chambers and the reward system of algorithms make social media users particularly vulnerable to propaganda, hate speech, and misinformation.

Using social media has been shown to have a negative impact on trust in democratic institutions and to promote propaganda.

“Hate and hate speech on the internet are symptoms of a societal disease.”

JOHANNA RINCEANU

platforms are also required to report certain criminally relevant content to the authorities.

Until the Digital Services Act came into force, this was done in Germany on the basis of the Network Enforcement Act (NetzDG). This legislation was seen throughout Europe as a blueprint and served as the basis for the new EU standard. For Rinceanu, however, this initiative was a failed attempt to combat hate speech and incitement to hatred online. She maintains that the desire to send a political signal in opposition to online propaganda and hate was well-founded. However, the law was passed too quickly and was not well thought out. For instance, it obliges private companies such as social media platforms to decide within a short period of time (between 24 hours and seven days) whether content is criminally relevant or not. “This is not the job of private individuals; rather, it is the job of the judiciary,” criticizes Rinceanu. Due to the short deadline for removing illegal

posts and the large amount of content, platforms have little time to adequately review it. “Although artificial intelligence and algorithms can help with this task, these systems are not yet able to detect many nuances. For example, am I posting an article in order to criticize it, or because I agree with the content and want to share it? Ultimately, these things always have to be evaluated by a human being.” But employees of private companies are not up to the task. Rinceanu summarizes the result: “The concern that the NetzDG would lead to an excessive amount of content being deleted and reported was absolutely justified, given the developments during the last five years.” She refers to other countries that have adopted the regulation. “Among them were many so-called ‘defective democracies’ and autocratic systems, such as Kenya and Belarus. In order to manipulate elections, the regulations were then used to ensure that content, for example, had to be taken down.”

The Digital Services Act, which holds both large and small online providers accountable, gives Rinceanu hope. She welcomes the fact that the regulation no longer imposes a specific time limit for removing posts. This gives platforms more time to properly review content. In addition, only content that poses a threat to people’s lives or personal safety, such as death threats, needs to be reported to the authorities. “We now need to see whether the Digital Services Act is merely a beautification or whether it will actually help to ensure that social media platforms are effectively regulated,” she says.

A lawyer goes online: Johanna Rinceanu examines which regulations can curb hate on the internet.



PHOTO: JESSICA ALICE HATH

A prominent application is the European Commission’s case against TikTok for shortcomings in protecting minors, lack of transparency in advertising, and lack of access to data for researchers. TikTok’s risk management regarding addictive design and harmful content is also under scrutiny. “Protecting children and young people is a top priority when regulating social media platforms. It is not surprising that the EU is now investigating what risk assessments and measures TikTok, as a very large online platform with over 135 million monthly users in the EU, is taking to prevent the risk of behavioral addiction and radicalization,” says Rinceanu. Violating the DSA can be expensive: TikTok could be fined up to six percent of its previous year’s global revenue if the European Commission finds it at fault. As yet, it’s unclear when the case will be concluded.

It remains to be seen whether an EU regulation will be enough to bring hate speech and incitement to hatred under control. In order to make a long-term difference, Rinceanu believes that regulatory efforts need to start much earlier: “Hate speech and the like are symptoms of a societal disease, and we must first unveil the underlying structures and dynamics in order to better distinguish between symptoms and causes. That is the only way to make a meaningful diagnosis and find the best form of therapy.”

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

HP protest: Police counted more than 2500 tractors at the Nuremberg fairground on January 12, 2024, during a demonstration against the planned abolition of agricultural subsidies.



PURE FREEDOM

TEXT: NINA SCHICK



PHOTO: NEWS / MERZBACH

Farmers' protests, democracy demonstrations, and pro-Palestinian assemblies: Germany is experiencing a wave of demonstrations like never before. At the same time, surveys show that many people feel they are not free to express their opinions. Wrongly so, says legal expert Ralf Poscher of the Max Planck Institute for the Study of Crime, Security and Law.

Large and green, a farmer's John Deere tractor sits at the on-ramp to the A10 highway near Berlin. "If the farmer dies, the country dies," reads a wooden pallet mounted on the radiator. It is allowed to stay here, the Berlin-Brandenburg Higher Administrative Court has ruled, and does not have to move after half an hour, as the police wanted. But it does have to make way for emergency vehicles. Next to and behind it, more tractors with protest slogans – green, huge and powerful. For days and weeks, they and others like them have blocked Germany's freeways, city centers and country roads.

75 years of freedom

"Freedom of speech (Article 5 of the Basic Law) and freedom of assembly (Article 8) are among the cornerstones of democracy," says Ralf Poscher, director of the Max Planck Institute for the Study of Crime, Security and Law in Freiburg. "Article 5 is intended to guarantee free intellectual debate – not only intellectual debate in the political sphere, but of course especially that," explains the professor of public law. The fact that both articles found their way into the Basic Law 75 years ago is still an achievement today.

- 36 Despite the constitutional guarantee of freedom of speech and assembly, both are increasingly perceived as restricted. As far as freedom of speech is concerned, a survey by the Allensbach Institute for Public Opinion Research and Media Tenor from December 2023 provides evidence: 44 percent of respondents said that it is better to be cautious when speaking in public, especially when it comes to conservative or right-wing populist views. Only 40 percent felt free to express their political opinion. Values have shifted significantly in the space of a few years. In 2017, a clear majority of 63 percent believed that they could speak freely. In 1990, the figure was actually at 78 percent.

"You have to distinguish between two things: on the one hand, what actions the state takes against expressions of opinion and assemblies, and on the other hand, what social sanctions you can expect if you hold certain views," says legal expert Poscher. As a fundamental right, freedom of speech is first and foremost a defensive right against the state and protects against state interference. Nobody is arrested for their opinions in this country.

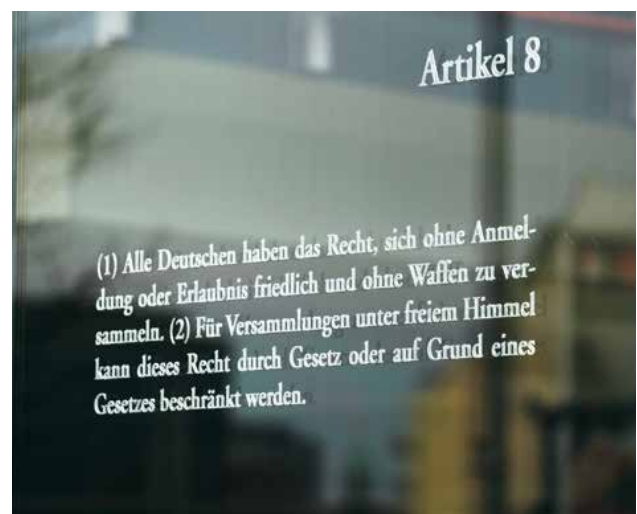
Samuel Salzborn, a political scientist at the University of Gießen, observes that populist parties in particular continuously rail against a lack of freedom of speech: "Freedom of speech is a constitutional right, so almost all the 'debates' that the far right instigates on this issue have absolutely nothing to do with questions of freedom of speech. It is a rhetorical ticket to delegitimize and destabilize democracy." If freedom of speech were seri-

ously restricted in Germany, no one could complain about it without risking state persecution.

The Federal Constitutional Court has repeatedly made clear in its rulings how highly it values freedom of speech. This also affects lower courts and law enforcement agencies, as in 2018 when a defamatory statement by the then AfD parliamentary leader Alexander Gauland against the Integration Commissioner was deemed to be covered by freedom of speech.

Freedom of speech also extends far into the political sphere. "As long as speech is focused on trying to convince others with arguments, positions, and opinions, we are free to debate," Poscher explains. "Even things that are not constitutional can be advocated. As long as you are simply presenting a personal opinion, you can even argue for the restoration of the monarchy."

The broad scope of this fundamental right is explained by history. The experience of the Weimar Republic, which was abolished not by a coup but in accordance with the constitution, influenced the Basic Law. Although Article 118 of the Weimar Constitution provided for freedom of speech, it was not – like today's fundamental rights – guaranteed in perpetuity, but could be suspended temporarily or permanently by emergency decrees, as it happened in 1933 after the Reichstag fire. This should not be possible with the Basic Law: democracy should offer freedom but be defensively resilient. It should, as the Social Democrat Carlo Schmid put it in a



Guaranteed: The right to protest is a cornerstone of democracy.

Professor Ralf Poscher in Freiburg is investigating how far the right to freedom of speech and protest extends.

PHOTO: BASCHI BENDER



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“Assembly bans are always the last resort.”

RALF POSCHER

speech to the Parliamentary Council in September 1948, “have the courage to be intolerant of those who want to use democracy to kill it.” For freedom of expression, what this means is: the leash is long when it comes to individual opinions. There is great confidence that the democratic framework is stable and that individual opinions will be smoothed out in discourse. Intervention takes place when this constitutional expectation is disappointed. “The idea that can be derived from the Basic Law’s provisions on bans on associations and parties, and also on the revocation of fundamental rights, is: democracy can defend itself against unconstitutional views if they become institutionally entrenched, especially in associations and parties,” explains legal expert Ralf Poscher.

Individual gatherings do not yet constitute such an entrenchment of an unconstitutional view. To return to the example of the monarchy: one could also demonstrate peacefully for the reintroduction of the monarchy. The Federal Constitutional Court gives freedom of assembly the same high value as freedom of speech. According to the Basic Law, assemblies do not even have to be registered. The fact that this must be done in practice – with the exception of spontaneous demonstrations – is intended to protect the assembly and ensure that the event runs smoothly. Ralf Poscher says: “The right of assembly is a right to enable assembly.”

However, the obligation to register does not equate to an obligation to approve. For example, if the authorities do not react to a registration, the assembly can still take place. Where the assembly must be registered varies from state to state. It could be the police or the municipal authority. If the authorities see a danger associated with the demonstration, they must try to mitigate it by imposing conditions – such as a change of route, a ban on the attendance of specific individuals, or time restrictions, as was the case with the recent farmers’ protests. “A permit to assemble can have a dozen conditions,” Poscher explains. “A ban is always the last resort.”



The rule of law does not take assembly bans lightly. If the assembly authority issues a ban, there are legal remedies and a decision is made quickly. Organizers can appeal to the administrative court, and from there possibly to the higher administrative court or the administrative court of appeal, depending on the state. For example, many blanket bans on pro-Palestinian assemblies following the Hamas terrorist attack on Israel on October 7 did not survive the first and second instances. In Frankfurt, only two days elapsed between the ban and the decision of the Hessian Administrative Court.

Courts as guardians

Where does the impulse to ban demonstrations come from? “Politicians are sometimes tempted to restrict the freedoms guaranteed by fundamental rights,” observes Poscher, co-author of the *Handbuch des Polizeirechts* (Handbook of Police Law). “Basic rights are also there to prevent such overreactions.” According to Poscher, who studies the history and dogmatic structures of public security law, it is crucial to rely on the courts in times of multiple crises: “They are the ones who subsequently weigh, correct, and restore the relationship between citizen and state.”

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Many of the decisions on the recent protests will be taken afterwards. The coronavirus crisis has recently shown how the rule of law must prove itself in a crisis situation with serious violations of basic rights – both during the acute situation and afterwards. Should judges decide, as they did in 2023, that the general ban on assemblies during the first phase of the coronavirus pandemic in spring 2020 was disproportionate, the demonstration cannot be made up for – but the ruling clarifies the legal position of those affected and can provide the basis for a better decision in a future case.

Freedom is not boundless. The Basic Law itself refers to limits on freedoms as restrictions, naming them in Article 5 paragraph 2: “These rights shall be subject to the restrictions imposed by the provisions of the general laws, the legal provisions for the protection of young people and the right to personal honor.” Public statements become legally relevant when they advocate serious crimes or incite hatred or violence, or fall under the offense of inciting hatred against sections of the population. This includes the use of prohibited symbols and slogans. Recently, the slogan “From the river to the sea,

Palestine will be free” has come to the fore. The river referred to is the Jordan, and the sea is the Mediterranean – with the State of Israel in between. Many therefore interpret the slogan as a denial of Israel’s right to exist. In early November 2023, Interior Minister Nancy Faeser issued a ban on the terrorist organization Hamas. In this order, she also banned the slogan – almost unnoticed at first – as a symbol of the terrorist organization.

The result: what is banned cannot be displayed. The police can confiscate posters bearing the slogan. In cases of multiple criminal acts, assemblies can even be broken up. Holding up signs saying “Kill XXX,” as seen in Wiesbaden during the farmers’ protests, is liable to prosecution (Section 111 of the Criminal Code, public incitement to commit a crime). The threat of hanging, as is often seen, falls into a legal gray area. “Context is always everything. But if it’s meant to signal: ‘We’re coming to hang you,’ that’s unacceptable,” says the lawyer Poscher. Even dung heaps on public roads can be a matter for the public prosecutor’s office. Weapons are expressly forbidden at assemblies, according to the Basic Law. The

Assemblies Act (*Versammlungsgesetz*) also prohibits the wearing of uniforms. “Assemblies must not intimidate others to the extent that they can no longer freely express or form their opinions. That’s why there is a ban on uniforms,” says Poscher. Ultimately, this also can apply to tractors; they must not be used as a means of intimidation.

It remains to be seen how the courts will subsequently assess the blockades of highway off-ramps, country roads, or squares by thousands of tractors in January. What is crucial is the conditions the protesters had to fulfill. For example, Legal Tribune Online reports that farmers in Saxony were only allowed to temporarily block on-ramps, while farmers in Mecklenburg-Western Pomerania were only allowed to stand by on-ramps and not directly on them. The judges of the Berlin-Brandenburg Higher Administrative Court, on the other hand, allowed unlimited blockades. The argument: highways can be avoided. The judges attributed greater importance to the expression of opinion.

So how do we explain the prosecution and conviction of “Klimakleber” (climate protesters gluing themselves to roads), which also paralyzed traffic in many places? According to legal experts, these were often individual actions which, because they were unannounced, did not

SUMMARY

Freedom of speech and freedom of assembly are essential elements of democracy. The Federal Constitutional Court considers them to be of paramount importance.

The limits of these freedoms must be constantly tested. Prohibitions and their revocation, controversial judgments, and subsequent findings of illegality are not signs of a restriction of freedom or arbitrariness, but evidence of a functioning constitutional state.

Eccentric, uncomfortable, and extreme opinions are protected, even if they are unpopular with the majority. However, criminal liability is the limit.

provide the police with a point of contact for coordinating security policies in advance. In Bavaria, climate activists were even taken into custody preemptively – an approach that Poscher, in a joint blog post with doctoral researcher Maja Werner, described as legally questionable, both in terms of its legal basis and its application. “This is also political,” Poscher comments.

However, the situation is different for the farmers, who, through their association, coordinated their protest with the security authorities in advance and used their work vehicles to get to the rally – and are allowed to use them. “If a street or a square is permitted as a place of assembly, the Road Traffic Act does not apply,” says

Ralf Poscher. Pedestrians and cyclists are also allowed on highways.

It was not only the tractors that dominated the cityscape for days, but also the millions of people who stood up for democracy and freedom – not only in the west, but also in the east of the country – that showed how impressive demonstrations can be. Powerful symbols for the 75th anniversary of a democracy that should always be aware of its freedom. “Assembly depends on physicality. Despite all that social media can offer today, nothing is as effective as people physically standing up for their opinion,” says legal expert Ralf Poscher.

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

Prosecuted: “Klimakleben”
(gluing yourself to the road to protest climate change by disrupting traffic)
has often been punished as coercion.



It is not uncommon for a scientist to hang up their lab coat and become a journalist. Martina Preiner did it the other way around. After a career as a science journalist, she switched sides again in her early thirties and returned to the laboratory. The reason for her change of heart was a fascination with the origin of life.

TEXT: CATARINA PIETSCHMANN

“You know what? Just come by.” This rather casually expressed invitation marked a turning point in Martina Preiner’s life. In 2011, biologist Bill Martin invited the freelance science journalist to his research laboratory in Düsseldorf, marking the start of her second career.

Seven years later, Martina Preiner headed the junior Geochemical Protoenzymes research group at the Max Planck Institute for Terrestrial Microbiology in Marburg. Behind the complicated term hides one of humanity’s greatest questions: How did life originate on Earth? For science, more than 4 billion years ago, when life began, the early Earth was a very murky place: an inhospitable planet often depicted with bubbling volcanoes, with an atmosphere of water vapor, carbon dioxide, and other gases that was hostile to life by today’s standards. “The conditions were completely different from those present today – that much is certain. But we don’t know exactly what the Earth looked like back then. And that makes it difficult to go back to the beginning of life,” says Martina Preiner.

Presumably, the first chemical reactions took place on rocks and in rock pores before the first func-

tional cell saw the light of day many millions of years later. This cell is known as LUCA – the “last universal common ancestor” – the last common ancestor of bacteria and archaea and thus also of fungi, plants, and animals. Martina Preiner conducts research on the transition between geochemistry and biochemistry, the point at which the precursors of today’s enzymes made more complex reactions possible. She studies reaction networks based on organic cofactors and other reaction products, and the question of whether porous rock could have acted as a precursor to cells.

Preiner’s journey here was anything but straightforward. It started in 1985 in Burghausen, Upper Bavaria – her mother a medical-technical assistant, her father a chemist. “Influenced” in this way, she decided to study chemistry and biochemistry in Munich. It quickly became clear that this was a bit reckless, having only studied basic chemistry in 12th grade – but Preiner stuck with it. However, she also felt that she was always interested in more than “just” chemistry. When she finally had her master’s degree in the bag, she had run out of steam. “I didn’t really feel like a scientist at the time,” she recalls. A doctorate and subsequent career in science or in the chemical industry seemed out of the question. But what to do instead?

During her studies, Preiner often listened to Munich student radio M94.5, where a school friend worked. She contacted her, became part of the editorial staff of the radio station and after a short time also the head of the science department. “I also had the supervisor of my master’s thesis, physicist Don

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VISIT TO

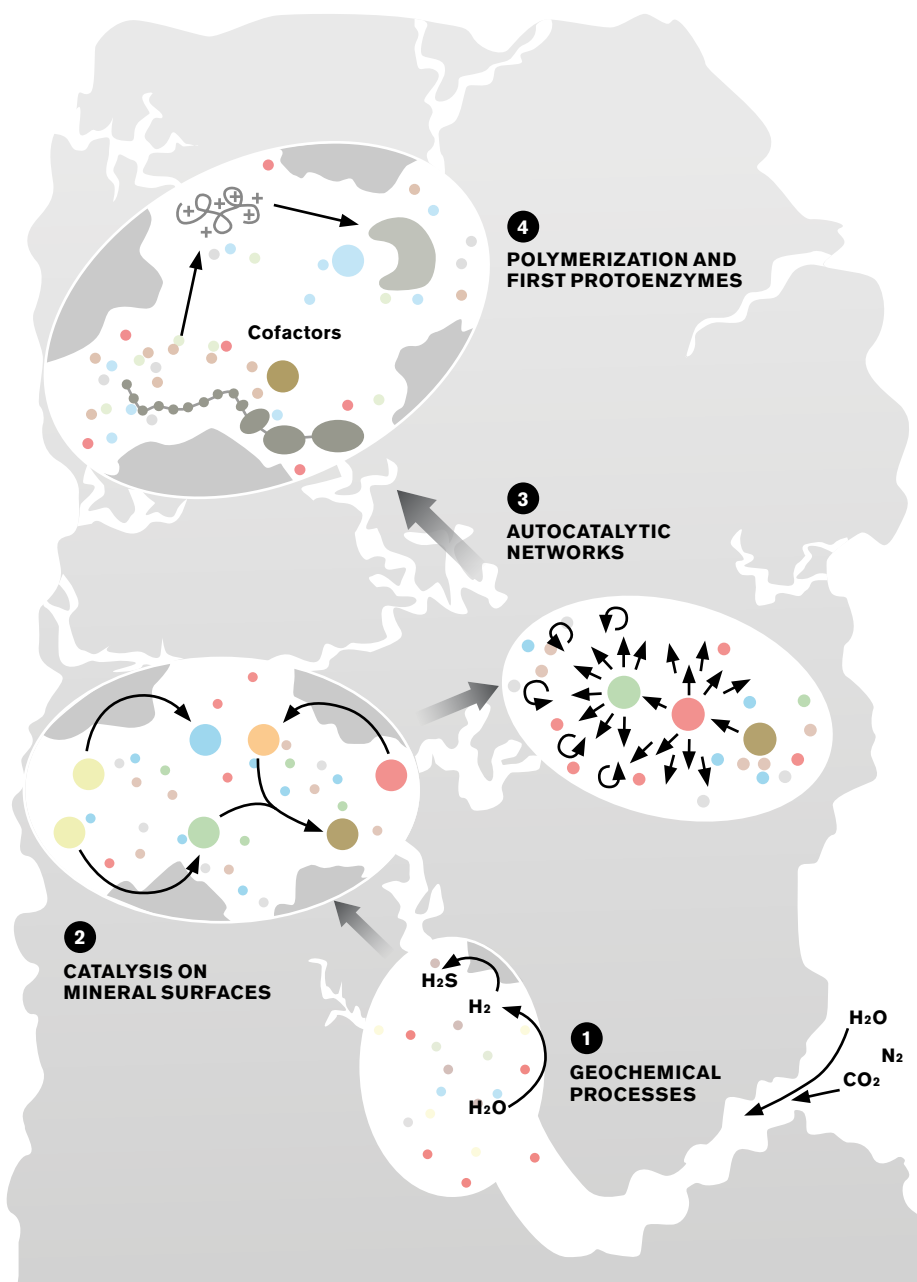
MARTINA
PREINER



PHOTO: KATRIN BINNER FOR MPG

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A balancing act that extends beyond the stairwell: Martina Preiner brings together different disciplines in her research group.



The first life processes could have taken place in cavities in porous rocks. The pores may have provided a protected environment and catalyzed the formation of hydrogen (1) and more complex molecules (2) via minerals. This could have resulted in reaction networks that could sustain themselves without enzymes, but with the help of cofactors, minerals and salts (large circles) (3). The next step in this scenario would be the formation of polymers and thus the first enzyme precursors that can catalyze reactions in a more targeted manner (4).

Lamb, to thank for this. He gave me one day off during the week, which I was able to make up for by working on Saturdays in the lab." It was exactly the view from outside the box that she needed. The next step was not long in coming. Through a tip-off, she became aware of the mentoring program of the Robert Bosch Foundation's Science Journalism Initiative.

After a journalistic crash course in Cologne, she completed internships at Deutschlandfunk and WDR, gaining experience in radio and, for example, on the

scientific TV show Quarks. That was in the spring of 2011. "It was shortly after the Fukushima reactor disaster, and science journalism was suddenly the focus of a lot of media coverage." Martina Preiner helped the editors working around Ranga Yogeshwar, the Quarks presenter at the time, to gather facts and deal with false information. She soon made her own contributions to the program.

Life as a freelance journalist was great and never felt boring. She produced radio reports for Deutschlandfunk and WDR about anxiety disorders, radio-

active radiation, adhesives, and the human voice. For Deutschlandfunk Nova, she joined a mushroom expert to collect boletuses and agarics in a Cologne cemetery, investigated science scandals, and interviewed one of the first commercial astronauts. From neurobiology to the VW scandal to climate research, everything was covered.

She had enough work; things were often quite tight financially. “I was restless at the time. If I had money left over, I traveled to India for a month or to South America for three months, usually I gathered journalistic material during these travels to finance them.” However, permanent positions were few and far between. And when she secured a job as a researcher at a Munich production company, it quickly became apparent that this “wasn’t right at all!”

life in the future. “Half joking, I said: ‘I could do that.’” However, Martina Preiner had been out of academia for six years. Was there even a way back? And then came the all-important sentence quoted at the beginning of the article: “You know what? Just come by.”

The thought of perhaps obtaining a doctorate had occurred to Preiner a few times. “But I wouldn’t have gone back to university for any topic other than the origin of life, I think.” In 2016, Preiner moved to Düsseldorf and set up a chemistry department in Martin’s laboratory, which focused purely on microbiological research, and began to investigate potential parallels between biological and geochemical binding of carbon. “I allowed carbon dioxide and hydrogen to react with minerals such as magnetite

“I wouldn’t have gone back to academia for any topic other than the origin of life, I think.”

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So she returned to self-employment. An article for the science magazine *Spektrum der Wissenschaft* would change all that. It dealt with the hypotheses of how life might have originated on Earth. According to the “RNA-first” theory, a kind of “primordial soup” simmered in ponds on the surface of the Earth, in which small nucleic acid building blocks were formed, which then combined to form larger molecules. The “metabolism-first” theory, on the other hand, postulates, among other things, that the first metabolic processes developed at hydrothermal vents in the deep sea.

Martina Preiner was mesmerized by the topic, the research of which involved very different disciplines, from geology and geochemistry to biology, biochemistry, chemistry, and physics. In the course of her research for the article, she also conducted an interview with the biologist Bill Martin from the University of Düsseldorf, a proponent of the metabolism-first theory. At the end of the conversation, the scientist mentioned that he would also like to explore the chemical processes behind the origin of

or the iron-nickel alloy awaruite, which can be found at hydrothermal vents, and analyzed whether these can enable the conversion of carbon dioxide.” In the aqueous solutions she found four small organic molecules: methanol, formic acid, acetic acid, and pyruvic acid. In other words, exactly the substances that are still at the beginning of the metabolism of many carbon dioxide-fixing microorganisms! This was proof that these first reaction steps can also be carried out on minerals.

However, Preiner could not leave journalism entirely alone. Alongside her work in the lab, she hosted a podcast. Together with her friend, science journalist and astrophysicist Franziska Konitzer, she had already applied for a science podcast on Amazon’s audiobook offshoot Audible before starting her doctorate. “For Undoder zum Quadrat (And/or square), we talked about gold, nitrogen, nuclear power, love, and death, among other things. It was great!”

In the laboratory too, Preiner soon found a like-minded person – postdoctoral researcher and biotechnolo-

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gist Joana Xavier, a free spirit like her. Irritated by some representatives of the various theories on the origin of life and their stereotypical thinking, Preiner and Xavier organized an interdisciplinary conference in 2018 just for doctoral researchers and postdocs studying the origin of life. Thanks to their request to refrain from using technical language as much as possible, the participants were able to communicate across disciplinary boundaries. “There was a totally relaxed atmosphere, everyone was very open about the pros and cons of the different theories of how life might have come about. They dared to do more because there was not the usual polarization you see at conferences.” In a joint publication, the researchers then presented how they see the future of their research area.

had already happened to her several times before. Initial overload, because she was the only generalist among the specialists and knew less about the basics than everyone else; then a steep learning curve, and in the end the rewarding feeling of having acquired a lot of new knowledge, this time about geochemistry.

She was in Utrecht with her young family for just six months when a colleague forwarded her an invitation to tender from the Max Planck Institute for Terrestrial Microbiology. They were building the leadership team for a junior research group within the new Microcosm Earth Center. As a chemist who deals with metabolic processes, going into microbiology, such an opportunity was too good to be true!

“If you focus too much on a single theory, you lose your openness and objectivity.”

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Two years later, the next conference followed, now organized by people who had participated in the first one. Finally, the Origin of Life Early-career Network (OoLEN) was formed out of these meetings, today counting over 200 members worldwide. “Hypotheses are of course indispensable. But if you focus too much on a particular hypothesis, you lose your openness and objectivity. I think the network has also advanced our field of research because it facilitates cooperation among researchers.”

Shortly after obtaining her doctorate in 2020, like so many others, Preiner suddenly had to contend with the complications brought by Covid-19. In addition, Preiner was also pregnant with her daughter. She initially stayed in Düsseldorf as a postdoctoral researcher before starting a job in Utrecht and on the Dutch island of Texel, “finally getting a chance to get out of the laboratory.” Aboard the research vessel *Pelagia*, as a scientific co-director with geoscientists, ecologists, and biologists, she sailed to the Mid-Atlantic Ridge and took samples of nanoparticles around hydrothermal vents on the seabed. What she experienced during her postdoc period

On the advice of friends and family, she applied despite her doubts. When she received the invitation to the selection process, she couldn’t believe it at first. But she got the job. And as it would soon turn out that, with her focus on the beginnings of metabolism, she was an excellent fit for the team. In her office, she sits opposite biologist Julia Kurth, who is researching methanogenic archaea – ancient single-celled organisms that bind carbon dioxide and convert it into methane. One door down works Judith Klatt, the third member of the team. The biogeochemist is a specialist in ecosystems in primeval oceans. And not far away, researchers are investigating what the first proteins could have looked like. “We are now thinking about whether we could reconstruct them and release them into an artificial geochemical environment,” says Martina Preiner. “Had we not all come together here, such ideas would not have come about.”

As is the case for many millennials, her career was full of unforeseen twists and turns. School, studies, doctorate, then permanent employment until retirement – these were relics of the past. Nothing is set in

Hot springs in the deep sea, known as “white smokers,” are a possible birthplace of life. Martina Preiner is now also researching other chemical environments in which the first life processes may have taken place. Carbon dioxide always plays a central role – albeit not in the form of dry ice as shown in this picture.



PHOTO: KATRIN BINNER FOR MPG

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stone anymore. “That’s why I sometimes advise students to do something besides academic research for a while to get their bearings. Because not everyone is or will be happy in academia and it is good to know what other options are out there.” The fact that she repeatedly jumped into cold water and also swam against the current is perhaps no coincidence. In her youth she was a competitive swimmer and started diving at the age of 14. From the cool Attersee in Austria to tropical coral reefs, she has been to the bottom of many bodies of water.

This year she will get her fins and diving mask out of the closet again after a long time and accompany her father on his final dives in Indonesia.

Martina Preiner has arrived at Max-Planck in Marburg for the time being. Reflecting on her career, it is clear that Preiner has consistently seized opportunities for further development instead of simply treading water. “That’s probably my motto for life,” she says, laughing. And it is likely a trait she has in common with the origin of life on Earth.

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IMAGE: ILLUSTRATION OF THE SRG WITH EROSITA AND ART-XC/DLR



DOUBLE TAKE

*MAX PLANCK INSTITUTE FOR
EXTRATERRESTRIAL PHYSICS*

Intergalactic: the eROSITA space telescope (pictured on the left) has captured the x-rays emitted by a record-breaking 900,000 objects from all directions by scanning space in a series of pirouettes.

Motion is necessary, because even when all seven individual telescopes are combined, the field of view is still very small, roughly equivalent to the area your fingernail would cover if you held out your arm to the sky. The German data (right) depicts high-energy x-rays as blue and low-energy x-rays as red. Only higher energy x-rays can penetrate the dust and gas in the Milky Way. The brightest point at the center of the image corresponds to the Vela supernova remnant, while the points of light beyond the Milky Way can mostly be attributed to active galactic nuclei. Their distribution and dynamics in intergalactic space provide clues to how the universe developed.

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A GENE FOR MALENESS

TEXT: ANDREAS LORENZ-MEYER

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Brown algae are outsiders – neither plant nor animal, neither fungus nor bacteria. Their unique position in the tree of life makes them very interesting to Susana Coelho and her team at the Max Planck Institute for Biology in Tübingen. The researchers want to find out whether evolution has taken two different paths to the same important innovation: the emergence of female and male individuals.

Brown algae rarely make the news, and when they do, lately the headlines have been negative. The reason for this is the “Great Atlantic Sargassum Belt,” an ever-growing carpet of brown *Sargassum* algae that has formed in the Atlantic every spring since 2011. It has since spread to the coasts of Florida and Mexico, where it threatens tourism and fishing.

Although *Sargassum* has yet to reach Tübingen, the incubators at the city’s

Max Planck Institute for Biology host a close relative: the brown alga *Ectocarpus*, which forms small, brownish clumps in glass flasks filled with seawater. The shapeless structures are gametophytes – the sexual phase, or generation, that produces eggs and sperm. Like mosses, ferns, and seed plants, brown algae alternate between sexual and asexual reproduction. A mostly unremarkable sexual generation is followed by one in which the algae use spores to reproduce asexually. In the case of *Sargassum*, the asexual generation is the one that is highly visible in the sea, sometimes covering vast areas.

Brown algae split off from green and red algae a billion years ago. A green algal ancestor went on to evolve into land plants, while brown algae went their

own way. Their name derives from the brown pigment fucoxanthin, which is produced in the chloroplasts along with chlorophyll and conceals the latter’s green pigment. The asexual generation takes a variety of forms depending on the species, ranging from small, branched cell filaments to organisms measuring several meters. The latter form extensive kelp forests along coasts.

Susana Coelho has been researching brown algae for years – first at the Station Biologique de Roscoff in Brittany, where the organisms populate the Atlantic coast, and starting in 2021, at the Max Planck Institute. In the Tübingen labs, incubators provide *Ectocarpus* with steady temperatures and precisely regulated artificial light. “Brown algae are tremen-

KNOWLEDGE FROM

— BIOLOGY & MEDICINE

The brown algae *Halopteris congesta* is found in tropical oceans. The fan-shaped cell filaments of the algae are easy to recognize under a microscope.

PHOTO: JEAN-CLAUDE WINKLER



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Susana Coelho at her lab in Tübingen. This is where she hopes to learn whether evolution took the same path more than once in producing male and female individuals.

dously adaptable and inventive. They perform photosynthesis and have leaves, stems, and claw-like structures resembling roots. They look like plants, but they're not. And they don't belong to the animal or fungi kingdom either."

Nature's misfits

That makes brown algae evolutionary mavericks. They have blazed their own trail to multicellularity, developing an ability to use the Sun's energy much like plants, but independently of them. Long ago, a single-celled an-

cestor of brown algae absorbed a photosynthetic red alga, which then provided its symbiotic partner with energy from sunlight. This formerly independent red alga gradually became the chloroplast of brown algae. The chloroplasts of plants, by contrast, originally came from free-roaming cyanobacteria.

Their independent evolution is what makes brown algae such promising research subjects for Susana Coelho. "They help us understand how evolution works. In the case of brown algae, for example, if we compare the genes that were crucial for the formation of

female and male individuals with those of organisms of other lineages, we can find out whether the algae used the same genetic toolbox.

Susana Coelho and her team at the Max Planck Institute in Tübingen are particularly interested in the sexual phase of the life cycle of *Ectocarpus*. They want to find the gene that determines whether a brown alga is male or female. A comparison with the gene that determines sex in other groups of organisms will help provide clarity.



Did brown algae inherit their type of sexual development from the last ancestor they share with other groups, or did they find a different form? “Hopefully one day we will find out if evolution determines sex across all lineages with the same master gene.”

The researchers have already discovered a candidate for the maleness gene. It resembles the SRY gene, which determines maleness in mammals. SRY stands for sex-determining region Y gene. It seems that the same kind of master gene, or a similar molecular mechanism, determines the sex of an individual brown alga just like with other lineages. Recently, the group described that an asexual individual emerged when removing the male master candidate from the *Ectocarpus* genome using the Crispr/Cas9 system, providing evidence that it is indeed the sex-determining gene.

Male algae with eggs

When it comes to sex, brown algae are flexible. For example, some male individuals are able to produce eggs as well as sperm, which might be an evolutionary step towards self-fertilization. This would enable them to reproduce even if they are unable to find partners in the vastness of the ocean. But how do males become such hermaphroditic creatures? That is what Daniel Liesner wants to find out. His approach is to study not *Ectocarpus*, but a brown algae called

Laminaria pallida. Liesner brought presumably bisexual specimens of this species from southern Africa. He holds up a Petri dish containing filtered sea water. There is nothing to see at first, even though there are a

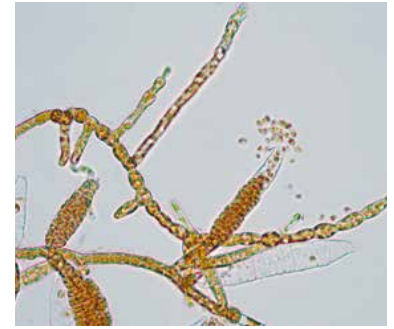
SUMMARY

Brown algae form their own lineage. They belong neither to the plant nor the animal kingdom.

They have a gene in their sex chromosome that determines whether an individual produces sperm or eggs. By comparing this gene with its counterpart in other groups of organisms, researchers hope to determine whether evolution followed the same path twice when determining sex.

Brown algae are of paramount importance for biodiversity and the global climate. One cause of their mass proliferation in some regions is the over-fertilization of the seas.

few hundred male *Laminaria* floating in the dish. “The individuals of the sexual generation are tiny filaments of cells measuring 10 to 40 micrometers in size. Only later do they



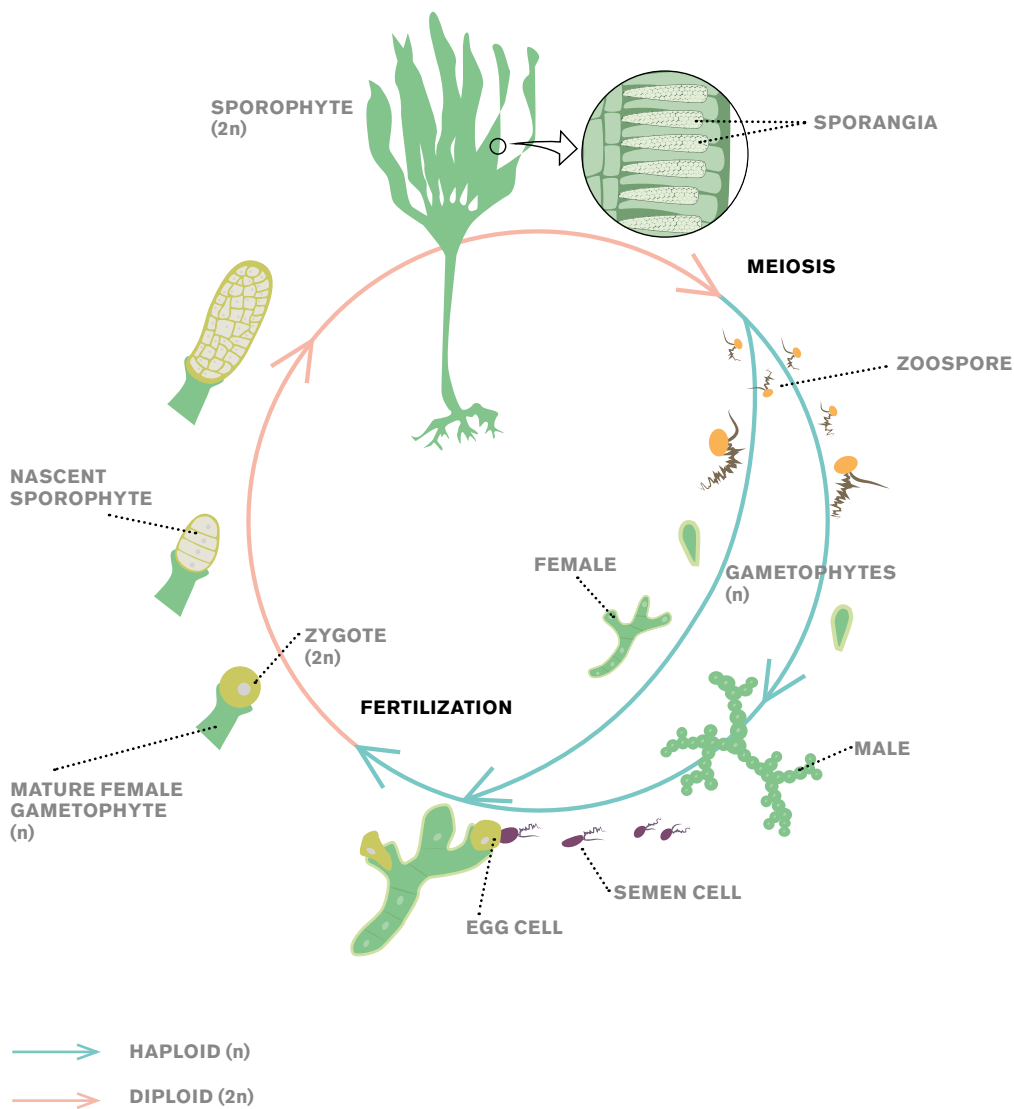
The sporophyte, or asexual generation, of an *Ectocarpus* alga releases spores from a spore holder. Whip-like appendages enable the spores to move.

develop into sporophytes, that is, the asexual generation. These are the big brown algae we see on the beach,” explains Liesner. The biologist places the Petri dish under a light microscope and focuses on one of the irregularly shaped brownish cell clusters. It is fringed here and there by small, whitish balls – the holders in which sperm are produced.

None of this is unusual for a male brown alga. However, the specimens in Liesner’s dish have a special feature: a cell that is much larger and darker than the others. “If this is a functional egg, the male individuals would actually be hermaphrodites,” says Liesner. The cell looks like an egg under the microscope, but tests have confirmed that only the male sex chromosome is present in the culture. It is yet unclear whether the egg (if it is one) is functional – in other words, whether the individual could fertilize itself.

In any case, brown algae have mastered additional forms of reproduction without the opposite sex. And these are being studied in Tübingen. Populations consisting exclusively of females have been discovered in the oceans. They reproduce clonally when unfertilized eggs divide inside them, giving rise to asexual sporophytes without the fusion of egg cells and sperm. This allows them to cir-





Reproductive cycle of the brown *Laminaria* alga, alternating between sexual and asexual reproduction.

The highly visible algal body of the *Laminaria* is the sporophyte, or the asexual generation (above). Spores produced in special holders undergo a unique form of cell division (meiosis) in which the genetic material is divided in a way that leaves each spore with only a single set of chromosomes (n). The spores grow into tiny little male and female gametophytes, which form the gametes. The zygote resulting from the fusion of semen and egg cells once again has a double set of chromosomes (2n) and goes on to develop into sporophytes.

GRAPHIC: GCO, ADAPTED FROM CAMPBELL BIOLOGY, 10TH EDITION, PEARSON

cumvent a problem faced by populations that reproduce sexually in the vastness of the oceans. How do sperm and eggs find each other? The egg cells help by releasing attractants into the water to attract sperm. Identifying these pheromones is another goal of the researchers. To this end, they study the air from the glass flasks where the algae grow in incubators at the Tübingen lab. The molecules of fragrance diffused from the algae water into the layer of air above it are filtered out and their chemical composition is analyzed using mass spectrom-

etry. The pheromones even have a noticeable odor. “They smell like gin,” says Susana Coelho.

Without a doubt, brown algae are fascinating organisms. And when they reproduce at normal levels, they are of paramount importance for the Earth’s biodiversity and climate. Kelp forests provide a habitat for countless species and bind huge quantities of carbon dioxide, which is why they are called the rainforests of the oceans. The carpets of brown algae that swamp the coasts every year show

how much brown algae ecosystems are already out of balance. This happens because large quantities of fertilizer used in agriculture ultimately end up in the sea, where they increase the concentration of nutrients. “This allows the *Sargassum* algae to multiply much more than before,” explains Susana Coelho. Changes to ocean currents due to climate change could also have paved the way for *Sargassum* to spread to new regions of the world. “Ultimately, there is only one cure. We need to drastically reduce nutrient input to the oceans.”



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PHOTO: MPI FOR METEOROLOGY / NASA WORLDVIEW

Lots of different shapes: in the tropics and subtropics, countless clouds form in a belt where the trade winds prevail. These trade-wind clouds cool the climate by reflecting sunlight. They can take different shapes – the one shown here is called a flower.

AN UMBRELLA OF FLOWER CLOUDS

TEXT: ROLAND WENGENMAYR

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Tropical trade-wind clouds act as a cooling element in the climate system: in the equatorial zone, they shield against warming solar radiation. But is it possible that human-induced climate change is reducing their numbers, and thereby amplifying global warming? The Eurec⁴a field study, co-initiated by Bjorn Stevens, Director at the Max Planck Institute for Meteorology in Hamburg, investigated these and other questions about tropical cloud activity – with surprising results.

In early 2020, climate researchers assembled an armada of ships and aircraft off the coast of Barbados, the likes of which had rarely been seen before: four research vessels, including the two German ships Meteor and Maria S. Merian, and five research aircraft, including the Halo jet of the German Aerospace Center (DLR), a French ATR-42, and a US Lockheed WP-3D Orion Hurricane Hunter, all went

cloud-surveying in the tropics. DLR's large-scale cloud radar Poldirad went into operation on Barbados. More than 300 researchers from 20 nations took part in this major operation. The object of study: small, low-lying trade-wind clouds.

The four-week campaign was called Eurec⁴a, which stands for “Elucidating the role of cloud-circulation coupling in climate.” Of course, the name also alludes to Archimedes, who is said to have discovered the law of buoyancy while bathing and exclaimed: “Eureka!” – “I found it!” As Bjorn Stevens points out: “Clouds are really about buoyancy!” As Director at the Max Planck Institute for Meteorology in Hamburg, Stevens conceived and led the Eurec⁴a campaign with his French colleague Sandrine Bony, Director at the Centre National de la Recherche Scientifique in Paris. They were joined on the ground by David Farrell, Director of the Caribbean Institute for Meteorology and Hydrology. Stevens also worked with

Farrell to establish the Barbados Cloud Observatory at the easternmost point of the island, which became operational in 2010. But why are climate researchers focusing so closely on tiny clouds in the tropics? Trade-wind clouds are low-lying clouds that form at an altitude of about 700 meters and, usually, extend no higher than two kilometers. Yet they're a heavyweight in the climate system because there are so many of them. They are as gregarious as a flock of geese and cover more than 30 percent of the total area of the trade-wind zone, which stretches like a belt across one-fifth of the Earth's surface in the tropics and subtropics. Together, the clouds form a large mirror that reflects much of the Sun's radiation back into space, effectively cooling the surface. Since trade-wind clouds cover a much larger area than the polar ice caps and are exposed to almost vertical solar radiation, their reflective effect on solar radiation is much more significant than that of the large areas of ice in the Arctic and Antarctic.

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All hands on deck! Members of the Eurec⁴a team help set up the Poldirad cloud radar. Researchers use it to study the formation of precipitation in trade-wind clouds.



PHOTO: MPI-M, F. BÄTTER

56 If the number of trade-wind clouds were to decrease as a result of climate change, this would have a crucial impact on the Earth’s climate. This concern was sparked by the results of several climate studies, most notably a scientific paper published in 2014 in the British journal *Nature*. To put it simply, the article showed that with warming the trade-wind layer would become dryer, leading to fewer clouds, and hence an increase in warming, which in turn would further increase the drying, reducing the clouds further, and so on. “Positive feedback” is the technical term for a vicious cycle of this kind.

That large, global climate models are effective in simulating global trends is not disputed, in addition, they provide one of several lines of evidence that underpin the scientific consensus that human greenhouse gas emissions are warming the planet. However, today’s climate models poorly represent cloud formation and the ways clouds respond to global warming. This leaves the magnitude of warming in doubt, as well as the regional impacts. Eurec⁴a was conceived to address this knowledge gap. The four-week campaign was de-

signed to collect data on what factors influence cloud numbers, and in particular their response to variations in weather similar to what might be expected with general warming. To this end, several research activities ran in parallel and were closely coordinated.

SUMMARY

The Eurec⁴a campaign used four research ships, five aircraft, and other instruments to study the tropical trade-wind clouds.

The density of the trade-wind clouds will not decrease in the foreseeable future due to climate change, as shallow mesoscale overturning circulation compensates for the moisture losses caused by global warming: the cooling effect of trade-wind clouds will remain for the foreseeable future.

A better understanding of how precipitation forms in trade-wind clouds, and why trade-wind clouds vary in shape, will help to improve climate models and their predictions.

The centerpiece of this cloud research was a cylindrical volume about 10 kilometers high and 220 kilometers in diameter. Within this volume, the team tried to record the air movements as completely as possible, particularly the subtle vertical motions that influence moisture transport. To put it in everyday language, cumulus clouds are produced from air that is warmer and moister than surrounding air, which makes the clouds buoyant and causes them to accelerate, something scientists call convection.

At an altitude of about 700 meters, the rising air has expanded and cooled to a point that it becomes saturated, and water vapor condenses into cloud droplets, explains Raphaëla Vogel. She participated in Eurec⁴a and is now a scientific research assistant at the University of Hamburg. “That is why these cumulus clouds have such a razor-sharp edge at the base,” she explains. This can also be seen in Europe during good summer weather. Vogel received her PhD from the Max Planck Institute for Meteorology and joined Bony’s group in Paris as a post-doc. Her job at that time was to coordinate the flight program as lead scientist. She flew mostly on the French

ATR-42 and occasionally on the German Halo. It was a very exciting time, she says enthusiastically, and the campaign helped the international team to bond.

Aircraft for every cloud level

The German Halo jet was responsible for the highest level. It flew the upper section of the cylinder 72 times over the four weeks, in addition to 13 such flights with the American WP-3D. And each time, Geet George, then a graduate student in Stevens' group and now an assistant professor at Delft University of Technology, sat in the back making a crucial measurement: At exactly 12 points on the 360-degree circle, like the five-minute markers on a clock face, he shot probes out of the plane. These then floated on parachutes 10 kilometers down to the surface of the ocean.

Their cardboard tubes contained a transmitter, three sensors for pressure, temperature, and relative humidity, and a GPS receiver. During their 12-minute descent, they transmitted their measurements and positions to Halo 2 to 4 times per second. The GPS data was particularly important because it provided information about how far the winds at each altitude blew the probes laterally. George used this data to calculate which air masses flowed through the imaginary wall into – or out of – the circumscribed measurement volume. Since the conservation laws of physics prohibit air from simply disappearing or being added, this makes it possible to calculate how convection behaves within the cylinder.

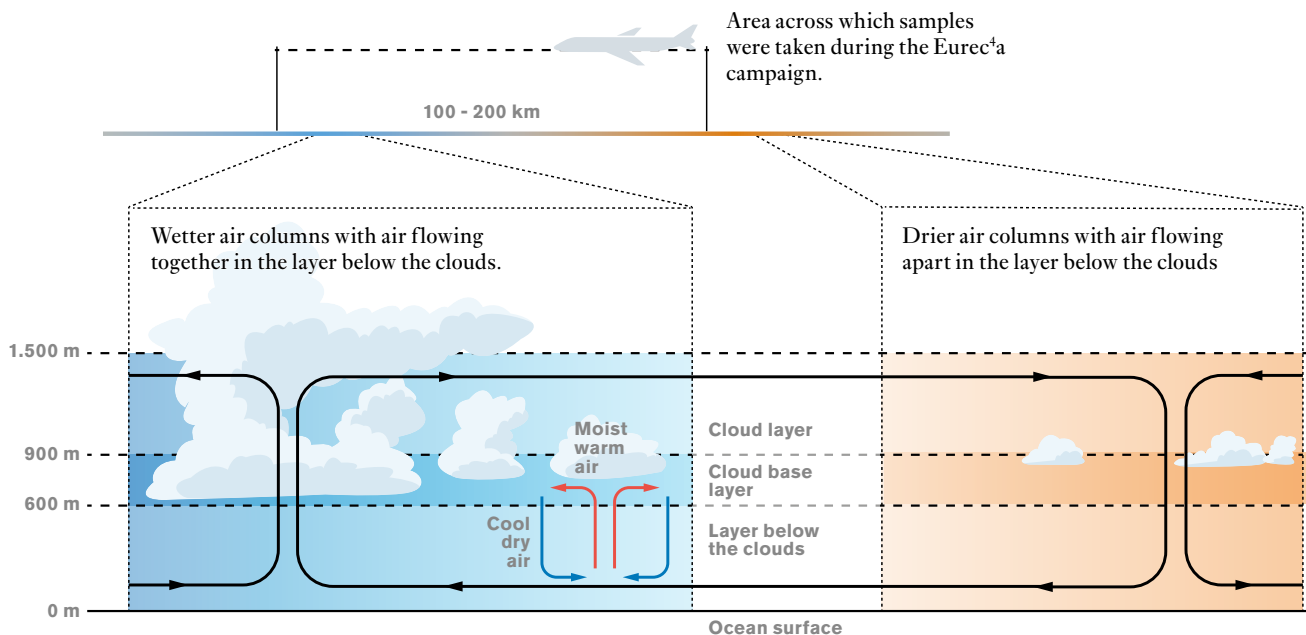
The French ATR-42 had the task of flying much lower inside the measurement cylinder, at the height of the cloud base. Instruments that scanned the clouds laterally with radar and lidar, a type of laser scanner, were par-

ticularly important. They provided information about the cloud droplets and their movements. To ensure that these instruments were aimed as horizontally as possible, the aircraft itself had to be aligned horizontally while flying straight and level. The ATR-42 therefore repeatedly flew a course consisting of two tight turns and long straight sections, not unlike an ancient Roman chariot race. Discipline was needed, even when there were hardly any clouds, in order to obtain an overall picture in all weather conditions over the four weeks. "It wasn't always easy to pull through," says Raphaela Vogel with a laugh, "when there was a nice thunderstorm a little further away." Looking back, she is particularly impressed by the reliability of the Eurec⁴a data. But what were the results?

First, the researcher explains what generally happens during cloud formation: moist air heated by the Sun rises above the water, while cooler, drier air



A previously unknown moisture cycle in the atmosphere: cumulus clouds form where warm, moist air rises; cooler, dry air descends between the clouds. This convective flow has been known for a long time. In the Eurec⁴a project, researchers have now discovered mesoscale air circulation over an area spanning 100 to 200 kilometers that brings moisture to where clouds form. There is therefore no reason to fear that trade-wind clouds will dry out as a result of global warming.



GRAPHIC: GCO BASED ON DATA FROM GEORGE, G., STEVENS, B., HONY, S. ET AL. WIDESPREAD SHALLOW MESOSCALE CIRCULATIONS OBSERVED IN THE TRADES. NAT. GEOSCI. 16, 584-589 (2023).

from higher up must sink to compensate. As the moist air rises in this convective lifting, its temperature drops and some of the water vapor condenses into cloud droplets. These moist air masses containing droplets mix with the drier air masses descending from above. This causes some of the droplets to evaporate once again. The water doesn't disappear; it simply becomes gaseous and does not contribute to the cloud. In a warmer climate, however, it is possible that fewer cloud droplets would form since global warming would mean that the air descending from above would be able to absorb more water vapor. As a result, fewer and fewer trade-wind clouds would form, which in turn would accelerate global warming due to the decreasing reflective effect. This would mark the positive feedback loop mentioned above.

According to the findings of the Eurec⁴a campaign, this feedback is nowhere near as strong as some climate models would have us believe. This was shown by a team led by Raphaëla Vo-

gel, including Bjorn Stevens and Sandrine Bony, in a publication on the main finding of the field study in the December 2022 issue of the journal *Nature*. "This is good news for us humans," says Raphaëla Vogel. Geert George explains why. He played a key role in a second major publication on the results, which appeared in *Nature Geoscience* in July 2023. The scientist explains that atmospheric circulations so small that they fall through the cracks of previous global climate models are crucial.

Sufficient moisture supply

These "shallow mesoscale overturning circulations" extend over areas about the size of that flown around by Halo and reach up to about 1.5 kilometers in height. "Mesoscale" means that we are talking about processes in the middle regions of the climate system, with an area of about 100 to 200 kilometers. This circulation mixes moist

and dry air masses more vigorously than some global climate models would lead us to expect. Basically, it works like the convection that creates clouds, except that in this case, it takes place in these middle regions that were flown around near Barbados. It provides enough moisture to largely compensate for the drying of cloud droplets in a warmer environment. The rising, moist air and the falling, dry air together form the ascending and descending parts of the shallow, mesoscale circulation – like an old-fashioned paternoster elevator that goes up one side and down the other, with differently occupied cabins.

"We have identified a new circulation system that is strongly associated with the variability of cloud cover," concludes Bjorn Stevens. "And this is a mechanism that doesn't exist in our current climate models!" Eurec⁴a's most significant finding was discovering how important this shallow circulation is in areas spanning between 100 to 200 kilometers for the present

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A clear view: Researchers use a laser to measure cloud properties, from which they derive temperature and humidity profiles.



PHOTO: MPEL/M. F. BÄTTER

and future existence of trade-wind clouds. In addition, there were other new insights into cloud activity, such as how the movement and organization of trade-wind clouds affect the precipitation that they release. Climate scientists are not yet able to explain the conditions under which cloud droplets become rain, snow, or hail. Yet, being able to do so is important for weather forecasting and simulations of regional climate change. To better understand how precipitation forms in trade-wind clouds, Jule Radtke, a doctoral researcher at the Max Planck Institute for Meteorology, analyzed measurements from Poldirad in Barbados. Poldirad stands for Polarization Diversity Doppler Radar. This technical term essentially means that the large device can track the movements of droplets in a cloud very precisely via radar echo. Poldirad is normally located at the DLR site in Oberpfaffenhofen. With financial support from the Max Planck Foundation, the system was dismantled for Eurec⁴a and sent across the Atlantic by ship. It arrived in Barbados several months later and initially got stuck due to customs formalities. But despite all the obstacles they ran up against, the team managed to get the radar up and running near the Barbados Cloud Observatory just in time.

Radtke used the data from Poldirad to study the influence of the herding behavior of trade-wind clouds on their precipitation. “It used to be said that these small trade-wind clouds are fair-weather clouds that don’t grow particularly tall and therefore don’t rain,” says the climate researcher, “and that they tend to spread out randomly.” Even before Eurec⁴a, however, it was clear that this picture was not correct. Radtke concluded that the herd instinct has a clear influence on the rainfall behavior of clouds. When clouds herd together, they rain more often. This is because they seem to protect each other from the sun. This creates a more humid atmosphere and prevents raindrops from evaporating before they reach the ground. On the other hand, less rain falls from clouds in the herd because less rain is formed in them. “This

Cloud chaser: Geet George was instrumental in taking measurements with Halo. He used probes to determine convection in the area where the research aircraft was flying.



PHOTO: DANIEL BECKMANN / DLR

could be because there are also younger or older clouds hanging around,” says Radtke with a laugh, “which either have yet to or no longer contribute to precipitation.”

Flowers and fish in the sky

During the preparations for Eurec⁴a, Bjorn Stevens’ team discovered that clouds’ ability to self-organize is very complex. Using machine learning and pattern recognition, the Hamburg team identified four different herd patterns in satellite images, which they named “sugar,” “gravel,” “flowers,” and “fish.” The latter structure does indeed resemble a fish skeleton. Together with Hauke Schulz, now a researcher at the University of Washington in Seattle, Stevens investigated whether a high-resolution climate model, which is limited to a smaller area to save computing power, could simulate these patterns with the Eurec⁴a data. The simulation was quite successful for “fish” and “gravel,” but not for “flowers.” The importance of being able to simulate these structures to a high degree of accuracy for future climate models remains to be seen, Stevens emphasizes. At the very least, the models need to calculate the average cloud cover as precisely as possible, and the shape of the clouds could be a relevant factor. The lesson from Eurec⁴a is that cli-

mate models need to be much more fine-tuned to simulate such meso-scale processes in a future warmer climate.

Bjorn Stevens is optimistic that the high-resolution climate models of the future will allow much more accurate predictions of small-scale processes. Only if climate models can better capture the processes in the atmosphere will they be able to predict phenomena such as regional changes in climate more accurately. The fact that more and more powerful supercomputers are becoming available for use in climate research will certainly help. However, even these computers will not be able to replace field research. A follow-up field study, Orcestra, will take place in August and September 2024, and Barbados will once again serve as its base.

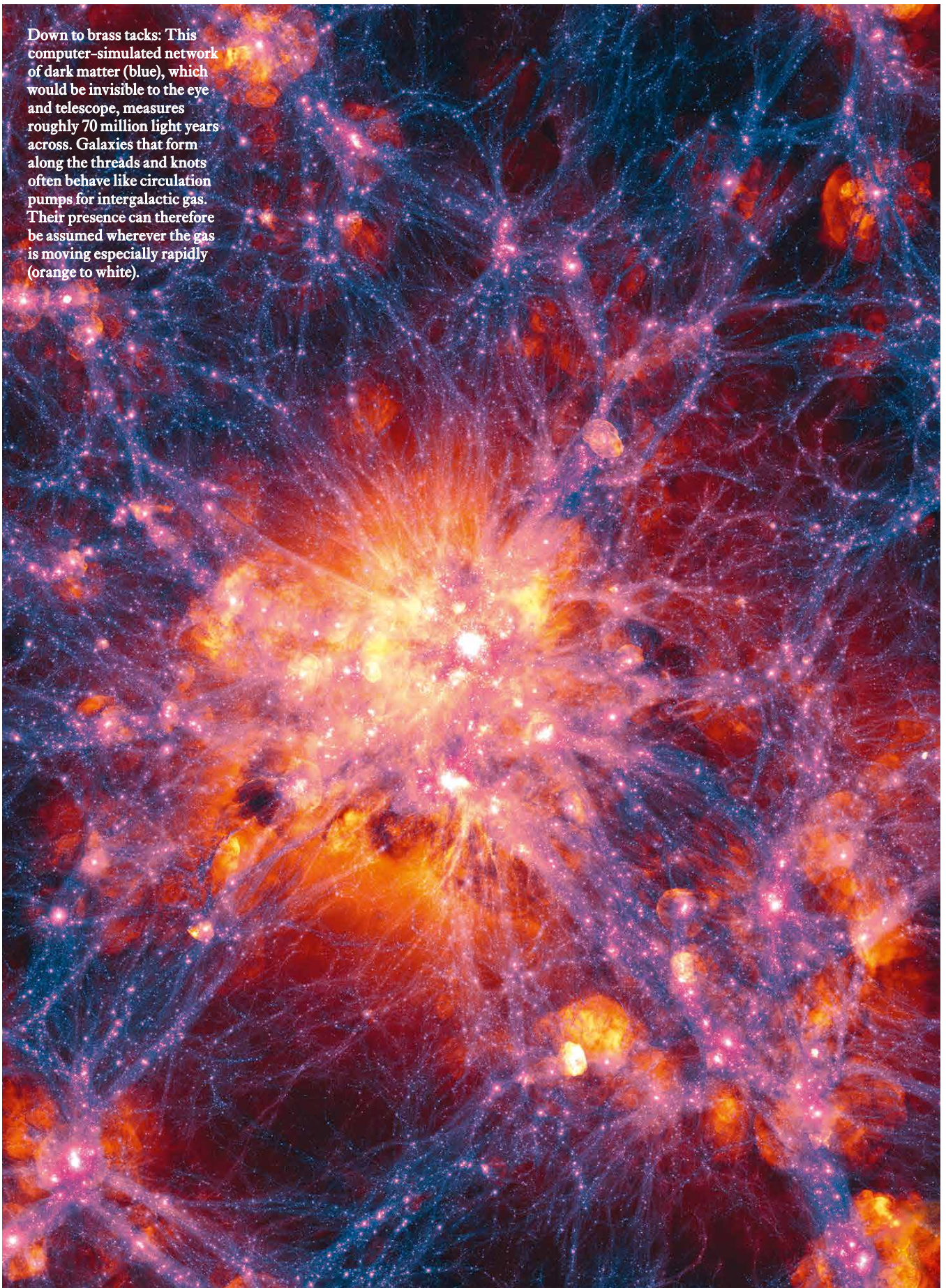
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GLOSSARY

SHALLOW MESOSCALE OVERTURNING CIRCULATION is the name of an air movement discovered as part of the Eurec⁴a campaign, in which warm, moist air rises and cold, dry air sinks in areas of 100 to 200 kilometers. The circulation compensates for the loss of moisture in the tradewind clouds caused by global warming.

Down to brass tacks: This computer-simulated network of dark matter (blue), which would be invisible to the eye and telescope, measures roughly 70 million light years across. Galaxies that form along the threads and knots often behave like circulation pumps for intergalactic gas. Their presence can therefore be assumed wherever the gas is moving especially rapidly (orange to white).



THE DIGITAL UNIVERSE

TEXT: THOMAS BÜHRKE

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Dark matter and dark energy determine how the universe looks. But that is pretty much all cosmologists know about these phenomena. Their nature is still completely unclear. While they cannot be directly observed, a team led by Volker Springel at the Max Planck Institute for Astrophysics in Garching is simulating how this mysterious matter and enigmatic energy have influenced the development of space, which has brought further insights about their properties as well as other aspects.

Dozens of black boxes stand like mystical monoliths at the Leibniz Supercomputing Centre in Garching. Combined, they form the SuperMUC-NG, the highest-performance supercomputer in Germany. This machine performs an unfathomable 27 billion calculations per second – ideal for Springel’s massive simulations. Springel joined the Max Planck Institute for

Astrophysics in the mid-1990s, just as British astrophysicist Simon White was beginning to build a research group. The much-lauded White is considered a pioneer in numerical simulations of the large-scale structure of the cosmos. In other words: he used computer models to examine how the diversity of galaxies and galaxy clusters we see today formed from hot gas in the billions of years following the Big Bang. The goal goes beyond just simulating the development of the universe so that it takes the same shape on the computer that we can observe today with telescopes: more importantly, when the calculations result in the correct outcome,

this is a good indication that the cosmologists have a proper understanding of the underlying processes.

Unlike most astronomers, Springel never felt the urge to observe the sky through a telescope. A desire to study physics was present from an early age, however, and as a high school student he had already begun exploring the numerical side of astrophysics. “I did, in fact, participate in ‘Jugend forscht’ [a science competition for young Germans] with a computer simulation,” he recalls. When White’s work caught his attention later on, he knew he wanted White to be his PhD supervisor. It turned out to be the right choice.

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Twenty years and several major breakthroughs later, Springel is now a much-lauded scientist in his own right.

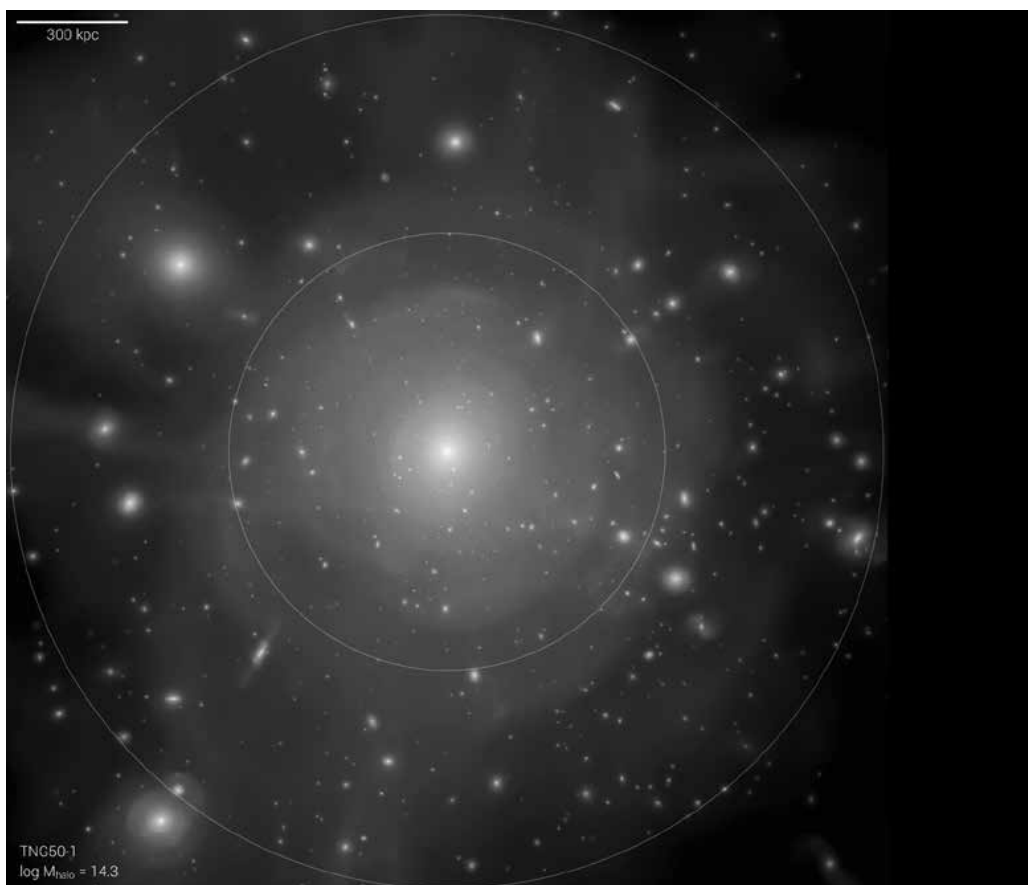
The cosmic simulations follow a relatively simple principle. Particles of virtual matter are placed in a digital volume. Their motion, determined solely by gravitational effects between the particles, is then tracked at specific increments in time. Fortunately, the initial configuration is known. It can be perceived in cosmic microwave background radiation. This arose around 380,000 years after the Big Bang and is detectable as an almost homogeneous distribution across the entire sky. “With Europe’s Planck space telescope, we have managed to determine a spot pattern with tiny fluctuations, which can be attributed to density variations in the primordial gas,” explains Springel. Consequently, the gas, too, must have had a relatively homogeneous distribution shortly after the Big Bang. And this observation provides the initial conditions for the simulations.

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The density variations in the primordial gas were so low that individual regions with more accumulated mass would have been unable to condense under their own gravity into today’s galaxies and galaxy clusters, even over billions of years. This is partly because when a gas contracts, it heats up, creating thermal pressure, which counteracts further contraction into, say, a star. The phenomenon is famil-

iar to anyone who has pumped a tire. If you hold the valve closed and compress the air, it warms up and can’t be compressed anymore. And yet galaxies exist – and this is why researchers 40 years ago were already postulating the existence of dark matter particles

they are made of. We know, however, that they account for around five times more of the total mass of the universe than ordinary matter, which quite clearly interacts with light and is therefore visible to telescopes. For that reason, numerical simulations of



SUMMARY

Numerical simulations on supercomputers allow researchers to reconstruct the development of the cosmos from hot primordial gas to today’s galaxies.

The calculations account for both the visible matter that every star and planet is made of and dark matter and dark energy, and they provide information on their distribution and properties.

as galactic midwives. When these particles compress under their own gravity, no pressure builds to counteract further compression. And that enabled the dark matter to form gigantic structures, which worked as gravity traps. Ordinary matter poured in, cooled slowly, and formed stars and galaxies. Simulations help us understand how dark matter is distributed in the universe and what properties it might have. Dark matter neither emits light nor absorbs it. Although a billion or so particles of dark matter presumably pass through our bodies every second, it remains unclear what

cosmic evolution always have to factor in both dark matter and the ordinary matter we can see. All stars, planets, and we ourselves are made of the latter.

Around 20 years ago, a team led by White and Springel attracted widespread attention with the Millennium simulation. The researchers succeeded in calculating how the distribution of dark matter in an expanding universe must have changed over billions of years. The simulation involved more than 10 billion dark matter particles in a cubical volume with

PHOTO: TNG COLLABORATION

sides measuring 1.6 billion light years. Impressively, the outcome coincided with the distribution of galaxies in the universe as observed from Earth with telescopes. Galaxies gather in groups and clusters of various sizes. These in turn are tied to galaxy superclusters,

mass of a small galaxy. The simulation therefore represented the distribution of dark matter at a very low resolution. Second, the Millennium simulation was only able to calculate the distribution of dark matter. Ordinary matter was added at the end in

axies, a top-tier algorithm runs a parallel simulation of ordinary matter, which forms automatically into galaxies along the dark matter's gravity trap. This requires a lot more processing power, because it has to factor in physical processes that do not occur with dark matter. When ordinary matter compresses, for example, it heats up until nuclear fusion is triggered in very dense parts of gas clouds, resulting in stars. Massive stars in particular change their environment in turn with intense radiation and strong particle winds until they explode as supernovae. The formation of cosmic structures therefore becomes a self-regulating process in which stars act on their environment, influencing the development of the next generation of stars and by extension the shape of the galaxy itself.

The Illustris simulation was the first to account for this complex interaction. A team led by Springel and Mark Vogelsberger of Massachusetts Institute of Technology ran the simulation to calculate the numerous physical interactions between dark and ordinary matter throughout the entire history of the cosmos. And although it simulated a universe only one 70th the size of the Millennium simulation, it was a real processor hog. Even so, the results were astonishing: the sophisticated models actually yielded a realistic population of galaxies like the ones we observe today.

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Close to reality: The TNG code simulated these two galaxy clusters with a bright galaxy in the center and smaller satellite galaxies on the periphery. The grayscale indicates stellar density: the whiter the region, the more stars it contains. These examples resemble the real Virgo Cluster, which borders our local galaxy group.

TNG50-1
log $M_{\text{halo}} = 14.0$

which form a bubble-like structure of threads and walls encompassing vast empty spaces, much like foam. The galaxies seem to have formed precisely where dark matter clumped together in the cosmological simulation.

Many months of computing time were required to simulate the development of dark matter particles from the Big Bang 13.4 billion years ago to today in 11,000 time increments – a resounding success, but with two caveats. First, each particle in the computer simulation represented a mass of 860 million solar masses, equivalent to the

the form of radiant galaxies using a simple and highly uncertain procedure.

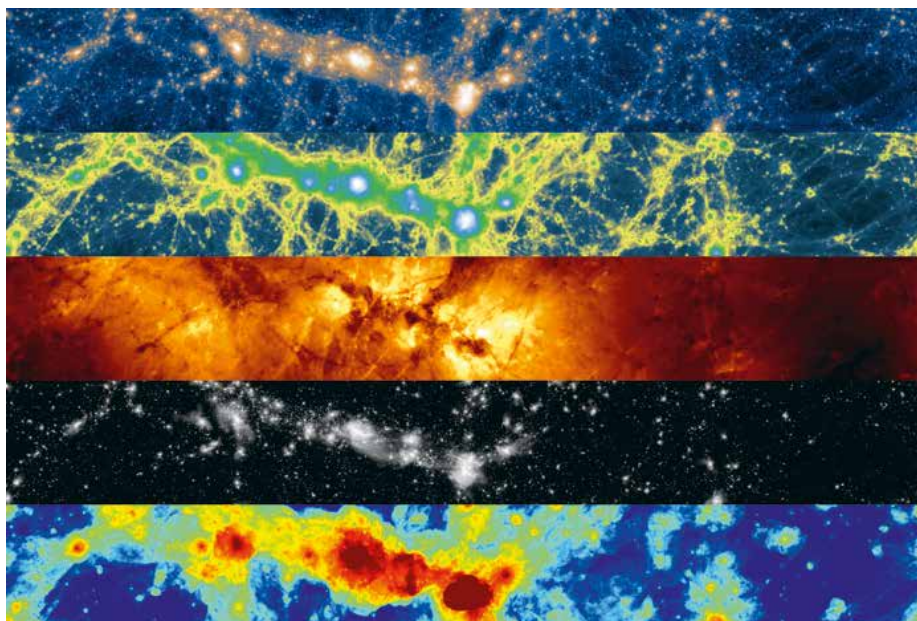
It would soon become clear that galaxy formation depends not only on the size of the dark matter structures, known as halos, but also on their time of formation and their rotation, shape, density distribution, and possible substructure. In other words, the formation of halos is a highly dynamic process. Dark matter halos can merge, resulting in larger structures with small subhalos. To approximate the actual, observable distribution of gal-

One trick played a decisive role in their success: the moving-mesh code known as Arepo. Rather than simulating the universe in the standard way as a rigid mesh, Arepo uses a moving mesh whose cells adjust their size dynamically depending on the circumstances. The mesh shrinks in areas where a lot is happening, so that small details can be calculated. Uneventful areas, by contrast, expand. This zoom technique significantly reduces computational effort.

In this way, the team observed how approximately 50,000 galaxies of vari-



PHOTO: TNG COLLABORATION



Multilayered: The same section measuring 350 million light years in diameter from the Illustris TNG simulation in different display formats. From top to bottom: Dark matter density, gas density, velocity distribution of the gas, star density, and gas temperature.

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ous sizes emerged and developed, and then compared the results directly with the observations. The researchers discovered that the simulated evolution of the universe produced all the types of galaxies classified by Edwin Hubble back in the early 20th century. The successor to Illustris, dubbed Illustris Next Generation or Illustris TNG, yielded simulations with different spatial zoom levels, allowing researchers to study galaxy clusters and the behavior of the galaxies they contain over billions of years. A few billion years ago, for example, the universe was particularly active. Galaxies merged, flushing large quantities of matter into the vicinity of supermassive black holes at the centers of galaxies. Clustered particle streams, known as jets, hurled some of that matter in turn into the intergalactic gas. These cosmic circulation pumps, also known as active galactic nuclei, can actually be observed. And they influence how many stars, if any, form in the galaxy, both in the simulation and in reality: another self-regulating mechanism.

Using Illustris TNG the researchers explored still other questions, for example, how the galactic matter became

enriched with heavy elements. Hydrogen and helium, the lightest elements, were almost the only ones to form shortly after the Big Bang. All the other, heavier elements on the Periodic Table, such as carbon, nitrogen, oxygen, and iron, were not formed until later through nuclear fusion in stars. From there, particle winds or stellar explosions carried them into the interstellar medium, where they became available as raw material for new stars and planets. Later generations of stars would therefore have to contain higher percentages of heavy elements than earlier ones. Scientists have actually observed this chemical evolution within our own Milky Way and in galaxies far, far away. The Illustris TNG simulation scores points in this area, too. Its predictions of the average age of stars and the percentage of heavy elements they contain correspond closely with observations.

And so the world simulated by the computer is already looking very similar to the real world. Massive processing power is partly to thank for this, as is clever computer code, which translates astrophysical relationships from observations into simulation parameters. This is necessary because Illus-

tris TNG cannot simulate the birth of individual stars directly. Even in variants with the highest resolution, every mass element of ordinary matter represents 85,000 solar masses, while every element of dark matter represents a whopping 450,000 solar masses. Because we now know most of the conditions (size, density, temperature) under which an interstellar cloud collapses and how many stars are born within it and with what masses, these processes can now be calculated as well. The result is an astrophysical evolution occurring virtually over billions of years.

Small meets big

From a cosmological standpoint, the volumes in which Illustris TNG simulates dark and ordinary matter simultaneously are still relatively small. With a new simulation called Millennium TNG, released last year, researchers have now built upon the Millennium simulation, which had simulated the largest section of the universe to date. Millennium TNG exceeds even this magnitude, simulating a space 1,000 times larger than Illustris TNG could manage.



Millennium TNG needed four months of computing time to determine how around 100 million galaxies developed in a region 2.4 billion light years in diameter. That made it the most complex of all the simulations run in Munich that year. “We had to increase the efficiency of the code dramatically just to get the program up and running,” explains Springel’s colleague Rüdiger Pakmor, a major contributor to Millennium TNG. One significant challenge was optimizing the parallelization of over 120,000 computing cores. “We couldn’t use all 300,000 cores, because that would have completely paralyzed other user’s activities at the time.

The work paid off: Millennium TNG has supplied more than three petabytes of simulation data – about enough to fill several hundred stan-

dard hard drives. So far, only part of the data has been evaluated. Many questions remain, such as how galaxies formed in the early universe. The James Webb Space Telescope recently detected galaxies whose extreme luminosity suggests they grew to enormous size just a few hundred million years after the Big Bang. “Our simulations have a really hard time with this rapid growth,” says Springel. “Maybe star formation was much more efficient shortly after the Big Bang than later on, or maybe massive, luminous stars formed in larger numbers back then, making those galaxies incredibly bright,” adds Pakmor. Simulations may yield clues to what really happened back then as well.

The simulations provide an impressive confirmation of today’s standard model of cosmology. It attains a preci-

sion no one would have dared dream of two decades ago. What’s more, it is free of internal contradictions, which was not always the case. However, it only works when the simulations include the ominous dark matter and the even more enigmatic dark energy. The latter allows the universe to expand at an accelerating rate. Today’s cosmologists are therefore faced with the astounding knowledge that although they can reconstruct the roughly 14-billion-year evolution of the cosmos quite accurately, they know next to nothing about the nature of the two main actors: dark matter and dark energy.

←

The creators of Millennium TNG at work: Volker Springel (left) and Rüdiger Pakmor work together to interpret the dark matter structures of the universe, which they’ve simulated with the help of a supercomputer.

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PHOTO: AXEL GRIESCH FOR MPG



What's that landing in the forest? This object made of bark tissue is designed to inspire ideas for architectural uses of tree bark. Max Planck researchers took it to a forest in Brandenburg for a photo shoot.

PHOTO: ALEXANDER MÄGERL/MPPI OF COLLOIDS AND INTERFACES

PACKAGING IN NATURE

TEXT: PETER HERGERSBERG

Functional materials are a matter of survival for plants. Trees use them in bark to protect against hail, rockfall, and even fire. And plants use them to package their seeds in a way that protects them from extreme heat and cold, enabling them to germinate when the weather conditions are favorable. Researchers from the Max Planck Institute of Colloids and Interfaces analyze how biomaterials get their properties and whether they could replace leather or plastic, for example.

It feels smooth, soft, and a little cool. The palm-sized, light brown sample looks like leather and feels like it in the hand. But what Charlett Wenig handed the visitor is not a tanned hide, but a piece of tree bark. “The resemblance surprised even us,” says Wenig, a scientist at the Max Planck Institute of Colloids and Interfaces. She beams enthusiastically: perhaps something that feels so similar to leather could also have similar applications, reasons the expert in industrial and product design – like clothing, for example.

Her interest in clothing – and bark for that matter – was not a clear starting point, but arose more or less spontaneously. In her work, Wenig seeks to combine design with materials science, searching for useful applications for what are generally considered waste materials. She was already doing this in her master’s thesis at the University of the Arts Bremen, where her initial research examined options for making useful things out of animal bones. Her inspiration came from buttons and knife handles from centuries past, which were sometimes made of bone. In her experiments, she partially dissolved inorganic components and other elements in the material so that only tough, flexible collagen remained. She would then use it to make, for example, protectors for sports such as skating, where bumps and falls are commonplace. But she didn’t want her doctoral thesis to be

about bones. If for no other reason: bones have a very unpleasant smell. So she reached out to Peter Fratzl, Director of the Biomaterials department at the Max Planck Institute of Colloids and Interfaces. While searching for natural waste materials to utilize, Wenig soon stumbled across an abundant scrap material from the production of furniture, panels, and paper: bark. This eventually led her to join a group led by Michaela Eder that studies plant materials with a view to potential applications.

In 2018, the woodworking industry disposed of around 500,000 metric tons of material used by trees to protect against external influences. Today, some types of bark are used as mulch for gardens and in particle board production, while tannins are extracted from others for use as tanning agents. For the most part, however, bark is



Like leather, but made of plants: Charlett Wenig (left) and Johanna Hehemeyer-Cürten sewed jackets from pine bark, which they made flexible with a humectant.



PHOTO: ARNE SÄTTLER FOR MPG

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burned to generate energy, even though many barks leave behind a lot of ash and some don't burn well – especially those whose function is to protect the tree from fire.

Shouldn't it be possible to make something more useful from the packaging of trees? Wenig called the nearest forester and immediately hit the jackpot. "He supported the project from day one – it could have easily gone another way." With his consent, Wenig carefully removed the bark from several felled pine trees in the largest sheets she could manage, resulting in several pieces of material the size of towels. It turned out to be a stroke of luck that the pine tree happens to thrive in the often sandy soil in the state of Brandenburg. This is because it covers itself with two kinds of bark: the covering is scaly on the lower trunk, where dead bark tissue cracks around the growing tree. Higher up, the trunk is packaged in smooth mirror bark consisting mainly of living tissue, lending it a sleek and shiny look. "As long as the smooth bark stays moist, it can be creased like stiff leather," says Wenig. And leathery bark obviously has potential applications. "Leather is considered extremely high-quality, and designers have done intensive research into how to replace it."

SUMMARY

Tree bark is considered waste, and today most of it is burned. Max Planck researchers are exploring the properties of bark in order to use it for applications in fashion and architecture or as a packaging material.

The seed pods of *Banksia attenuata* release their seeds in two steps: they open slightly during fires and fully when it rains, so that nutrient-rich ash and moisture is present during germination.

Seed coats protect the plant embryo from environmental influences such as ice crystals and UV radiation. They could inspire the development of sustainable packaging materials, which could be derived, for example, from tree bark.

Bark could therefore serve as a plant alternative to the animal product. But first, Wenig had to solve a problem. The material lost its flexibility as it dried, becoming brittle. However, a few days in a bath of water and glycerin, which is also used to keep foods

and cosmetic creams moist, made the bark as soft as when it was fresh from the tree. The pine bark probably owes its flexibility to a characteristic that frequently plays a central role in the Potsdam team's research: the cellulose microfibril angle. This characteristic indicates how cellulose fibers are oriented in relation to the longitudinal axis of the plant cell. If the angle is large, as in pine bark and in the trunks of young trees, the plant material is easy to shape. As trees grow older and stronger, they form bark with a smaller cellulose microfibril angle, making the trunks stiffer. Eder explains the effect in terms of a thick, straight wire and a coil spring made of the same wire. The straight wire stands for a cellulose fiber that is parallel to the direction of growth and therefore has a small cellulose microfibril angle. It cannot bend. The coil spring, by contrast, winds around the longitudinal axis, which corresponds to the direction of growth, in a wide angle with respect to the cellulose fiber. And so it doesn't take much force to deform the spring.

The fact that pine bark feels so supple in the hand – at least when moist – gave Wenig the idea of making clothes from bark. "Bark is the protective layer of the tree. How would it feel for

a person to be dressed in bark, to wear a jacket made of bark, for example?” Wenig shared the idea with fashion designer Johanna Hehemeyer-Cürten, who also works at the Max Planck Institute in Potsdam. “The plan was a little risky, because it required us to use almost all the material we had.” Nevertheless, they tailored a short jacket with a stand-up collar for their colleague Friedrich Reppe.

Apart from a few sewing issues, the project went swimmingly – right up until the photo shoot. Wenig asked her colleague to remove his glasses for the camera. “I can’t,” he answered helplessly. He couldn’t raise his arms. The bark turned out to be much stiffer than it had felt – not a good feature in clothing. But Wenig and her colleagues weren’t discouraged by the setback. They cut the remaining material into strips as thin as fettuccine and wove them together. The resulting jacket was much more flexible. “If the weaving pattern were developed further, it would be possible to produce a jacket that feels a lot like leather to the wearer,” says Hehemeyer-Cürten. The problem, in any case, is that bark is more brittle than leather. The researchers are also exploring whether tree bark could be used not

just for clothing, but for accessories like shoes and bags. Among other things, they’ve produced a collection of shoes with distinctive soles made of black locust bark. Their goal in making jackets, shoes, and bags is not just to design marketable products. “The point of the designs is more to start a conversation about the sustainable use of materials,” says Wenig. She and her colleagues also want to encourage ideas outside the fashion industry, such as in architecture, for example. To provide inspiration in this context, they used woven bark elements to construct a sphere that is accessible through an opening at the bottom and the installation on a metal frame. It normally stands in the foyer of the Institute. “We could imagine bark being used for buildings that are needed for a relatively short time, for example,

pavilions at trade fairs or exhibitions,” says Hehemeyer-Cürten. Building huts from bark is not a new idea, she points out. To this day, huts made of tree bark are preserved and maintained at the New Garden in Potsdam, located just a short distance from the Max Planck Institute.

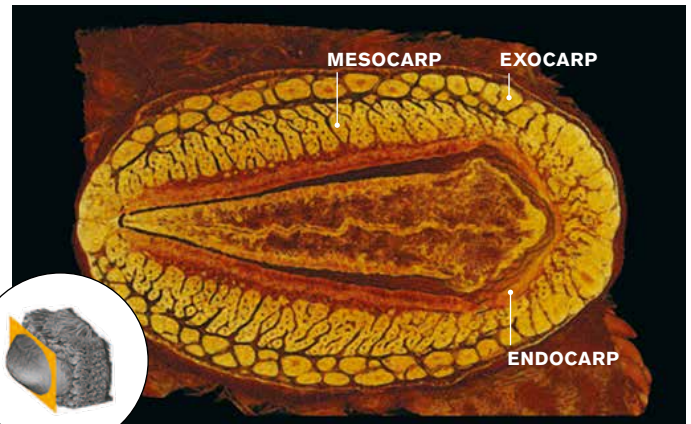
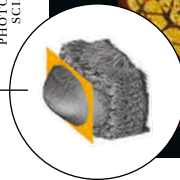
Bark panels

It isn’t just huts that could be constructed from bark: according to a study by the team in Potsdam, the material could be used as an alternative to conventional particle board. The idea for the research occurred to Wenig while fixing the stretched, moist bark to a frame in order to shape it into flat panels and dry it. At the time, she wondered whether bark



PHOTO: FRIEDRICH REPPE

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A jump-start programmed into the material. The seed pods of the Australian tree *Banksia attenuata* sit unevenly distributed in an infructescence (left). The walls of the seed pods consist of three layers, the endocarp, mesocarp, and exocarp, which can be seen in the tomography image (above). The inner layer appears reddish, the outer layer can be recognized by the roundish yellowish structures. The three layers are structured in such a way that the capsule initially opens slightly at the points marked with arrows, when a fire has brought nutrients into the soil. Only after rain do they open completely.

could also be pressed flat. Why not try it? And so she lay two pieces of each type of bark, including oak and larch, on top of each other with the bumpy or scaly outer sides facing each other. Then she pressed the pieces together for 20 minutes at 90 degrees Celsius. The result was a solid panel with a smooth surface that did not require any adhesives to produce. The possibility to connect pieces of bark without glue gives it an advantage over particle board. “Glue makes it hard to recycle the material,” says Wenig. But at least equally important from an application standpoint is that from the very first mechanical tests the panels proved to be comparable to standard particle boards. “This is surprising,” says Eder, “because particle boards have undergone decades of optimiza-

tion.” Oak bark panels were particularly resistant against mechanical loads. The researchers are not yet sure why oak bark is so stable. However, they could imagine panels like these being used as non-load-bearing elements in house construction, as flooring or in furniture design. In furniture carpentry it could be beneficial that the bark panels can be bent into curved shapes without much effort. “And who knows? Maybe oak paneling will make a comeback – nothing is impossible,” says Wenig.

Well packed seeds

The search for applications for soft bark has led the team to pursue a new idea. The researchers are considering it as a

potential replacement for plastic packaging. Nature is full of suggestions on this front. After all, it isn't just trees themselves that are protected by resilient materials. When it comes to the packaging of plant seeds/embryos, evolution has shown itself to be especially inventive. That's because seeds have to stay protected for as long as necessary from cold, heat, and diseases. But once conditions for germination are right, they need to be released. This has fascinated Eder since she started her research group at the Max Planck Institute in Potsdam in 2011. Since then, her interest in plant materials that have to withstand extreme conditions has never waned. First, she wants her research to contribute to a better understanding of the plants themselves. Second, she



seeks to learn from the plants in order to optimize material systems that are exposed to extreme conditions. As an avid climber, her first impulse was to research Alpine plants, which have to deal with extreme cold, UV radiation, and short growing seasons. But over time, flora from a different ecological niche began to interest her more from a materials science standpoint. One that is characterized by food scarcity, dryness, heat, and fire. “Banksias were an obvious choice.” Banksia species occur almost exclusively in Australia, where the bushes and trees of the genus have to protect their seeds from periodic bushfires. “When I started working with seed pods, opening temperatures of 450 degrees Celsius were reported,” Michaela Eder. “I asked myself how they do that, and

above all, how they protect the seeds in the process.”

However, Eder soon learned that the pods release their contents at much lower temperatures. She and her team also quickly realized that the way the plants give their offspring the best possible chance starting out is at least as interesting as the supposed high opening temperature of the seed pods. Banksias have developed an ingenious mechanism to ensure that their seed pods open and distribute seeds into an inhospitable environment at precisely the right moment. Eder’s research focused primarily on the seed pods of *Banksia attenuata*. With their two shell-shaped halves, the pods sit unevenly distributed in an infructescence resembling a conical bottle brush. They open in two steps: first, after a bushfire returns nutrients to the barren soil in the form of ashes, a narrow crack forms between the two halves. Only when it rains does the crack widen until the seeds fall out. The two-stage opening mechanism involves no living tissue and is solely due to the structure of the capsule walls. It is programmed into its structure, so to speak.

Protection from ice crystals and UV light

Studying how dead plant material reacts to external stimuli is Eder’s specialty. She and her team examined the material properties of the Banksia pods with a range of tools, including micro computed tomography (μ CT), which makes very small structures visible. μ CT scans reveal that the seed pod walls have three layers. The cellulose fibers in each layer are oriented differently. To put it more precisely: the middle layer has a larger cellulose microfibril angle than the inner one, and the outer one has no preferred orientation. As a result, the middle layer swells more in the longitudinal direction than the other two when the seed pod ripens and dries. The resulting inner tensions are released when the plants are exposed to fire, causing the pod to crack open. The pod opens fully when it dries off after being

moistened by the rain. Friedrich Reppe, another member of Eder’s group, is currently working on a description of how exactly this works. It is clear that the mechanism is extremely complicated and that the swelling properties of the cellulose fibers play an important role.

The much thinner seed coats of many plants are constructed every bit as elegantly as some seed pods. They surround the embryo and the endosperm, which supplies the latter with nutrients when germinating and protects the embryo from environmental influences, for instance, from UV radiation and ice crystal formation in Alpine regions. When the weather is right in spring, however, they set the embryo free. Because seed coats are significantly thinner than seed pods, they are better suited to serve as an inspiration for sustainable packaging materials. This is one reason Eder and her group plan to focus more on seed coats in the future. They will investigate the seed coats of plants at extreme locations – this time primarily the mountains. The Volkswagen Foundation is funding the project over four years with approximately 1.2 million euros. Admittedly, the seed coats themselves are not suitable for packaging – they’re too tiny. But another material is bigger and in abundant supply: tree bark, which the team has already studied extensively. Once the researchers have understood why seed coats are so resilient, they will search among the wide variety of tree barks for those with similar properties. And so, bark may one day serve as sustainable packaging – not for people, but for certain products currently sold in plastic.

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Johanna Hehemeyer-Cürten, Michaela Eder and Charlett Wenig (from top) study plant materials. First, they want to understand how plants specialize for their ecological niche. Second, they are searching for potential applications for their versatile functional materials.



GLOSSARY

CELLULOSE MICROFIBRIL ANGLE is the angle of the cellulose fibers with respect to the longitudinal axis of fibrous plant cells. The angle largely determines the mechanical properties and swelling behavior of plant materials.



Polarstern moored to an ice floe during the ArcWatch-1 expedition. Researchers set up measuring instruments on the ice and take samples to study the effects of climate change on the Arctic.

72 Max Planck researchers collaborate with partners in more than 120 countries. In this article, they write about their personal experiences and impressions. Christina Bienhold from the Max Planck Institute for Marine Microbiology in Bremen spent two months on the research ice-breaker *Polarstern* in the central Arctic. As co-leader of the ArcWatch-1 expedition she reached the North Pole in summer 2023.

90° 00' N. Light fog. Around us, a mosaic of ice floes and open water, just like in most areas of the summery Arctic Ocean nowadays. However, a glance at our ship's positioning system proves that we are at the North Pole! *Polarstern*, which was launched in early 1982, has reached the northernmost point of the globe for the seventh time. It's a first for me and most

others on board. Researchers and crew stand on the bridge, clapping. The ship's horn sounds. There is champagne. Our chief scientist Antje Boetius and our captain Stefan Schwarze give a speech.

The polar regions and the deep sea have fascinated me since I was a child. My father is a biologist and worked in politics in Bremen. As part of his job, he was in contact with many of the marine research institutes. I often flicked through annual reports of the institutes in his office and dreamed of becoming a marine researcher one day. While still at school, I got my first hands-on experience as an intern at the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI).

Today, I am actually a scientist and research bacterial communities of the deep sea floor. By using various elements such as carbon to generate en-

ergy, microorganisms of the deep sea play an important role in global element cycles. So far, however, we know little about which species occur in the Arctic depths, how communities are changing as a result of climate change, and how this affects matter turnover. Therefore, we urgently need to conduct surveys at regular intervals to capture the changes. For this purpose, we collect sediment samples from the seabed. Using genetic analyses, microorganisms in the sample can later be identified in the laboratory.

Polarstern is the largest ship in the German research fleet. In 2012, I was already part of an expedition to the central Arctic to collect sediment samples. Last summer, I had the opportunity to accompany the ArcWatch expedition to the North Pole as a co-chief scientist. A total of 54 scientists and 43 crew members from 15 countries participated in the expedition. To make the best use of time, we

POST FROM

THE NORTH POLE

worked in shifts – day and night. The continuous daylight of the Arctic summer proved advantageous here.

Technically, we were well equipped on Polarstern. We had a multiple corer to collect sediment samples. A modern towed camera system allowed us to film at great depths. Our expedition thus succeeded in providing the first images of the seafloor at the North Pole. Sponges, sea cucumbers, fish, and cephalopods – the Arctic deep sea is teeming with life! Especially common are the spoon worms, which collect small food particles from the sediment and leave characteristic star-shaped traces in their wake.

Overall, the expedition was a great success – despite considerable challenges with the ship's technology. The bow thruster was defective, so we lacked an important maneuvering element to position the ship. To stop for our ice stations along the way, we had to im-

provise and moor Polarstern to a floe with the help of an ice anchor. Despite the difficulties, we were able to accomplish large parts of our tightly scheduled research program. We did not have much free time, but we were still able to use it in a variety of ways. On board there is a swimming pool and a sauna, a gym, and the ship's bar "Zillertal." We even had a band that formed on board, the ArcWatchers. The atmosphere was excellent!

Since the 1980s, the Arctic has lost 12 percent of its summer sea ice per decade – an area almost the size of India. These changes have repercussions down to the deep sea, about which we still know so little. I want to change that with my research. My family supports me in this: while I was at sea for two months, my husband and the grandparents took care of the children. They are five and eight years old. I hope I can pass on some of my fascination with the oceans to them.



PHOTO: PERSONAL

Christina Bienhold

43, is a marine biologist and conducts research in the HFG-MPG bridge group for deep-sea ecology and technology – a collaboration between the Max Planck Institute for Marine Microbiology and the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI). Her work focuses on the microbial ecology of the Arctic and the deep sea.

FIVE QUESTIONS

ABOUT EUROPEAN SECURITY AND DEFENSE POLICY

FOR CAROLYN MOSER



Ms. Moser, cyber attacks, election manipulation, and military threats: which dangers are the member states of the EU currently exposed to, often without being aware of it?

74 CAROLYN MOSER: The EU's Strategic Compass, adopted in March 2022, provides a fairly accurate description of the current security landscape. It identifies power politics as a threat, while territorial defense has regained relevance. Additionally, terrorism and extremism continue to pose acute challenges, as do hybrid attacks. As you can see, there is a wide range of threats that the member states are generally responsible for countering. In addition, the EU institutions take legal and political measures – sanctions are imposed at the EU level – or provide major stimuli, most recently for the defense industry.

The retiring commission is working on a “Defense of Democracy Package.” What kind of protection does this package provide for, and how do you assess it?

The goal of the package is to safeguard democratic institutions and processes within the EU from foreign influence. Lobbying and party financing are gateways for this type of influence. Therefore, the package proposes introducing a uniform regulation to enhance transparency regarding interest representatives from third countries, along with recommendations for transparent party financing. Generally speaking, we in the EU need to

improve our toolbox so that we are better armed against agents, including those from third countries, who are increasingly attacking our democratic foundations and our social order.

If Ursula von der Leyen gets a second term in office as Commission President, she wants to appoint a defense commissioner. What do you think about that?

This approach aligns with the need to prioritize defense issues in the EU. Russia's war of aggression against Ukraine served as a wake-up call, prompting urgent efforts to enhance the EU and its member states' defense capabilities as quickly as possible. However, in the EU, defense remains a prerogative of member states, with the European Commission playing a passive role, except in matters related to the defense industry. If it were up to the Commission, armaments would, in future, primarily be procured jointly and in the EU, which would constitute a true paradigm shift. The new member of the Commission would thus have a long list of tasks.

How are we in Europe protected against attacks? Is there a European command and control structure?

In the event of an armed attack, the right to self-defense applies, which also includes a collective dimension. This means that other states can provide assistance and support to the state under attack; in fact, they must do so as part of bi- or multilateral mutual assis-

tance clauses. NATO's mutual defense clause is the most significant, as it includes the U.S. nuclear protection shield. The EU also has a mutual assistance clause, but its military structures are rudimentary. This can change, however, if the transatlantic security guarantees weaken.

If defense is needed, could France provide nuclear weapons and place them under EU authority?

In principle, a state that is providing support to an attacked state is free to decide what resources it will make available. These resources can range from humanitarian aid and logistical support to the supply of weapons, combat operations, and also nuclear defense. Yet, nuclear weapons cannot simply be shared, given existing obligations under international law – nor are most nuclear powers prepared to do so. In the wake of Brexit, France remains the only nuclear power in the EU, and the only one in Europe that could act independently of the US. As a result, there are now discussions about whether and under which conditions France would share its nuclear deterrent with other EU states. However, we are still a long way from a European atomic bomb...

Interview: Michaela Hutterer

Carolyn Moser is Research Group Leader at the Max Planck Institute for Comparative Public Law and International Law. She also holds the Alfred Grosser Chair at Sciences Po (Paris).

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