

# Max Planck RESEARCH



The Science Magazine of the Max Planck Society 4.2018



## Digital Society

POLITICAL SCIENCE

Democracy in decline in Africa

ASTRONOMY


The oddballs of the solar system

BIOMEDICINE

A grain of brain

LEARNING PSYCHOLOGY

The nature of children's curiosity



Daniel Hincapié,  
Research Engineer at  
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Munich

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## Spacewalk for research

The International Space Station (ISS) orbits the Earth around 16 times a day from an altitude of approximately 400 kilometers; each orbit takes a good 90 minutes. The ISS, which is about the size of a football field and has been manned continually since November 2000, is constantly being converted and expanded – also in the services of science. On August 15, 2018, during an outboard mission that took almost eight hours, the two Russian cosmonauts Sergei Prokopyev and Oleg Artemyev installed the antenna for the Icarus system on the outside of the ISS. Now all the Icarus components on board are complete and the test phase, which will last several months, can begin.

Icarus (International Cooperation for Animal Research Using Space) – a joint project involving the Max Planck Institute for Ornithology, the Russian space agency Roskosmos, and the German Aerospace Center (DLR) Space Administration – is intended to provide a new, improved understanding of animal migration worldwide. Even small animals such as songbirds can be fitted with the Icarus transmitters without altering their behavior. Although they weigh less than five grams, these so-called tags not only record the animal's location but also collect data on acceleration, ambient temperature, and orientation relative to the Earth's magnetic field. When the ISS passes overhead, the tags send the recorded data to the space station.

The space antenna can simultaneously record data on many hundreds of animals – in other words, whole flocks. The goal is to find out more about the lives of animals on Earth: the conditions in which they live and their migratory routes. Even more than a hundred years after the first birds were ringed for scientific purposes, surprisingly little is known about this in detail. The findings will not only serve the purposes of behavioral research and species protection, but will also facilitate research about the spread of infectious diseases, the effects of ecological phenomena such as climate change and ultimately, could even be used to predict natural disasters.

 <https://youtu.be/4g12a3cmXNs> (in German)



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We have hardly any control over where information about us, or even photos with our likeness, are made public. However, in future we may at least be able to prevent photos of us being published on other people's Facebook pages when we are not involved. The technology for this purpose was developed by researchers at the Max Planck Institute for Software Systems in Saarbruecken.

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Artificial intelligence is advancing rapidly – literally as well as figuratively: robotic nurses could soon be moving into our homes. However, their behavior is still open to negotiation. Researchers at the Max Planck Institute for Innovation and Competition in Munich are investigating how legal means can ensure that artificial intelligence adheres to human values.

ON THE COVER The digitalization of our society is advancing ever more rapidly – and requires brand new security strategies: how can we effectively control fake news in social media, for example? How can we ensure that robotic nurses equipped with artificial intelligence will act as intended by the inventor? And what about photos of us that appear on platforms such as Facebook? Max Planck researchers are looking to find solutions to these problems.

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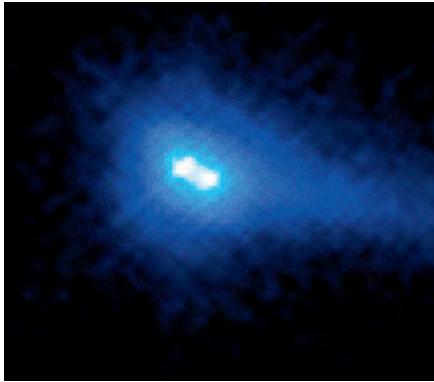
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# An important visitor in Vancouver and Ottawa

Federal research minister Anja Karliczek visits German-Canadian cooperation projects of the Max Planck Society



Interested in quantum technology: Federal Research Minister, Anja Karliczek, learned about the Max Planck Center in Vancouver from Max Planck Director Bernhard Keimer (left) and his Canadian colleague Andrea Damascelli.

Committee on Education, Research, and Technology Assessment. In Vancouver, the delegation gained insights into research projects at the Max Planck-UBC-U Tokyo Center for Quantum Materials. The Center is home to a close collaboration between several Max Planck Institutes, the University of British Columbia in Vancouver and the University of Tokyo. Two of its Co-Directors, Bernhard Keimer of the Max Planck Institute for Solid State Research and his Canadian colleague Andrea Damascelli, presented the minister with an overview of initial successes that have emerged from collaboration in the area of high-temperature superconductors. On the visit to the Max Planck University of Ottawa Centre for Extreme and Quantum Photonics, researchers explained to the delegation how they are developing high-intensity laser sources with a view to optimizing manufacturing processes in the future.

As part of a trip to Canada, the German Federal Minister for Education and Research, Anja Karliczek, also paid a visit to the Max Planck Centers in Vancouver and Ottawa. "The Max Planck Centers

make key contributions to the exploration of quantum technologies and the international exchange of scientists," said the minister, who was accompanied by members of the Bundestag

## Fields Medal for Peter Scholze

The new Director at the Max Planck Institute for Mathematics is awarded the highest distinction in his field

The Fields Medal is considered the Nobel Prize of mathematics, and this year the International Mathematical Union chose to award it to Peter Scholze. The professor at the University of Bonn's Hausdorff Center for Mathematics and Director at the Max Planck Institute for Mathematics received the award during the International Congress of Mathematicians in Rio de Janeiro. The 30-year-old is only the second German ever to receive the prize. Peter Scholze was awarded the medal in recognition of his groundbreaking contributions to arithmetic geometry. Combining number theory with geometry, this field of mathematics explores the properties of integers using geometrical methods. This approach has been able to prove centuries-old problems, such as Fermat's Last Theorem, which could not be solved using methods based purely on number theory. Arithmetic geometry

Exceptional talent: Peter Scholze, a professor at the University of Bonn and Director at the Max Planck Institute for Mathematics.

also provides the basis for many modern encryption methods. The Fields Medal is awarded every four years to recognize "outstanding mathematical achievement for existing work and for the promise of future achievement." Recipients must be no more than 40 years of age.



## “Our limit value is unacceptably high”

Jos Lelieveld speaks about the lethal consequences of air pollution, especially as a result of fine particulate matter

In the year 2015, air pollution caused the premature deaths of some 4.5 million people worldwide, including 237,000 children. This is the conclusion reached by a team working under Jos Lelieveld, Director at the Max Planck Institute for Chemistry, in a study in the journal *LANCET PLANETARY HEALTH*. By way of comparison, smoking causes around 6.4 million premature deaths each year. Researchers have found the most dangerous pollutant to be fine particulate matter with a particle size of less than 2.5 micrometers – this alone was responsible for the deaths of 4.3 million people in 2015.

*Mr. Lelieveld, how do you know which airborne pollutants lead to which diseases and how many deaths they cause?*

**Jos Lelieveld:** The method we use is the same as that for determining the number of premature deaths due to smoking. It is based on cohort studies involving over a million people, primarily in Europe and the U.S. These studies record the conditions in which people live and the risk factors they are exposed to, taking account not only of environmental factors but also of diet, for example. Statistical methods are then used to attribute the diseases to the risk factors.

*In 2013, you estimated the number of deaths due to air pollution to be 3.3 million. Why are death rates considerably higher now?*

The epidemiological data has improved considerably since then. That being said, our figures are still very conservative. There are indications that death rates due to air pollution are even higher in India and China, for example. In some parts of China, India, and Africa, the air is far more polluted than in the U.S. and Europe, where the cohort studies are conducted. The effect could therefore be even greater. It also turns out that we have not yet considered all the diseases that could – at least partly – be caused by air pollution.

*What needs to happen in order to reduce the number of premature deaths, especially among children?*

In poorer countries, such as in Africa, many children die of pneumonia due to airborne

pollutants, primarily as a result of poor diet and inadequate medical care. Action is therefore needed on three different fronts. Of course, the air needs to become cleaner, but improvements are also needed in diet and medical care. In India, for example, this approach has already yielded positive results: although air pollution increased between 2010 and 2015, the mortality rate for children fell by 30 percent. Indeed, children in India probably develop pneumonia more often nowadays, but improvements in medical care mean it's less likely to be fatal.

*Are politicians doing enough to tackle air pollution?*

That's not the impression I get. Unlike with malaria and HIV, the problem of air pollution is yet to register with politicians, particularly in Africa. In many poorer countries, refuse is burned on almost every street corner, partly due to the absence of a proper system of waste disposal. Here, it would help to explain to people that this is putting children's lives in danger. On top of that, many deaths among children could be prevented with simple, economical programs, such as the use of clean fuels for cooking and heating. This has been shown to work in India, where the widespread burning of cow dung was a major contributor to air pollution. The government therefore provided people with better ovens and access to clean fuels, often with support from private donors. If it wasn't for this, the country's air pollution would probably be even worse today.

*According to your study, many people still die as a result of air pollution, even in Central Europe. Has the region's air quality not improved?*

Although air quality has improved significantly since the 1970s, it still isn't good. Moreover, the high population density means that many people are exposed to poor-quality air, and so the mortality rate in Central Europe is similar to that in India. This is also because the air quality here is generally poor – unlike in India, where there are areas with very bad air but also some with cleaner air.



Jos Lelieveld

*Why does this problem primarily affect old people in our society?*

The excellent medical care available here means that children very rarely die of pneumonia. Similarly, older people generally don't die of pneumonia brought on by airborne pollutants, but rather of cardiovascular diseases. Arteriosclerosis, the main cause of such diseases, develops over the course of many years.

*What is your assessment of the EU's limit values?*

The limit value for fine particulate matter is 25 micrograms per cubic meter of air. In comparison, the limit is 12 in the U.S. and 10 in Canada, which is also the figure recommended by the WHO. However, we only talk about truly clean air at levels below 2.5 micrograms per cubic meter. Our limit value is therefore unacceptably high, and it is even more unacceptable if it is exceeded in some German cities. A limit of 25 micrograms is not sufficient to prevent diseases.

*Are we setting the right priorities with the debate surrounding nitrogen oxides from diesel cars?*

The debate isn't really getting us anywhere. In my opinion, fine particulate matter is a bigger problem. Generally speaking, diesel vehicles are very dirty. Cars meeting the Euro 6 standard are much cleaner, but I'm worried about how effective they'll be at reducing emissions in ten years' time. Besides, although fine particulate matter is partly formed by nitrogen oxides from traffic, there are also other sources – especially coal-fired power plants and agriculture.

Interview: Peter Hergersberg

# Award for pioneering achievements in palaeogenetics

Max Planck Director Svante Pääbo receives the lucrative Körber Prize 2018



Award ceremony in Hamburg: Svante Pääbo (center) is awarded the Körber Prize 2018 by Max Planck President Martin Stratmann (left) and Lothar Dittmer, chairman of the executive board of the Körber Foundation.

After making a name for himself with his revolutionary insights into the origins of humankind, he has now received another prestigious science award: Svante Pääbo, Director at the Max Planck Institute for Evolutionary Anthropology in

Leipzig, has been awarded the Körber European Science Prize 2018. One of his most important scientific achievements is the decoding of the Neanderthal genome. "His work has revolutionized our understanding of the evolutionary history of modern humans," the jury said in their decision. They also cited the major role that his work has played in the realization that Neanderthals and other extinct hominids contributed to the evolution of modern humans. Even as a doctoral student, Pääbo succeeded in proving that DNA can survive in ancient Egyptian mummies. In the mid-1990s, Pääbo and his colleagues were the first to decipher part of the mitochondrial DNA of a Neanderthal. In 2014, the team in Leipzig succeeded in completely reconstructing the Neanderthal genome. The Körber Prize, which Pääbo received in Hamburg in September, is one of the most lucrative research prizes in the world, carrying EUR 750,000 in prize money.

## A journey through time in Dahlem

A new smartphone app provides users with information about the science hub in Berlin

The Dahlem research campus in southwest Berlin made scientific history in the early 20<sup>th</sup> century. From 1912 onwards, it was the birthplace of numerous Institutes of the Kaiser Wilhelm Society, the forerunner to the Max Planck Society. Adolf Butenandt, a biochemist who conducted research in Dahlem in the 1930s, went so



far as to say it felt like being in "science heaven". Like many colleagues working in the vicinity, Butenandt received a Nobel Prize for his research. To this day, traces of the site's checkered past can still be found in Dahlem. Now, a new smartphone app allows anyone to discover the campus for themselves. The illustrated audio guide takes in ten locations, which visitors can find easily thanks to a map featuring GPS tracking. The audio texts provide information about historical buildings and tell the stories of those who worked there and their discoveries. Examples include Otto Hahn and Lise Meitner, Albert Einstein, and Fritz Haber. The now legendary German uranium project at the Kaiser Wilhelm Institute for Physics brought the possibility of a German atomic bomb within reach during the National Socialist era. The reason why this never happened is revealed in the app, called DahlemTour Berlin.

The former home of many great minds: among others, the researchers in Dahlem included Lise Meitner, Fritz Haber, and Albert Einstein.



# Award for an animal-friendly technique

German agriculture ministry presents Animal Welfare Research Prize to Max Planck scientists

Dirk Görlich and Tino Pleiner from the Max Planck Institute for Biophysical Chemistry in Goettingen have succeeded in developing a technique that eradicates the need for large numbers of laboratory animals. For this work, the two scientists have been awarded this year's Animal Welfare Research Prize from the German Federal Ministry of Food and Agriculture. They developed what are known as secondary nanobodies, which can replace the most widely used antibodies in medicine and research. As a result, significantly fewer animals will be needed for antibody production in the future. Nanobodies are fragments of mini-antibodies, with particularly simple

structures, that can be formed in the blood of camel-like animals such as alpacas. Once these nanobodies have been extracted from a small blood sample taken from an alpaca, they can be reproduced in the laboratory on any scale and as often as necessary using bacteria. Until now, large-scale antibody production has required the use of tens of thousands of laboratory animals each year. In addition to their natural function of affording protection against disease-causing organisms, antibodies are indispensable tools in biomedical research and in medical diagnostics and treatment. For example, they are used in pregnancy tests and to establish blood groups.



Special immune system: the antigens that alpacas form in their blood can be reproduced in the laboratory using bacteria.

Photo: Swen Pförtner/Max Planck Institute for Biophysical Chemistry

## Berlin's economy is booming.

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Berlin: party with live chemistry show.



Hanover: trying on cleanroom suits.



Duesseldorf: interactive experiments for children.



## Max Planck Day

Eighty-two Institutes present their research as part of a nationwide initiative

From Freiburg to Rostock and from Cologne to Dresden: on 14 September 2018, 35 German cities held a series of events centered around this colorful hashtag. The Max Planck Society used this logo and the question “What are you looking for?” to spread the word about Max Planck Day in the run-up to the festival, which saw a total of 82 Institutes invite citizens to experience research firsthand. Events included tours and interactive experiments, science slams and debates, children’s activities, and quizzes. The program generated a great deal of interest, with the science market in Munich alone attracting over 5,000 visitors. Likewise, Max Planck Institutes across the rest of the country also reported large crowds – amounting to some 22,000 people in total.



Hamburg: talks by the “Flying Professors” on the underground.



Frankfurt: “Thirst for Knowledge” – a bar evening with short talks.



Munich: science market featuring 20 Institutes and an on-stage program.



Stuttgart: science stand-up Vince Ebert.

Photos: Thomas Eisenkrätzer, O. Burmeister, Yasmin Ahmed Salem, MPI für Eisenforschung, Friedemann Bayer, Axel Griesch, MPI for Empirical Aesthetics, Johanna Detering/MPI for Comparative and International Private Law (clockwise from top left)



# The heads of the first Dioscuri Centers

Aleksandra Pekowska and Grzegorz Sumara will each set up a group at the Nencki Institute in Warsaw

The leaders of the first two Dioscuri Centers have been chosen. In the selection procedure, Aleksandra Pekowska and Grzegorz Sumara prevailed against 45 applicants from all over the world. The Dioscuri program was initiated by the Max Planck Society and aims to establish internationally competitive research groups with the support of German partners, initially in Poland and potentially also in other Central and Eastern European countries at a later stage. Starting next year, Aleksandra Pekowska will establish the Dioscuri Center for Evolutionary and Functional Genomics of Astrocytes – specific cells in nervous tissue – at the Nencki Institute for Experimental Biology in Warsaw. Pekowska is currently conducting research at one of the U.S. National Institutes of Health. Grzegorz Sumara's Center, which is also being established at the Nencki Institute, will focus on the elucidation of signaling pathways that play a role in metabolic diseases. Sumara is currently working at the University of Wuerzburg. Each of the Dioscuri Centers of scientific excellence will be financed with up to EUR 1.5 million for a



Strengthening Polish research: Aleksandra Pekowska is moving from the U.S. to Warsaw, Grzegorz Sumara from Wuerzburg.

period of five years. The costs will be shared equally between the Federal Ministry of Education and Research (BMBF) and the Polish government, with the host institutions in Poland providing the infrastructure.

## On the net



### Harnack Lecture 2018

This year's Harnack Lecture – an honorary event organized by the Max Planck Society to commemorate Adolf von Harnack (1851 to 1930), the German science reformer – was delivered by Steven Pinker on 24 October in the packed Goethe Hall of Berlin's Harnack House. Pinker's speech was a passionate plea for an optimistic worldview as well as an appeal to the assembled scientists to dare more optimism. Pinker believes that thinking positively is far from being a naïve hope, but rather grounded in facts. He argues that the world has become progressively better in the last three hundred years. Ultimately, the driving force is science, the findings of which have not only led to an improvement of living conditions, but also to the humanitarian ideas that have made human. You can watch his lecture on the MPG's YouTube channel.

<https://youtu.be/YUNSDy9esio>

### Research is curiosity

"What are you looking for?" was the question posed by the Max Planck Society this summer, when it called on people to put their questions to academia. At the same time, the two video bloggers MrWissen2go and Doktor Watson went on a Germany-wide tour to visit various Max Planck Institutes. The pair met scientists to discuss interesting topics at a series of unusual locations, such as the value of goods in a wine store or gravitational waves at a flooded gravel pit. The 16 resulting videos can be found on the *wonachsuchstdu* ("whatareyoulookingfor") website along with the submitted questions and the Max Planck researchers' answers. The site also invites readers to browse and ask questions of their own.

[www.wonachsuchstdu.de](http://www.wonachsuchstdu.de) (in German)

### Kaleidoscope of science

A collection of 30 striking photographs from the MPG's Images of Science exhibition is currently on show at the Phillip and Patricia Frost Museum of Science in Miami Florida, presented by the Max Planck Florida Institute for Neuroscience. The images, which will be shown from December 15, 2018 – June 16, 2019, showcase the scientific research from some of the MPG's work around the world. In addition to a purely scientific documentation of research objects, sometimes images are created that feature surprising aesthetic forms and structures — abstract works of art from a world normally hidden to the human eye. The images will be on display from December 15, 2018 – June 16, 2019. A short by trailer by Max Planck Florida introduces the exhibition.

<https://youtu.be/9ajksGC3VRU>



# Democracy in decline in Africa

Despite some gains in the past decade, democracy is in trouble in Africa. Only nine countries on the continent are currently classified as democratic according to the Economist, with more than half under authoritarian rule. Elections are habitually manipulated, the opposition is harassed, civil society is suppressed, and demonstrations are violently dispersed. Autocrats are also increasingly relying on modern technology and foreign “consultants” to maintain power – and are largely allowed to do so undisturbed. As our author critically notes, Europe and the U.S. far too often look away out of fear of instability. This allows incumbents to cling on to power and gradually erode the institutions and expectations sustaining democracy.

TEXT **ELENA GADJANOVA**

**E** lectoral landslides, particularly in newly-democratizing states, are often a sign of trouble. Scholars of comparative democratization have long noted that the margin of victory in national elections is inversely related to a country’s quality of democracy. In October 2017, Uhuru Kenyatta, Kenya’s incumbent president,

Optimism in Kenya quickly turned to cynicism, apathy and fear

won 98% of the vote in a repeat election after the one in August was invalidated by the country’s Supreme Court. Uhuru’s ‘victory’ makes him a member of the rather dubious club of Paul Kagame of Rwanda, re-elected with 98.8% of the vote, Omar al-Bashir of

Sudan (95%), Salva Kiir of South Sudan (93%), and Teodoro Mbasogo of Equatorial Guinea (94%).

Kenya’s opposition boycotted the poll, turn-out was a meagre 35% (in comparison, close to 80% of eligible voters cast a ballot in August the same year), and clashes between the police and opposition supporters resulted in a number of deaths in opposition strongholds.

Things looked very different just a month earlier, in September 2017, when there was widespread optimism that Kenya would firmly set out on a pro-democracy path. The country’s Supreme Court annulled the August 2017 presidential election because of “massive irregularities and illegalities”, and ordered a new vote. The move was historic and was widely heralded as a triumph of the rule of law and

Lenient monitors: electoral observers from the Commonwealth found no irregularities in the presidential election in Kenya in August 2017. Four weeks later, the Kenian constitutional court annulled the election.



due process over political impunity. Kenyan citizens were told by their own court that they could and should expect more from their institutions and politicians. This was important because elections in

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### Analog monitoring tools are no longer suitable for digitalized vote counts

Africa often suffer from ‘the tyranny of low expectations’: lower standards are tolerated because of fears of political instability. Foreign election observers frequently overlook irregularities and rubber-stamp contests in Africa that would not be tolerated elsewhere because of the perennial expectation of violence and political unrest. This allows incumbents to subtly manipulate the vote and is deeply subversive to efforts to hold elected officials fully accountable.

Kenya’s Supreme Court decision invigorated pro-reform forces in the country and across Africa. At least for a brief moment, there was hope that justice would triumph over the desire to maintain the stability of the political system at all costs.

But measures designed to ensure free and fair repeat elections were never put in place. Citing “lack of time”, the electoral commission was not reformed and the same election officials who had botched the August poll were allowed to oversee the repeat election. Provisions were not made to better safeguard the security of the election transmission system, which had been severely compromised in August. The ruling Jubilee Party rammed a new election law through parliament, which limits the ability of the Supreme Court to annul elections in the future and stipulates that if a candidate withdraws from the election, the other candidate automatically wins. Supreme Court judges were intimidated to the point

where a last-minute petition to halt the October poll was not heard for lack of quorum because only two of the seven justices showed up.

So it is that the few remaining institutional safeguards of democracy in Kenya are being eroded one by one. The Electoral Commission and Parliament were put in the service of the regime, and it appears that the courts are being neutralized. There is evidence that the police engaged in ethnic profiling and violence targeting communities believed to support the opposition. Dozens of people were shot. Civil society organizations are stifled on a daily basis. The media, which in the past was regarded as one of the freest and most objective in Africa, have been turned into a mouthpiece for the ruling party.

The optimism of September 2017 quickly turned to resignation, cynicism, apathy, and fear. Thus, democracy in Kenya retreated back several decades over the course of a few months only: the speed of this transformation was remarkable. Autocrats elsewhere on the continent felt emboldened in turn.

Kenya’s election drama and autocratic retrenchment over the last year provides a template for the decline of democracy in the rest of Africa. Democracy’s prospects suffer when moments of hope and opportunity are squandered because a regime refuses to

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### It appears that the courts are being neutralized

loosen its grip on power. We see this bleak scenario currently play out in Togo, where protesters against Faure Gnassingbe, whose family has been in power for the past 50 years, were beaten and shot at, in Burundi, where President Nkurunziza’s move to extend his tenure to 2034 led to violent clashes, and in Uganda, where a vote to remove the presidential age limit descended into a physical fight on the floor of





the parliament. In Zimbabwe, Robert Mugabe's firing of his vice-president in November 2017 in order to install his wife as successor precipitated an army coup. At the time of writing, the army is shooting at protesters in the capital Harare after the opposition disputed the results of the July 30 election.

In Zambia, which appeared to make strides towards democracy in the late 1990s, key democratic institutions such as the judiciary, civil society organizations, the police, and the Electoral Commission have gradually been co-opted, threatened, or silenced. Those in power show obvious disrespect for the rule of law and intolerance of any opposition voices. In result, the population has lost trust both in elected politicians, and in the democratic process as a whole. This growing apathy among voters is deeply corrosive to democracy in the long run.

In Tanzania, President John Magufuli's administration banned political activities and demonstrations and moved to jail key leaders of the opposition. Abduction, torture, and political assassinations have been noted by civil society organizations and churches since 2016. In a sign of desperation, opposition members marched to the offices of the European Union delegation in Dar es Salaam in February 2018 to seek protection and support.

It has also become painfully evident over the past year in Africa that the international community needs to rethink its role in and approach towards "democracy promotion" on the continent. There was a collective failure of multiple election observation missions – by the EU, African Union, and U.S.-based NGOs alike – to detect and sound the alarm on irregularities in the August 2017 Kenyan election. The preoccupation with stability and the tendency to overlook irregularities that has been common to election observation missions in Africa in the past decade is part of the explanation. But another factor is that monitoring tools are no longer suited to the electronic process of tallying the vote count characterizing present-day African elections.

Countries have adopted electronic registers and vote counting techniques that allow for tampering on an entirely different scale, and which is much harder to detect. It also occurs after the ballots are cast and often after election observers have already left the country.

To paraphrase Kenyan analyst, writer, and blogger Nanjala Nyabola, the international community still uses analog monitoring tools for Africa's increasingly digital vote counts. For effective democracy promotion in Africa and beyond, the interna-

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## Cambridge Analytica influenced elections to benefit those in power

tional community needs a change in expectations, tools, and methods. Withdrawing from observing elections, as the majority of missions did with Kenya's repeat poll in October 2017, is not the answer either. It emboldens autocrats and further curtails pro-reform forces internally.

Another deeply subversive foreign influence on African democracy has been the increased involvement of international campaign "consultants" in the elections in various countries. The now notorious Cambridge Analytica is the most well-known, but far from the only example of this phenomenon. Boosted by novel micro-targeting techniques, the international campaign consulting business when combined with local autocrats and lax to non-existent privacy protection is highly dangerous. Hired by incumbents in Kenya and Nigeria, Cambridge Analytica planned and executed a campaign of ethnic fear-mongering and intimidation targeting the opposition. It spread rumors and false information through social networks and targeted text messages. In a country with a history of ethnic violence around elections, this is particularly sinister. >



The harvesting of personal data from social networks without users' knowledge and consent and its use for micro-targeting in election campaigns has become a global problem with far-reaching implications for governance and democracy worldwide. Cambridge Analytica was also involved in the 2015 Nigerian election, the June 2016 Brexit referendum, and Donald Trump's 2016 election campaign. The firm's work has exposed an underlying gap between the spread and growing importance of social networks in political communication and the lack of proper regulation of this increasingly popular information medium. The implications of this gap are only now beginning to play out. To what extent it was able to sway election results is questionable, but it certainly contributed to a climate of fear and misinformation, which undermines people's faith in the democratic process.

And in a striking parallel to the double standard that election observers have long applied to elections in Africa, while Facebook issued a formal apology to its users in the U.S. and the UK for allowing personal data to be used by election consultants, no such apology was forthcoming in Kenya, Nigeria, or anywhere else. Facebook was effectively signaling that on the global marketplace for personal data, some

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### Autocrats undermine the institutions from within

users should receive better treatment and deserve more protection than others. This is a boon to autocrats seeking to bend the rules to remain in power, as they can add an additional powerful tool to their already extensive manipulation toolkits.

In sum, incumbents intent on clinging on to power by any means is the biggest threat to democracy in Africa and beyond. Autocrats maintain the

façade of elections in order to legitimate their rule, but gradually and relentlessly undermine the institutions supporting democracy – the courts, electoral commissions, media, civil society – from within. Foreign election consultants are allowed to operate

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### Unregulated micro-targeting in elections as problem for democracy worldwide

with impunity and have further tilted the playing field in favor of incumbents. Citizens have grown increasingly cynical, resigned and apathetic, and there is evidence support for democracy is dwindling across the continent. Voter apathy and fear in turn mean that increased authoritarianism is not met with outrage and counter-mobilization, allowing it to continue with impunity.

Still, it is very important to note that democracy is not in decline everywhere in Africa. After a prolonged political crisis threatening to rip Ethiopia apart along ethnic lines, the country's new prime minister expressed support for multi-party democracy, committed to holding elections, decriminalized opposition parties, and ruled out prolonging his tenure. It is clear that suspending human rights and civil liberties at a time of crisis is a political choice, not a security imperative.

Ghana held its sixth consecutive peaceful election resulting in the third turn-over of power in the country in December 2016 when the opposition party won the presidency and a majority in parliament. Elections have been very closely fought between two relatively consolidated and evenly matched political parties. In 2008, the margin of victory in the presidential race was less than 0.5%, with 2% in 2012 – 2% and 9% in 2016. Yet the results were

accepted by the losing sides and all incumbents stepped down after being defeated at the ballot box. This was in large part because the Electoral Commission enjoys significant confidence and is seen as effectively managing the electoral process in the country. Botswana's incumbent also recently stepped down after his term limit of 10 years in office was reached. Elections in the country are scheduled for 2019.

In general, incumbents relinquishing power when their terms in office are over or after being defeated at the ballot box is the one key difference between Africa's democratic success stories and its failures. It builds confidence in the election process and in institutions, diffuses social tensions, and encourages all sides to invest in connecting to voters within existing democratic structures, not outside of them. Today's election losers believe they can be tomorrow's winners, so they have an incentive to continue playing the game. Voters in turn are reassured that they can demand accountability and affect change through the ballot box, so becoming

## Suspending human rights is not a security imperative

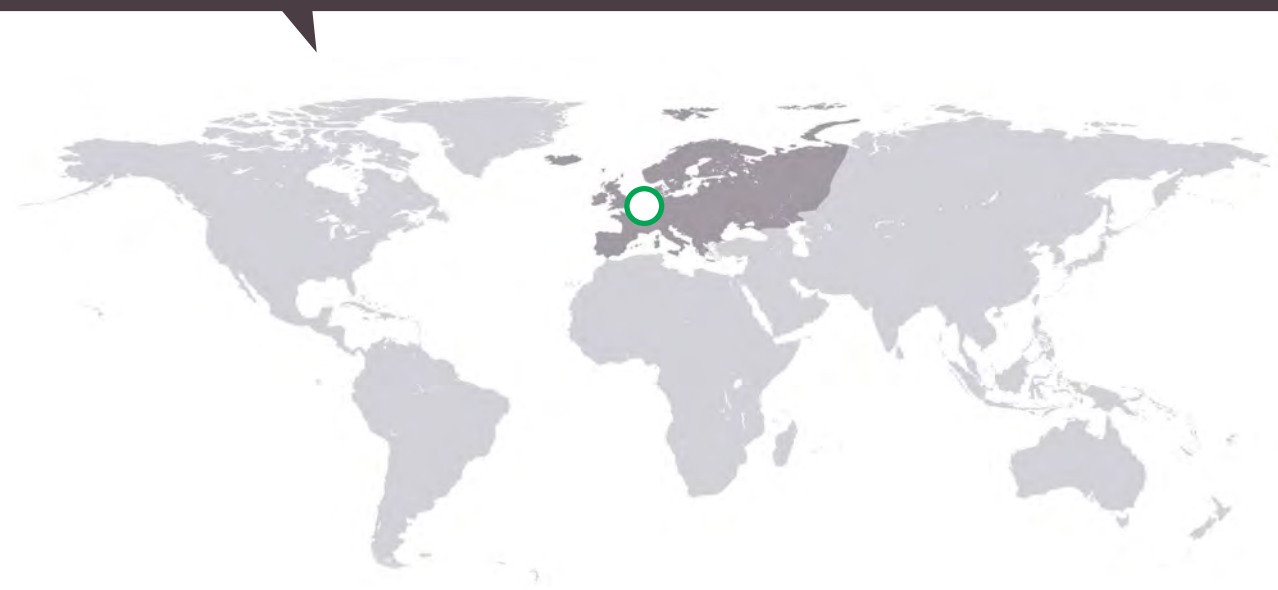
protective of the system. Ghana's democracy has become a great source of pride locally: in a survey I fielded in December 2016 asking people what makes them proud to be Ghanaian, many quoted the country's track record of free, fair, and peaceful elections. When a regime type is seen as a value in itself and becomes integral to a positive national self-image, attacks and efforts at subversion are not likely to be tolerated and are less likely to be attempted. Resilient democracy thus requires a commitment both to its intrinsic value and to its processes and institutions. ◀



### THE AUTHOR

**Elena Gadjanova** is a Lecturer in Politics at the University of Exeter and associate faculty at the Blavatnik School of Government, University of Oxford. Previously, she was a Post-doctoral Fellow at the Max Planck Institute for the Study of Religious and Ethnic Diversity in Goettingen. Her career has also taken her to Princeton and Geneva. Her research focuses on political communication, elections, and ethnic politics in Sub-Saharan Africa. Gadjanova is also the co-editor of the interdisciplinary journal *NEW DIVERSITIES*.





# Between baby and doctorate

Scientists from 100 countries work at the Max Planck Institutes. Here they write about their personal experiences and impressions. Julia Misersky, doctoral student at the Max Planck Institute for Psycholinguistics in Nijmegen, recently started her maternity leave. Here she introduces her research topic, explains how she plans to juggle her doctoral studies with motherhood, and talks about her commitment to improving conditions for young parents.

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I recently started my maternity leave, which is somewhat shorter in the Netherlands than in Germany. Pregnant employees here are only entitled to 16 weeks. I have postponed the start of my maternity leave until four weeks before the birth date so that I can spend as much time as possible with my baby after the birth. I am also still entitled to some vacation, which I will take when my maternity leave ends.

My partner will also take six weeks of unpaid vacation after the birth. As soon as we are both back at work, we will make use of the Dutch *Ouderschapsverlof*. This is a legally regulated entitlement to additional parental leave, in which employees can take unpaid vacation depending on their regular working hours.

In my research, I am interested in how various linguistic backgrounds – meaning the differences in grammar and vocabulary between various languages – influence the way in which we perceive the world around us. For my doctorate, I am investigating when and how language affects perception. To this end, we are conducting experiments in which we manipulate what the participants see, when they see it, and for how long.



**Julia Misersky**, 30, studied psychology at the University of Sussex. After obtaining her Bachelor's degree, she switched to Radboud University in Nijmegen and completed a Master's degree in cognitive neuroscience. In November 2016, she joined the Max Planck Institute for Psycholinguistics in Nijmegen, where she is working for her doctorate in the Neurology of Language Department under Director Peter Hagoort. Julia Misersky represents the Humanities, Social and Human Sciences Section of the Max Planck Society's PhDnet platform.

We try to design our experiments in line with the way in which people perceive the world on a daily basis. We do this by using virtual reality methods, for example. Moreover, the participants have different linguistic backgrounds. This means that we can analyze how their respective native languages influence, how the participants perceive the world, how they evaluate specific situations, and how their brains react to certain stimuli. So far I have used eye tracking and neuronal imaging techniques for this purpose.

Our baby will start daycare at the crèche at the age of just three or four months – but only for two days a week. The situation isn't ideal compared to the standards we are familiar with from Germany, but it's a compromise we can both live with.

The fact that everyone at my Institute reacted with incredible understanding and is very supportive is tremendously encouraging. My supervisor, for example, who has just had her second child, and the administrative staff have helped me out wherever they could. They told me about the legal situation in the Netherlands as regards work and parental leave and explained the childcare facilities offered by the Max Planck Society, the MPS *Schnullerprogramm* (childcare program).

I am aware that my situation cannot necessarily be applied to others. In recent months, I have gathered information on the experiences of many other doctoral students on this topic – both positive and negative. Reconciling parenthood and career is ranked high on the agenda of this year's PhDnet Steering Group, which is why we have set up a working group in cooperation with the General Administration. I am optimistic that the results will help make doctoral studies and parenthood reconcilable options for everyone involved.

After my maternity leave, I still have a few years in which to complete my doctorate. For this reason, I can't yet say what will happen afterwards. First of all, I will find out what it means to have a family. Time will tell what happens next.

# Early alert system for fake news

Fighting fake news in social media more efficiently and accurately:  
**Manuel Gomez Rodriguez** of the **Max Planck Institute for Software Systems**  
combines artificial intelligence techniques and human judgments to design  
an early alert system for fake news.

Fact checking before the Internet era:  
Pinocchio's nose gave away his lies.  
However, this would not help prevent  
fake news on social media platforms.





TEXT RALF GRÖTKER

**F**ake news is dangerous. In some cases, it is even life threatening. On December 4, 2016, a man with an assault rifle entered the pizza restaurant Comet Ping Pong in Washington, D. C. He had set out on a mission: to free the imprisoned and abused children that were supposedly held hostage in the restaurant. Just like millions of other Internet users, he had learned on the *Reddit* and *4chan* social media platforms that the basement of the pizza restaurant was the stronghold of a pedophile ring. At the center of the ring, so the tale went, was Hillary Clinton, presidential candidate at the time. Donald Trump's temporary National Security Advisor Michael T. Flynn and his son were among those involved in spreading this hoax.

The "Pizzagate" affair marks one of the high points of fake news to date. Various social networks have meanwhile begun to ask their users to report fake news. Some networks are also cooperating with journalist organizations that check facts. One example of this in Germany is *correctiv.org*.

Manuel Gomez Rodriguez, Group Leader at the Max Planck Institute for Software Systems in Kaiserslautern, and his team are working on sophisticated methods for identifying fake news more accurately and efficiently. These methods are interlinked, much like the pieces of a jigsaw puzzle, and aim to analyze different aspects of the pieces of information that social media users receive in their news feeds, considering their respective context. "We are using a hybrid approach," explains Gomez Rodriguez. "We combine artificial intelligence techniques and human judgments to design an early alert for fake news."

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## Pope Francis shocks world, endorses Donald Trump for president



The claim that Pope Francis approved of Donald Trump being elected as President was shared by millions. However, it was a complete invention. This could have been revealed very simply: the website *WTOE 5 News* that published the news item refers to itself as a fantasy news website.

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"Curb" has been presented by the researchers as a central result of their work. This algorithm is designed to prioritize which content should be most urgently checked and possibly marked as fake by a limited number of human fact checkers, signatories of the Poynter's International Fact Checking Code of Principles. The objective is to ensure that fake news are read by as few people as possible, before it is marked as fake.

### A METHOD WITH A DYNAMIC THRESHOLD

A crucial aspect of the method is that it enables an elaborate analysis of the ways in which users handle content. This includes the frequency with which users share posts and the rate at which such content is then spread, as well as

the number of users that mark a post as fake. These are important criteria to estimate the speed at which a possible hoax will spread. Gomez Rodriguez: "While most social media platforms are currently merely choosing to fact check news items with more than a fixed predefined number of user complaints, our method uses a dynamic threshold that changes over time and reacts to the viral nature of a news item as well as the likelihood of it being a hoax."

More specifically, the algorithm developed by Gomez Rodriguez and his team focuses on the relation between complaints on the one hand and *shares* without complaints on the other hand. The more often a news item is proportionally shared without a complaint being made, the more likely it is that it is *not* a hoax. However: the faster a news

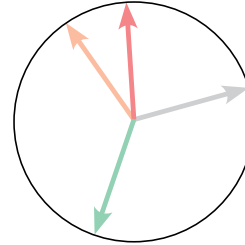
Comments

I like red candy!
I like green candy!
Candy is good and red is the best!
Candy is bad for you!

Voters

1	2	3	4	5
👍		👎		👍
👎	👎	👍	👍	👎
👍			👍	👍
👎	👍	👍	👎	👍

Opinions



Text analysis of user ratings: Max Planck researchers from Kaiserslautern analyze the degree of differentiation or polarization of statements made online, based on agreement (thumbs up) and disagreement (thumbs down) with statements that are part of a sequence (center). They use this information to determine vectors that are used to locate the statement within the opinion space (right). The illustration shows that the statements "I like red candy" (red vector) and "I like green candy" (green vector) represent opposing views. The researchers use the candy example to illustrate their approach.

item spreads, the greater the potential damage in cases where it is a fake news item after all. This problem is addressed by Curb by simultaneously monitoring and constantly updating information about distribution speed and the likelihood of a news item being fake. The algorithm's job is to optimize the balance between these two criteria.

For example: assume a news item is shared ten times an hour, and the likelihood of it being fake is fifty percent based on user ratings. It can then be mathematically concluded that, *on average*, five users an hour are exposed to a hoax. However, this calculation is now adjusted whenever a user shares the news item in question, and either *flags* it as a fake or does not object to it,

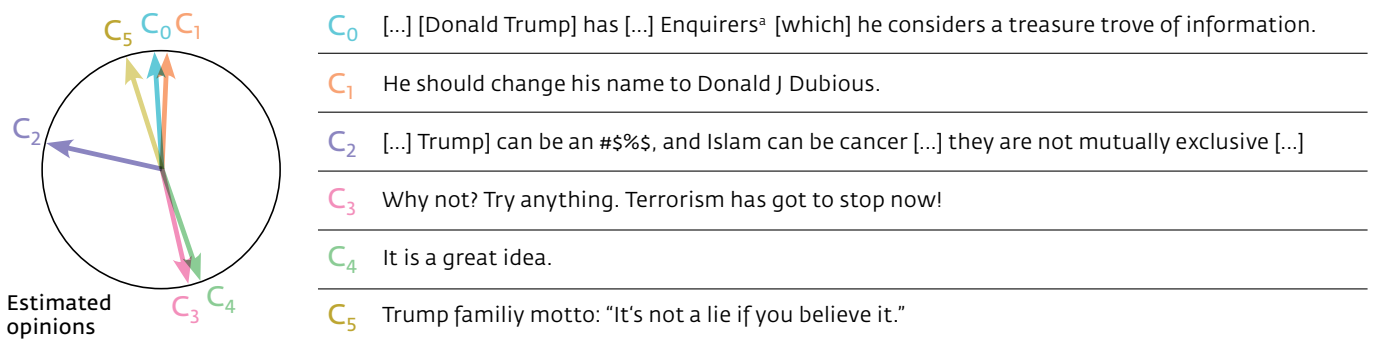
assuming it to represent a solid piece of information. The algorithm therefore dynamically creates an optimized balance between the endeavor to expose as few people as possible to undeclared fake news on the one hand and efficiency in using human fact checkers on the other.

TESTS USING DATA FROM TWITTER AND WEIBO

The ultimate test for Curb was an experiment conducted with real data that researchers from the Korean KAIST university had previously gathered from two popular social media sites, Twitter and Weibo, by means of web crawling, which they made publicly available.

The larger of the two datasets is the one from Weibo, with more than 4,600 individual news items, which 2.8 million users had posted or shared 3.7 million times. "We had information about the network structures in the dataset; that is the number of followers of each user, and we also knew which news items had been declared fake by the fact checking organization Snopes," explains Gomez Rodriguez.

What the researchers did not know was how and when the users from the dataset had flagged the posts. The researchers had to use a trick to solve this problem. They relied on other surveys about the number of times that users had flagged news that was actually fake. This enabled them to make well-



<sup>a</sup> National Enquirers is a well known entertainment magazine in US.

Orientation guideline within the spectrum of political opinion: the way in which users assess the comments made in an online debate about Donald Trump provides an insight into the political view on which the comments are based, which can be recorded as vectors in the opinion space. Statements C<sub>0</sub>, C<sub>1</sub> and C<sub>5</sub> were clearly made by individuals whose political view is entirely different from that of the individuals who made statements C<sub>3</sub> and C<sub>4</sub>.

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## Vote Hillary from home! Save time & avoid the line!



The advertisement claiming that supporters of Hillary Clinton could cast their vote by sending a text message was intended to mislead voters. The advertisement bearing the Clinton campaign logo was distributed via Twitter. However, those who followed the appeal lost their vote, as it was not actually possible to vote by text.

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founded assumptions about how effectively users recognize items of fake news, and how often they also mark them as such on average. “We simply made our algorithm try out a wide spectrum of plausible flagging behavior,” explains Gomez Rodriguez.

In the experiment with real data from Twitter or Weibo, the researchers from Kaiserslautern tested how effective their algorithm was in submitting suspicious posts for fact checking compared to other methods. The methods that Curb competed against included the pseudo-method Oracle, which in the testing scenario had access to the information as to whether a news item was a hoax or not, and which accordingly submitted the post for fact checking.

Other comparison methods employed simple general rules: an algorithm which – like the method created by the team from Kaiserslautern – determines the level of urgency of fact checking based on the simple ratio between the number of flags and the number of shares; another algorithm that submits a post for fact checking as soon as a certain number of flags has been reached; and finally, an algorithm that only considers the distribution rate of a post in order to prioritize a news item for fact checking.

### FURTHER APPLICATIONS FOR THE CURB ALGORITHMS

The result of the comparative tests: Curb was almost as good as Oracle at preventing the spreading of fake news that had not been identified as such. The three methods based on general rules were less effective.

Despite the successful test, Gomez Rodriguez is not yet able to predict how Curb will be used in practice in the future: “It remains to be seen if, at the end of the day, Curb is worth considering as a solution, or if only certain components of our method will prove to be of interest to commercial providers,” says the researcher. “However, one of the developers of Curb has recently done an internship at Facebook’s fake news team.”

Algorithms similar to Curb can also be used in different fields. “Language learning software, for example, could be optimized by methods similar to Curb, by improving predictions of which content should be presented to the learners repeatedly in order to allow them to memorize this content,” says Gomez Rodriguez. Another area of application is the field of viral marketing. The basic structure of Curb was originally developed by the researchers for this type of application: to find out how posts can be spread most effectively in social media.

Nevertheless, there is one problem that Curb fails to solve: what happens

if users choose to sabotage the system, by flagging solid news items as fakes, or by deliberately spreading fake news? Such extreme behavior would make it hard for Curb to correctly assess how urgently a post should be submitted for fact checking. Gomez Rodriguez and his colleagues have developed “Detective” to address this very issue.

The Detective algorithm is also intended to reduce the distribution of false information. Gomez Rodriguez’ team presented the method at the Web Conference in Lyon this spring. While Curb considers all users to be equally reliable, Detective aims to identify users who object to fake news particularly reliably and those who deliberately mark solid news items as fake in order to undermine the system.

For this purpose, the Detective algorithm considers the results of fact checking and uses these to estimate the extent to which users are to be considered reliable in recognizing and flagging fake news. “We monitor a user over a certain period of time,” explains Gomez Rodriguez. “While doing so, we





Fighting fake news with artificial intelligence: the work performed by Manuel Gomez Rodriguez and his team includes the development of methods that allow for efficient prevention of the distribution of fake news that is not recognizable as such.

repeatedly submit posts they create or share for fact checking.”

However, the Detective algorithm is also subject to a conflict of interests. In order to be able to assess the reliability of the greatest possible number of users, fact checkers should, on the one hand, verify posts that have been shared by as many different people as possible. This includes posts that according to user flagging are unlikely to be hoaxes. They thus gather information about which users assess information reliably. On the other hand, here too, the limited number of human fact checkers should also be used only for posts that are likely to be hoaxes. The most efficient way to achieve this would be to simply trust the judgment of those users that were found to be reliable in the past. For further users to achieve this status, however, the machine learning techniques used by Detective must be exposed to the behavior of as many individuals as possible. Among the achievements of the Detective algorithm is its ability to find an ideal compromise between these two requirements by means of machine learning.

Just like Curb, Detective also passed the test with empirical data sets with flying colors. The results achieved by the method in the experiment were very nearly as good as those of a pseudo-algorithm that was familiar with the users’ flagging behavior. In practical application, Detective combined with Curb should be useful for administrators wishing to use the algorithm to allow for most efficient human resource planning in fact checking.

Based on the Detective rating, administrators would also be able to give users access to information about the reliability of other individuals within their social network when it comes to flagging posts as fake. “In reality, however, this is limited by data protection regulations,” Gomez Rodriguez admits. Many users even find it unacceptable if their “friends” or “followers” are able

to see which posts they like. “Marking a post as a piece of fake news can be just as problematic, because this often involves disclosing an aspect of one’s own political orientation.” This is why the results need to be suitably anonymized by Detective. “Ten percent of the reliable individuals in your network have flagged this post as ‘fake’: you could display this type of information,” says Gomez Rodriguez.

### POLARIZING NEWS ON SOCIAL MEDIA PLATFORMS?

However, indicating that certain individuals are particularly reliable may also cause the opposite of the desired effect: users that lean towards conspiracy theories might choose to follow individuals who deliberately flag solid news items as fakes and who spread fake news – because they believe this information to be the truth that is withheld by the mainstream media. However, Detective proved to be rather robust when it comes to dealing with the deliberate distribution of incorrect information – especially thanks to the fact that the algorithm takes the users’ reliability into account.

In addition to the endeavor to effectively reveal hoaxes, Gomez Rodriguez’ team also addresses the issue as to what extent news items – whether they are fake or not – contribute to a polarization of views on social media platforms. The researchers have developed another algorithm to answer this question. This algorithm analyzes ratings such as “Thumbs up!” or “Thumbs down!” for text-based posts such as comments in online debates.

Instead of opinions regarding individual questions, the researchers consider entire opinion sequences. Gomez Rodriguez uses the following statements to illustrate this approach: “I like red candy!”; “I like green candy!”; “Candy is awesome, and red candy is the best!” and “Candy is unhealthy.” The respective view on which an individual com-

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## Paid fake protesters were bussed in to the anti-Trump protests in Austin, Texas.

ment is based cannot be reliably determined using software that, for example, analyzes text for certain words and compares it to other statements. This is not the case for opinions that are expressed by users, by agreeing or disagreeing to comments in such a chain of statements. The researchers analyzed these views expressed by different users, and on this basis were also able to calculate the view that is reflected by an individual comment.

When analyzing views that are reflected both in an individual comment and in the ratings for a sequence of statements, Gomez Rodriguez and his colleagues focused on two characteristics.

On the one hand they considered the degree of complexity, or the number of axes based on which the opinion space can be depicted. For example, if all participants of a debate hold either the same view or exactly opposite views regarding an individual issue, the answers can be sorted along a *single* axis. This type of debate is literally one-dimensional.

At the same time, the researchers also determined how far apart individual opinions are from each other. To do so, the attitudes on which the comments that make up the sequence are based are represented as vectors that form an opinion space. The respective vector is determined by the algorithm, by analyzing the way in which other users assess a comment. The arrangement of vectors provides information about the diversity of opinions. As Gomes Rodriguez stresses: "We are able to locate text-based posts that differ greatly in their semantic content, which comprise completely different words, and which may even include irony, in relation to each other within the opinion space."

An analysis of a large dataset from online comments on the pages of Yahoo News, Yahoo Finance, Yahoo Sports and the Yahoo Newsroom app has found that 75 percent of online debates take place on two or more axes in the




These photographs of numerous buses were the only evidence used by questionable news pages to support the claim that paid protesters were taken to Austin to take part in a march against Donald Trump. The buses were actually on their way to an event at a congress center located several miles from the starting point of the protest march. No evidence was provided of participants being paid.

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opinion space, and are thus not held in a polarized manner. "This is a clear sign that debates on these online pages have not fallen victim to demagogues," says Manuel Gomez Rodriguez.

The algorithm therefore enables debates held on online forums or on social media platforms to be assessed, and the results obtained to date contradict the impression that such debates held in the anonymity provided

by the Internet are generally undifferentiated and are largely polarized by demagogues. As is the case with Curb and Detective, the algorithm shows that a hybrid approach using artificial intelligence and human assessments can help to promote objectivity in such debates. ◀

 [www.mpg.de/podcasts/digitale-gesellschaft](http://www.mpg.de/podcasts/digitale-gesellschaft) (in German)

### SUMMARY

- A hybrid approach comprising artificial intelligence and human assessments can, in various ways, help to promote the objectivity of debates held online.
- The Curb algorithm prioritizes the urgency with which a post should be subjected to a fact check in order to prevent a possible item of fake news from being spread without being marked as such. To do so, it repeatedly reanalyzes how quickly a post spreads and how many users have flagged it as fake.
- The Detective algorithm is also intended to prevent the distribution of fake news, while at the same time takes into account the reliability of the users that mark a post as fake.
- A further algorithm analyzes the degree of differentiation of debates held on the Internet. It has been found that 75 percent of debates are not held in a polarized manner, which is a sign that the majority of users do not follow demagogues.

# Photo without a face

We have barely any control over where information about us and even photos bearing our likeness are displayed. In the future, however, it may at least be possible to prevent ourselves from appearing as bystanders in photos on other people's Facebook pages. This is thanks to technology developed by a team working under **Paarijaat Aditya, Rijurekha Sen** and **Peter Druschel** from the **Max Planck Institute for Software Systems**.

TEXT **TIM SCHRÖDER**

**W**e are experiencing a cultural change: smartphones have transformed our everyday habits, especially when it comes to taking photographs. Nowadays, we not only take photos while on vacation and at family celebrations, but also while shopping, in the bar, or out for a walk. After all, the advent of the smartphone means we always have a camera at hand. The quality of the built-in cameras is now so good that they're virtually the only one you need. Also, no camera is as readily accessible as the one in your trouser pocket.

Figures obtained by the online industry association Bitkom confirm the trend toward taking photos with mobile phones: seven out of ten Germans use their smartphone to take photos while on vacation – and six out of ten amateur photographers immediately share the photos using Facebook, WhatsApp, or other services. There's no doubt about it: smartphone photography is an omnipresent phenomenon.

But this very phenomenon can become a problem when snaps capture not only friends and acquaintances but also

bystanders who accidentally appear in the photo. Many people feel uneasy when a stranger takes their picture – particularly because in the era of social media, you never know where the pictures might turn up in the future. It would therefore be reassuring if bystanders were simply unrecognizable in photos.

## **BYSTANDERS' FACES ARE PIXELATED**

This was also the initial premise for Paarijaat Aditya and Peter Druschel of the Max Planck Institute for Software Systems in Saarbruecken. Together with colleagues from the neighboring Max Planck Institute for Informatics, the two researchers have developed a technique that pixelates bystanders' faces in photos, rendering them unrecognizable, while showing the faces of intentional subjects clearly. I-Pic, as they have named their app, could one day be installed as a special function in smartphones.

"These days, when it comes to taking photos, many people are concerned about their privacy," says Paarijaat Aditya. "Before we started developing

I-Pic, we launched a survey of our own. One thing we learned was that this depends a lot on the situation, among other factors: for instance, people find it particularly unsettling if their photo is taken in the hospital, while doing sports, or at the beach." In general, the researchers found that, even in the same situation, different people have different privacy preferences when it comes to photographs of themselves, and that an individual's preferences also vary considerably from one situation to another. Clearly, therefore, it was essential that I-Pic be able to take account of individual people's wishes depending on the situation.

I-Pic is currently at the prototype stage. In a video on YouTube, Paarijaat Aditya demonstrates how it works, taking a selfie that also captures people standing in the background. When the photo appears on the camera screen, the people who don't want their photo to be taken are pixelated, whereas the others are clearly visible. At first glance, I-Pic seems very straightforward. However, if you think about it for a moment, there is one puzzling aspect: how on earth can the camera know who





Photo: istockphoto

My image belongs to me: in snapshots taken by strangers, the I-Pic software pixelates the faces of people who don't want to be photographed accidentally.

» Even in the same situation, different people have different privacy preferences when it comes to photographs of themselves – and the preferences of the individual also depend strongly on the situation.

wants to be photographed and who does not? It quickly becomes clear that there's something special about I-Pic.

“Our achievement lies in the linking up of several sophisticated technologies in order to get the whole system to work,” says Paarijaat Aditya. The prerequisite for providing effective protection against unintended walk-on parts in photos is that the photographer's and bystanders' smartphones must all be equipped with I-Pic technology. And, of course, it must be possible for the smartphones of everyone visible in a photo to communicate with the photographer's device – in order to tell it whether their owners want to be recognizable or not. With I-Pic, this communication takes place via Bluetooth, a classical wireless standard that allows devices to exchange data over distances of a few meters.

### SMARTPHONES TRANSMIT PERSONAL PREFERENCES

To begin with, each user configures the software according to their personal preferences, i.e. whether or not they wish to be photographed by strangers in various situations or at various locations. Every phone equipped with I-Pic transmits this information constantly via Bluetooth. All nearby smartphones therefore tell the photographer's smartphone which people agree to appear in the photo that has just been taken and which do not.

Of course, the smartphone also receives Bluetooth signals from people who aren't visible in the image – for example, from bystanders standing just

out of shot. The photographer's smartphone must therefore be able to determine which Bluetooth signal belongs to whom or, to be precise, whether it originates from one of the people seen in the picture.

For this purpose, I-Pic is first fed with portrait photos of the smartphone's owner before it is able to do its job. Around ten photos is all it takes for I-Pic to get to know its owner's face and to store a record of its characteristics. All mobile phones equipped with I-Pic constantly transmit this facial information over the surrounding area – including to the smartphones of anyone taking a photo within Bluetooth range. This allows the photographer's smartphone to compare the faces in the photo it has just taken with facial information from people in the surrounding area.

In addition to data relating to faces, the photographer's smartphone also receives information about people's preferences (“Wants to be visible/Doesn't want to be visible”) – and can then make the corresponding faces unrecognizable.

For the facial recognition, the team had to incorporate powerful algorithms known as “classifiers” into the software. These can recognize faces quickly and reliably – even in photos with poor lighting, shadows, or back-lighting. Researchers led by Bernt Schiele, Director at the Max Planck Institute for Informatics, have developed an extremely effective piece of software for facial recognition.

“However, exchanging personal data – such as facial information – between smartphones is an extremely sensitive area in terms of data protec-

tion,” says Peter Druschel, Director at the Max Planck Institute for Software Systems. For this reason, the researchers have also equipped I-Pic with sophisticated encryption technology, allowing it to convert all of the data into encrypted combinations of characters before it is sent back and forth. Information about the face is not therefore transmitted simply as a JPEG image or in a similar format. Instead, I-Pic encrypts the numerous characteristics of the face into what is known as a high-dimensional vector.

### COMPARISON BETWEEN ENCRYPTED SETS OF DATA

I-Pic then compares the faces in the photo with the facial information sent to the photographer's smartphone via Bluetooth. The key thing is that the comparison takes place between the encrypted files. In other words, the picture information is not revealed at any point in time. “It may sound strange, but it's actually possible to process two encrypted files together,” says Rijurekha Sen, another researcher at the Max Planck Institute for Software Systems. “This is referred to as homomorphic encryption. It allows you to determine whether two images are the same without actually having to reveal them.”

As a result, the photographer's smartphone never stores a person's real image data if they have set their preference to “not recognizable”. The face is not shown as such in the picture that has just been taken, nor is it possible to read the picture information sent from the other mobile phones via Bluetooth.





And the face in the picture has already been pixelated by the time it appears on the phone's screen.

But there is more to I-Pic than Bluetooth, facial recognition, and encryption technology. During the software's development, the researchers were faced with another problem: securing data by encryption always involves highly complex computing processes. These calculations require a great deal of RAM and consume huge amounts of power. In locations where lots of photographs are being taken, I-Pic would have to perform a large number of image calculations, quickly draining the phone's battery or overburdening its processor.

The researchers therefore equipped I-Pic with technology that outsources the encryption and comparison of image pairs to the cloud – a worldwide network of computers – via a mobile data connection. The encrypted data is therefore processed on a large server elsewhere, which reports back to the smartphone with the result of the “Wants to appear in the photo/Doesn't want to appear in the photo” analysis.

“I-Pic works astonishingly well despite all this complexity,” says Paarijaat Aditya, who has already presented I-Pic at an international IT conference, where it attracted considerable praise. Peter Druschel adds: “We're the first team in the world to devise such an application and to have put it into practice successfully despite the wealth of technologies involved. And we're already thinking about how to expand it.”

Specifically, the question is how to make faces unrecognizable in photos in an aesthetically pleasing manner. >



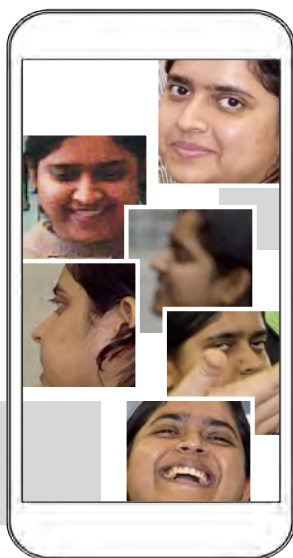
If the people in a photo have the I-Pic app installed on their smartphone, it synchronizes their facial information and data protection preferences with the photographer's device. Those who do not wish to be recognizable are then blurred out in the final image.







Helping to safeguard the right to one's own likeness: Paarijaat Aditya and Peter Druschel developed the I-Pic app based on technically sophisticated components (above). The central feature of this app is technology that recognizes a person even when they are photographed from totally different angles, while partly obscured or in poor lighting (below).




After all, images with pixelated faces are not particularly attractive. Peter Druschel therefore wants to extend I-Pic with a software module that can modify faces, make them look older, or specifically manipulate the skin and hair color as well as other characteristics: "In the photo, unfamiliar faces are no longer simply pixelated. Instead you see people who, in reality, don't even exist."

There is another thing to consider: I-Pic should allow users to configure their preferences in detail. Those selecting "Never wants to appear in strangers' photos" as standard could run into problems. For example, photos taken at large family gatherings might actually be welcome, but the person would always be pixelated in the images. The Saarbruecken-based researchers are therefore developing a set of preferences for future users to choose from.

For example, one possibility could be to allow contacts stored on the phone to make the owner's face visible in photos. Apparently, it will also be possible to set preferences for various locations in the future. Users could therefore select the unrecognizable mode for the office or gym but allow their likeness to be displayed unpixelated in all other locations.

It may also be possible to adapt the I-Pic technology to similar applications, such as videos. "At any rate, I-Pic has reached the stage where it can soon be refined into a market-ready product," says Peter Druschel. "Ideally, the technology would be adopted by smartphone manufacturers and installed in mobile phones as standard – that would represent a huge gain in terms of privacy and data security."

 [www.mpg.de/podcasts/digitale-gesellschaft](http://www.mpg.de/podcasts/digitale-gesellschaft)  
(in German)

### SUMMARY

- Now that smartphones are equipped with powerful cameras and people are taking more and more photos, there is a growing risk that bystanders will be photographed and that their images will be distributed on social media without their consent, for example.
- The I-Pic software could ensure that people are only recognizable in photos if they have given their approval. Faces of people who do not wish to appear in the photo would then be pixelated or rendered unrecognizable.
- In order to safeguard the right to one's own likeness, I-Pic combines various technologies, such as facial recognition based on artificial intelligence and the encryption and comparison of image data in the cloud.

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# Rules for robots

Artificial intelligence is gaining in importance and advancing rapidly – literally as well as figuratively: robotic nurses could soon be moving into our homes. However, their behavior is still open to negotiation. At the **Max Planck Institute for Innovation and Competition** in Munich, **Axel Walz** is investigating how legal means can be employed to help ensure that artificial intelligence adheres to human values.



Ready for use: "iPal" robots by the Chinese-American company AvatarMind have been developed as electronic babysitters and companions for older people. Whether or not they will be accepted in these roles remains to be seen.



TEXT SARAH MÜHLBERGER

**T**hey bring food and remind patients to take their medication, help out in the shower and fold back the bed covers. Some of them tell jokes, while others sing or play memory card games. They are called Pepper, Justin, Riba or Garmi – and may be the future of German nursing homes: the robots being tested up and down the country.

### A SMART FRIDGE ORDERS KOSHER FOOD

As yet, nobody knows whether these robots will really be able to significantly relieve the strain on the nursing care system – after all, there is already a shortfall of more than 36,000 nurses. At the same time, there are more problematic areas that need to be addressed. Who will the robotic nurse ultimately obey? Will it incapacitate the patient, or will individual human ideas take precedence? How can robotic nurses be protected from hackers? After all, they will have access to the most sensitive of all personal data and know all about the patient's health and habits.

Questions like these require urgent answers, says Axel Walz, Senior Research Fellow at the Max Planck Insti-

tute for Innovation and Competition. As a legal expert, he has always been driven by the question of what the consequences of innovation are for consumers. "In a time in which artificial intelligence and autonomous systems are gaining in importance, I am particularly concerned with how jurists can help ensure that artificial intelligence adheres to ethical standards."

"Ethics" is a complex term that means many things, from individual morals, religious norms and values anchored in law to the protection of human dignity. "It's all about the principle of ethical plurality," says Walz.

This is why a whole amalgam of measures is needed. A graduated regulatory model has to be employed and each case analyzed in close detail to establish how far the legal system can employ regulatory measures or other incentives to uphold ethical considerations. The protection of human life and human dignity is the exigent duty of the legislator. Existing laws have to be reviewed and adapted to the particularities of artificial intelligence whenever necessary. "And if I want to set specific individual standards for a technological product, a contract between two partners is typically the ideal regulatory instrument. I can use it to define a list of stringent conditions that match my ideas."

Certificates are a good solution when it comes to making sure that technological products give particular consideration to the values of a specific group of people – here Walz is thinking of religious communities, for example. This would reassure Jewish consumers that their smart fridge will only order groceries from kosher supermarkets and Muslim patients that the robot will only give them halal medication.

### CERTIFICATES COULD BE INSPECTED BY TUEV

Certificate solutions of this type could for example be inspected by facilities such as TUEV, the German technical control board, "something that is already happening today, for example in the case of data protection standards," explains Walz. Appreciable legal consequences would also be a way of disciplining manufacturers if their systems were hacked.

During the course of his research, Axel Walz has been talking to developers of new technologies and potential users. For the next step, he will be reviewing the current legal situation. "With this in mind, we will then attempt a kind of risk analysis: what are the advantages of new technology, and what are the possible negative effects



**Left** The cuddle factor: electronic sensors enable Japanese therapy seal "Paro" to move its head and react to stroking with sounds of pleasure. Japan is a pioneer in the development of robots for nursing care.

**Right-hand page** Bearing the burden: "Robear" was also constructed in Japan and is intended to help frail people get out of bed or go to the bathroom.

that could offset them?" It will then be possible to assess whether regulatory measures are needed.

Robotic nurses are a particularly vivid example of the importance of ethical discussion – after all, technology of this kind comes particularly close to human beings and affects their most private spheres. Some people are already trying to fight back against the use of robotic nurses by drawing up special patient directives.

However, these robots are still visions for the future, at least when they are imagined as intelligent helpers that could largely replace nurses. Robotic assistance systems that are each only capable of single functions are currently being used on a trial basis, for example to help disabled people cook, clean or go shopping, or to help nursing staff lift and shower patients.

"In general, the tasks that could currently be performed by robotic systems only make up a very small part of the nursing process," says Patrick Jahn, Director of Nursing Research at the University Hospital in Halle. "They would

not yet be able to relieve the strain on nurses in the way that is generally expected." To date, most models have merely had the character of projects and are far from ready to be launched on the market.

### ROBOTS HAVE MAINLY BEEN USED FOR ENTERTAINMENT

According to Jahn, the most advanced robots are the humanoids that specialize in communication, entertainment and information. In North Rhine-Westphalia, "Robbie" and "Paula" play with the residents of a nursing home or encourage them to take exercise. In other places, "Paro", a robotic seal that reacts to being stroked, is used in the care of patients with dementia. Moreover, the robotic nurses "Justin" and "Edan" will be moving into a home for the aged in Garmisch-Partenkirchen this year, where they will hand the residents drinks or medication, fold back their bed covers, press the elevator button, and also raise the alarm if a patient falls.

For the FORMAT project, specialists in nursing science, doctors and computer scientists in Halle are seeking and developing application scenarios for robotic systems that are already able to offer added value. After all, even robots that are "only" able to entertain elderly people can be of use to nursing staff if they make nervous, aggressive patients more relaxed, says FORMAT Project Leader Patrick Jahn.

One example is "Pepper". The 1.20-meter character with big black eyes and a monitor in its chest is currently being used to give informative talks preparing patients for MRI scans. This saves time for the doctors and nurses. The current developments in technology would also enable robots to notify patients of medical appointments and take relatives to the patient's room, i.e. they could serve as robotic ward assistants. Both of these functions were developed during workshops with nurses. "Application scenarios of this kind are also important because there has so far been a lack of specific, convincing examples of use," says Jahn.



»» When we have the feeling that things are too complex to understand, we tend to trust in them blindly.

There are still numerous restrictions, and the system is still not stable. An environment that is too loud can disrupt communication because “Pepper” is insufficiently able to understand its human counterpart. Robots are also confused by the dynamic hospital environment; “Pepper” becomes disoriented if beds suddenly appear in a ward hallway where there were none the day before, for example.

FORMAT follows the “Bertha Benz principle,” explains Patrick Jahn: the automobile pioneer got started right away rather than waiting until the new mode of transport was able to travel without difficulty at 100 kilometers an hour. Benz discovered other important requirements such as the importance of filling stations during her first overland journey; not until her

practical test was she able to help the new technology make a breakthrough.

#### **ALGORITHMS ARE NOT ALWAYS OBJECTIVE**

Jahn believes that this approach could also be effectively transferred to the utilization of robotic systems in nursing care: “Even though we are still far away from the vision we all have in our minds – of the intelligent helper that significantly relieves the strain on nursing staff – we have to work with our limitations so that these robotic systems can be quickly integrated into practical scenarios. Otherwise the development dynamic cannot gather momentum.”

Axel Walz believes that Germany should be involved in the develop-

ment of artificial intelligence. “At the same time, we have to make sure that we develop a qualitatively sustainable, high-quality intelligence that meets the appropriate ethical criteria.” In his view, the normative goal should be a humane society that stands by its established values and that uses technology to continue supporting them – without being allowed to dehumanize them under any circumstances.

Walz calls for open debate that also addresses the question of “whether and where there are red lines that should not be crossed. In other words, how far should I actually be allowed to furnish products with artificial intelligence?” According to Walz, such questions are only rarely made the subject of wider discussion due to people’s faith in technology. “When we have the feeling that



» Artificial intelligence is developing itself – that makes it a black box. It should always be possible to comprehend why a certain result is generated.

things are too complex to understand, our psychological response tends to be to trust them blindly and rank them above our own decision-making competence. In this respect, we have too little confidence and believe that algorithms are more objective and neutral than humans.” In fact, the opposite is true, “because algorithms are trained with data, and the selection of this data is influenced by the programmer’s bias,” explains Walz.

### NURSES LOCKED ROBOTS IN A CUPBOARD

In the case of artificial intelligence, matters are made more difficult by the black box phenomenon. A traditional algorithm functions inasmuch as data is entered and a result is produced at the end, typically in accordance with the so-called “if...then” principle. This is not the case with artificial intelligence: these algorithms are capable of learning, i.e. they can assimilate information, evaluate it, and draw conclusions. This means that they are in a sense able to learn from their own experiences. “Rather than being static, algorithms are therefore continually developing themselves. However, it seems that not even the programmers have a clear idea of what exactly happens while they are doing so,” concludes Axel Walz.

One possible answer could lie in the approach adopted by the interna-

tional engineering society IEEE, which has established a global initiative addressing ethical considerations when developing autonomous systems. Besides laying a theoretical foundation, the initiative also aims to develop concrete ethical standards for technology. One of the objectives is a so-called transparency standard. “It is intended to ensure that algorithms for artificial intelligence are programmed in such a way that it is always clear which data were used and why a specific result was generated,” explains Axel Walz, who was in regular contact with the IEEE initiative.

The human factor has also by no means been adequately researched to date. How does working with or alongside robots affect employees?

The effects on nursing staff are the focus of the interdisciplinary project “Orient”, which is funded by the EU initiative “More years, better lives”, and in which economists are involved along with innovation researchers from Finland and nurse scientists from Sweden. “We are investigating the preconditions that have to be met before assistance systems can be used and accepted in the nursing field,” explains Kirsten Thommes, Professor of Organizational Behavior at the University of Paderborn.

In future, much more attention will have to be paid to the needs and demands of those directly affected by

the use of robotic systems: the nurses and patients. “Until now, robotics have mainly been the domain of engineers,” says Kirsten Thommes. The scientists in Paderborn are studying the needs and attitudes of nursing staff: what do they need to know about the robots beforehand, and what not? Will the content of training courses have to change, and will future nurses have to learn programming? In which areas could robots relieve workloads? Where might there be areas of friction? An assistance system that tells the nurse which patient she should attend to first, regardless of her routine, is clearly encroaching upon her area of competence. Moreover, studies of individual cases in Japan in which nurses switched off the robots or locked them in a cupboard showed that the constant recording of data by the systems can easily lead to a feeling of being under surveillance.

“As yet, there are no studies of the attitudes of average nurses towards assistance systems and the concerns that are widespread among them,” says Thommes. However, there are certain reservations among the general population about the use of robots. A survey showed that when asked what they associate with the word “robot”, more than 70 percent of Germans think of the “Terminator” – the humanoid machine played by Arnold Schwarzenegger in the eponymous



movie of 1984. “This kind of negative image naturally reduces people’s willingness to engage seriously with the concept that robotic systems could one day be a great help and relief,” says Kirsten Thommes. “This is not wholly, but at least partly due to the shortfall in nursing staff.”

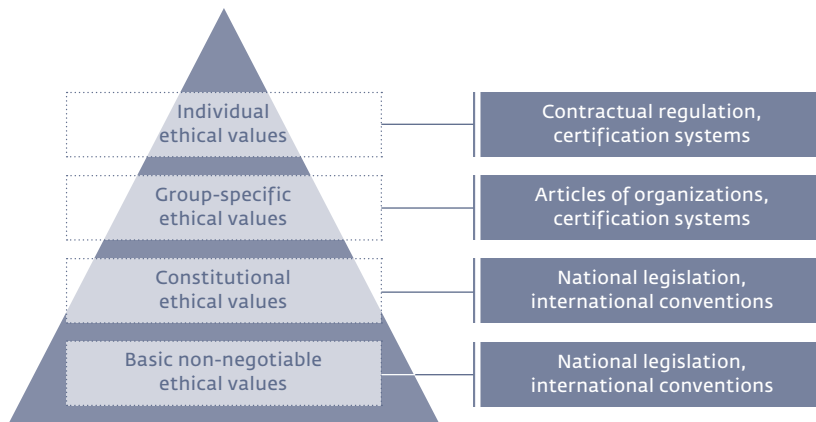
### MIDDLE GROUND BETWEEN AUTONOMY AND ASSISTANCE

Researchers at the Charité Hospital in Berlin are also studying how robots and other technologies could be of assistance in the future. The “Age and Technology” working group sees itself as an interface between target group and technology, patients and manufacturers, explains working group leader Anika Steinert: “We translate the respective requirements and evaluate the added value of a technology, how it is accepted, and how it can be utilized.”

Scientists working on project “Robina” are currently developing a robotic arm for ALS patients whose cognitive functions are unimpaired but who are suffering from muscle wasting. >

At hand: robotic arm “Robina” can be controlled by gestures, language, or with the eyes. It was designed for patients with ALS whose cognitive faculties are unimpaired but are suffering from muscle wasting. The arm can give the patient drinks or scratch itches.





**Left** Legally sound: ethical and legal requirements relating to robots, particularly in the nursing sector, range from general principles such as human rights to individual needs, for example due to religious laws. They therefore have to be regulated on various levels.

**Right-hand page** Close links: legal expert Axel Walz regularly compares notes with developers and engineers with the aim of applying ethical standards in practice.

While defining how the arm should be supported during the run-up to the project, the wishes expressed by participating patients were relatively modest: “scratching”, for example, trivial activities for which the ALS patients would sooner not have to call for help every time.

Numerous questions have to be answered before the development work can begin: what should this arm look like? Should it be mobile or a fixed installation? How should it be controlled, what design should it have, and what should it feel like? However, there are also ethical and legal questions, “as even scratching is a very complex requirement,” explains Anika Steinert. How can patient and nurse safety be guaranteed in view of the fact that the arm has to come very close while performing its task? What should the arm be allowed to do, and what not? Should it be permitted to store information on how often it has scratched the patient? Or how often it has given the patient water? Furthermore, should it be able to take the initiative and give the patient a glass of water if he or she has not

drunk anything for three hours? Or should it only react when it is spoken to or controlled? “It’s always important to find middle ground between the patient’s need for autonomy and the assistance provided by the technology,” says Steinert.

### INTEREST IN ETHICAL STANDARDS IS GROWING

Only a few concerns were expressed beforehand. ALS patients are after all accustomed to being dependent on aids in their everyday lives. They are typically somewhat younger than geriatric patients. “However, the results of the project can be applied to many different target groups.” Often it is the nursing staff who express reservations during the project, for example because certain safety aspects are weighted more heavily from their perspective. When cooperating with manufacturers, the scientists in Berlin often find how little grasp there is of the ethical considerations relating to the product. All the same, “the subject has clearly gained in importance in recent years,”

says Anika Steinert. “People make fun of questions like these much less often than before.” This is apparently also due to the increased interest being shown by politics in ethical standards for artificial intelligence.

Axel Walz from the Max Planck Institute for Innovation and Competition sees these standards as an important potential determining factor on the way to a humane digital society oriented on the established fundamental values of humanity. “One very simple way to influence the development of a new technology right from the start is only to promote projects that conform to the corresponding ethical value set.”

The legal expert finds it important to emphasize that the intention is not to inhibit innovation by regulatory means; on the contrary: “Regulatory instruments can help show that the fears and concerns of the general population are taken seriously and can even assuage them if our existing standards are transferred to new technologies. We are in the midst of a massive revolution and have to take society along with us





»» There is no justification for robots with as many human traits as possible. They put the singularity of human life at risk.


when faced with such far-reaching technological developments.”

Walz himself does not see any reason for humanoid robots, i.e. robots that have as many human attributes as possible. The ban on cloning primarily refers to biological reproduction. “However, the meaning and purpose of the ban is to protect the singularity of human life, and I believe this is just as much at risk if someone makes a bio-mechanical copy.” The associated objectification of humanity would clearly violate Article 1 of the Basic Law.

Particularly in the nursing sector, there is no reason to use android robots, says Walz. Robotic nurses should not replace human workers; instead, they should at most provide support. “As support in the everyday nursing routine, particularly in the case of repetitive mechanical activities, robots are a great opportunity in view of the problem of nursing staff shortages, and they could

also help improve the quality of nursing services.” However, this would require robots in nursing homes to be used in such a way that the staff have more time to give patients their personal attention, to take better care of them from a humane perspective. “It would be an admission of human defeat if one day we were actually to try to transmit affection

and empathy through robots,” says Axel Walz. “Respect for human dignity should therefore be the paramount principle guiding the development and use of robotic nurses.” ◀

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(in German)

#### SUMMARY

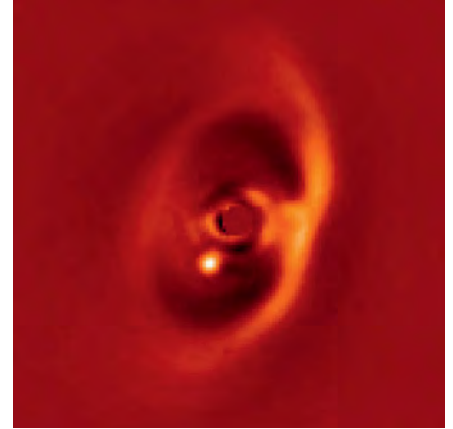
- When developing robotic nurses, legal and ethical aspects should be taken into account right from the start in order to meet the needs of patients and nursing staff.
- Patients must be certain that the robots will not collect more data than is absolutely necessary, and that this data is protected. Moreover, the robots should not be allowed to incapacitate the patients.
- The nurses also have to be protected from surveillance; the use of robotic systems should be restricted to repetitive mechanical activities.
- A legal framework could help strengthen the acceptance of robotic nurses.

# Birth of a planet

A detailed image shows the young celestial body PDS 70b in the midst of a circumstellar disk

Researchers have so far identified more than 3,800 exoplanets orbiting alien suns. Now, they have discovered an extremely young member of this class of planets: the object PDS 70b is located in the gas and dust disk surrounding its mother star, PDS 70 and thus in the environment where it was born. The planet therefore offers a unique opportunity to test models of planet formation and to learn about the early history of our solar system. Located some 370 light years from Earth, the celestial body was tracked down by a team working with doctoral student Miriam Keppler of the Max Planck Institute for Astronomy using an instrument at the Very Large Telescope in Chile. The images show an extended gap in the circum-

stellar disk of the star PDS 70: presumably, the young giant planet is still accumulating material and, over time, clearing a vast area as it orbits its mother star once every 120 years. With several times the mass of Jupiter, PDS 70b is encircled by clouds and has a temperature of just under 1,000 degrees centigrade. Furthermore, the separation of 22 astronomical units (equal to 22 times the distance between the Earth and the Sun) confirms the theory that gas giants such as Jupiter are formed at a relatively large distance from their central star. ([www.mpg.de/12136833](http://www.mpg.de/12136833))



Cosmic birth: this image, captured using the Very Large Telescope, shows the protoplanetary disk around the star PDS 70. The young exoplanet PDS 70b is clearly visible as a bright spot at the inner edge of the gap (dark area). The emission from the central star is not shown.

# Neutrino from a remote galaxy

MAGIC telescopes have detected the origin of a particle that appears to come from the black hole of a blazar

Astrophysicists from the Max Planck Institute for Physics and colleagues have succeeded for the first time in locating the source of a high-energy cosmic neutrino. It is very likely that it comes from a blazar, an active black hole in

the center of a distant galaxy in the constellation of Orion. Neutrinos are difficult to detect. The largest detector in the world, which goes by the name of IceCube, only detects about 200 of these particles per day, most of them originating from the Sun. On 22 September 2017, IceCube detected a neutrino that was special: its very high energy of roughly 290 teraelectronvolts indicated that the particle might have traveled here from a distant source. Moreover, scientists were able to identify its incoming direction with a high degree of precision, demonstrating that the particle originated from the blazar TXS 0506+056, which is approximately 4.5 billion light years away. The object also emits gamma rays in the very high energy region of at least 400 gigaelectronvolts, according to observations made using the two MAGIC telescopes on the Canary Island of La Palma. This is another indication that the neutrino captured by IceCube actually came from the blazar. ([www.mpg.de/12131369](http://www.mpg.de/12131369))



Eyes into space: the two MAGIC telescopes provided valuable information about the course of a high-energy neutrino, which originated from the distant blazar TXS 0506+056.

## An eye for character

A new computer system uses artificial intelligence to identify people's personality traits based on their eye movements

Computers are gradually learning to interpret human behavior – and can now also do so by analyzing the way people use their eyes. A team led by researchers from the Max Planck Institute for Informatics has developed a software system that can recognize a person's character traits by using artificial intelligence to evaluate their eye movements. The technique analyzes how neurotic, agreeable, extrovert, and conscientious the test subjects are. These four factors are an essential part of how psychologists gauge a person's character. In addition, the software determines how curious a person is. People also tend to make subconscious assessments of character on the basis of visual behavior. The character studies produced by the Saarbrücken researchers' software are not yet reliable enough for practical applications. However, with more extensive training data, they should become significantly more accurate and could then help to make cooperation between humans and computers more social, efficient, and flexible. ([www.mpg.de/12185266](http://www.mpg.de/12185266))

## Self-healing seed pods

In plants of the Australian genus *Banksia*, special waxes seal small fissures in the fruit wall

Some Australian plants need a lot of patience when it comes to propagation – and their seed pods must be able to repair themselves. Seeds of some species of *Banksia* remain in their lignified two-part pods for up to two decades before being released during bush fires. *Banksia* is a genus of evergreen plants that are only found in Australia. Some species use their fiery opening mechanism to ensure that the seeds encounter the perfect conditions for germination. In order for the seeds to remain intact over the long period beforehand despite changing weather conditions, it is possible that a self-healing mechanism prevents permanent damage to the seeds. Researchers at the Max Planck Institute of Colloids and Interfaces in Golm, Potsdam, suspect that this may be the purpose of waxes found at the seam between the two halves of the pod. Their analyses show that the waxes are irrelevant once the pods open. However, they melt at temperatures of 45 to 55 degrees centigrade, which are reached in some areas of Australia in summer. The researchers therefore hypothesize that the waxes patch up small fissures in the pods. ([www.mpg.de/12123073](http://www.mpg.de/12123073))

Photo: MPI for Evolutionary Biology/M. Schwarz

## Egg cell seeks sperm

Female gametes prefer sperm cells with different immune genes

Through clever selection of a particularly suitable partner, animals can increase the future success of their offspring. In some species, this selection process appears to continue even after the sex act: researchers at the Max Planck Institute for Evolutionary Biology in Ploen have discovered that the egg cells of a stickleback have a say in which sperm fertilize them. They seem to make their decision based on the sperms' immune genes – or rather based on the major histocompatibility complex (MHC). A complex consisting of many different gene variants leads to a strong immune system. For a highly varied gene complex, an egg cell must therefore merge with a sperm that possesses complementary gene variants. Indeed, the researchers' experiments show that sperms whose MHCs differ from that of the egg cell have the highest chance of fertilization. Researchers do not yet know how the egg selects the sperm. Given that selecting the correct immune genes has played an important role in human evolution, it is also possible that human egg cells are involved in choosing their partner during fertilization. ([www.mpg.de/12308867](http://www.mpg.de/12308867))



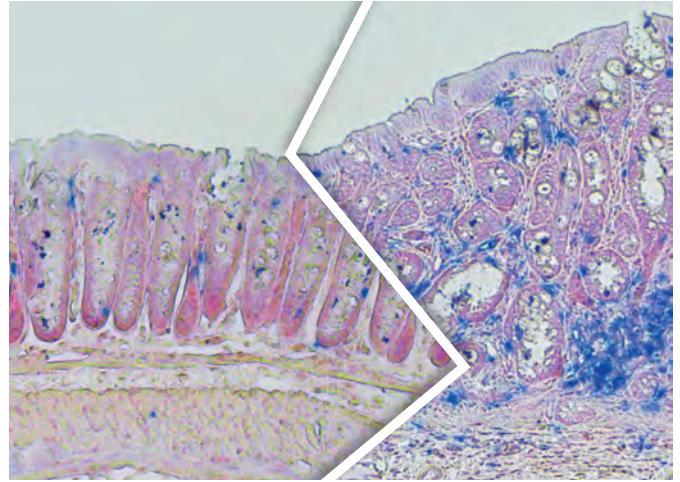
A male stickleback displaying courtship colors. In this species, the females choose their mating partners carefully. However, a female stickleback cannot be sure that her offspring will receive the best immune genes, because each sperm contains only one of the two gene variants of a fish. The egg cells have therefore found a way to select a sperm with suitable immune genes.



# Fatty tissue causes stress

Researchers clarify the relationship between excess weight and bowel cancer

Overweight people have a higher risk of developing bowel cancer. According to scientists from the Max Planck Institute for Metabolism Research in Cologne, this may be partly due to a stress response in fatty tissue when the body is required to store an ever-increasing amount of excess fat. Persistent excess weight therefore puts the body in a permanent state of stress. This raises the alarm for the body's immune defenses, which trigger inflammation in the fatty tissue and ultimately throughout the body. As a result, the immune cells are reprogrammed so that they no longer combat the cancer cells repeatedly developing in the body, but rather aid their survival and thereby support tumor growth. The researchers also tested potential new treatment approaches on mice: they eliminated some of the immune cells and modified the animals' genetic make-up so that immune cells could no longer be reprogrammed despite a fatty diet. In both cases, the inflammation subsided in the mice's fatty tissue, and the immune system began to combat the cancer cells again. ([www.sfm.mpg.de/1871353](http://www.sfm.mpg.de/1871353))



Colon tissue from thin (left) and overweight mice (right). The latter shows more immune cells (blue) and tumors.

# Early dentistry for horses

More than 3,000 years ago, Mongolian herders removed problematic teeth from young animals

Members of a Mongolian pastoral culture from the period between 1300 and 700 BC are thought to have been the first people to practice dentistry on horses. This is the con-

clusion reached by an international team of researchers working under William Taylor of the Max Planck Institute for the Science of Human History in Jena. By analyzing rem-

nants of skulls from almost 30 archaeological sites associated with this culture, the scientists showed that the herders began removing painful teeth from young animals in around 1150 BC. Dentistry for horses appears to have emerged in parallel to the introduction of bronze and iron snaffles, which allowed humans to achieve more nuanced control of horses as animals used for riding. However, the use of these mouthpieces led to pain in what are known as the "wolfteeth" – vestigial teeth that develop in the jaws of some horses. This led the herders to develop a method for removing these problematic teeth – similar to the way veterinary surgeons remove them today. The ability to treat this problem was an indirect prerequisite for the settlement of new areas of Eurasia by horse-mounted peoples from the first millennium BC onward. ([www.mpg.de/12120068](http://www.mpg.de/12120068))



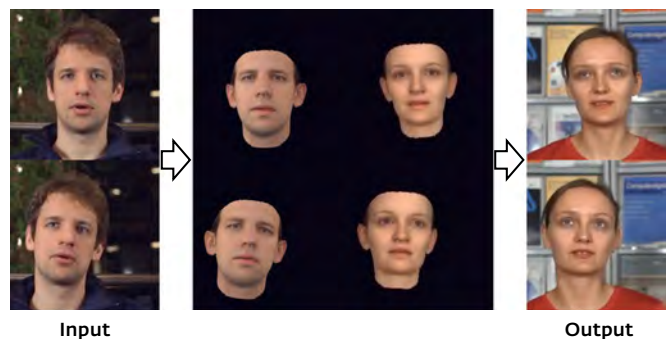
The root of the problem: a healthy set of teeth is important in horses so that the mouthpiece of the bridle does not cause the animals pain.

# A puppet show with facial expressions

A new piece of software adapts the facial expressions of people in videos to match a translation dubbed over the film

Dubbing films could become significantly easier in the future. A team led by researchers from the Max Planck Institute for Informatics in Saarbruecken has developed a software package that can adapt actors' mouth movements and complete facial expressions to match the film's translation. This removes the need to coordinate the spoken words with the video. To synchronize an actor's facial expressions with the sound, the researchers use a 3D model of the face and artificial intelligence (AI) methods that allow the software to derive realistic movements of the actor's face that correspond to the dialog. The technique could save the motion picture industry a considerable amount of time and money when it comes to dubbing films in the future. It can also boost the impression of a natural conversation setting in video conferences. People in these meetings typically look at their own screen and not into the camera, and the software can correct for this. Given the potential for misusing video footage with this technology, the scientists are

researching methods for automatically detecting such modifications in videos and advocate that edited material should be watermarked. ([www.mpg.de/12226519](http://www.mpg.de/12226519))



A person's facial expression, lip movements, gaze direction and head pose (input) can be transposed onto another individual (output) using the *Deep Video Portraits* technique, which works using 3D face models (center).

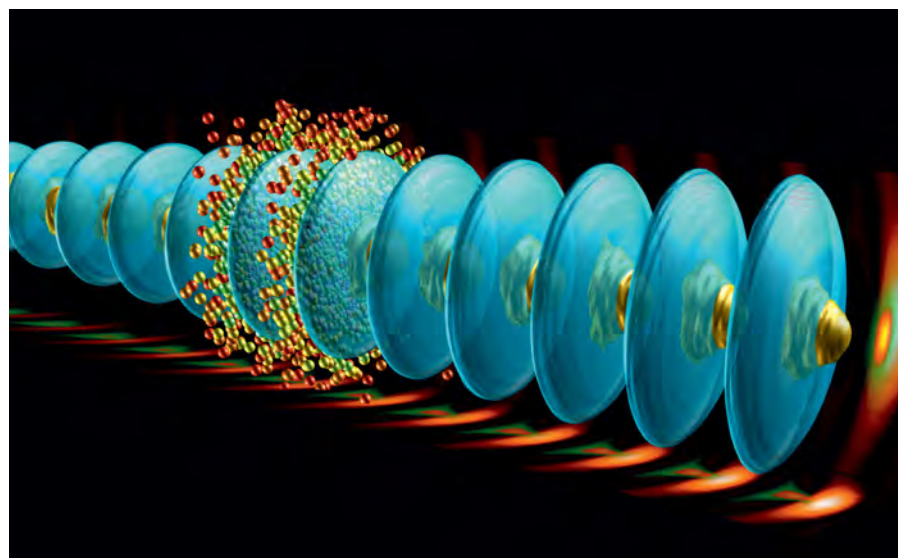
# Electrons ride plasma wave

First successful test of a new concept for the particle accelerators of the future

There is a good chance that a new door will soon open to physicists, offering them fresh insights into the mysteries

of the universe. The international AWAKE collaboration, which also involves scientists from the Max Planck

Institute for Physics, has made a breakthrough in its efforts to build a new type of particle accelerator. For the first time, the researchers have accelerated electrons by letting them surf on a plasma wave – a wave of positively charged atoms and negatively charged electrons. They expect that particles in future accelerators operating according to this principle will gain as much energy in 1 meter as they would in 50 meters in the Large Hadron Collider at CERN in Geneva. Physicists could therefore cause particles to collide with significantly more energy than has been possible to date – and gain new insights into the Big Bang and the structure of matter by studying the traces of the collisions. ([www.mpg.de/12240838](http://www.mpg.de/12240838))



Surfing particles: in the AWAKE experiment, protons (bullet-like structures) form a plasma wave (ellipsoidal structures) that accelerates electrons (small spheres) to high energies.



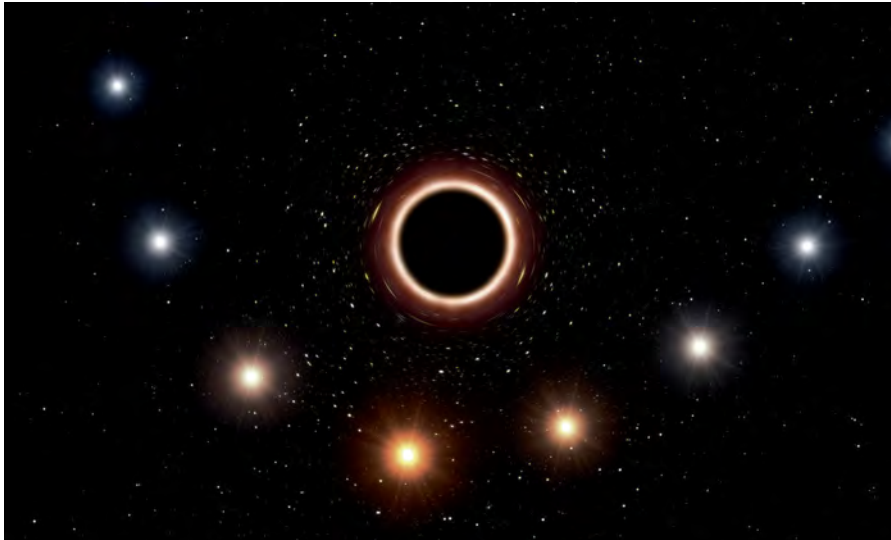
# In the gravity field of the black hole

Astronomers conduct successful test of Einstein's general theory of relativity in the galactic center

The black hole at the heart of the Milky Way is an ideal cosmic laboratory for all kinds of physical tests. Its extremely strong gravitational field influences the surrounding area and has an im-

act on the motion of stars passing nearby. Now, scientists at the Max Planck Institute for Extraterrestrial Physics have recorded an effect that Albert Einstein predicted with his gener-

al theory of relativity over 100 years ago. The researchers used all four mirrors of the Very Large Telescope in Chile to observe the galactic center. They turned their attention to a star called S2 and followed it on its orbit around the black hole. In May 2018, S2 came particularly close to this gravitational giant at a distance of approximately 14 billion kilometers. The star was moving at a speed in excess of 25 million kilometers per hour. The measurements clearly showed an effect known as gravitational redshift: light from the star S2 was stretched to longer wavelengths by the enormously strong gravitational field, making it appear red. This change in wavelength agreed precisely with Einstein's prediction. ([www.mpg.de/12146084](http://www.mpg.de/12146084))

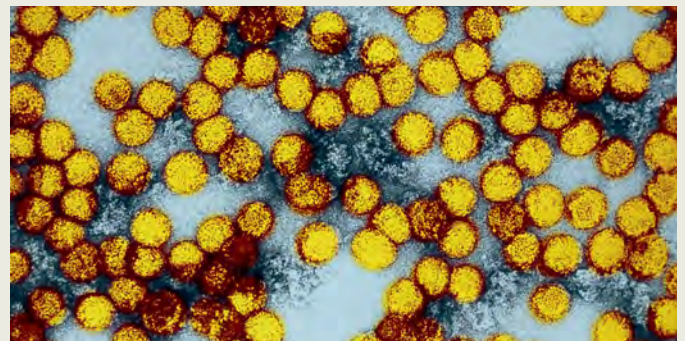


Relativistic color change: this illustration shows the star S2 passing the black hole in the galactic center. The gravitational redshift caused by the extremely strong gravitational field is clearly visible.

# Vaccines without eggs

Highly concentrated reproduction of some flaviviruses in bioreactors will be possible in the future

Vaccines against some life-threatening infections could become more readily available in the future. A team led by researchers from the Max Planck Institute for Dynamics of Complex Technical Systems in Magdeburg has now used bioreactors containing cultures of duck cells to produce yellow fever and zika viruses such as those used for live vaccines. By combining various approaches, they achieved higher concentrations than were previously possible with any other method. For example, they optimized the viruses so that they would multiply particularly well in the duck cells. They also used what are known as perfusion reactors, which allow the efficient supply of fresh nutrient solution to the host cells. Last of all, they monitored the cell concentrations constantly and adapted the supply of nutrient medium accordingly. The production of vaccines currently requires about half a billion chicken eggs per annum, leading to continual bottlenecks as this type of production cannot be ramped up flexibly according to demand. Now, the Magdeburg-based research-



Yellow fever viruses under an electron microscope.

ers are investigating whether other viruses, such as the influenza pathogen, can also be multiplied using their method. ([www.mpg.de/12300448](http://www.mpg.de/12300448))



# Parrots think in economic terms

The birds forgo an immediate benefit if they expect a greater reward in the future



Sometimes, it pays to wait – for example, when it comes to choosing between an immediate, but small, reward and a greater reward at a future date. Parrots have clearly grasped this concept: contrary to the saying “better a bird in the hand than two in the bush”, they are capable of learning when it is better to wait for a greater reward. Researchers at the Max Planck Institute for Ornithology in Seewiesen taught parrots to exchange tokens for food, with different tokens representing cereals, sunflower seeds, and walnuts – foods of a low, medium, and high nu-

tritional value for birds. The parrots were then invited to choose between an immediate reward and a token that they would later be able to exchange for food of a higher nutritional value. The results show that the parrots generally only forwent an immediate reward in favor of a token if it represented a higher nutritional value than that of the immediate reward. Parrots are therefore capable of making a rational decision and maximizing the benefit to themselves. The birds perform just as well as chimpanzees in similar experiments. ([www.mpg.de/12250812](http://www.mpg.de/12250812))

An African gray parrot facing the decision “food or token”. The bird generally chooses the token if it can later exchange it for food of a higher nutritional value.

# Our fractured African roots

Diverse in form and culture, our ancestors lived scattered across the entire continent of Africa

It is generally accepted that the origins of modern humans lie in Africa. For a long time, it was assumed that the early ancestors of *Homo sapiens* were a single, relatively large demographic group. Now, an international study led by Eleanor Scerri, a researcher at the University of Oxford and the Max Planck Institute for the Science of Human History in Jena, has called this view into question. According to the study, stone tools and other artifacts suggest that a similar process of cultural development took place in various regions independently. Human fossils also show a complex mix of archaic and modern features at multiple locations and at different times. Genetic findings also support this picture. The researchers believe that this was caused by climatic changes and a resulting shift in habitable zones. As suggested by a detailed reconstruction of Africa’s climate zones and habitats over the past 300,000 years, the individual groups of people experienced many phases of isolation. This likely led to corresponding local adaptation, the development of unique cultures, and specific biological features – followed in turn by periods of genetic and cultural mixing. ([www.mpg.de/12131917](http://www.mpg.de/12131917))



The puzzling history of humankind: archaeological finds, fossils, genetic data, and insights into habitats are painting a new picture of human development.

# Rendezvous in the Stone Age

Different forms of humans have interbred more often than previously assumed



Until around 40,000 years ago, two forms of humans inhabited Eurasia: Neanderthals in the west and Denisovans in the east. Together with the Neanderthals, the also extinct Denisovans are the closest relatives of modern humans. The two groups of early humans probably didn't encounter one another very often, but when they did, they must have mated fairly frequently. Otherwise, there would be no way to explain why the small number of early humans that researchers have studied so far includes a direct offspring from a union between Neanderthals and Denisovans: researchers at the Max

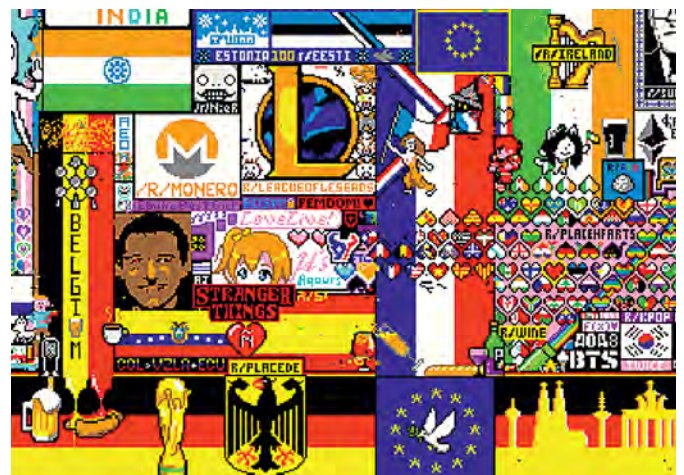
Planck Institute for Evolutionary Anthropology in Leipzig analyzed the genetic make-up of a prehistoric woman and discovered that her mother was a Neanderthal and her father a Denisovan. This union was not the first of its kind, for the woman's father counted at least one Neanderthal among his ancestors. The analyses also indicated that the mother was more closely related to Neanderthals living in western Europe than to Neanderthals from the Denisova Cave. The Neanderthals must therefore have migrated between western and eastern Eurasia before their disappearance. (www.mpg.de/12208106)

The bone fragment found in the Denisova Cave in Russia in 2012 is just a few centimeters in size. It comes from a woman whose parents belonged to different hominin groups.

## Art in the midst of competition and cooperation

An online project shows parallels with the dynamics of cultural evolution

Scientists from the Max Planck Institute for the Science of Human History in Jena have used an art project on the popular web platform Reddit to explore how culture evolves. Over the space of three days, Reddit opened up a digital canvas on which every user could place just a single pixel in a given period of time. More than a million users took part. As the canvas filled up quickly, small groups had to learn to work together or drive out rival teams in order to place an element, such as the flag of their home country, in the picture. For Thomas Müller and James Winters from the Institute in Jena, the project provided an opportunity to test the dynamics of cultural change. The striking thing was that the elements became increasingly dependent on one another for survival – especially as the canvas ran out of space. These findings corroborate the view that cultural change follows a similar logic to that of biological adaptation: the success of individuals manifests itself in the skillful defense of their territories, but cooperation is ultimately the key to lasting success. (www.mpg.de/12251403)



Joint work: a section of the 1,000 by 1,000 pixel canvas at the end of the art project on Reddit. Max Planck researchers used the initiative to understand mechanisms of cultural development.

# Gene. mix up

A disease is considered «rare» if only 5 out of 10,000 people suffer from it – often making it difficult for medics to come up with an accurate diagnosis. The Foundation supported Stefan Mundlos at the Max Planck Institute for Molecular Genetics. His technology enables the genetic data of patients to be specifically compared to data relating to rare diseases, thereby increasing the effectiveness of diagnosis and therapy.

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# The oddballs of the solar system

Small bodies orbiting the Sun are either comets or asteroids – for many years, this was the official line in textbooks. At the **Max Planck Institute for Solar System Research** in Goettingen, **Jessica Agarwal** is studying “active asteroids”, small solar system bodies that don’t quite fit into the traditional categories.

TEXT **THORSTEN DAMBECK**

**T**hose who cast their gaze to the night sky in the Advent season between December 4 and 14 can hope for a special gift: shooting stars. If you extend the trails of light backwards, the meteors appear to be coming from the constellation Gemini, and they are therefore known as the Geminids. These shooting stars are made up of tiny grains of cosmic dust, and Earth is in precisely the right position every Advent for this dust to burn up in its atmosphere. When it does, it produces the fleeting bursts of light that will make a secret wish come true, as popular belief would have it.

Taking a more rational view, astronomers have long known the origin of the dust. It comes from Phaethon, an asteroid identified in 1983 that orbits the Sun on an elongated elliptical path. In the course of each orbit, its distance from the Sun varies considerably – every 1.4 years, Phaethon approaches the Sun

to a distance of 0.14 astronomical units (AU), or around 20 million kilometers. At this point, the temperature on the surface of the body, which is just five kilometers wide, rises to over 700 degrees centigrade, and the radiation pressure from the intensive sunlight can catapult tiny dust particles off the surface and out into space.

## **MOST ASTEROIDS ORBIT IN THE MAIN BELT**

“It’s highly unusual for an asteroid to be the source of a meteor stream,” says Jessica Agarwal of the Max Planck Institute for Solar System Research. “Normally, meteor streams come from comets.” The latter have been known about since ancient times and can sometimes produce impressive tails of gas and dust when they are close to the Sun. Then, the spectacular goings-on in the night sky even become a talking point among the general public. The

dust that comets release into space is swept away by sublimating ice and is the origin of the periodic meteor streams. At any rate, that is what has long been taught in textbooks.

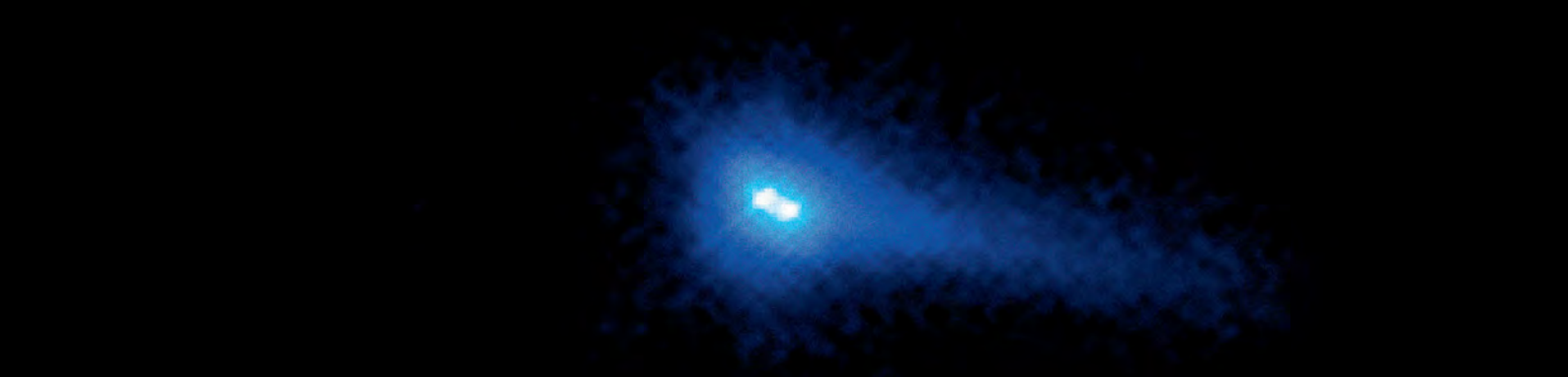
Phaethon is different: although it too emits dust, it does so in the absence of ice. Asteroids have only been known about for around 200 years. The first example, Ceres, was their largest representative for a long time but is now considered a dwarf planet (see box on page 51). These objects have since been cataloged in their hundreds of thousands, with most of them orbiting the Sun in what astronomers call the *main belt*. This lies between the two large planets Mars and Jupiter. >

An optical illusion! This sequence of images from the *Hubble* Space Telescope shows that the asteroid 288P consists of two parts orbiting one another. In addition, the celestial body exhibits the key characteristics of a comet – a coma, which envelops the two nuclei, and a dust tail.



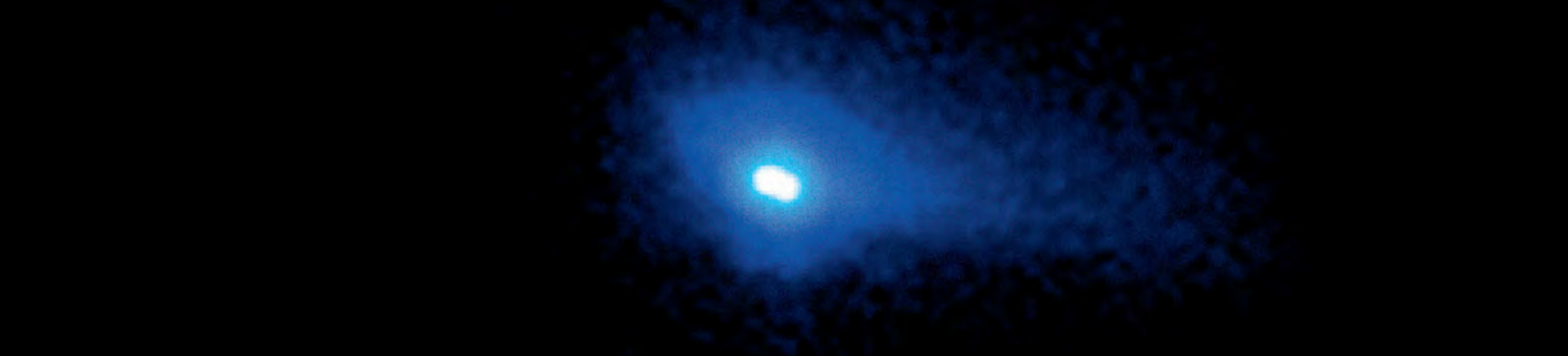
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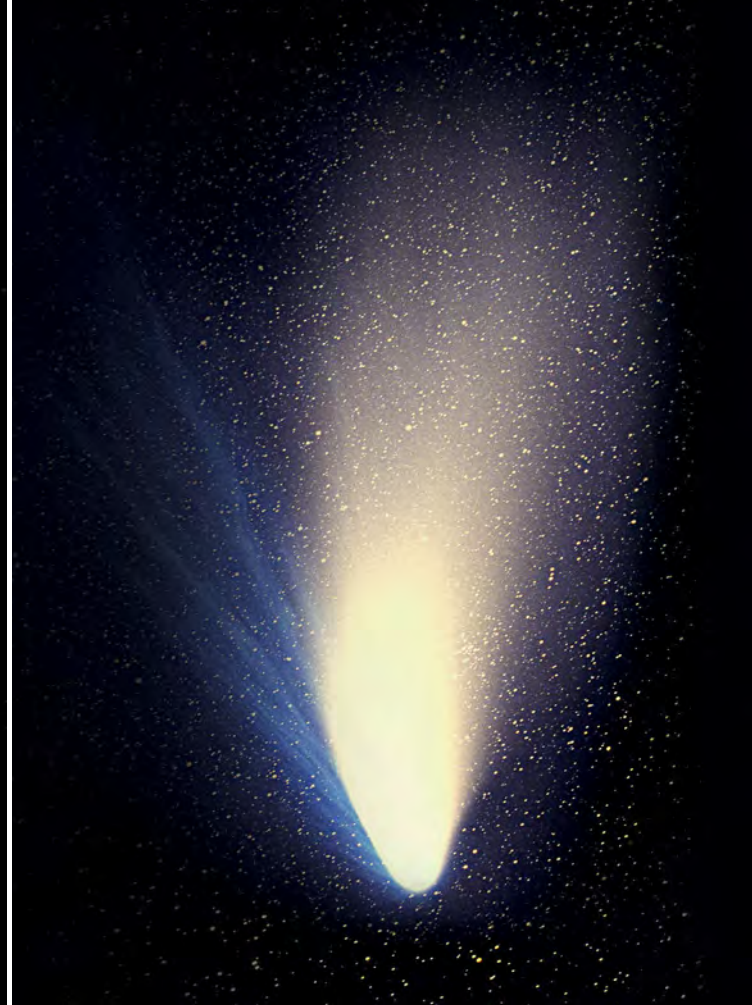
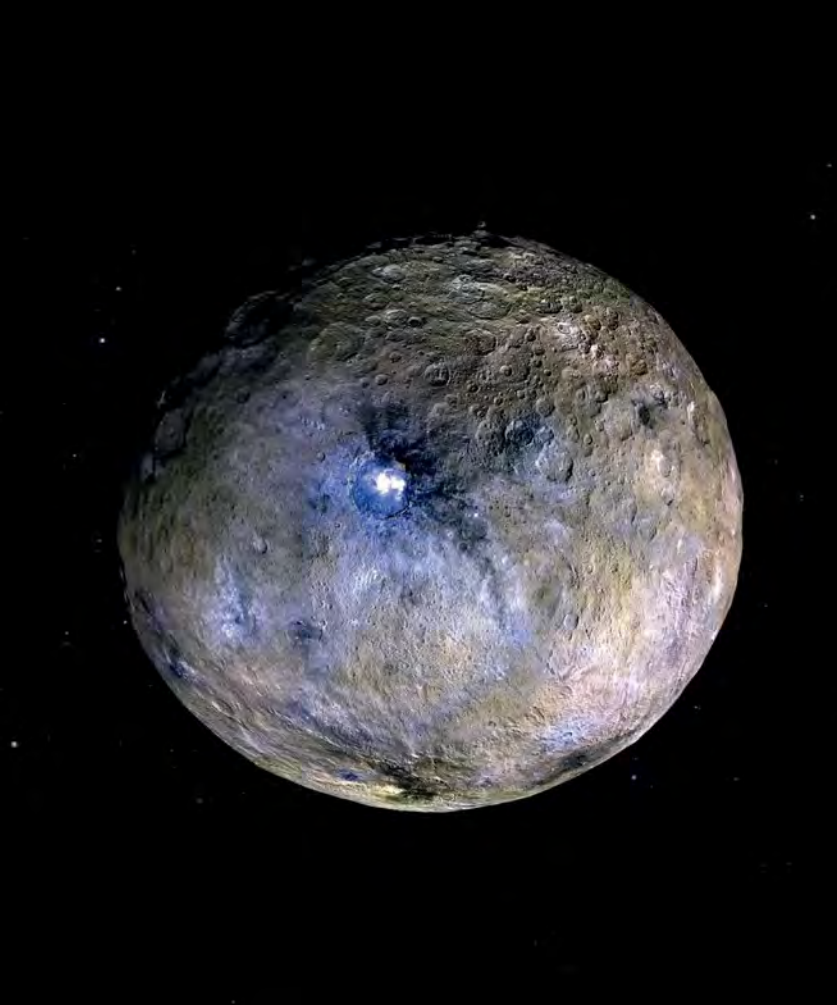


September 20, 2016

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September 29, 2016



Cosmic odd and ends: the dwarf planet Ceres (left) is an asteroid, whereas Hale Bopp belongs to the family of comets. Until a few years ago, astronomers drew a clear distinction between the two classes because of their different features, but the boundaries are becoming increasingly blurred.

Asteroids and comets – Jessica Agarwal knows her way around both fields, as well as the boundary region between them: “We conduct research at the interface between astronomy and geophysics,” says the Goettingen-based astronomer, whose work examines physical processes that can have a profound effect on these small celestial bodies. One focus of the scientist’s work is an even more elusive subgroup of the minor planets: the so-called active asteroids. Phaethon belongs to this particular group of oddballs, whose common feature is that they can emit dust. A paper published in 2015 already included 18 such specimens, most of which are only a few kilometers in size, with the notable examples of Scheila and Ceres, which have estimated diameters of 113 and 975 kilometers respectively.

Asteroids become smaller and smaller due to collisions with other small bodies in what Agarwal compares to a grinding process. One example is the collision that struck the object P/2010 A2

and which the researchers dated back to the year 2009. The following year, they observed the developing tail of P/2010 A2 for five months using the *Hubble* Space Telescope. It turned out that it was different from a normal comet’s tail because, since comets emit gas and dust almost continuously while they are near the Sun, they usually have a fan-shaped tail.

#### A UNIQUE X-SHAPED STRUCTURE IN THE DUST TAIL

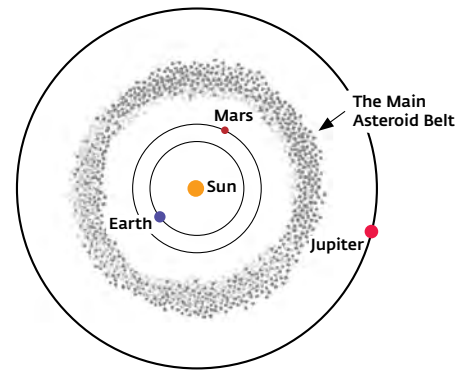
In contrast, the linear tail of P/2010 A2 suggested that it was formed by a single, brief event. On the first detailed *Hubble* photos, the researchers noticed a spot of light and estimated the diameter of the corresponding object to be around 120 meters. “The nucleus almost seemed to be detached from the dust cloud,” says Agarwal, who at that time was still analyzing the images at the ESA’s research center in Noordwijk, the Netherlands. The experts interpret-

ed the spot of light to be a large fragment from an asteroid collision. An X-shaped structure in the dust tail, directly behind the fragment, makes this asteroid a unique specimen.

Some of the active asteroids are also referred to as *main-belt comets*. In their case, the astronomers suspect that the dust emission is driven by water ice or other volatile substances that sublimate and sweep near-surface dust particles away in the process, as happens in comets. One example of this group of objects is 288P, which follows an elliptical path in the outer main belt and takes 5.3 years to complete a full orbit of the Sun.

This minor planet has only been known about since 2006, after the Spacewatch telescope in Kitt Peak National Observatory, Arizona, discovered a small, weak spot of light; this telescope is specially designed for small solar system bodies. Just five years later, the object was observed during several months of activity close the Sun. The





Rich source: most asteroids orbit the Sun on trajectories between the planets Mars and Jupiter, in what is known as the main belt.

photos clearly showed a short dust tail pointing away from the Sun and an approximately six-times-longer trail running along its direction of motion. Even at that time, the long period of activity pointed to the sublimation of ice as the driving force for dust emission.

September 2016 offered especially favorable conditions for observing 288P, which came as close as 1.45 AU to Earth, providing a great opportunity for Jessica Agarwal and her colleagues to unravel further secrets about their object of study. High-resolution photos taken by the *Hubble* Space Telescope now clarified what previous images had only hinted at: 288P is binary! In other words, it consists of two separate components of roughly the same size, which orbit about their common cen-

ter of gravity; both have a diameter of around 1.8 kilometers. The striking thing is their relatively large separation of approximately 100 kilometers.

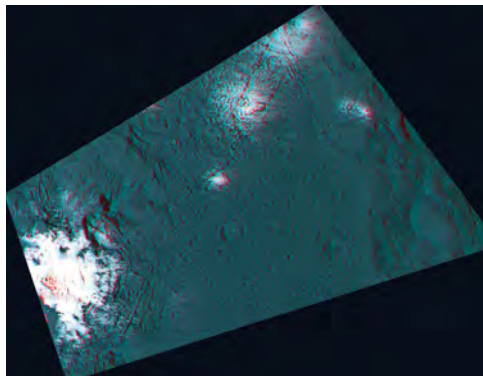
The active binary asteroid is a good example of how these bodies can turn out to be fascinating objects. They allow researchers to study – live, so to speak – the processes of change they are undergoing. 288P probably originates from a collision that long ago destroyed a precursor body with a diameter of around 10 kilometers. That instant, some 7.5 million years ago, marked the birth of not only 288P but also a whole family of asteroids. At least eleven members of this group have already been identified, with their similar orbits around the Sun betraying their common origin. Astronomically speak-

ing, it is a very young family. A second collision at a later stage might then have split 288P into two fragments. Or it might already have been a binary object when it emerged from its violent birth. “Neither option can be ruled out,” says Jessica Agarwal. “We don’t know exactly what happened.” >

## AN ACTIVE GIANT

On the scale of the entire solar system, Ceres is only a dwarf, with an average diameter of 975 kilometers and just 0.28% of the mass of the lightest planet, Mercury. However, it is a giant among the active asteroids, most of which are just a few kilometers in diameter. Since June 2018, the space probe *Dawn* has been orbiting Ceres on a new, highly elliptical path. At points, this NASA probe is only around 35 kilometers from the surface, bringing *Dawn* closer than ever to its object of study since its arrival in March 2015. From this short distance, it has now been able to take detailed photos, some of them with ten times better resolution, of the 90-kilometer-wide Occator crater (see image), providing the best view yet of the ominous bright spots that *Dawn* had previously discovered there.

In the middle of this impact crater is a depression with a strikingly bright,



asymmetric hilltop rising from its center – this is the scene of past cryovolcanic activity. Scientists from the Max Planck Institute for Solar System Research have discovered that salt solutions escaped from this location until well into recent geological history. When the water evaporated, it left behind light-colored deposits that spectroscopic measure-

ments have identified as sodium carbonate. Further bright spots in the eastern part of the crater are probably also points at which a water/salt mixture came to the surface. Several current studies suggest that the crust of Ceres contains large quantities of water ice. It is likely that a steady stream of smaller meteorite impacts and landslides uncover deposits of ice, which then evaporate. This creates an extremely thin atmosphere of water vapor, or “exosphere”.



Total disintegration: the asteroid P/2013 R3 practically crumbled before the astronomers' eyes. Presumably, the object was once a loose agglomeration of large lumps of rock. In the end, it disappeared from the scene entirely and has never been seen again.

There is, however, another plausible scenario. Small celestial objects can also be torn apart by centrifugal forces, in other words, when they rotate too quickly around their own axis. Such events, which have already been known to occur in comets for some time, also affect asteroids – and a drama of this kind can be triggered by various causes. “For example, if there are patches of ice near the surface, then the recoil from the subliming gas could produce a jet-

like effect that speeds up rotation relatively quickly – until it exceeds a critical level that the body can no longer withstand,” says Agarwal.

Therefore, the asteroid could break up after just a few thousand years. The latest analyses suggest that this “jet engine” effect tore 288P apart through precisely such a process of escalating rotation. This effect may also have played an important role in the development of the mutual orbit, causing the two

components to move further and further apart until they ultimately reached the large separation seen today – which allowed *Hubble* to reveal the binary nature of 288P in the first place.

Experts also know of another process that can alter a body's rotation: over long periods of time, the so-called YORP effect can cause the rotation of a small, irregularly shaped celestial body to speed up – simply due to illumination with sunlight and the re-radiation of heat – until the centrifugal forces eventually tear the body apart (see box below). Another variant, known as the binary YORP effect, can bring the components of a binary system back together again – or move them further and further apart.

A particularly dramatic example of this led to the fragmentation of the asteroid P/2013 R3, as witnessed by David Jewitt of the University of California in Los Angeles along with Jessica Agarwal and other colleagues in 2014. The researchers had an almost live view as the asteroid fell victim to its own rapid rotation, which was probably caused by the YORP effect: at least ten fragments have been identified, the largest of which has a radius of less than 200 meters. This was accompanied by a cloud of dust and debris, whose mass the researchers have estimated at 100,000 tonnes.

Photos taken by *Hubble* and the Keck telescope, on Hawaii, can be used to extrapolate the trajectories of the individual fragments. This indicates that the asteroid began breaking up in several stages between February and September 2013 – just a few months before it was discovered. P/2013 R3 was probably nothing more than an agglomeration of dust and large lumps of rock, loosely held together by the body's weak gravitational pull to form what is known as a rubble pile asteroid.

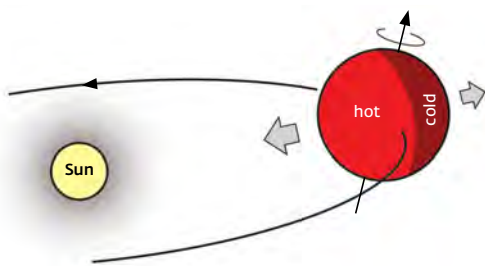
As the celestial body released large quantities of dust, thereby producing a distinct tail, the researchers first mistakenly classified it as a comet. Could the

### SHREDDED ASTEROIDS

The YORP effect is a gradual alteration of the rotation state of small celestial bodies, such as asteroids, under the influence of sunlight. It occurs when thermal radiation is emitted from the body directionally, producing a continuous torque. This can alter the spatial position of the body's axis of rotation, which then aligns parallel, perpendicular, or antiparallel to its orbital plane. In addition, the effect can cause deceleration or acceleration of the asteroid's rotation (see image).

The effect was first demonstrated in 2007 by studying the asteroids YORP and Apollo. Evidently, the rotation of the active asteroid P/2013 R3 was accelerated by the YORP effect to such an extent that it broke up into at least ten fragments due to the resulting centrifugal forces. The name of the effect is an acronym of the first letters of the researchers Yarkovsky, O'Keefe, Rad-

zievskii, and Paddack.



asteroid also have been destroyed by an impact? Agarwal thinks this is unlikely because, as she explains, the speed of the fragments is far too slow to have resulted from a collision. Likewise, “jet effects” due to the sublimation of frozen substances – above all water ice – are highly unlikely, as there was no indication whatsoever of prolonged sublimation-driven dust activity.

### VANISHED NEVER TO BE SEEN AGAIN

When studying active asteroids, you always have to be prepared for surprises. “P/2013 R3 disintegrated, disappeared, and has never reappeared since. The object P/2016 G1 was obviously just a dust cloud, or at any rate the nucleus was too small to be visible. P/2013 P5, on the other hand, exhibited nine highly individual dust tails,” says Jessica Agarwal. This booming area of research has also drawn the attention of the space agencies. In January 2018, for example, the ESA considered launching a mission to several active small solar system bodies, although initially this was merely a theoretical study. The Japanese space agency, JAXA, has made more progress: with the *Destiny+* space probe, it is planning to venture forth to the source of the Geminid stream – that is, to Phaethon – with a launch planned for 2022.

Four years later, if everything goes to plan, a dust detector on board the probe could be inspecting the raw material that brings shooting stars to Earth’s sky each December; the instrument is being developed at the University of Stuttgart. But Phaethon has a volatile nature, with active phases also followed by long periods of relative tranquility. If Jessica Agarwal could wish for a target object for a space probe, her choice would be a different one, however: “288P! It shows comet-like activity, and the large separation between its components is unique. That would be my favorite.” ◀



An eye for the unusual: Jessica Agarwal from the Max Planck Institute for Solar System Research in Goettingen dedicates her time to studying active asteroids. These celestial bodies have special characteristics, such as being made up of multiple nuclei or outwardly resembling a comet.

#### SUMMARY

- In recent years, researchers have discovered that there is no clear dividing line between tail-forming comets and asteroids.
- A group of transition objects in the planetary system are referred to as active asteroids because they can release dust and form tails.
- Asteroids have also been discovered that consist of a binary body.
- Some asteroids seem to consist only of a dust cloud, while others break up before researchers’ eyes.

#### GLOSSARY

**Astronomical unit:** One astronomical unit (AU) is the average distance between Earth and the Sun and is equal to 149.57 million kilometers.

**Cryovolcanism:** A form of volcanism in which volcanoes do not eject hot lava, as on Earth, but rather methane, carbon dioxide, water, or ammonia. These substances are present in a frozen state inside a planet or moon.

**Sublimation:** On Earth, substances such as water pass from the solid state to the liquid state and then into the gaseous state. When one of these phases is skipped and a substance passes directly from the solid to the gaseous state, the process is known as sublimation.



# A grain of brain

Skin cells, liver cells, neural cells – the human body is made up of various different cell types. **Hans Schöler** and his team at the **Max Planck Institute for Molecular Biomedicine** in Muenster have successfully turned these specialists back into generalists that are capable of cell division. These are able to produce different types of cells, and to develop into organ-like structures, for example into so-called brain organoids. The scientists use these to study basic processes in the human brain and the formation of diseases such as Parkinson's.



TEXT HARALD RÖSCH

**W**hen Hans Schöler began to examine the cells in early embryos back in the 1980s, he could never have guessed where his research would take him one day. His journey started with his discovery of a gene called Oct4 during his work at the Max Planck Institute for Biophysical Chemistry in Goettingen. Thirty years later, this would enable him to grow and examine different parts of the human brain.

Until quite recently, most of Schöler's peers were convinced that cells could

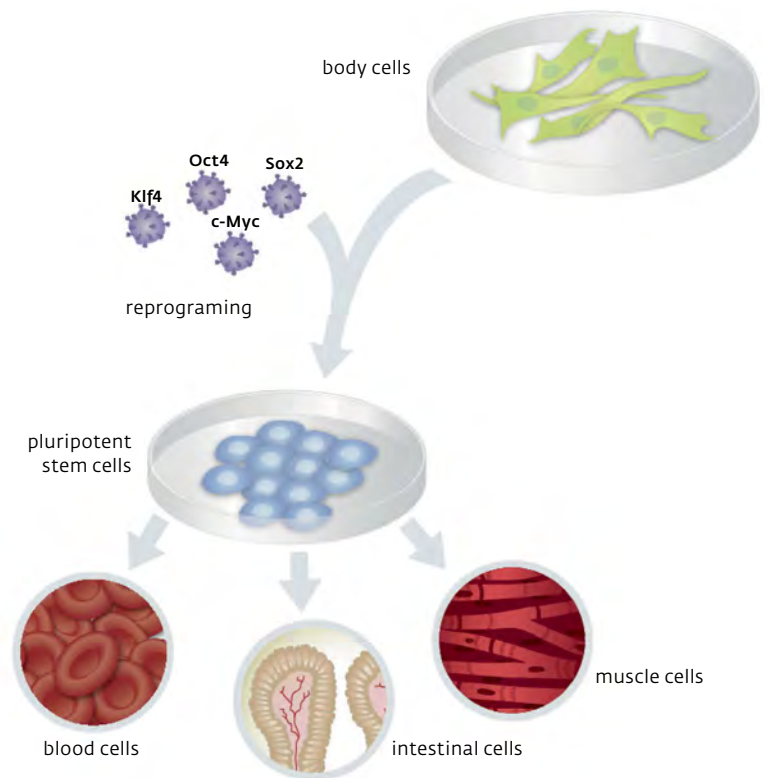
only develop in one direction: from generalists, known as pluripotent ("all-rounder") stem cells to mature specialists that are optimized for performing specific functions. Such stem cells can thus differentiate into any type of cell found in the body.

#### **SPECIALISTS ARE TURNED BACK INTO GENERALISTS**

The dogma of cell development as a "one-way street" is now history, since it is possible to use specialists to produce generalists that are by all means

able to replicate. One example of this are so-called induced pluripotent stem cells. For this transformation to be possible, the genes for the transcription factors Oct4, Sox2, Klf4 and c-Myc in particular need to be active. These genes are also activated during the early stage of embryonic development. Researchers can trigger the transformation into generalists by equipping specialized cells in a culture dish with these genes. In 2012 the Japanese stem cell researcher Shinya Yamanaka was awarded the Nobel Prize for this discovery. "When cells are transformed, their

Brain organoids in the petri dish: in the red nutrient solution, the pin-head sized neural cell clusters can be kept alive and examined over a long period of time. The darkened regions of the six month-old brain organoids are caused by pigment deposits.



From specialist to generalist to specialist: body cells can be turned back into all-rounders simply by adding viral transduction of the cells with the genes for four transcription factors. These cells are then able to develop further into any type of cell. If the transcription factor Oct4 is replaced by Brn4, the resulting cells are not all-rounders but merely multi-talented cells. These neuronal stem cells are able to generate different cell types of the nervous system.

biological clock is turned back almost to zero,” says Schöler. If it were turned back all the way, the cell could develop into an entire organism including the placenta. Cells would then be totipotent. However, this kind of reprogramming is not currently possible.

Whether a cell is a generalist or a specialist thus depends primarily on the genes that are active inside the cell. Researchers are able to control this by adding transcription or growth factors. Schöler – who is now a Director at the Max Planck Institute for Molecular Biomedicine – found out that his old friend from his time in Goettingen, the Oct4 gene, acts like a captain steering its cell vessel towards pluripotency. The other three genes in Yamanaka’s mixture could be described as the vessel’s crew: Sox2 and Klf4 can be replaced with related genes, and c-Myc is entirely expendable.

In 2012, Schöler and his team in Muenster made another important discovery: by replacing the Oct4 gene

with the related Brn4 gene, they are able to transform a mature connective tissue cell, which are part of the human skin, into a certain type of stem cell. This type of stem cell is no longer able to produce all cell types of the body, but can produce the cells of the central nervous system. Mature specialists are thus transformed back into juvenile “multi-talents”. These neural stem cells are not pluripotent but merely multipotent. “To obtain multipotent stem cells, the biological clock is not turned back quite as far as for pluripotent stem cells,” explains Schöler. Scientists refer to such cells as induced neural stem cells.

### REDUCED RISK OF CANCER

The advantage of this method is that it is safer to reprogram skin cells into neural stem cells, as no pluripotent cells are produced. The risk of tumor formation is reduced as a result. However, in the future, the scientists would rather

transform mature brain cells into neural stem cells in order to produce neural precursor cells to replace degenerated neural cells.

Unlike mature cells of the central nervous system, neural stem cells are capable of cell division. Their daughter cells become the different cell types that also exist in the human brain: different types of neural cells and the far more numerous glial cells. Whereas most cells in the brain and spinal cord have lost their ability to divide, in a few areas of the brain, neural stem cells exist naturally even into adulthood. “When we introduce these reprogrammed cells into appropriate niches in brains of fully grown mice, they continue to grow and produce specialized cells that are not able to divide further,” says Schöler. This is a central requirement for medical use, as tumors, whose growth is almost unlimited, might otherwise form in the brain.

If this approach also works for humans, the method could be used to re-





The generation of brain organoids is still manual work, which makes the process unnecessarily lengthy and error-prone. The scientists from Muenster are therefore developing a robot system in order to generate large numbers of organoids in a standardized manner. This system will also be used for drug screening on brain tissues. In the future, this work may give rise to personalized therapies for all patients. The robot enables the scientists to generate, care for and test up to 20,000 brain organoids a day. By way of comparison: no more than a few hundred organoids can be cared for by hand each day. These also vary greatly and are therefore unsuitable for drug development.

place brain cells that were lost due to an illness or an accident. Induced neural stem cells would, however, need to be injected directly into the patient's affected brain areas – a difficult and unpleasant procedure. This could be avoided if scientists were able to reprogram cells that already exist in the brain into multi-talents. For example, this could be achieved with the help of RNA or other molecules that would activate genes which are responsible for transforming cells into multi-talents.

This is what the scientists are currently working on. They cultivate human skin cells in culture dishes at a temperature of 37 degree Celsius, in nutrient solutions that contain growth factors that promote cell division. The

development into neural stem cells is then triggered by viruses that integrate a "cocktail" of genes comprising Brn4, Sox2, Klf4 and c-Myc into the cells' genome. After a short time, the bottom of the dish is covered in a layer of neural cells.

#### CELL CLUSTERS IN A PETRI DISH

Austrian scientists and peers from the United Kingdom developed a method that allows cells not only to form a two-dimensional cell layer, but to grow in all directions – in other words, a 3D cell culture. A protein-based gel is used to provide scaffolding for the dividing cells. In this way, pin-head sized cell

clusters are generated that have a striking resemblance with the brains of early embryos.

These small cell clusters are of great interest to Hans Schöler and his team, since like the brain, these brain organoids consist of different, interconnected regions. "We are able to watch the first developmental steps of the brain, and to examine, for example, how manipulations of the genome affect development," explains Schöler. Another advantage is that the organoids consist of human cells. The scientists therefore no longer need to resort to brain tissue from mice or rats, as has generally been the case to date. This tissue differs from human tissue in many ways. >

**Top** Hans Schöler with a 3D model of Oct4. He has dedicated a significant part of his research career to studying this transcription factor. He discovered that the protein plays a decisive role in the formation of stem cells (The different molecular regions are shown in blue, green and red; grey: DNA).

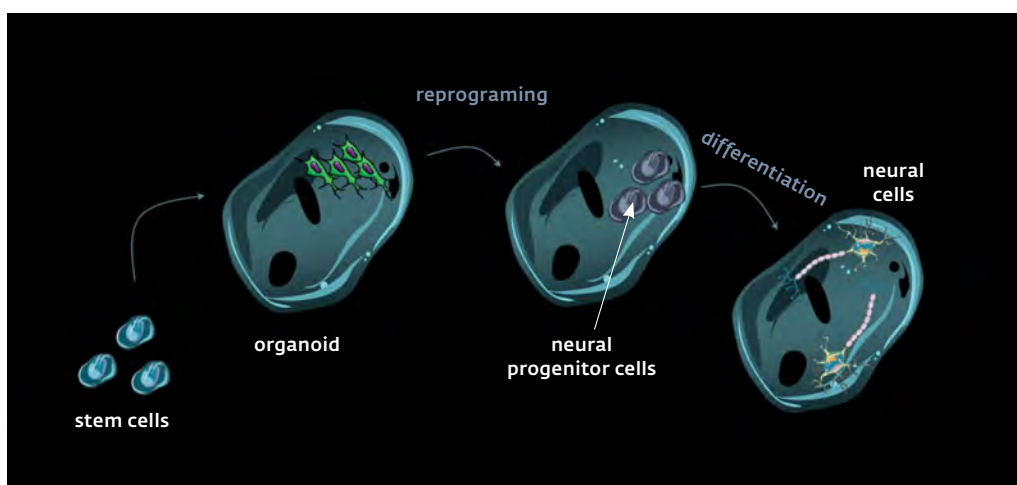
**Bottom** Pluripotent stem cells can specialize in the laboratory and form three-dimensional brain organoids. Scientists use these to study the reprogramming of different cell types into stem cells. These are again able to produce different types of neural cells.



The structure of the brain organoids is almost identical to that of an early fetus brain: it may for example resemble a cerebral cortex with different cell layers, into which new neural cells migrate along glial cells until they find their final position. Neural cells in brain organoids can also feature characteristics that are typical of cells in the hippocampus, a brain region that is important for learning and memory formation. Even a precursor of the retina in the eye may form.

## SYNCHRONOUS ELECTRICAL ACTIVITY

Within ten to twelve weeks, the initial few thousand connective tissue cells thus develop into a cluster of brain tissue the size of a pin-head – unremarkable in appearance, yet extraordinarily complex. The cells themselves also appear to develop in the same way as they would in a natural organism. Their appearance is exactly identical to that of their natural counterparts. Electrical activity in the neural cells is also similar to that of the corresponding natural



cells. Neural cell networks that synchronize their electrical activity are formed as a result. This gives rise to wavelike activity patterns that resemble those that are made visible in EEG examinations of natural brains – albeit far less complex.

After two months, a brain organoid has reached its final size, with a diameter of up to one millimeter. “This is

the limit of what is possible without blood vessels, as oxygen and nutrients cannot sufficiently diffuse in the cell complex to supply the cells at the center,” Schöler explains. However, even if the organoids do not grow further, it is possible to keep them alive for a long time: “In our laboratory we have maintained organoids in culture for as long as a year.”

The brain organoids open up undreamt-of possibilities for scientists. They allow not only for an examination of the development of the central nervous system in the early stage, but also of the development of diseases. Schöler and his team focus in particular on neurodegenerative diseases such as Parkinson's.

### DYING NEURAL CELLS

In 90 to 95 percent of cases, Parkinson's disease develops without a known genetic cause. In these cases, the disease therefore does not appear to be hereditary. The most obvious symptoms of the disease – movement disorders, stiffness, tremor and finally dementia – are due to a loss of neural cells in the *Substantia nigra*, a region in the midbrain that is responsible for controlling movement. These cells release the neurotransmitter dopamine to pass on their signals. Medication that counteracts the decrease of dopamine can alleviate the symptoms and slow down the disease's progress, but it cannot stop it.

To this date, it is largely unclear why the neural cells degenerate in this area of the brain in the first place. One of the reasons for this lack of information is that no suitable model system of Parkinson's had been available so far. "There are mouse models with mutated genes as can be found in many Parkinson's patients. Although these animals show some of the typical symptoms of the disease, there are significant aspects of the disorder that cannot be examined in rodents. The brains of mice and men just differ too much," says Schöler.

Brain organoids from human cells are expected to solve this problem. A

tiny tissue sample from Parkinson's patients is sufficient for isolating connective tissue cells. These cells feature the exact genetic alterations that cause the patient's condition. Once they have been reprogrammed into neural stem cells, they will pass on these mutations to their daughter cells. The scientists also strive to discover the mechanisms that cause the Parkinson's disease in non-inherited cases. Schöler: "The advantage compared to the previously examined mice brains is that we are able to work with human cells that develop under relatively natural conditions. This makes for a far more realistic model for studying the disease than a mouse."

A few years ago, Hans Schöler and his team used this type of genetically modified stem cells and discovered the effects of a mutation that occurs in some patients suffering from a hereditary form of the disease. To do so, the researchers took a skin biopsy containing connective tissue cells from Parkinson's patients who had a mutation in the LRRK2 gene, and reprogrammed

these into induced pluripotent stem cells. After various growth factors were added, the stem cells developed further into dopamine-releasing neural cells, like those typical for the *Substantia nigra* region that is particularly affected by Parkinson's. The scientists found that the mutated LRRK2 gene activates another enzyme called ERK in such a strong manner that this causes a misregulation of other genes and subsequently the degeneration of mature neural cells. The premature death of these cells could be prevented when the scientists rectified the mutation of the LRRK2 gene.

### HELP FOR PARKINSON'S RESEARCH

Schöler and his team were able to gain important insights into the changes that occur in the cells of these Parkinson's patients. Schöler expects that in the future, even more findings will be made with the help of brain organoids. Unlike the cell cultures used in the survey, the three-dimensional brain

### THINKING BRAIN ORGANOID?

Today's brain organoids are a long way from the visions shown in some science fiction movies, in which entire human brains are floating in nutrient solutions, communicating with the outside world via cables. The neural cells in the organoids are electrically active and they communicate with each other. However, they contain far fewer cells than a fully grown human brain and are therefore unable to form networks that are nearly as complex as those present in their natural counterparts. The organoids also receive hardly any signals from their environment, as they do not possess any sensory organs. This is why the scientists from Muenster prefer to refer to these brain-like structures as brainoids, rather than using the term "mini-brain" that is used in many articles about this subject.



Brain organoids at different ages: complexity that increases with age can be seen under the fluorescence microscope. While the brain organoids consist mostly of neural stem cells (green) and precursor cells (magenta) to begin with (day 10), mature neural cells (red) join the precursor cells (gray) on day 30. Mature (red) and young (gray) neural cells and glial cells (green) dominate on day 70. The nuclei are shown in blue.

organoids enable the scientists to study the effects that mutations, such as in the *LRRK2* gene, have on the connectivity and functioning of neural cell networks.

### LESS ANIMAL TESTING

Brain organoids from the Schöler lab may have another advantage: one day they could make many experiments redundant that are currently conducted with experimental animals. Although the brains of mice and other animals that are used as model organisms in neurosciences differ more or less strongly from human brains, there is currently no generally recognized alternative to animal experiments. Monolayer cultures of differentiated neural cells that are frequently used, are no real alternative, either. The culture conditions do not truly mimic the natural environment of the human brain. Using brain

organoids, Schöler aims to replicate the complex processes within and between neural cells, to resemble those that occur in the natural human brain as closely as possible.

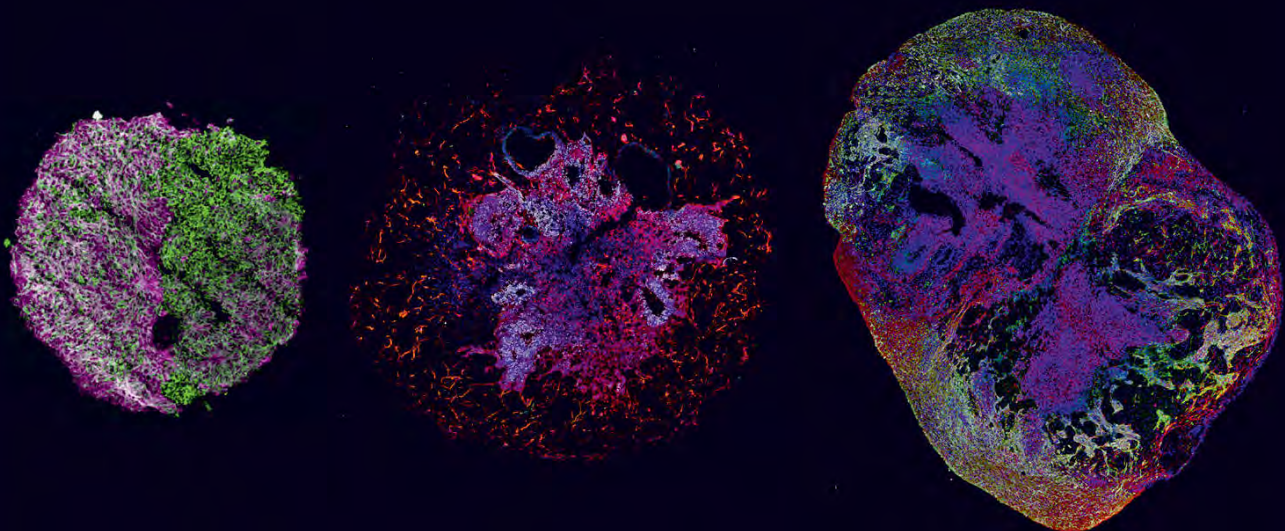
While this would not render animal experiments obsolete, brain organoids may still be a valuable alternative for many scientific questions. Schöler's work is in line with the objectives of the Max Planck Society as set out in 2017 in a general policy statement regarding animal experiments in basic research. In this statement, the Max Planck Society commits to improving the quality of research while reducing the number of animal experiments at the same time. Additional funding is therefore provided by the Max Planck Society for Schöler and his team.

To translate this vision into reality, the scientists need to meet a number of prerequisites: the brain organoids still differ too much from each other, as each

Day 10

Day 30

Day 70



» Important aspects of Parkinson's disease cannot be examined using mice, as the brains of mice and humans differ too much. Brain organoids of human cells are therefore a more realistic model for studying Parkinson's.

organoid is unique, even if generated under identical culture conditions. While under natural conditions, brain development is oriented along the body axes, cells in culture dishes do not receive this information. This is why it is difficult to predict which brain regions will be formed to which extent, making it almost impossible to achieve reproducible results. This is the main structural problem at the moment, when using three-dimensional tissue structures in culture dishes as model organs.

## BRAIN ORGANOID FOR DIFFERENT BRAIN REGIONS

The first task of the scientists is therefore to improve the reproducibility of brain organoids. Their initial focus in this context is to generate organoids, which can transform into another brain region through altered reprogramming techniques. For example, they would like to produce brain organoids representing either the cerebrum, cerebellum, diencephalon, mesencephalon or myelencephalon in a reproducible quality.

Furthermore, the scientists make use of "Small Molecule Neural Precursor Cells". These are a special type of multi-talented cells that are not only capable of virtually unlimited cell division, but that can also develop into different types of neural and glial cells of the central and peripheral nervous system. One example of such cells are the dopamine releasing neural cells that exist in the *Substantia nigra*. The midbrain organoids that develop from

these precursor cells are not only far more homogenous in their structure than previous brain organoids, but can also be produced much faster and more efficiently.

Finally, the researchers from Muenster use robot systems that automatically perform and control the individual steps through to finished brain organoids. For now, the stem cells still need to be laboriously cared for by hand, and each organoid must be analyzed indi-

vidually. This process is too error-prone and too expensive for a model system. In the future, such laboratory robots will be used for drug screening on a large scale and under standardized conditions. Many animal experiments for preclinical studies will become obsolete as a result. When young Hans Schöler discovered the Oct4 gene back in his time in Goettingen, he would certainly never have dreamt that any of this would happen. ◀

### SUMMARY

- Using a 'cocktail' of transcription factor genes comprising Oct4, Sox2, Klf4 and c-Myc, mature body cells can be transformed into stem cells that can produce almost all cell types that occur in the body (induced pluripotent stem cells).
- If the Oct4 gene is replaced with the related Brn4 gene, neural stem cells are produced instead of pluripotent stem cells. These are able to produce all cell types of the central nervous system.
- This approach allows for human skin cells to be reprogrammed into neural stem cells and to develop into brain-like organoids with a size of a few millimeters. Scientists can use these to perform research into diseases such as Parkinson's or Alzheimer's without the use of experimental animals.

### GLOSSARY

**Transcription factors:** These proteins regulate (turn on and off) genes. This means that they can activate or inhibit gene expression.

**Human induced pluripotent stem cells:** All cells that are able to replicate by means of cell division and to develop into specialized cells are referred to as stem cells. By activating specific genes, cells in an adult that are already specialized can develop back into stem cells capable of cell division, which can produce many different cell types (pluripotency).

**Neural stem cells:** Unlike pluripotent stem cells, neural stem cells are "only" able to produce the different types of neural and glial cells. While they occur frequently in the embryonic brain, much smaller quantities of neural stem cells are present in the adult brain.



# A nose for feelings

Before **Jonathan Williams** discovered atmospheric chemistry, he had a problem: he was fascinated by so many things that he didn't know which scientific discipline to devote himself to. Even today, the scientist at the **Max Planck Institute for Chemistry** in Mainz has varied research interests. In recent years, for example, another new topic has awoken his curiosity – the trace that our emotions leave behind in the air.

TEXT **KLAUS JACOB**

**J**onathan Williams has come quite a long way, not just geographically speaking but also in terms of his research topics. Although he has now been a researcher at the Max Planck Institute for Chemistry for 20 years, he – like many scientists – has lived life as something of a globetrotter. The Englishman was actually born in South Africa in 1968, where his father spent a few years working as an engineer. However, Williams no longer has any memories of that time, and he completed school and university in England.


He then attended the University of East Anglia in Norwich, where he studied chemistry and French – he struggled to choose a single subject because there were simply too many things that interested him. It was not until he went to a seminar about the climate in France that

he realized which field he wanted to work in: atmospheric chemistry. He was particularly fascinated to learn that, unlike in the oceans, processes in the atmosphere take place at very high speed. This makes it a varied and exciting area of research: “A normal researcher’s career provides plenty of time to discover something new,” Williams smiles.

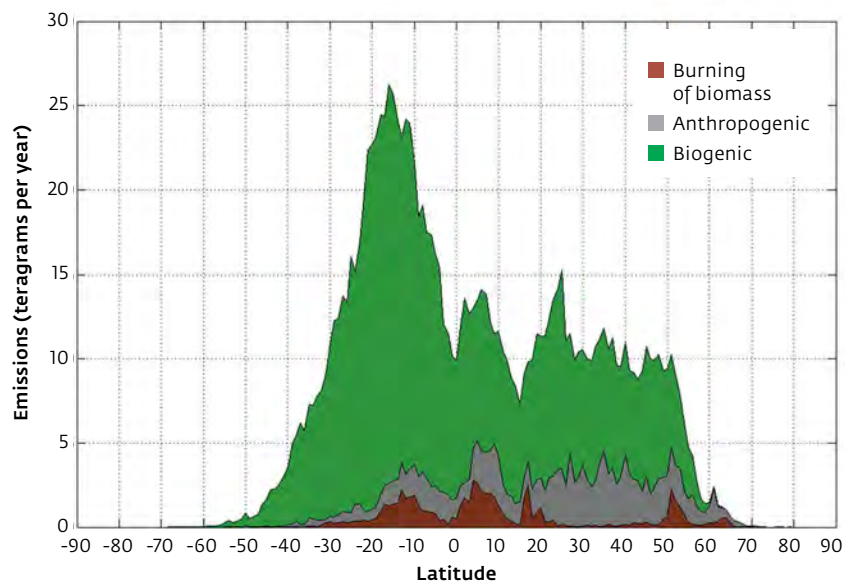
## **THE INFLUENCE OF VOLATILE ORGANIC COMPOUNDS**

With a strong tradition of atmospheric research, the University of East Anglia was the perfect place for Williams to study the field he had now discovered. And so it was here that he completed his PhD on oxidative processes in the air, which play an important role in the atmosphere’s self-cleaning capacity. >



A man with short, light-colored hair, wearing a light-colored checkered shirt, is sitting in a large, empty movie theater. He is looking towards the camera with a slight smile. The theater has rows of dark brown seats, and the walls are covered in a dark, textured material. The lighting is warm and focused on the man.

Uncharted territory for an atmospheric chemist: for several years now, Jonathan Williams has been investigating whether feelings during films leave behind traces in the air in movie theaters.



**Left** The sources of volatile organic compounds: this graph of VOC emissions by latitude and origin shows that most of the substances are released by plants, primarily in the tropical rainforests. In locations where the continents are heavily populated, VOCs also originate from the burning of fossil fuels.

**Right-hand page** Aiming high: to determine the average emissions of volatile organic substances in the tropical rainforest, researchers must also take their measurements at the greatest possible height – for example, using an 80-meter tower in the Amazon rainforest. The red hoses carry the air samples to the mass spectrometers at ground level.

During his doctoral studies, he also dealt with volatile organic compounds (VOCs) for the first time, and these remain the subject of his research to this day. Ultimately, they are the substances we can smell – in the scent of roses, for example, or in the heady plastic whiff of a new car. There are thousands of them, and although they are only present in trace quantities in the atmosphere, at considerably lower concentrations than carbon dioxide, their influence is nevertheless huge: “They make the music,” as Williams says. For example, they play a key role in the formation of near-ground ozone and fine particulate matter.

### VOCS FROM PLANTS CONTRIBUTE TO OZONE FORMATION

Soon after completing his PhD, Williams accepted a position at the National Oceanic and Atmospheric Administration (NOAA) in Boulder, Colorado, where he continued to focus on the role of VOCs in ozone formation. The authorities in the U.S. had done a great deal of work on tackling near-ground ozone, but there had been barely any reduction in the atmospheric load. For example, cars in America had been fitted with catalytic converters since the

1970s in order to remove hydrocarbons from their exhaust gases, with unburned fuel residues considered a key factor in ozone formation.

To investigate why the air in the U.S. still contained too much ozone despite the strict emissions standards, Jonathan Williams sought the help of so-called hurricane hunters, whose aircraft normally collect data on the development and path of cyclones. Outside of hurricane season, however, Williams loaded them up with his own instruments. The hundreds of hours he spent on board the aircraft paid off: the atmospheric chemist’s analyses showed that, when it comes to ozone formation, VOCs of plant origin had taken on the role that was previously played by substances derived from the hydrocarbons in fuel prior to the introduction of catalytic converters in cars.

This was what aroused his interest in biogenic VOCs. In fact, most of these volatile compounds in the atmosphere come from vegetation, with only around ten percent considered to be anthropogenic. In this quest study how VOCs, above all those plant origin, contribute to atmospheric chemistry, Williams moved to Mainz in 1998. He was keen to work at the Institute of Nobel Prize winner Paul J. Crutzen and ex-

plains that Mainz “is the center of the universe for atmospheric researchers.” However, the ideal large-scale laboratory for his area of research is located not in the capital of Rhineland-Palatinate, but in South America: the Amazon rainforest exudes huge quantities of VOCs and is the perfect location for Williams’s analyses.

### A JUNGLE ODYSSEY TO THE ATTO MEASUREMENT TOWER

Twice a year, Williams travels to this lush, green wilderness, where he initially took measurements from an 80-meter scaffold. Then, two years ago, the Max Planck Society erected a 325-meter-high tower by the name of ATTO, which allows measurements to be taken at various heights. Williams uses this tower to study how the highly reactive VOCs react with components of air and how the VOCs change in the process.

The journey to ATTO is like an odyssey every time: the atmospheric chemist has to swap from a large aircraft to a small one before continuing his journey by road, and ultimately by river, in order to penetrate deep into the heart of the jungle. From there, his journey takes the form of a sweaty





mountain hike up to the tower. In reality, this is nothing more than an open staircase held in place by steel cables, and it takes the scientist around three quarters of an hour to climb the 325 meters to the top.

Ten years ago, at this remote research station, his research took a new turn due to the actions of a few inquisitive students. As always, the young academics were accompanying the Englishman on his excursion, when, out of curiosity, they blew into the sensitive device that was actually designed to capture the forest air. Lo and behold, their breath contained numerous substances that are also released by the jungle – and especially the major constituent known as isoprene. The obvious question was therefore whether, in addition to vegetation, humans might also be contributing significantly to the inventory of VOCs found in air. Might humans even be more important than the tropical forests? After all, there are now around seven billion of us living on Earth.

Instead of dismissing this question out of hand, Williams set about getting to the bottom of it. But how can you measure the quantity of organic substances that humans release into the air? The problem is not the equipment. The mass spectrometers in Mainz can

measure several hundred different substances simultaneously in under a second. Moreover, they can do so with extremely high accuracy, to the extent that they can even detect substances in air at a concentration of less than ten parts per billion (ppb). Accordingly, the devices can be used to record respiration of any kind in real time.

### THE AVERAGE BREATH SPECTRUM OF MANY PEOPLE

You could therefore put a single test subject in a sealed box, measure the changes in the air, and multiply the results by the number of humans – that is, by seven billion. But it's not that easy, because people differ fundamentally from one another when it comes to respiration. Variations in diet, the last time they ate, illnesses, dental problems, age, individual idiosyncrasies, hygiene – all of these factors affect a person's VOC emissions. What you therefore need is an average value – a cross section of the emissions from a large number of people.

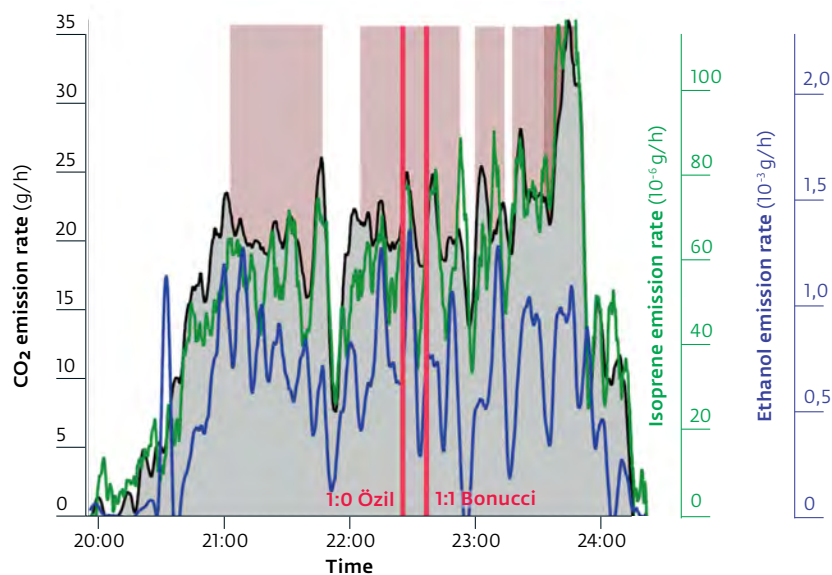
It didn't take Williams long to come up with a place where crowds of people regularly come together. As a soccer fan, he suffered a few sleepless nights during the last World Cup, which saw

his home country make it to the semi-finals. What's more, the Max Planck Institute in Mainz is not only the place where he met his wife, who is a geologist, but also where he developed his love of the soccer team Mainz 05. Particularly when the team was still playing in the second division, he went to their matches regularly. It therefore seemed like an obvious idea to take measurements in the stadium.

The Opel Arena is just a stone's throw away – indeed, he can see it from the Institute building. The box-like structure is partly open at the top and provided excellent conditions for a series of measurements. "Although the people from the club were initially surprised by our request, they were ultimately very cooperative," says Williams. He and his team arrived for an evening match against Wolfsburg and set up their equipment, which stands about six feet tall, in the upper part of the stadium, near the police observation post. The arena gradually filled up until, as Williams says, it eventually "resembled a red and white jungle." In addition to the VOCs, he also measured the concentration of carbon dioxide exhaled by the crowd.

While the approximately 31,000 visitors were looking for their seats, the





Soccer from a chemical perspective: Jonathan Williams and his colleagues measured the levels of various substances in the air while the Germany vs. Italy match was shown in a movie theater in Mainz during the 2016 European Football Championship. When Mesut Özil's goal in the second half put Germany in the lead on 1:0, the airborne isoprene concentration rose because the audience was excited. The ethanol concentration also increased – people were clearly drinking to celebrate the goal. When Leonardo Bonucci scored the equalizer, only the isoprene level went up. During the penalty shootout, there was a considerable increase in the airborne concentrations of both isoprene and CO<sub>2</sub> – in the latter case because the audience was breathing faster.

CO<sub>2</sub> concentration in the stadium rose continuously from around 400 to 500 parts per million (ppm). The value dropped again slightly during halftime as many fans left their seats to buy beer or sausages beneath the stands. Williams was impressed to find that the graph of CO<sub>2</sub> concentration also reflected the course of the match, rising in response to critical situations, such as a free kick or corner – in other words, when emotions were running high. The small peaks showed that breathing accelerated as people's pulses rose.

The VOC measurements also produced some interesting results. Whereas the VOC spectrum is dominated by isoprene in the rainforest, in the stadium it was dominated by ethanol – better known as alcohol. The reason for this is quite simple: many fans came to the stadium a bit tipsy. As the stands filled up, the ethanol level therefore rose, before dropping again slightly in the first half because the fans lacked supplies. During halftime, they bought more beer and the graph went up again.

A second substance also stood out, one that is well known to Williams: acetonitrile. In the Amazon rainforest, caution is advised when levels of this substance are high, because it means that a fire is raging somewhere and dis-

torting the measurements. In the stadium, this value is pushed up by smokers, producing a slightly different graph from that for alcohol: particularly during the halftime interval, the cloud of cigarette smoke led to peak values. “At this point, the fans are extremely nervous,” says the scientist.

### THEN CAME THE IDEA OF MEASURING EMOTIONS

Overall, the soccer stadium measurements showed that humankind's impact on the VOC level in the atmosphere is significantly smaller than that of the tropical rainforest, for example. The initial question had therefore been answered. But Williams was not yet satisfied, since he had now realized that the measurements could be used to gauge people's behavior. This is where the idea of measuring emotions came from. Williams was annoyed that neither side had scored a goal during the match he had analyzed; otherwise, he might have identified a chemical marker for joy and euphoria. With this in mind, he began planning further studies.

His plans are by no means far-fetched. After all, odors transmitted by VOCs play a key role in many organisms. In a sense, they were the first

words that organisms exchanged, and plants still communicate extensively via VOCs. Many plants emit chemical substances to warn members of the same species when their leaves are being gnawed, or even to attract insect predators that eat their attackers.

In insects, too, the substances play an important role in the form of pheromones, and many mammals – such as dogs, for example – are guided by their noses. Although humans have other ways of communicating, we all know only too well that we also attach meaning to smells. Otherwise, nowhere near as many of us would wear perfume when we want to make a special impression. And when Germans don't like someone, they even have an – almost literal – expression that they cannot stand their smell. In that case, why shouldn't emotions also be expressed through chemicals in the air?

To investigate this question, Williams looked for a closed building with no interference from turbulence, unlike in an open-roofed stadium. His search led him to Cinestar, the local multiplex movie theater, which provides an almost perfect laboratory: the movies provide the emotions, and the people's responses reach the apparatus almost in real time thanks to the ventilation system, which



blows fresh air in beneath the seats and extracts it at the ceiling. The audience's emissions therefore ends up in the exhaust air shaft almost immediately, and so all the Max Planck team had to do was tap into the air flow.

The researchers have now taken measurements at hundreds of showings. There were no surprises when it came to the ethanol values – that is, the alcohol level. This was far higher on Saturday nights than in showings on a Monday morning, for example. The siloxanes found in deodorants and shampoos showed some interesting behavior: their concentration rose at both the start and the end of a movie, when the audience took off their jackets and sweaters or put them on again, raising their arms in the process. Over the course of the day, the siloxane concentration decreased from one showing to the next as the scents gradually evaporated. However, it rose again sharply for the evening showing: "People have had a chance to get dolled up again after work," Williams explains.

The atmospheric chemist was particularly impressed to find that his graphs even contained clues about what was going on in the film. Every exciting or moving scene led to a small fluctuation, and the graph showed ex-

actly the same trend when the film was shown again the next day.

This was particularly evident in the levels of carbon dioxide and isoprene. The carbon dioxide behaves just as in the soccer stadium: a fast pulse, goose pimples, tense muscles – all of these things speed up people's breathing and cause a higher output of respiratory gases. Isoprene seems to behave in a similar way: the substance is stored in muscle tissue but escapes through our breath during movement. "We seem to move involuntarily when we're tense or nervous," says Williams. "This also causes us to breathe out more isoprene." In addition, the graph also rises sharply when the audience gets up at the end of the film. This was very helpful for the measurement team, who were hidden deep in the catacombs of the multiplex and couldn't see the film themselves – it let the researchers know that the auditorium was emptying.

#### **YOU COULD LITERALLY SENSE THE TENSION IN THE AIR**

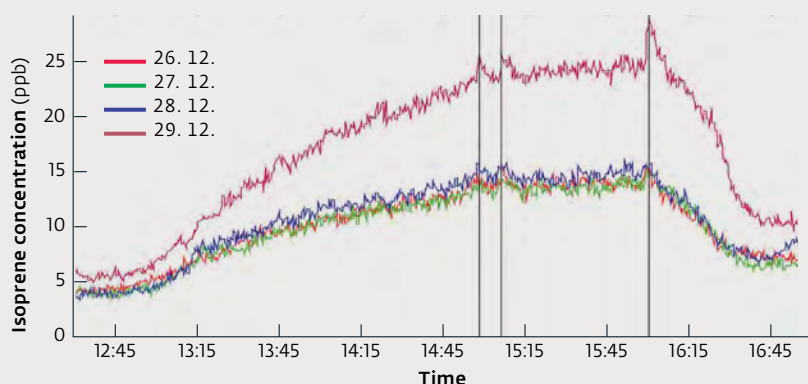
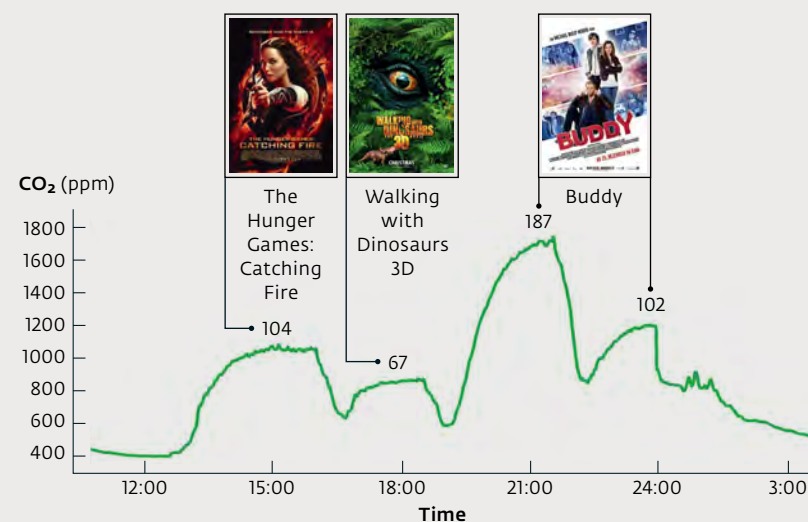
During the measurement series at the movie theater, the goal Williams had been waiting for finally came. The multiplex showed some matches in the 2016 European Football Champion-

An unusual fan project: since Jonathan Williams started working as a researcher in Mainz, he has been a supporter of Mainz 05. It therefore seemed like an obvious idea to set up his mass spectrometer (left) in the local stadium in order to measure the VOC emissions from large crowds of people – especially since the arena is just 500 meters from his Institute.

ship, including the game between Germany and Italy. When goals were scored, the carbon dioxide and isoprene concentrations both rose sharply, and the values almost doubled during the penalty shootout. You could literally sense the tension in the air. Different responses were observed after the German and Italian goals, particularly in relation to the ethanol concentration. When the German team took the lead, people evidently drank to celebrate the goal, causing the level to rise. After the equalizer, however, the response was more muted, revealing which fans were present.

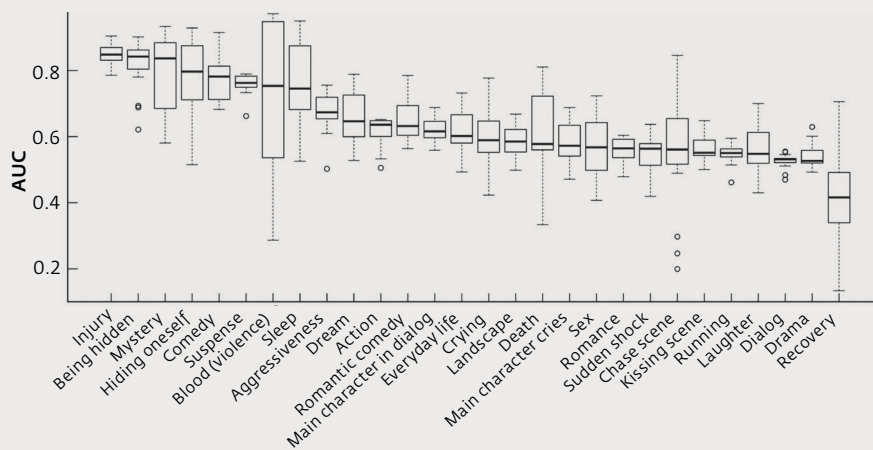
However, the question of whether feelings can be measured in the composition of breath was still only partly answered. Williams therefore dissected each movie and classified the individual schemes according to their content. The list is long and ranges from blood, death, and screaming, through dreams,





**Above** Showings at the multiplex movie theater in Mainz, Williams's team tracked the CO<sub>2</sub> concentration in the air (in parts per million, or ppm). As the viewers entered the auditorium, the concentration increased. After a while, an equilibrium was established between the audience's emissions and the influx of fresh air. The more people who watched a movie, the higher the concentration rose – as revealed by the respective audience sizes shown above the graph. During showings on four separate days, the isoprene concentration always followed the same pattern (in parts per billion, or ppb). In the movie *The Hunger Games*, for example, it rose twice at the beginning because the viewers were particularly rooting for the main character. At the end, it increased because the viewers were leaving their seats.

**Below** Various movie scenes can be identified from traces in the air with a differing degree of success. One measure of this is the *area under the curve* (AUC). The relationship is very clear for scenes in which the main character is injured or hiding, as well as for mystery scenes and comedy. Below a value of 0.5, the airborne VOC profile is no more meaningful than guesswork.



action, and kissing, to landscape, entertainment, and comedy. There were 28 topics in all, and it wasn't easy to identify a relationship between them and the several hundred VOCs. Realizing that task could not be completed manually, Williams sought the help of computer specialists at the neighboring university. This research group, which otherwise spends its time studying stock prices and other economic fluctuations, set about scouring Williams's data for traces of individual emotions in breath.

This produced a statistic indicating the likelihood that specific scenes could be detected in the measured VOCs. The relationship was clearest in scenes where a principal character was injured. Sympathy therefore appears to trigger physical responses. Likewise, scenes involving mystery, secrecy, or hiding could also be detected in the data. However, it was not possible to obtain conclusive evidence of specific feelings in the movie theater. The succession of emotions was too quick for that: one minute the hero would be fighting for his life and the next there would be a love scene.

### WILLIAMS IS AN ENTHUSIASTIC COOK

However, Williams and his team did achieve a modicum of success: they discovered a relationship between the isoprene concentration in the air and the movie's age rating. As the isoprene con-





centration reflects the tension felt by the audience, it also provides an indication of how stressful a movie might be for children and adults. The motion picture industry could use this as an objective criterion for age ratings, so that these would no longer depend entirely on a panel's subjective assessment.

Even in his leisure time, Williams likes to dabble with aromas: he is an enthusiastic cook and even risks the occasional foray into molecular gastronomy, such as by using liquid nitrogen to create ice cream and foams. "Cooking is chemistry," he says. In the kitchen, however, he is more passionate about the results than the underlying science. And his three children – two boys and a girl between the ages of eight and twelve – have long since inherited his love of aromas: "They're very well informed about VOCs."

Until now, Jonathan Williams has hunted for the smell of feelings alongside his actual research projects in atmospheric chemistry. For example, he took most of the measurements in movie theaters during the Christmas holidays, when the expensive equipment was just standing around and wasn't needed for his principal area of work. In the future, however, he will no longer need to rely on holidays, as this "secondary" line of investigation, so to speak, has now become a research project in its own right. Williams has been amazed by the public response,

and he is virtually overrun with journalists. His years of work in the jungle generated far less interest, but it seems as if everyone wants to report on his measurements at the stadium and movie theater. Williams shakes his head in amusement.

In any case, he wants to continue pursuing his new research direction. His next step is to target his measurements at individual emotions, and to overcome the disadvantages of rapid scene changes and emotional fluctuations, such as those typically encountered in the movie theater. To this end, he is seeking a collaboration with the Max Planck Institute for Psycholinguistics, in the Dutch city of Nijmegen. There they have a virtual lab whose applications include confronting police officers with frightening scenarios with the help of virtual reality. Williams could use this technology

Jonathan Williams and his most important measuring device: along with his team, he analyzes volatile organic compounds in the air using a combination of a gas chromatograph and a mass spectrometer. The former separates a mixture of volatile substance into its components, while the latter can be used to identify the individual substances.

to search for specific emotional markers during virtual roller coaster rides or in the face of virtual threats, for example. If he succeeds in finding chemical markers that humans emit when they experience certain emotions, this clearly leads to another research question: how do other people respond to these substances? ◀

## GLOSSARY

**Volatile organic compounds:** Also known as VOCs, these carbon-containing substances evaporate even at normal ambient temperatures and low pressure. They include many substances that stimulate the sense of smell.

**Mass spectrometer:** This analytical device is used to identify substances. The compounds are first vaporized and ionized, often breaking up into typical fragments in the process. The particles are then sorted according to their mass-to-charge ratio, so that each compound produces a characteristic spectrum. Today, mass spectrometers are often combined with gas chromatographs, which separate mixtures of substances into their individual components.

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Tippe auf eine Karte, um die Anzahl der gesammelten Früchte zu sehen.





# The nature of children's curiosity

Children explore their environment with all their senses, and their curiosity knows no bounds. From a certain age onwards, they never seem to stop bombarding adults with questions. Many people consider this form of active learning to be ideal. Until now, however, almost nothing has been known about the strategies that children use on their own initiative. At the **Max Planck Institute for Human Development** in Berlin, **Azzurra Ruggeri** and her team are developing sophisticated tests in order to understand the way children learn.

TEXT **TINA HEIDBORN**

It's Friday at the Natural History Museum in Berlin. In a closed-off, quiet corner in the area at the back of the museum, a "magic machine", clearly self-made, a cardboard pyramid painted black and with small silver stars stuck on, has been placed on a table. At the front, it has a small, rectangular balcony containing an egg that rattles when it is shaken. If the egg rattle is placed on the balcony, a colored ball on the tip of the pyramid starts to rotate, lighting up and making sounds.

Five-year-old Marta is impressed: "Wow," she says, and yes, she'd like to play this game. While for Marta this is a game, for the team led by the developmental cognitive psychologist Azzurra Ruggeri at the Max Planck Institute for Human Development, this is a sophis-

ticated experiment conducted by her Research Group "iSearch – Information Search, Ecological and Active Learning Research with Children".

According to the researcher, "active learning" does not just refer to children moving a lot while learning. The term "active" also refers to being able to make learning decisions yourself, engaging in *self-directed learning* as it is known in research terms. Azzurra Ruggeri uses the word "ecological" to describe the ability to tune, adapt one's own learning behavior to the specific task's circumstances and requirements to be able to learn in the most effective way possible. Professor Ruggeri's first results suggest that even very young children are able to collect and evaluate information "ecologically," selecting the learning path that promises the greatest success. >

Colorful, but difficult: with the monster game on the tablet, ten and eleven-year-olds are asked to learn the connection between the properties of the monster – friendly, cheeky, funny – and the number of fruits picked, shown on the top right-hand corner of each card.





**Top** Rattles when shaken: the egg (center) is hidden in one of the four colorful round boxes, which are then placed in the two larger black or white boxes. Pre-school children are asked to find out where the egg shaker is hidden by shaking or opening a large box. In this game, when children find the egg shaker, they get to play with the magic machine, which lights up and moves.

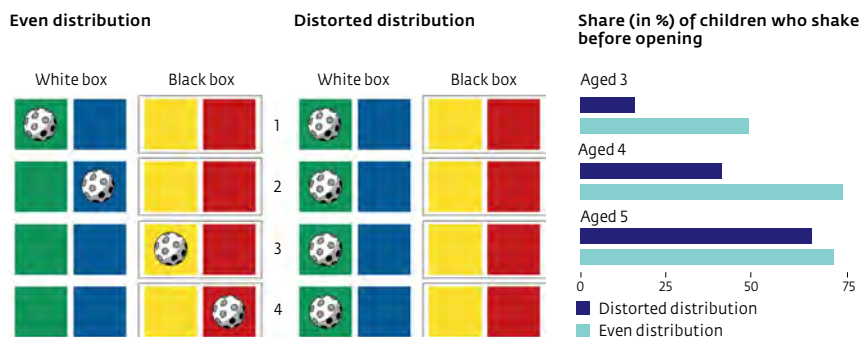
**Below** The egg shaker is either hidden in the green, blue, yellow or red box in a fixed sequence (“uniform condition”), or always in the same box (“skewed condition”). In the final hiding game, 3- to 5-year-olds adapt their searching strategies to the condition they were in: they tend to shake the large box more often in the “uniform condition”, where they don’t know where the egg could be hidden, as compared to the “skewed condition”, where they are more likely to open the box where they learned the egg should be hidden.

Individual sub-aspects of this area of study are now being intensively researched, according to Azzurra Ruggeri. Examples include how children learn by asking questions, to whom they direct these questions, and how much information they obtain from the way in which they ask them. After all, children find out about the world through questioning. According to a study by the University of California, Merced, children aged two to five ask an average 76 to 95 questions per hour when talking to an adult.

The question-asking games that Azzurra Ruggeri and her team use in their research sound playful: why was the Monster Toma late to school? Who lives on Planet Apres? Even toddlers can judge which questions are the most informative and use the answer they receive

to solve problems, or to decide to whom they should continue to direct their questions. However, it is particularly challenging to study young children of pre-school age. This is a key task of the “iSearch” Research Group. The purpose of the tasks is to observe how children spontaneously, actively learn. Azzurra Ruggeri describes her work as studying “children’s potential for learning.” This is the approach used by Jean Piaget, the Swiss biologist and pioneer of cognitive development psychology, who observed the development of his own children and developed his seminal theories on this basis.

The “iSearch” team is developing new kinds of tests in order to achieve its goal. One particular challenge arises from the fact that pre-school children do not have fully developed cognitive abilities or a rich vocabulary. In many of the standard question-asking tests, children generally ask questions that are way less informative than those asked by adults. Questions asked in these tests can be categorized into two types: *hypothesis-scanning questions*, in other words, those that check a single hypothesis or option (for example, “Is Toma late because he woke up late?”), and *constraint-seeking questions*, which tend to narrow down the available options by targeting features shared by several options (for example, “Is Toma





late because of something he forgot?") and are usually considered more informative. In general, children up to age seven tend to predominantly ask hypothesis-scanning questions; later, this tendency becomes less prevalent and they grow out of it, until adulthood, when constraint-seeking questions are reliably preferred. However, Azzurra Ruggeri and her team have been able to demonstrate that even very young children can *identify* the most informative questions: if both types of question are presented, even 4- to 5-year-olds select the more general, constraint-seeking type when it is more effective. Their results suggest that by age 4, children are already able to assess the anticipated information gain from the different types of questions, even if they are not able to generate the most informative questions from scratch.

Indeed, to ask good questions from scratch, one has "to first identify features that can be used to ask questions, categorize objects at different levels according to these features, select the category that makes more sense to target, and then succeed in verbalizing the question," Azzurra Ruggeri explains. "This is extremely difficult!" Therefore, when very young children fail to do well in certain question-asking tasks, this does not mean that they are no good at learning. Here, Azzurra

Ruggeri quotes her doctoral thesis supervisor, the well-known psychologist Gerd Gigerenzer: a hammer is a good tool if you want to bang a nail into a wall, but it is not a good idea to try to bang a screw into the wall. That is, one needs methods that are suitable and tailored to the problem to be investigated. Is it possible to study the effectiveness of young children's information search in a non-verbal paradigm? This is why the doctoral student Nora Swaboda and the research assistant Eva Kell asked five-year-old Marta to *search for the egg-shaker* in the Natural History Museum in Berlin. She plays the game enthusiastically, although it wasn't really planned: she was there just to visit the museum.

#### **EVEN INFANTS MAKE USE OF PROBABILITIES**

The training phase. First, Marta observes Eva, the experimenter, hiding the egg in one of four small, round boxes, each of a different color. Marta watches attentively. The four boxes are inserted into two larger, rectangular boxes – one is white and the other is black. Half of the children, like Marta, are playing the game in the "skewed condition", where Eva always places the egg shaker in the *same* small box, for example into the green box on the

Playful challenge: Silvia Martín Lence, a student assistant, explains the rules of another learning game on the tablet to one of the young participants.

outer left-hand side. The other half of the children play the game in the "uniform condition", where the egg is always placed into a different small box. Thus, in the "skewed condition" children should learn that the egg is probably to be found in the green, outermost left-hand box, whereas in the "uniform condition" they should not know where the egg might be. Then Eva demonstrates to Marta that there are two ways of finding out whether a large box contains the egg shaker in one of the two smaller boxes inside: shake the big box or open it. Opening corresponds to a hypothesis-scanning question, whereas shaking is similar to asking a constraint-seeking question. During the test, Eva hides the egg shaker once more, and this time Marta has to close her eyes. Then Eva closes all boxes, and asks Marta to look for the egg shaker. Eva tells her she can open *only* one big box. What is Marta going to do? Because Marta was in the "skewed condition", she should have a strong intuition that the egg shaker is again hidden in the green box – after all, Eva always hid it there! In this sense, she should just go on and open



the large box that she knows contains the green small box, and then open the green box. However, if she had been in the “uniform condition” she could not have known where the egg shaker could be hidden, and would have had to shake a large box first, to *hear* which large box makes the rattling sound, indicating that the egg shaker had been hidden in one of the two small boxes it contains. “If you don’t know where the egg is, it makes sense to shake one of the large boxes first, so that you don’t risk opening the wrong box. However, if you have an idea where the egg might be, because the tester always hid it in the same box, you can immediately open the large box and then the small box you know has it inside: you have a strong intuition about the solution, and you take what you think is a high chance for a quick win,” Azzurra Ruggeri explains. Although Marta learned in the “skewed condition” that the egg is always hidden in the green box, she still decides to shake the large box first. It rattles. After hesitating briefly, she opens it, followed by the green round box, to find the egg shaker, which she immediately places onto the magic machine. She watches

proudly as the ball on the pyramid lights up and starts to rotate.

Then it’s her friend Jonathan’s turn. He, too, is five. Eva hides the egg in the small green box – it’s the *skewed condition* again. This time during the test, Jonathan decisively opens the correct large box and the green round box inside. Once again, the magic machine starts to move.

The study, now completed, found that 3- to 5-year-olds in the “uniform condition”, i.e. when the egg is always hidden into different boxes, tend to shake a large box first, rather than open one, as expected. However, preschoolers in the “skewed condition” are more likely to open the box where the egg has always been hidden during training. According to Azzurra Ruggeri, this is a sign of their ability for ecological learning.

#### THE CHILDREN MAY BE INFLUENCED UNINTENTIONALLY

If we look at the individual age groups, another result emerges: most of the 3-year-olds immediately open a large box, whereas over half of the 4- and 5-year-olds shake a large box first. Over-

all, the younger children are, the more they tend to open the boxes rather than shake them. This resonates with the results of the traditional question-asking tasks, where the younger children are, the more they tend to ask hypothesis-scanning questions targeting a single object or hypothesis.

Azzurra Ruggeri says that she loves the challenge related to designing such studies/games. This sounds like logical puzzle work: extremely well thought through in advance and finely nuanced. What game could I develop to investigate this question? If I receive this answer at this point, what options do I then offer children? What patterns of results would I expect, how would I interpret them? When testing children, these highly complex basic research questions and hypotheses have to be packaged in a simple, quick, exciting game. Indeed, children must enjoy participating, and the game cannot last too long. For this reason, every game usually requires an extensive pilot phase, during which the team modifies and improves the details of the task, stimuli and instructions. For example, according to doctoral student Nora



Age-appropriate preparation: it is important that children enjoy the games during which their learning behavior is observed. These include the fun-looking drawings of monsters, the special powers of which they can only discover by asking clever questions.

Swaboda, the team worked for a long time down to the tiniest detail on how to arrange the training phase of the egg shaker game for children.

Nothing that the research assistant Eva does in the Natural History Museum in Berlin is improvised. Every action is precisely planned in advance. Even the words that the student uses to explain the game to the children have been learned by heart – always the same words, in the same order, with the same emphasis, but without sounding like a robot. Right at the end, Eva reminds the children of the two actions that can be performed to find out if a large box contains the egg shaker – shaking or opening. She alternates saying: “You can shake the box or open it,” and in the next test run: “You can *open* the box or shake it.” Children might just opt for the last option that she presented.

On this Friday morning, there’s no lack of children and parents willing to take part. The idea of going to museums to conduct the tests was brought by Azzurra Ruggeri from the U.S., where she spent two years as a researcher at the University of California, Berkeley. Together with the egg shaker and its magic machine, there is also a tablet at the Natural History Museum in Berlin, with a kind of card game for seven- to ten-year-olds. With this game, the team is studying how children gather information when learning the correlation between the features of a card and its power, so to speak. The tablet initially shows 27 cards, each card displaying a different monster. Each monster has three qualities listed in on the cards, one below the other (“friendly”, “cheeky”, “funny”). Each property has a value, ranging from 1 to 5, indicating how strong the monster is on that feature. Each monster card also has an ad-

ditional two-digit number on the top right-hand corner of the card, which is initially hidden. This is the number of fruits that the monster has picked. What is the connection between the qualities of the monster and the number of fruits?

A brief look at the tablet screen filled with the monster cards already shows that while the game is attractive and colorful, it is also quite difficult. The players are confronted with a fairly complex learning environment, a very large amount of fragmented information from which conclusions have to be drawn – a high level of uncertainty.

### ONLY A MATHS PROFESSOR WON FULL POINTS

There are two different variants of the game. In the “active” version, the player is allowed to select which cards they want to see: when they click on them, the number of fruits that monster picked gets revealed. In the “passive” version, the monster cards on which the player is allowed to see the number of fruits are selected randomly by the program. During the test, after this learning phase, the children are presented with the feature profile of some new monsters, and are asked to estimate how many fruits that monster has picked. For every correct answer, they are given ten cents, because – unlike for younger children – pocket money is a very good incentive for older ones to play the game at their best.

Can children learn to predict the number of fruits a certain monster picked by looking at the monster’s feature profile? Does learning success vary depending on the game variant? What methods do the children use to collect information? Indeed, the scientists ob-



serve which cards the children select in the active variant. For example, do they prefer to look up cards on which the monsters have extremely high or extremely low values for one of the three monster qualities, “friendly”, “cheeky” and “funny”? This tendency can indeed be observed: many players initially select cards with an extremely high or low value for the property on top of the card (which property that is – funny, cheeky or friendly – is randomized across participants), and then cards where the second property has an extreme value, and finally cards where the property on the bottom is extreme. It is too early to draw conclusions and answer these questions, as the data collection is still ongoing. However, in another project, the group led by Azzurra Ruggeri has already demonstrated that children aged seven and above perform better in a memory game under active learning conditions than in a more passive condition, thus providing proof of the advantages of active learning.

With this tablet game, the maximum amount that can be won is seven euros. Many of the ten and eleven-year-olds



A psychologist with a penchant for logical puzzle work: Max Planck Research Group Leader Azzurra Ruggeri is developing sophisticated but funny games to investigate children's active learning.

go home with around six euros and more. This is not much less than the adults with whom doctoral student Angela Jones previously conducted the test. Among the children, the seven-year-olds whom Angela Jones has also already tested, those who were already in their second year of school often did better than those who were still in their first year. It is likely that the second graders were helped by their more advanced knowledge of maths. "Mathematical skills do play a role here," explains doctoral student Angela Jones, "but so does intuitive learning." The only participant to be rewarded with the full seven euros was a professor of maths.

Onyun, an eleven-year-old from Switzerland, is very happy with his 5.80 euros, which he is putting into his pants pocket. How did he do it? "I guessed and relied on luck" – at least, that's what he says. The evaluation of the data collected from his game session will likely provide a more precise insight.

"I wanted to do something concrete, find a way to get answer to the

questions I considered crucial," says psychologist Azzurra Ruggeri. In Italy, she studied philosophy for five years, focusing on logic, philosophy of science and decision theory, until she began to find it too abstract. She was no longer interested in investigating decision theory only from a logical and philosophical perspective. She switched to psychology and came to Germany. She already enjoyed working with children as a scout group leader.

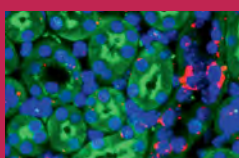
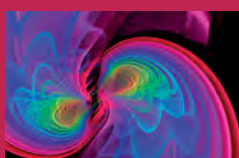
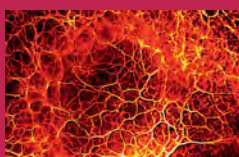
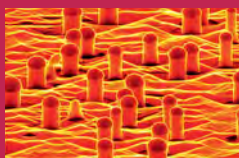
With "iSearch", Ruggeri and her team are now conducting empirically supported basic research. Many of Azzurra Ruggeri's games are conducted in several variants. Ruggeri can also envisage studying learning at earlier and later stages in life. Currently, she is designing an eye tracking study to investigate how babies actively learn by looking at where babies focus their attention. The results contribute to building a more complete, fine-grained picture of children's learning. Her goal is to expand current empirical research, to obtain greater knowledge as to how children learn, and then to put this knowledge into practice. Indeed, she hopes that her findings will later be applied in educational settings – wherever children learn. The basic research that she makes look so playful is later intended to make a contribution towards making it easier and more effective for children to learn, for example in schools, capitalizing on what they can already do from an early age. However, only when there is detailed knowledge of how this complex process works can it be supported purposefully. Although instructional methods inspired by active learning are spreading, the scientific findings that should inform such interventions are still very limited. "There are many myths and assumptions," she says. Currently, Azzurra Ruggeri is also a professor of cognitive and developmental psychology at the School of Education at the Technical University of Munich. ◀

#### SUMMARY

- It is only possible to understand how children actively learn with the help of a large number of observations and tests. To date, only few findings are available.
- Pre-school age children can already differentiate between more and less effective given questions. From about age seven and above, they are able to generate more effective questions themselves.
- Children from age seven and adults perform better in memory games when they are given active control on the materials to be studied.
- One goal of the research is to make learning easier and more effective, capitalizing on what children can do already from an early age.



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# Connecting Science and Business





# In the blazing inferno of the Sun

They looked like oversized spools of thread, were packed full of technology from various Max Planck Institutes, and aimed to considerably improve our understanding of the Sun and the interplanetary medium: over 40 years ago, the two **Helios probes** were launched on a daring mission to the searing heat of our home star. However, the two spacecraft were also a symbol of successful scientific collaboration across national borders.

TEXT **HELMUT HORNING**

The date is the 10<sup>th</sup> December 1974, Launch Complex 41, Cape Canaveral in the U.S.: a *Titan 3E Centaur* towers above the launch pad. The countdown goes according to schedule. When it reaches zero, the rocket is shrouded in white smoke and seconds later disappears into the Florida sky, leaving behind a trail of fire. The engines accelerate the launch vehicle to an immense speed of over 14 kilometers per second, which is necessary to deliver the precious cargo in the nose cone safely to its destination – close to the Sun itself. The cargo in question is the *Helios 1* space probe, and American and German researchers have high hopes for the mission.

It all began back in 1966, when German Chancellor Ludwig Erhard and U.S. President Lyndon B. Johnson signed an agreement to conduct a joint mission in our solar system. The two countries were anything but equal partners: on the one hand, the Americans were racing the USSR to the Moon at the height of the Cold War and had already achieved considerable success in relation to space travel; on the other, the Germans had practically no experience in this area and hadn't yet built a single probe of their own.

At first, the mission's destination was deliberately left open. That was a question for the scientists to worry about. This was where the then Max Planck Institute for Physics came in. In the early 1950s, the Institute's Astrophysics Department was led by Ludwig Biermann. The fact that comet tails always have a similar shape led the researcher to conclude that the Sun must constantly emit an invisible stream of electrically charged particles into space. Indeed, the Soviet *Luna 1* probe managed to detect this so-called "solar wind" on its way to the Moon in 1959; the wind was primarily made up of protons and electrons, as well as helium-4 nuclei. Now, a decade later, the plan was to take a more detailed look at the solar wind and conditions close to the Sun, as well as analyzing the interactions between the central star and our planet.

In June 1969, the mission agreement was officially ratified and fleshed out in more detail. Two more or less identical probes would be fired into space. They were named after Helios, the Greek god

who rides his sun chariot – drawn by four fiery stallions – across the sky every day and bestows light and heat upon the Earth.

The probes were built by Messerschmitt-Bölkow-Blohm, acting as the main contractor, in close collaboration with the German Federal Ministry of Research and Technology and the German Test and Research Institute for Aviation and Space Flight. Seven of the ten experiments on board were developed by German scientists, and four measuring instruments originated from the Max Planck Institutes for Aeronomy, Astronomy, Nuclear Physics, and Extraterrestrial Physics. The U.S. National Aeronautics and Space Administration (NASA) supplied the two launch vehicles and made its Deep Space Network available for communicating with the probes. The project cost 700 million marks in total, of which the Germans contributed 450 million.

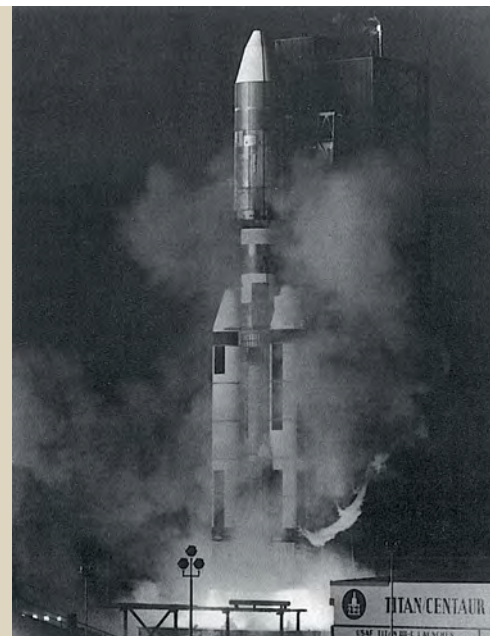
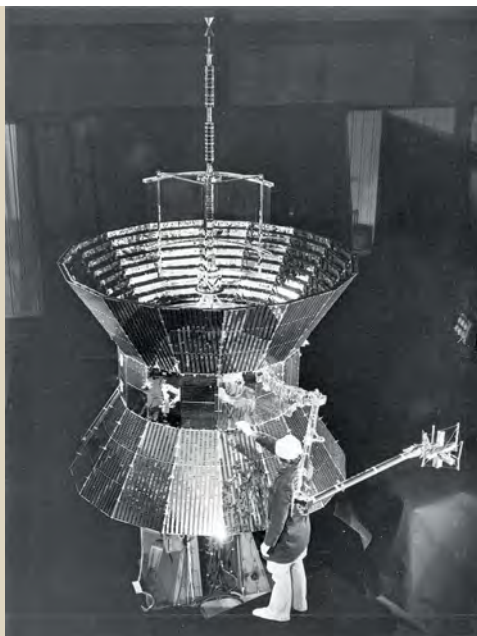
For West Germany, this was not simply about scientific knowledge. In the early 1970s, the country was also keen to expand its knowledge of technology and the management of large-scale projects, with the aim of one day being able to conduct national and international research programs successfully. With *Helios*, those responsible were therefore entering uncharted territory in every respect.

"It was a bold plan, carried out without a great deal of risk assessment," recalls Eckart Marsch. The physicist joined Helmut Rosenbauer's group at the Max Planck Institute for Extraterrestrial Physics as a postdoc in 1976 and spent the next few years working on the analysis of data from the plasma experiment and the instrument for magnetic field measurements. Even the orbits represented a risk, as they brought the probes to within 50 million kilometers of the Sun. At this distance, the terrestrial scouts were exposed to eleven times as much heat as the Earth and reached temperatures in excess of 350 degrees centigrade – hotter than the melting point of lead.

"The shape of the probes was designed based on thermal engineering considerations," says Marsch. In brief, the "spools of thread" were two meters high, weighed 370 kilograms, and were

**Left** An oversized spool of thread: the shape of *Helios* was designed based on thermal engineering considerations. The outer body of the probe is alternately covered with special mirrors and solar cells that supply the spacecraft with energy.

**Right** A successful start: the Titan 3E Centaur rocket lifts off punctually to deliver *Helios 1* to its destination close to the Sun. The mission is a huge success, as is that of the twin probe, *Helios 2*. A third probe was also built, but this was not launched into space and instead ended up in the Deutsches Museum in Munich.



covered with optical reflectors – known as “cold mirrors” – that reflected around 90 percent of the incident light back into space. The entire underside of the skin was lined with insulation. Lastly, the spools of thread rotated about their axes once a second in order to distribute the incident heat evenly over the surface and avoid “sunburn”. With all of these design measures, the spacecraft were so well insulated that the inside temperatures never rose above 30 degrees centigrade, and the probes even needed to be heated while at the furthest point of their orbit from the Sun.

After a smooth launch and a three-month journey through the solar system, *Helios 1* (denoted by some authors as *Helios A*) reached the closest point of its orbit to the Sun (“perihelion”) on 15 March 1975. Moving at a record speed of over 252,000 kilometers per hour, the probe raced past the Sun at a distance of 46.29 million kilometers, approximately a third of the distance between the Earth and the Sun. Two days later, the scientists working un-

SÜDDEUTSCHE ZEITUNG, 18 MARCH 1975



With surprise and astonishment, the participating scientists tracked the German-American solar probe *Helios* as it completed its flyby of the Sun.

der project leader Herbert Porsche at the control center in Oberpfaffenhofen expressed their satisfaction. “All of the probe’s components are working perfectly,” Porsche said at the time. *Helios* was, he said, exceeding expectations “including in terms of the quality of the data.”

A press conference was hastily convened to present the initial scientific findings. For example, the solar wind was stronger than expected, moving through interplanetary space at speeds of up to 850 kilometers per second with relatively large fluctuations in intensity and showing exceptionally rapid temporal and spatial variations. It was also considerably warmer than assumed and followed a 27-day cycle corresponding to the rotation of the Sun. Close to the star, the number of interplanetary dust particles increased tenfold relative to that encountered at Earth’s orbital radius. And the “protective wall” of the solar magnetic field was so dense that the low-energy cosmic radiation couldn’t penetrate it.

*Helios 1* also specifically examined zodiacal light – a diffuse light that can be observed at our latitudes after sunset in the west or before sunrise in the east. This phenomenon is attributed to the reflection and scattering of sunlight by particles in the interplanetary dust and gas cloud, which forms a ring-like disk around the Sun in the ecliptic plane. As the probe approached the Sun, the on-board “Experiment 9” did not record a significant change in the color of zodiacal light. This confounded expectations, leading the researchers to conclude that the particles, which are only a few thousandths of a millimeter in size, do not get smaller near the Sun. However, the brightness of the zodiacal light was shown to increase 15-fold relative to that observed on Earth.

Exactly ten months after this spectacular rendezvous at the heart of the solar system came the launch of the twin probe, *Helios 2* (*Helios B*). With a perihelion of 43.5 million kilometers, the second probe managed to get even closer to the Sun than *Helios 1*, if only slightly. For this probe, too, communication took place via the three large 64-meter antennas of the NASA Deep Space Network, the 100-meter dish of the Max Planck Institute for Radio Astronomy in Effelsberg, in the Eifel mountains, and – as a transmitting station – the 30-meter antenna in Weilheim, Upper Bavaria.

This was the first ever double mission of its kind. “However, it was also unique because no mission before or after it has ever taken in situ measurements so close to the Sun,” says Eckart Marsch, adding that the mood in the *Helios* team was buoyed by this success. The lifespan of the probes was also impressive: originally designed to last 18 months, *Helios 2* continued operating until December 1981, and *Helios 1* until March 1986 – that is, for over ten years. “Strictly speaking, the mission isn’t even dead yet,” says Marsch. “After all, the scientific data is still being analyzed today, for example, at Kiel University.”

Indeed, no other space probe in the past 40 years has flown as close to the Sun as *Helios*. However, this is set to change: on 12 August 2018, NASA launched the *Parker Solar Probe*. After a series of complicated orbital maneuvers over the next few years, the probe will approach the Sun to a distance of just over six million kilometers, from where it will study the outer layers of its atmosphere. Early November this year already saw the spacecraft approach to within around 25 million kilometers, breaking the record of the legendary *Helios* scout.

# Digital worlds at the Harnack House

From September 20 to 23, the Harnack House in Berlin was once again transformed into a second home for around 200 alumni and junior scientists from the MPG



Max Planck Vice President Angela D. Friederici opened this year's alumni conference.

alumna of the IMPRS for Neurosciences in Goettingen, added that it is often “seemingly coincidental events during a career” that open up new possibilities. Moreover, another important factor should not be forgotten: luck. However, the Max Planck Symposium focused not only on career paths but also on the challenges and prospects of digitalization: “At present, we are teaching our children subjects in which they are already being outperformed by machines; mathematics, for example. However, if we want to remain competitive in the future, we have to foster those attributes in our children of which machines are not yet capable – creativity, empathy and complex interpersonal networking.”

This was the third conference of junior scientists and MPG alumni in Berlin. This year's plenary lectures, panel discussions and workshops focused on the topic of digitalization and the wide variety of career options it encompasses, from autonomous driving through legal tech to artificial intelligence in biomedicine. The speakers included founders and CEOs from the fields of industry and science, among them Vice President of Bayer AG and alumna of the MPI for Molecular Genetics, Monika Lessl. During the interdisciplinary presentations and networking sessions, the alumni reported on their career paths, which were “extremely diverse and by no means predictable,” as Max Planck Vice President Angela D. Friederici expressed in her opening speech. During the panel discussion, Pooja Rao, CEO of Qure.ai and

This is how Tosja Zywiets, alumnus of the Fritz Haber Institute and CEO of Rosenberger Hochfrequenztechnik, aptly summarized the future challenges associated with digitalization. “In just 20 years, machines will already be controlling and simplifying large parts of our lives that are currently managed by people, as a matter of course,” adds Zywiets. Moreover, the challenge is not digitalization in itself, but the way in which society handles it. Zywiets concluded with the words: “Rather than flying to Mars, let us make sure that clean water is available to everyone free of charge.” On the second day, separate topics ranging from artificial intelligence to data science were explored in career workshops. As is tradition, the intensive daytime program ended with evening conversation and a jam session in the garden and the Einstein Lobby.

## 18 Max Planck scientists secure high levels of EU funding

The European Research Council (ERC) has awarded the Starting Grants for 2018

The award winners included eight female scientists and ten male scientists from various Institutes of the MPG. They will each receive up to EUR 1.5 million for their research projects. The ERC awards Starting Grants every year. Scientists who completed their doctoral studies between two and about seven

years ago can apply provided they realize their project at a European research institution. From all the applicants throughout Germany, the MPG was again the most successful institution in this round, ahead of the Ludwig Maximilian University in Munich (10 grants) and the Helmholtz Association (6 grants).



# Step by step to greater sustainability

Sustainability group at MPI Magdeburg presents its projects at a symposium

The MPG and its scientific projects are contributing to an environmentally friendly future. Making research operations greener is the goal of a voluntary initiative at the MPI for Dynamics of Complex Technical Systems. Jakob Schweizer, one of the founders, presented the initiative's work at a sustainability symposium organized by the Federal Ministry of Education and Research (BMBF). Environmentally friendly research, do we need it? Is it even possible? "Yes, of course," says Jakob Schweizer. "At the MPI in Magdeburg, we are proving that it's possible – and that it makes sense!" Almost 300 colleagues in the fields of science and research were invited to the symposium in Munich, at which Schweizer reported on the small but important steps that the group has taken since it was established in 2015: "Our first project wasn't particularly spectacular, but neither was it unimportant," says the Research Group Leader. "We wanted our printers to be switched to recycled paper." This seems downright trivial, yet lack of thought or the alleged inferiority of recycled paper means it is often not used even though energy, water and chemical consumption could be cut significantly by doing so. The changeover, which was preceded by a complex coordination process at the Institute, is still not running absolutely smoothly. However, the sustainability group is optimistic that documents will soon be printed in a more environmentally friendly way at the MPI in Magdeburg.

Another topic at the symposium in Munich was the BMBF's initiative, which has been funding scientific research projects for purposes of sustainable development (FONA) since 2010. These include measures to structure research processes and scientific institutions themselves more sustainably. Sustainability in this context is understood to encompass ecological, social and economic aspects such as the CO<sub>2</sub> footprint of scientific work and family-friendly human resources management. Several universities and non-university insti-



The sustainability group with symbols of their projects: Peter Schulze, Emilija Kohls, Andreas Voigt, Hannes Buchholz, Sophia Pistorius, Stefanie Markstein, Sara Grundel and Jakob Schweizer (from left).

tutions are involved in FONA. Even though the MPG is not a part of FONA, its Institutes are implementing numerous projects to promote climate protection and biodiversity. Researchers at the MPI in Magdeburg, for example, are working on improving the integration of renewable energies into existing energy systems by developing methods of converting superfluous energy from wind farms into synthetic gas. "This should not stop us from making the way in which we do research more sustainable," says Jakob Schweizer. Following other initiatives such as the establishment of a bike rental system at the Institute, the sustainability group is also planning bigger projects – for example to reduce the CO<sub>2</sub> footprint.

A large proportion of the CO<sub>2</sub> emitted during the course of scientific operations comes from air travel. "Scientific exchange is essential for successful research, yet we have to ask ourselves

whether every service trip is essential and whether we need to go by air when traveling within Germany," says Sara Grundel, team leader at the MPI in Magdeburg. "And if we do have to fly, we should at least be thinking about compensatory measures for offsetting CO<sub>2</sub> emissions." The German Travel Expenses Act allows for such additional expense, emphasizes Sara Grundel. The Federal Chancellery and a number of authorities, for example, are already practicing CO<sub>2</sub> offsetting. The Alfred Wegener Institute is taking action in the scientific sector. However, the Magdeburg sustainability group does not want to focus solely on projects at its own MPI. "We would like to connect with sustainability initiatives at other MPG Institutes," says Jakob Schweizer. After all, he has just experienced at the BMBF's symposium how inspiring it can be to talk with other people, also in the area of environmentally friendly research.

# Strengthened and focused

Annual PhDnet conference in Tuebingen sets new topics for 2019 and beyond

Career planning, reconciling career and family life and the abuse of power: these were the topics of this year's PhDnet conference in Tuebingen. A survey of doctoral students was also conducted and a new committee elected.

"It was an exciting year for us with plenty of work," said spokesperson Jana Lasser in her opening speech. "The main projects we decided on in 2017, career & mentoring, parenthood and political commitment, particularly in Germany's nationwide N<sup>2</sup> network, were joined by another topic that became highly relevant due to the reports published in summer: the abuse of power. The position paper published on the PhDnet website was intended to make a clear statement. We are delighted that the task force established by the MPG with the mandate to investigate working atmosphere was able to commence its work with the involvement of PhDnet," added Lasser.

A survey was again conducted this year with the aim of underpinning PhDnet's future work with statistics. In total, 2,522 doctoral students participated in the survey, equivalent to a response rate of 50 percent. The themes addressed included supervision, good scientific practice as well as career and family planning. "It became clear that we will have to focus even more strongly on subjects such as vacation regulations, weekend work and the many reasons for breaking off doctoral studies," commented a spokesperson from the working group that conducted the survey. All in all, however, doctoral students at the MPG are still very satisfied with the facilities at their Institutes and the international working environment.

A new committee was also elected; this consists of Spokesperson Alexander

Filippi (MPI for Chemistry), Vice Spokesperson and Treasurer Nikki van Teylingen Bakker (MPI of Immunobiology and Epigenetics), Secretary General Esther Tabitha Earbin (MPI for Foreign and International Criminal Law) and the

Section Representatives for the BMS, Lisa Linhoff (MPI for Experimental Medicine), for the CPTS, Lindsey Bultema (MPI for the Structure and Dynamics of Matter) and for the HSS Raquel Sirotti (MPI for European Legal History).



## Pathways in science

Whether in industry or in science, there are many ways in which postdocs can use their experience and interests to build a successful career. In order to raise awareness of these possibilities, the organizers of the event, which is held in cooperation with alternating partner universities, invited 100 postdocs from the LMU and various MPI to attend presentations, workshops and networking sessions in Munich on 12 October (photo). Two Career Steps are scheduled for 2019: in summer at the MPI for Brain Research in Frankfurt and in the fall at the Friedrich Schiller University in Jena.

# Research Establishments

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

## The Netherlands

- Nijmegen

## Italy

- Rome
- Florence

## USA

- Jupiter, Florida

## Brazil

- Manaus

## Luxembourg

- Luxembourg



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