ASTRONOMY

Cosmic Magnetic Fields
Which technologies will shape our lives in the decades ahead? The online magazine Pictures of the Future reports on the most important trends in technology and offers insights into the laboratories at Siemens. It designs future scenarios, describes exciting research activities in feature stories, reports and interactive 360° features, and provides a platform for experts from all over the world. www.siemens.com/pof
Around 7,000 languages are currently spoken worldwide. Quite a number of them are at severe risk of dying out though, as they are spoken by only a small number of people and are no longer being passed on to future generations. Scientists therefore anticipate that a third, at most – but perhaps only one-tenth – of the languages spoken today will still exist by the end of the 21st century. The significance people attach to their own language depends heavily on social and economic circumstances. Particularly under threat are the languages of population groups with a low social reputation. Even worse is the fact that, with each language that disappears, cultural and intellectual identity is also being lost.

In order to at least document languages and dialects under threat and preserve them for posterity – and for future researchers – the DOBES Program was launched in 2000. As part of this project, scientists from the Max Planck Institute for Psycholinguistics are conducting research in many parts of the world. In northern Namibia, for example, they are focusing on the Khoisan languageǂAkhoe Haïlom, which contains many click sounds. In standard orthography, these are represented by the symbols !, ǀ, ǁ andǂ.

In preparation for a workshop on minority languages in southern Africa, one of the project’s local staff members, teacher Mariane Kheimses, interviewed AbakupǁCamligaeb about his thoughts regarding his mother tongue. The members of the community couldn’t imagine allowing just a single representative to speak for everyone at the workshop. Instead, a series of video interviews was shown at the event, enabling all possible opinions to be represented.
Cosmic Magnetic Fields

18 Protective Shields in the Solar System
In the planetary system, magnetic fields can be driven by snow formed from iron or metallic hydrogen. Measuring them provides researchers with insights into the processes that change the internal mechanisms of the planets. Ulrich Christensen, Director at the Max Planck Institute for Solar System Research in Göttingen, investigates the broad diversity of these magnetic fields.

26 Stars with Great Attraction
They are some of the most exotic objects in space: neutron stars. Incredibly dense and only 20 kilometers across, they rotate about their axes at breakneck speed, emitting cones of radiation out into space in the process. Some of these cosmic beacons have particularly strong magnetic fields. Michael Gabler from the Max Planck Institute for Astrophysics in Garching studies these magnetars – and so learns a thing or two about their nature.

34 Forces that Rule in Galaxies
Magnetic fields spanning 100,000 light-years permeate entire galaxies and envelop their central black holes. Researchers working together with Rainer Beck, Silke Britzen and Sui Ann Mao at the Max Planck Institute for Radio Astronomy in Bonn are teasing the secrets out of these invisible force fields.

ON THE COVER. We can’t see them, but they are omnipresent: magnetic fields. They surround planets, permeate our Milky Way, and are present not only in galactic gas, but also in the suns formed from it. And magnetars, neutron stars having diameters of only about 20 kilometers, have the strongest magnetic fields in the universe. This artist’s impression shows an aesthetic view of such an exotic object – a view that is invisible to telescopes.

Prepared: It is hoped that special services will help respond to the consequences of climate change.

PERSPECTIVES
06 Toward an Objective Discourse on Animal Experimentation
07 New Lab Opened in Argentina
08 Lifelong Friendship
08 Animal Tracker Wins Prize for Citizen Involvement
09 Technology Transfer Networks
09 On the Net

VIEWPOINT
10 The All-in-One Climate Package
Global warming is changing the world. Climate service providers seek to help decision makers from the realms of government, public service and private enterprise respond appropriately to this multifaceted change.

FOCUS
18 Protective Shields in the Solar System
26 Stars with Great Attraction
34 Forces that Rule in Galaxies
Crafted: Elena Conti produces images of vital molecular machines.

Altered: The flu virus changes constantly, so we are in constant need of new vaccines.

Poached: Rhinoceros horn is highly sought after and is traded on the black market at horrendous prices.

SPECTRUM

Micro-Scallops for Medical Applications
Magnetic Fields as Midwives for Stars
The Dark Fingers of the Sun
Collision of Two Galaxy Clusters
Don’t Be an Outsider!
More Daycare Centers Doesn’t Always Mean More Children
Duality in the Human Genome
Look First
Choreography of an Electron Pair
Smiling Builds Trust
Obesity – Like Father, Like Son
A Nano-Lamp with a Lightning-Fast Switch
Superconductivity without Cooling
Computer-Based Brain Games Fail to Deliver on Their Promise

BIOLOGY & MEDICINE

Architect in the Cellular Cosmos
Personal Portrait: Elena Conti

MATERIAL & TECHNOLOGY

Vaccines from a Reactor
In the event of an impending global flu pandemic, vaccine production could quickly reach its limits. Scientists are therefore working on a fully automated method for production in cell cultures that could yield vaccines in large quantities in a crisis.

ENVIRONMENT & CLIMATE

Life on a Climate Roller Coaster
Climate change is radically altering the Earth’s plant and animal life. This is due not only to the rise in mean temperatures throughout the world, but also to the changes in temperature variability between both day and night, and summer and winter.

CULTURE & SOCIETY

The Black Market as a Gray Zone
Counterfeiting in Argentina, the mining and trade in diamonds in Sierra Leone, the trade in rhinoceros horn and financial market crime – these are some of the topics researchers are addressing in an innovative project in economic sociology.

REGULAR FEATURES

On Location
Post to – Tehran, Iran
Making Life More Predictable
Flashback
A Palace Pond in a Beaker
Max Planck Community
High Tech at a Lofty Height
Open Access Needs the Young Generation
Career Conference for Postdocs in Garching
Science Is International and Colorful
Research Establishments
Imprint
Toward an Objective Discourse on Animal Experimentation

Since spurious video footage was broadcast on stern TV in September 2014, the Max Planck Institute for Biological Cybernetics in Tübingen has been exposed to a constant stream of abusive criticism. Max Planck President Martin Stratmann had his say in December in a byline article in the SCHWÄBISCHES TAGBLATT newspaper. In the following, he calls for an objective discourse on research involving animal experimentation.

Brain research is one of science’s most successful endeavors. Extensive anatomical studies have been carried out for centuries. They have provided scholars with great detail about the brain’s structure, but little insight into how it works. This required experimentation on animals – and still does.

The first valuable insights into functional areas of the brain emerged during the 18th century through the investigation of function losses in patients with localized brain injuries. However, their observation didn’t enable systematic assessment of these parts of the brain. That wasn’t achieved until toward the end of the 19th century – namely as a result of experiments on apes.

When we push a patient into the tube of an MRI scanner today, we are drawing on this knowledge that has been continually expanded upon over the past 100 years – thanks, in part, to the results of research conducted in Nikos Logothetis’ department at the Max Planck Institute for Biological Cybernetics.

The renowned neurobiologist has succeeded in building an invaluable bridge between animal experimentation and knowledge acquired from humans through his work. He and his team successfully combined electrical discharge from individual nerve cells with functional magnetic resonance imaging. Opponents of animal experimentation are mistaken when they claim: “Today’s technologies enable researchers to examine the brain in the tiniest detail – without drilling holes into the skull. Modern imaging technologies such as MRI enable the processing of nerve stimuli in the brains of volunteers to be investigated.”

That is simply not true. Functional magnetic resonance imaging makes active brain areas visible because they require more oxygen and blood. It measures oxygen saturation and blood flow, but not the actual electrical activity of the nerve cells. The conclusions drawn often ignore the method’s actual limitations.

The strength of the fMRI signal can’t be quantified in such a way that it accurately reflects differences between the brain areas or between tasks within the same region. The combined investigative approach developed by Logothetis enables a significant improvement in the interpretation of fMRI data. This is of great importance, for instance, in the field of neurosurgery.

The debate over the pros and cons of research involving animal experimentation is nothing new. British animal rights activists first pushed through legislation on scientific testing on animals in 1876. It is nevertheless worth bearing in mind that the first successful operation to remove a brain tumor was carried out in 1879 on the basis of knowledge acquired from apes.

I firmly believe that we must constantly provide well-founded justification for carrying out animal experimentation in research. This, however, presents us with an ethical dilemma. Animal suffering must be weighed up against human suffering. Animal experimentation should aim to contribute to the avoidance or at least the alleviation of human suffering. Deliberate renunciation of experimentation on animals would be tantamount to intentional abandonment of the desire to develop treatments for the many still-uncontrollable diseases, especially neurodegenerative and psychiatric ones.

However, the current campaign against the Max Planck Institute for Biological Cybernetics doesn’t permit any objective discourse at all. None of the secretly recorded footage by the animal rights activist who infiltrated the institute as an animal care worker shows the normal animal management conditions there. Various indications have since emerged to suggest that the images were incited by manipulation of the animals or their environment, or interpreted incorrectly simply to discredit animal experimentation and to encourage putative animal lovers to make donations.
New Lab Opened in Argentina

Cooperation project seeks active substances to combat Alzheimer’s and Parkinson’s

The Max Planck Society has increased its presence in Argentina. After the opening of the Partner Institute for Biomedicine in Buenos Aires in 2011, the Max Planck Laboratory for Structural Biology, Chemistry and Molecular Biophysics was officially inaugurated in Rosario in November 2014. The laboratory is a cooperation project between the Max Planck Institute for Biophysical Chemistry in Göttingen and the Universidad Nacional de Rosario. It is located on the university campus of Rosario, Argentina’s third-largest city, 300 kilometers northwest of Buenos Aires. Using state-of-the-art magnetic resonance scanners, the researchers there can investigate the structure of biomolecules directly inside cells.

The scientists are endeavoring to identify potential active substances to combat neurodegenerative diseases such as Alzheimer’s and Parkinson’s. In total, around 30 million pesos (approx. 2.8 million euros) have been invested in the building and its laboratory and equipment. Argentine scientist Claudio Fernández is head of the laboratory. He also recently led a research group as part of the Max Planck Society’s partner program.

Official inauguration: Darío Maiorana, rector of the Universidad Nacional de Rosario, Jorge Capitanich, Head of Cabinet of the Argentine Government, Juan Manzur, Minister of Health, Lino Barañao, Minister for Science, Research and Technology and Claudio Fernández, head of the new laboratory (from left).
Lifelong Friendship

Alumni set up Max Planck friendship groups in four countries

The initiators: Albert Presas i Puig (seated), Javier Ordóñez, Jürgen Renn and José M. Pacheco (from left) at the Max Planck Institute for the History of Science.

Animal Tracker Wins Prize for Citizen Involvement

The award-winning app involves the work of Max Planck ornithologists

Director Martin Wikelski of the Max Planck Institute for Ornithology in Radolfzell and his team impressed the jury of the “Citizen Science” competition in Science Year 2014. The bird-watcher app enables anyone to follow animal migratory movements and even contribute to the research.

Scientists equip birds and other wild animals with transmitters, enabling their whereabouts to be tracked via GPS. An online database documents the distances covered.

Downloading the animal tracker onto a smartphone allows users to see the routes taken by the animals in the database. Moreover, if someone is in the vicinity of one of the animals, they can provide the researchers with valuable additional information: Is the animal eating, and if so, what? Is it alone or accompanied by conspecifics? Observations and photographs can also be directly uploaded via the app, allowing all members of the public to actively support the scientific work – which is the idea behind “Citizen Science.”

The competition, which is organized annually by the Wissenschaft im Dialog (Science in Dialog) initiative, the Museum für Naturkunde in Berlin, and the Federal Ministry of Education and Research, encourages scientists to use digital media to involve the general public in their research. The winners receive a professionally produced video to raise the profile of their project.

Alumni support, for example in the form of associations for former staff or invitations to institute celebrations, has existed at the Max Planck institutes for many years. The close ties with the Max Planck Society are nevertheless often lost when researchers pursue a career elsewhere, whether in science or industry. “In a friendship group, we can achieve more, such as raising the profile of the Max Planck Society and its values in our home countries,” explained Albert Presas i Puig, the initiator of “Amics de la Sociedad Max Planck.”

The former staff member of the Max Planck Institute for the History of Science, together with other alumni and one of the Directors, Jürgen Renn, founded the friendship group in Spain in September 2014. Presas i Puig has a clear vision of how the association can achieve its goals: “We can, for instance, organize symposia with universities and local research institutions, or help people relocating here to settle in.” Three further friendship groups in Argentina, South Korea and California have now also adopted the model of the Spanish alumni.
Technology Transfer Networks

Munich Innovation Days bring science and business together

The two-day event held in downtown Munich in early December 2014 was opened by Max Planck President Martin Stratmann. In his address, he emphasized the importance of “not just bringing technologies and companies together in an abstract sense, but actually connecting the people who ultimately realize them.” The Innovation Days provided a forum for precisely that. The program included best-practice examples for successful cooperation, a startup financing event and a panel discussion on open innovation, in which Max Planck Director Dietmar Harhoff also took part. At the core of the conference was the presentation of 40 selected research projects with application potential. Also 13 Max Planck representatives presented their work.

The annual Innovation Days event promotes the transfer of research results to application, and aims to establish strong links between science and business. This time, the lead was taken by Max Planck Innovation, the service provider for technology transfer in the Max Planck Society.
Research into climate change has advanced significantly since the year 2000. By the end of the 20th century, scientists had learned enough about the causes of observable climate change to be able to evaluate the extent to which human actions influence the Earth’s climate. Recently, their focus has shifted to estimating the future consequences of climate change on our interlinked environmental and social systems.

As a result, the scientific debate now focuses on a range of new and urgent issues, so that the social sciences must now become involved. These new priorities include questions regarding the physical and social vulnerabilities resulting from climate change, the ability to withstand these strains, and the choice between adaptation and prevention strategies. Calls for climate predictions for individual seasons, years and decades are also growing louder – a demand that modern-day science can currently meet only in terms of rough seasonal forecasts in lower latitudes, and even then only in part.

Leaders from the realms of government, public service and private enterprise need reliable climate information based on up-to-date research findings in order to make informed decisions on how to adapt to climate change. The scientific community is perfectly aware of this need, which is why it helps draw up detailed climate reports such as those produced by the Intergovernmental Panel on Climate Change (IPCC), for example. These reports are policy-relevant and form the scientific basis for international negotiations like the UN Framework Convention on Climate Change. Each of these reports takes several years to prepare.

The current trend is to make predictions about the regional consequences of global warming.

As a result, the scientific debate now focuses on a range of new and urgent issues, so that the social sciences must now become involved. These new priorities include questions regarding the physical and social vulnerabilities resulting from climate change, the ability to withstand these strains, and the choice between adaptation and prevention strategies. Calls for climate predictions for individual seasons, years and decades are also growing louder – a demand that modern-day science can currently meet only in terms of rough seasonal forecasts in lower latitudes, and even then only in part.

Leaders from the realms of government, public service and private enterprise need reliable climate information based on up-to-date research findings in order to make informed decisions on how to adapt to climate change. The scientific community is perfectly aware of this need, which is why it helps draw up detailed climate reports such as those produced by the Intergovernmental Panel on Climate Change (IPCC), for example. These reports are policy-relevant and form the scientific basis for international negotiations like the UN Framework Convention on Climate Change. Each of these reports takes several years to prepare.

The task of enabling knowledge transfer isn’t an easy one, as there are often conflicts of interest involved. The views and opinions of the scientists are often very different from those of social stakehold-
ers. Even though the scientific community generates sufficient data and users are well informed about the subject matter, large gaps remain when it comes to integrating, analyzing and evaluating the data and translating the results into a context outside the subject area.

As a result, the knowledge gathered by the IPCC is also of only limited use, for example for regional companies, cities and municipalities, as well as for the general public. First and foremost, the IPCC compiles scientific information that is of global relevance, based on global model projections. Like others, however, the IPCC is also experiencing the growing demand for statements about climate consequences, vulnerability and adaptation on a regional scale. A decentralized communication mechanism could be set up to better account for the needs of the decision makers. It must ensure that the research knowledge and the local knowledge of the decision makers – the product of years of experience – complement each other. Climate service providers such as the Climate Service Center in Hamburg are able to implement such a mechanism. As early as 2001, the National Research Council (NRC) of the American Academy of Sciences defined the term climate service as “the timely production and delivery of useful climate data, information and knowledge to decision makers.” The report states that an improved information management system is necessary for the advancement of measures relating to climate change.

In a later report, the NRC recommends developing a comprehensive greenhouse gas monitoring and management system that is coordinated by climate service institutions. Again, there was a call for customized information that must be made available to the social interest groups. According to the NRC, the key functions of climate service providers include expanding monitoring systems, intensifying efforts to develop vulnerability analyses on a regional scale, sustainably interacting with all participating actors, conducting new kinds of research to assess demand, and utilizing a suitable communication strategy.

The task that climate service providers are expected to perform therefore goes far beyond the mere production of knowledge. They must develop product prototypes, meaning new, research-based and customized information and methods that are produced and tested for feasibility together with the users. They support the decision-making process, for example when identifying measures to adapt to climate change.

The product prototypes are created using a top-down approach, but they also require extensive interaction (bottom-up) with the respective stakeholders so that hands-on experience can be incorporated into the process. The top-down approach is based on climate projections and takes into account the corresponding uncertainties. The bottom-up approach refers to analyses that evaluate the effects of climate change on socio-ecological systems. The innovative task of climate service providers is to combine both of these approaches.

In so doing, climate service institutions can eliminate a deficit of the past, as efforts to communicate knowledge on climate change have often failed in recent decades. Even though the scientific community was able to make steadfast statements regarding important questions about climate change and disseminate them widely (for example via the IPCC reports and the summaries thereof targeted at decision makers), many decision makers remain skeptical and show no signs of changing course in favor of adaptation to climate change.

This inefficient process has several underlying causes. Firstly, individual scientists repeatedly ask critical questions that, if they prove to be justified, could challenge their conclusions. This is actually a healthy process that is common in many different disciplines. Scientifically founded doubts have often set new courses for research and thereby ultimately led to success. Secondly, there are politically motivated individuals who unnecessarily exaggerate the uncertainties communicated by the scientific community. Their goal is to set up “orchestrated campaigns” that cast doubt on the quality of work and the integrity of the international scientific community – often with the financial backing of large international corporations and politically motivated
groups. After all, the press – always in search of controversial headlines – is often tempted to give statements made by the majority of international scientists the same weight as frequently unfounded statements made by a very small minority. This causes great confusion among the general public, because the population isn’t able to weigh up the scientific facts or analyze in detail the quality of the information that is spread.

Public opinion has a major influence on the decisions made by government officials and politicians. Citizens absolutely are interested in climate change – they are, after all, often directly affected by it. Their views on this subject depend largely on the statements made by scientists – but not exclusively, because each person is also significantly shaped by societal beliefs (especially religious and family values), as well as by the individual’s personality structure. Likewise, their perceptions are influenced by the currently dominating social structures, political systems and economic values. In addition, they are exposed to confusing messages disseminated by the media.

Complicated knowledge about the Earth’s climate can therefore be conveyed only by developing communication strategies that can do justice to the overall complexity and multidimensional character of this subject matter. That goal requires laborious dialog processes that go far beyond classic knowledge transfer, where information is typically passed on from so-called experts to so-called laypersons.

The type of information that needs to be communicated is also an important factor. Only a small number of interest groups actually require original data, such as the information that hydrometeorological service institutions draw from scientific databases. What most practitioners need are analyses and expert opinions that link this data with specific, local knowledge about new insights. Many questions refer to very specific situations, special regions and particular local conditions. It is imperative to also be familiar with the social, economic and cultural circumstances of such a region, and to form a network with the actors there, both on a local and on a national level.

Despite significant advances in science, this kind of application-oriented knowledge about the Earth’s climate and climate change wasn’t yet available to the public at the start of the last decade. That’s why, in 2007, the German federal government decided to set up a German Climate Service Center designed to bridge the gap between climate research and the general public. Initially envisioned as a five-year project in 2009, it has since become a permanent institution at the Helmholtz-Zentrum Geesthacht. It complements the existing range of institutions that have been successfully providing climate services in Germany for many years, including the Deutscher Wetterdienst (German Meteorological Service), the Regional Climate Offices of the Helmholtz Association of German Research Centers (HGF), and KomPass, the Climate Impacts and Adaptation in Germany initiative sponsored by the Federal Environment Agency.

Many new climate service institutions are also being set up on an international level. The European Centre for Medium-Range Weather Forecasts (ECMWF), for example, is currently developing a service structure for climate and adaptation services, as well as a comprehensive database. And the European Environment Agency (EEA) in Copenhagen is setting up a platform designed to help countries and municipalities devise adaptation strategies.

The EU Research Framework Program Horizon 2020 sponsors projects that aim to disseminate climate information. The European Joint Programming Initiative (JPI) Climate, comprising 14 member states, seeks to improve the coordination processes between national and European climate research efforts. Climate-KIC, a major EU climate innovation initiative, is already involving European businesses in its activities. These are just a few examples from a long list of European initiatives in this field.

In addition, most countries in Europe and elsewhere in the world have established climate service institutions with a broad range of functions and tasks. Global network initiatives have also been developed. The goal of the UN-wide Global Framework for Climate Services (GFCS), which was set up by the

Customer-specific climate services can gain trust only if they remain impartial
World Meteorological Organization (WMO), is to foster the global exchange of knowledge about climate change.

Climate service providers face a large number of challenges. They must remain impartial and neutral, shouldn’t let their actions be dictated by interests, and should use high-quality basic data and methods. Only then will users trust their products. Industry- and sector-specific risks and opportunities that arise from climate change must be mastered in unison with the relevant actors. The products should be customer-specific and customized in accordance with the respective demand.

Even though there are already many institutions that – at least to some extent – offer climate services, there is no universal concept for these types of facilities. It is essential that tasks be clearly divided and that joint initiatives function as planned. In addition, research conducted into the effects of climate change, vulnerability and adaptation must be drastically increased. Apart from developing application-oriented products, climate service providers should also report their users’ existing needs back to the scientists so that their efforts can directly benefit society as a whole.

Gaining a better understanding of the public’s need for climate-change-related knowledge and finding ways to foster productive dialogs between the actors and the science world requires targeted research. However, the scientific community has thus far not fully committed itself to this. Scientists, users and climate service providers should therefore be encouraged to develop products in a joint effort. It is also vital to find effective and objective ways to measure the success of climate services.

Initial experiences have shown that it is difficult to translate research results into practical knowledge that can flow directly into the planning processes of the decision makers. When developing climate services, it is important to identify and link the necessary tasks and factors. Databases containing meteorological, oceanic and hydrological data, as well as re-analyses, model simulations and projections, are indispensable, as is additional data on greenhouse gas emissions, population density, deforestation and urban growth, for example.

Close cooperation between data providers, modelers and hydrometeorological centers is crucial. The ideal solution would be to have these groups work together under the same roof in meteorological centers in order to foster the liaisons between modelers and climate researchers at universities and other scientific institutions. Furthermore, such a facility should also employ a team of communications experts whose main task is to establish connections with potential customers from the various sectors of the economy. The communication experts ascertain their level of demand, answer queries and translate the scientific knowledge into a user-oriented, easy-to-understand format.

Yet climate service institutions don’t just prepare user-specific information and services; they also advise on how to react to climate change in an appropriate manner. That means they also serve as an “adaptation service provider.” First and foremost, this bottom-up approach involves experts from the fields of social, economic and political sciences, as well as engineers. Here, the focus lies primarily on tried-and-tested strategies, solutions and guidelines, as well as on local aspects rather than on global change.

The language used by this scientific community differs from the conventional terminology applied in the natural sciences, which hampers the dialog between the two. Here, it is less about climate predictions and projections, robust results, uncertainties and scenarios, and rather more about vulnerability, resilience, adaptation, governance and international negotiations.

Another key question is whether there is really a market for climate products and services. Once again, experience has shown that large parts of the market still need to be developed. While companies and public services do, in fact, have a need for information on climate change, it isn’t certain whether this need is always recognized.

However, taking a step toward improving cooperation between science and potential users means first having to overcome several obstacles. Firstly, there is a discrepancy between the various time ho-
rizons that scientists and decision makers apply to different sectors of society: scientists apply mainly very long-term climate projections, typically spanning the next 50 to 100 years. Entrepreneurs in private corporations and decision makers in public service, on the other hand, require information pertaining to the next five to ten years. That is why it is essential to advance the development of climate predictions on a time scale that spans individual seasons or decades.

Secondly, the business model of most institutions providing climate services doesn’t match that of their customers. It is usually based on contractual relationships, and customers are viewed as subsidizers – by research institutions, for example. However, this model is often incompatible with customer requirements, as the customers expect a very speedy response to their industry-specific queries.

This is where consulting companies from the private sector could serve as a further useful link in the information chain, bridging the gap between scientists and decision makers to help satisfy customer demands. However, these consultants often don’t possess the specific expert knowledge of that particular field, and don’t have close ties to the scientific community, so the services they provide don’t always stand up to the quality expected by science. One solution could be for publicly financed climate service providers to develop prototypical products and then hire a private consulting firm that subsequently sells these products to the societal actors. In doing so, however, the role of these publicly financed institutions would be radically changed, because their primary focus would then no longer lie on communication and information dissemination, but instead on applied research and innovation.

The Authors

Guy Brasseur, born in Belgium in 1948, studied engineering at the Free University of Brussels, where he obtained his doctorate in 1976. Today he is a senior scientist and project leader at the Max Planck Institute for Meteorology in Hamburg, where he previously also served as Director. Furthermore, he was Associate Director at the National Center for Atmospheric Research in Boulder, Colorado (USA). As a scientist, he is particularly interested in atmospheric chemistry, aeronomy of the upper atmosphere, and solar-terrestrial interactions, as well as climate sciences and climate services. From 2009 to 2014, he set up the Climate Service Center of the Helmholtz-Zentrum Geesthacht in Hamburg. He currently holds the position of Chairman of the World Climate Research Programme’s Joint Scientific Committee.

Irene Fischer-Bruns, born in 1956, studied meteorology at the University of Hamburg, where she obtained her doctorate in 1986. As a climate researcher, she was involved in a range of different projects at the university and at the Max Planck Institute for Meteorology, where her main interests included the effect of aerosols on the climate, atmospheric dynamics – particularly in the North Atlantic – and statistics. Starting in 2009, she worked as the scientific assistant to Guy Brasseur for five years, and was involved in setting up the Climate Service Center of the Helmholtz-Zentrum Geesthacht, since renamed Climate Service Center 2.0, where she still works today.
Making Life More Predictable

When I chose the Max Planck Institute for Informatics for my doctoral work, I had no idea where it was located. Unlike Tehran, a city with a population of almost 16 million, Saarbrücken is certainly no bustling metropolis. But that has its advantages: it helped me a great deal with settling in, because you always see familiar faces wherever you go – on the street, in shops or when going for a night out. What’s more, the inhabitants of Saarbrücken are very open-minded and tolerant. Due to the fact that the town lies just seven kilometers from the French border, it is quite international, and the residents are very accustomed to meeting people from different cultural backgrounds.

I often take trips to nearby cities in France; even Paris is only two hours away by train. Whenever I travel there, I notice how much I’m already used to the way things are done in Germany. I greatly appreciate German dependability and punctuality, for example. I am also very comfortable with the fact that Germans are so rational and direct. Unlike in Iran and Canada, where I lived before moving here, most people here tell you quite bluntly what they think. I like that, because it means you know where you stand.

However, the situation here is by no means perfect. Germany does have one of the best social security systems, and in fact that was one of my motivations for choosing this country. But as a foreigner, you have to make sure you’re not put at a disadvantage. Not knowing enough about the system, I ended up having a stipend that needs to be renewed annually. While this covers my living costs, I’m disappointed that I can’t pay into the social security...
Adrin Jalali, 30, is a doctoral student at the Max Planck Institute for Informatics in Saarbrücken. After suffering political persecution in his native country of Iran, he emigrated to Canada in 2011 to pursue his doctorate at the University of British Columbia. However, he wasn’t happy in Vancouver, and therefore decided to move to Germany in 2012. In Thomas Lengauer’s department, he develops machine-learning algorithms that automatically classify biological data gained from microarrays or DNA methylation analyses, for example. In his spare time he enjoys going on excursions to the surrounding region.

system. That’s really important to me – not only to benefit from, but also to contribute to a system of solidarity that I endorse politically. Furthermore, newcomers to Germany quite often become victims of prejudice. Some people mistake cultural differences or language difficulties for signs of scientific incompetence.

However, I rarely come across such attitudes at our Max Planck Institute. The people in our group come from many different countries, yet we work together perfectly as a team. And the scientific work here is really great! It’s a fascinating challenge to be involved in improving cancer treatment by developing computational tools.

People sometimes ask me whether I miss Iran and life over there, but apart from family and friends, I really don’t miss anything at all. On the contrary: I can’t imagine going back after what I experienced there. In Tehran, I spent 105 days in jail as a political prisoner – initially 11 of us were detained in a confined space that was so small that we couldn’t even lie down to sleep. Unlike numerous others who were sentenced to many years or even life in prison, or unlike a friend of mine, Jafar Kazemi, who was hanged, I was fortunate and was acquitted in the end. But I wouldn’t risk being arrested a second time. Life in such a system is absolutely unpredictable, and I know that the authorities are still extremely suspicious. At least I can occasionally meet up with my family in Turkey, as we are all able to travel there without a visa.

I want to stay in Germany for good – either in Saarbrücken or in another city. And, ideally, I would like to continue working in science, because it’s important to me that my work is openly available for public benefit rather than having it remain a trade secret locked away behind closed doors. As soon as I moved to this country, I started learning German. It’s tough, but I’m beginning to notice that I’m slowly making progress. Unfortunately, I’m not yet proficient enough for German literature. Reading the works of Marx and Hegel in the original version – that’s my goal.
Protective Shields in the Solar System

Snow formed from iron or metallic hydrogen – both of these phenomena can drive magnetic fields. Measuring them provides researchers with insights into the processes that change the internal mechanisms of the planets. Ulrich Christensen, Director at the Max Planck Institute for Solar System Research in Göttingen, investigates the broad diversity of these magnetic fields.

In the 1950s, radio astronomy was still in its infancy. But the observatories were by no means small – quite the opposite, in fact: the astronomers strained their ears for celestial radio sources on enormous, open spaces. In 1955, US researchers made a lucky find with such an installation near Seneca in the US state of Maryland, where more than eight kilometers of antenna wire had been erected. While observing the Crab nebula 6,300 light-years away, this monster of an antenna detected a transmitter that was much, much closer, and that interfered every now and then in the short wavelength range: Jupiter.

On its journey through this constellation, the planet had reached just the right position for its interfering action. Very soon the astronomers received further radio emissions from it, this time at higher frequencies and almost constant over time. A consistent picture emerged: In order to manage all this, Jupiter had to be surrounded by a magnetic field – because the high-frequency waves originate from electrons hurtling around the giant planet, trapped in its magnetic field. The first planetary magnetic field beyond Earth had been found.

Today, on-site measurements are expediting the research into Jupiter’s magnetic field. Since 1973, eight space probes have made their contribution to this, and further missions are en route or in the planning stage. The robotic discoverers have been lucky on other planets, as well: Saturn, Uranus and Neptune also have global magnetic fields, as does the smallest planet, Mercury. The properties of these fields are quite different, though.

A RAPID ROTATION AIDS THE DYNAMO EFFECT

“There is a confusing diversity,” says Ulrich Christensen. The globes of the celestial bodies are lined up in the window of his office at the Max Planck Institute for Solar System Research in Göttingen: Earth’s moon and Mars, neither of which, according to the space probes, currently has a global magnetic field. Venus also has a window seat. The planet has long been called “Earth’s sister” – but unlike our home planet, it also has no magnetic field of its own.

So what distinguishes these planets from the magnetic planets? “Celestial bodies without a magnetic field lack an active, planetary dynamo,” says Christensen, who is an expert on the numerical simulation of such dynamos. All global magnetic fields originated deep below the surfaces of the planets. “This is where flows have to set electrically conductive liquids in motion. A sufficiently rapid intrinsic rotation is also very helpful for a dynamo process.” This is lacking in Venus, for example, which requires no fewer than 243 terrestrial days to rotate once about its own axis. Jupiter completes a rotation in less than ten hours; its magnetic field resembles that of Earth in some respects. Although it is more than ten times stronger, researchers basically measure a simple dipole field like that on Earth, comparable, in a sense, to a gigantic bar magnet. The field is also inclined by around ten degrees with respect to the planetary

Special status: Ganymede is the only moon to have its own small magnetosphere. It lies in the middle of the Jovian field lines, which deform close to the moon and partially mix with those of Ganymede. Where the field lines open up, particles from Jupiter’s magnetosphere penetrate into the thin atmosphere and generate polar lights, also called aurorae.
axis of rotation. This doesn’t, however, mean that the same processes occur in Jupiter’s interior as in the Earth’s, because, being a gas giant, its structure is completely different.

The role played by the liquid iron whose currents in Earth’s core give rise to our magnetic field is adopted in Jupiter by hydrogen – the substance of which the planet is largely composed. But it is a different hydrogen than the one we know. The high pressure to which the element is exposed in the interior of the planet has a radical effect on its properties.

Not only are the atoms squeezed together so closely that they form a liquid, but most importantly, their electrons are no longer limited to their former home atoms, but can migrate almost at will: the insulator thus becomes a metal. This is indicated not only by theoretical computations, but by laboratory experiments as well – for example at the Max Planck Institute for Chemistry in Mainz. The researchers there put hydrogen under great pressure until it reaches values similar to those that occur in the interior of gas planets. In 2011, they registered an increase in the electrical conductivity at several million bars.

**JOVIAN MOON GANYMEDE IS LARGER THAN MERCURY**

The largest planet is also the focus of Johannes Wicht’s work. A staff member at the Max Planck Institute for Solar System Research, he hit on a double structure that he described recently with his colleague Thomas Gastine in Geophysical Research Letters: “Our simulations show that the earth-like component of the magnetic field is generated in the depths of the atmosphere,” explains Wicht.

In addition to this, there is a second dynamo process that occurs at the transition to metallic hydrogen. The magnetic field of the gas giant may appear to be similar to Earth’s, but it has its origin in exotic processes.

A total of 67 known satellites orbit Jupiter – a kind of miniature solar system. With Ganymede, it plays host to the largest of all moons; its diameter is 5,268 kilometers, making it larger than the planet Mercury. Between 1995 and 2003, the American *Galileo* space probe
explored the Jovian system and the giant moon also appeared several times on the schedule of visits.

It was during these visits that Galileo's magnetometer discovered a unique feature that characterizes the moon to date: Ganymede is the only moon to have a global magnetic field – and it is three times stronger than that of the planet Mercury ("The Sun's magnetic neighbor," left-hand page). A recently published study by Ulrich Christensen in the journal Icarus provides a look into Ganymede's interior. "As on Earth, the source of the magnetic field is a liquid core," says the Max Planck Director. At the same time, he rejects older ideas that the saline subsurface ocean, a feature of both Ganymede and its neighboring moon Europa, could be where the dynamo effect takes place.

"Ganymede's core probably also contains quite a bit of sulfur," says Christensen. This isn't unusual, it is assumed that Earth's core also contains up to 10 percent of lighter substances, probably a mixture of sulfur, oxygen and silicon, in addition to the metallic components. The processes in Ganymede's core, which Christensen has modeled, appear to be bizarre neverthe-
Investigates the magnetic fields in the planetary system: Ulrich Christensen, Director at the Max Planck Institute for Solar System Research in Göttingen.
Ringed sphere: The planet Saturn with its extended system of rings is already a fascinating sight in the small telescope. The Hubble space telescope reveals fine details, such as a light blue structure around one of the poles (image above). This is an aurora that emits UV light and is associated with the magnetic field of the planet. Like the magnetic fields of Earth and Jupiter, this one (graphic below right) resembles a giant aerodynamic body, with the ringed planet being located in its head. The spatial region of the field is fed with particles that are constantly released by the moon Enceladus. The moon orbits Saturn together with others, such as Tethys and Mimas, in a plasma torus of positively charged particles (graphic below left).
The most obvious proof of the magnetic activity on the ringed planet is offered by light phenomena in its northern and southern polar regions: the aurorae. Just like on Earth, they occur when solar wind particles that were trapped in Saturn’s magnetic field spiral down along the magnetic field lines to the magnetic poles, colliding with molecules of the atmosphere in the process. Unlike our polar lights, Saturn’s aurora doesn’t radiate in visible light, but at ultraviolet wavelengths. And while high levels of polar light activity are typically over after a few hours on Earth, on Saturn they can sometimes be observed for days.

SEVERAL CIRCUTS IN THE MAGNETIC FIELD BOOST ENERGY

Saturn’s magnetosphere is the venue for high-energy processes, as it is filled with fast-moving particles. These originate mainly from Enceladus: the geologically active mini-moon ejects 100 to 300 kilograms of water vapor and ice particles per second, some of which can leave the moon’s weak gravitational field. “The H₂O molecules are ionized by the solar UV radiation and accelerated in the magnetic field. They can be encountered outside of Enceladus’ orbit in the whole magnetosphere,” says Norbert Krupp.

Primarily protons and electrons, which can attain energies of up to 100 mega-electronvolts (MeV), collect in a number of radiation belts. “How exactly they achieve this is still the subject of intensive research. They may have already done several circuits in the magnetic field when they hit the detectors with such energy,” explains Krupp. The absorbing effect of the rings and the inner moons means that these belts aren’t as distinct as their terrestrial counterpart, the Van Allen belt.

The moons of Saturn are exposed to the particles as they rain down. Norbert Krupp and his colleague Elias Roussos are therefore also investigating what effect the constant bombardment of high-energy particles – especially electrons – has on the surfaces of the moons. Experts use the term “space weathering” when they describe the chemical weathering of the surface of a celestial body brought about by the effects of open space.

The latest analyses, recently published in the journal *Icarus*, indicate that the sides of the ice moons Mimas, Tethys and Dione that face Saturn are being chemically altered by electron bombardment. These electrons have so much energy (a few MeV) that they drift perpendicularly to the magnetic field, but in the opposite direction to the orbital motion of the moons. Simultaneously, they shuttle to and fro between the north and south poles along the magnetic field. Experts can use this pattern of motion to calculate the impact zones on the respective moon. It has been revealed that some of the surface characteristics in the equatorial regions observed by *Cassini’s* onboard cameras match the calculated distribution pattern of the particles.

Back to the inner solar system: The red planet allows us to study what happens to a terrestrial planet when its magnetic shield is extinguished, because Mars probably also had an active dynamo at some point: a mosaic of magnetized rock on its surface still serves as a reminder of this magnetic era. Markus Fränz, also from the Max Planck Institute in Göttingen, has eval-
Scarred by the weather in space: The surface of Saturn’s moon Tethys shows clear traces of chemical weathering. The bluish streak in the right half of the image is caused by high-energy electrons that bombard the ground under the influence of the planetary magnetic field.

uated the plasma measurements of the *Mars Express* probe, which has been orbiting Mars since 2003.

Is it still possible to measure how the water of the unprotected planet falls victim to the solar UV radiation and the solar wind? “We measure the decomposition products of the H₂O molecule, so to speak, namely the oxygen ions. Recently we have also been incorporating the measurements of the radar instruments into our analyses,” says Fränz. This allows the researchers to obtain a more complete picture, because they also see the lower-energy, cold plasma that remains hidden from the actual plasma instrument.

The ion outflow obtained in this way can be used to do a back calculation to obtain the amount of water initially present, and the result is a dramatic drying up. According to these calculations, the water contained in a global Martian ocean several hundred meters deep escaped into space over billions of years. “The real value is probably even higher since, in its youth, the Sun likely went through phases when it was considerably more active than today and, back then, decimated the water reserves with particular ferocity,” assumes Markus Fränz.

What started with Jupiter’s radio waves six decades ago has since provided many findings about the planet. And a further rendezvous with the gas giant is already scheduled: a magnetometer (JMAG) will also travel into the Jovian system on board the aforementioned *Juice* probe, and Christensen, Krupp and Roussos in particular are looking forward to receiving its data.

Also on board will be a particle instrument called the *Particle Environment Package (PEP)* incorporating important contributions from Germany. Fränz and his colleagues want to use this instrument to measure the thin gas atmospheres of Jupiter’s moons, as well as the neutral particles and ions that romp in the magnetic fields there. Markus Fränz is certain: “The discoveries will continue.”

**TO THE POINT**

- Although magnetic fields are widespread in space, not all planets in our solar system possess one. Venus and Mars have none.
- Even though they are very diverse and have very different structures, all global magnetic fields originate deep below the surfaces of the planets and require an active dynamo.
- The Jovian moon Ganymede is thought to be the only moon to have a global magnetic field; it is three times stronger than that of the planet Mercury.
- The magnetic fields of the gas planets Jupiter and Saturn are particularly extensive. Jupiter’s magnetosphere is the largest structure in the planetary system next to that of the Sun.

**GLOSSARY**

**Aurora:** This phenomenon, which is also called the polar lights, is a luminous phenomenon in the polar regions of a planet. It is caused by particles in the solar wind – mainly electrons and protons – that collide with heavy ions in the upper layers of a gaseous atmosphere where they ultimately cause fluorescence.

**Space weathering:** Specialist term for the chemical weathering of the surface of a celestial body that has no atmosphere. This type of erosion is caused by effects from open space, such as the impact of micro-meteorites, cosmic radiation or solar UV radiation.

**Van Allen belt:** A ring (torus) named after American astrophysicist James Van Allen (1914 to 2006) and made up of high-energy charged particles that are trapped by Earth’s magnetic field. The belt essentially consists of two radiation zones. Other planets also have similar structures.
Stars with Great Attraction

They are some of the most exotic objects in space: neutron stars. Incredibly dense and only 20 kilometers across, they rotate about their axes at breakneck speed, emitting cones of radiation out into space in the process. Some of these cosmic beacons have particularly strong magnetic fields. Michael Gabler from the Max Planck Institute for Astrophysics in Garching studies these magnetars – and so learns a thing or two about their nature.

TEXT HELMUT HORNUNG

On the fifth day of the journey, a huge storm came up, sweeping the boat further and further off course – directly toward the magnetic mountain. Even prayers were of no help: “The force of the mountain began to draw the ship toward it, causing it to break up.” The knights in Herzog Ernst, a popular German epic from the late 12th century, must battle this danger in addition to fighting terrifying snakes and other monsters that lurk in the depths of the ocean waiting for the seafarers of yore. Terrestrial magnetic mountains are the stuff of fiction – but magnetic stars really do exist.

Magnetic fields are omnipresent in space. They surround planets, permeate our Milky Way, and are present not only in galactic gas, but also in the sun formed from it. Most stars, however, have only very weak global magnetic fields. In the 1950s, astronomers discovered so-called Ap stars. Their atmospheres were found to contain large quantities of metals, such as manganese and chromium. These celestial bodies have two to ten times the mass of our Sun – and a magnetic field that is one thousand times stronger. The Alioth star in the handle of the Big Dipper is part of this family, for example. The researchers also found a few magnetic stars among the white dwarfs, the burnt-out nuclei of conventional stars.

A POTENTIAL HAZARD FOR INTERSTELLAR SPACESHIPS

But the magnetars beat everything. These remnants of supernova measure around 20 kilometers across, are extremely densely packed and rotate very rapidly about their axes. During the birth of this type of neutron star, it is not only the matter that is tightly squeezed together, but also the magnetic field is greatly compressed, and a dynamo effect shortly after the collapse can then amplify this field even further.

In this way, the corpses of these stars attain field strengths corresponding to those of 100 billion commercial bar magnets. “A magnetar as far away as the moon would delete all the data from the credit card in your pocket,” says Michael Gabler. For interstellar spaceships, these stars could thus present a real hazard. However, the researchers at the Max Planck Institute for Astrophysics aren’t really interested in fiction, as magnetars are exciting enough for science, as well.

The objects have a turbulent history. They form upon the spectacular death of a sun, a supernova, when a star with a mass of between 8 and 20 solar masses has gotten itself into an energy crisis. The fuel that fed its nuclear fusion over many million years has been spent. Its nuclear furnace is extinguished. The sphere, like an onion, now consists of shells of all possible chemical elements that were created during the fusion. The last step is the formation of an iron core in the center. Density and temperature continue to increase until the atoms of iron effectively vaporize.
Cosmic sphere: Magnetars are extremely densely packed, rotating neutron stars with unusually strong magnetic fields.
Gravitation exerts an ever-increasing pressure until the point comes when the core, roughly the same size as our moon, can no longer withstand it: it collapses in fractions of a second. Matter plummets toward the center, which is simultaneously compressed even further – until this matter rebounds. Like a spring that is first pressed together and then released, the energy suddenly escapes toward the outside, sweeping the matter along with it into open space. The density in the remaining central sphere of 1.4 solar masses resembles the density in an atomic nucleus. This is the hour of birth of the neutron star. (Although hour of birth is much exaggerated, as this all takes places within milliseconds.) The neutron star heats up to temperatures of up to 500 billion degrees and produces vast quantities of neutrinos.

These neutrinos – electrically neutral particles with an extremely low mass and hardly any interaction with matter – are crucial to the explosion process, because the shock wave that races outward and is supposed to tear the star apart actually fizzles out after just a few hundred kilometers. The neutrinos, on the other hand, carry so much energy from the core to the shock wave that the star’s outer layer is ultimately hurled away after all. A supernova flares up.

A SUPERNova EXPLOdes IN THREE DIMENSIONS

The exact scenario of such a cosmic catastrophe with neutrino heating is much more complicated and is the subject of intensive research, also at the Max Planck Institute for Astrophysics in Garching. The scientists there use supercomputers in their attempts to model stellar explosions. In 2014, a group led by Thomas Janka was the first to succeed in simulating a supernova in three dimensions with all physically important effects.

Michael Gabler deals with what remains after the blazing inferno: the neutron stars. “Their properties can’t be reproduced in a laboratory on Earth,” he says. The density alone surpasses that of an atomic nucleus. And a piece of stellar matter the size of a sugar cube would weigh no fewer than one billion tons on Earth.

What is the structure of a neutron star with the same diameter as a city the size of Munich? Which interactions do the smallest constituents of stellar matter experience – that is, neutrons, protons and electrons, but also such exotic particles as pions, kaons and quarks? “In order to get answers to these questions, we have to understand the structure of a neutron star,” says Gabler. And this is where the magnetars come in handy.

These objects are the most powerful magnets in the universe. The magnetic fields on their surfaces reach values of up to a few quadrillion gauss. By way of comparison, the terrestrial magnetic field tips the scales at a mere one gauss, and magnetic fields of at most ten million gauss can be generated in the laboratory. But there is one
similarity between Earth and the magnetars: both have a strong magnetic dipole field. And the generation of both of these fields is based on the dynamo effect, which in turn is caused by the motion of conductive matter. In the case of Earth, this is mainly the liquid iron in the core; with the neutron star, it’s the ultra-dense matter. “The stars are very hot. The neutrinos carry the energy away, creating a great deal of internal dynamic activity,” says Gabler.

What’s more, the precursor star also had a more or less strong magnetic field that was compressed during the collapse and baked into the neutron star, as it were. The rotation plays an important role as well, as the stellar dipole emits energy that it acquires from the rotation. This is why a neutron star can be observed in the first place. If this were not the case, a 20-kilometer object a few hundred or a few thousand light-years away couldn’t be observed at all, even with the best telescopes.

Along the axis of the magnetic field, the rotating neutron star emits a narrowly focused cone of radiation. Similar to a lighthouse, this cone sweeps through space. If, in the process, it sweeps across the line of sight to Earth, astronomers observe a rhythmic flashing whose frequency corresponds to the rotational period of the star. In 1967, Jocelyn Bell in England accidentally discovered the first of these objects.

Today, the researchers are aware of more than 2,200 of these pulsars. Their radiation covers the entire electromagnetic spectrum and ranges from radio waves to gamma rays (MaxPlanckResearch 4/2013, p. 48 ff.). Around 10 percent of all neutron stars observed belong to the magnetar family. However, these occur only as very weak pulsars. The reason for this lies in their rotational speed: “From their pulse frequency we can deduce that magnetars usually rotate very slowly, unlike many other neutron stars,” explains Michael Gabler. The values range from two to ten seconds per rotation.

As already mentioned, the dipole emits electromagnetic energy at the expense of the rotation. In a nutshell, the rotational speed continuously decreases. Astronomers actually observe such a slowing down, which becomes no-
noticeable in the pulses; with magnetars, it typically amounts to around three milliseconds per year.

The slowing down can be plotted as a function of time. From such a “spin-period/spin-down rate diagram,” the experts calculate the strength of the magnetic field directly. The rule is: the larger the decrease in the pulse frequency, the stronger the magnetic field. The researchers can thus quickly ascertain whether an observed pulsar is a magnetar. Gabler and his colleagues use primarily the data from the Swift gamma ray satellite and the Rossi X-ray satellite.

FIELD LINES TWIST LIKE RUBBER BANDS

The observations can also be used to derive the mass and the radius of the neutron star. The former is two solar masses at most and can be determined from simple laws of celestial mechanics if the star is a partner in a binary system. The radius escapes direct measurement – the astrophysicists have to derive its value indirectly, from the varying light intensity, for instance.

Once the scientists have a magnetar in their sights, further measurements over a longer period are worth the effort. A number of these celestial bodies sometimes exhibit giant flares, usually in the gamma and X-ray range. These indicate the catastrophic collapse and subsequent reorganization of the outer magnetic field, as the neutron star also has a second, inner magnetic field. Over time, this forces its configuration
Deep in the heart of a neutron star, the density is three times that of an atomic nucleus, and the temperature is around one billion degrees.

onto the outer field, which is why the outer field lines twist more and more, like rubber bands.

“At some point, the stress is too great, and the lines suddenly break open and rearrange themselves. This re-connection generates the radiation that is measured,” says Gabler. A sort of fire-ball of hot plasma is created and is trapped in the magnetic field. During the few tenths of a second that such a flare lasts, the star releases as much energy as our Sun in 1,000 years.

In some objects, the flares are followed by further, weaker bursts after hours or years. The strong magnetic field also plays a role in the case of such a soft gamma-ray repeater. It apparently has an effect on the crust of the neutron star, setting it in motion, maybe even breaking at one point or another.

How do we know this? Each explosion changes the light from the object, meaning the astronomers observe a number of specific frequencies in its X-ray spectrum. According to theory, they originate from oscillations of the neutron star. In analogy with seismology, which investigates earthquake waves, or helioseismology, which studies oscillations on the Sun, it should be possible to use asteroseismology to analyze the structure of a neutron star. In fact, the task now is to construct, on the computer, a neutron star that delivers the observed frequencies. “The orders of magnitude of the frequencies match those of elastic shear oscillations of the stellar crust very well,” says Gabler.

The astrophysicists also observe a further type, called Alfvén oscillations. This kind of magnetic wave occurs on the Sun, as well, where they apparently help to heat up the outer atmosphere (corona). In the case of neutron stars, the Alfvén oscillations aren’t restricted to the crust, but also provide information on the liquid core. More on this later.

THE OSCILLATIONS SEEM TO INDICATE STARQUAKES

Michael Gabler and colleagues from other institutes have developed a model in which they couple the two aforementioned types of oscillations. Computer simulations show that the oscillations fit very well with the assumption of starquakes. Moreover, the strength of the coupling depends on the magnetic field: with weak magnetic fields, the shear oscillations in the crust dominate; with strong magnetic fields, it is the Alfvén waves in the core.

Core, crust, magnetic fields – so what exactly does the interior of a neutron star look like? According to the model accepted by most researchers, the density deep in the heart of a neutron star is three times that of an...
atomic nucleus, with a temperature of around one billion degrees. Under these conditions, the matter can be described, at best, by the laws of quantum mechanics; it may be a mixture of free quarks and gluons. The outer core consists of 95 percent neutrons, while the remainder is protons and electrons. This is followed by “nuclear pasta,” in which the atomic nuclei are elongated to a spaghetti-like form; further inside, these spaghetti look like the layers of lasagna, and yet further toward the core, the structure resembles Swiss cheese. The crust of the neutron star consists of an ordered crystal lattice, as can be found in terrestrial solids. It is thought that its surface is covered by an ocean of liquid matter only a few centimeters deep, and this, in turn, is covered by an even thinner atmosphere of hot plasma.

Gabler’s magneto-elastic model likewise provides an unusual state for the neutrons: they appear to be superfluid. Accordingly, they have no internal friction (no viscosity) and have an infinitely high thermal conductivity. In a terrestrial laboratory, superfluidity can be observed only at extremely low temperatures and for only a few elements; with helium, for example, it occurs at minus 270 degrees Celsius.
Experts use the term “nuclear pasta” to describe what is just outside the core. In the outer region of this zone, the atomic nuclei are elongated into the form of spaghetti. Further inward, these spaghetti form slabs, which are similar in structure to lasagna. Even further toward the core, the spaghetti is compressed under increasing pressure to form a uniform dough-like mass in which only very few cavities remain. “The whole thing resembles Swiss cheese,” says Gabler.

THE OCEAN ON THE SURFACE SLOSHES TO AND FRO

The overall crust is around one kilometer thick and consists of an ordered crystal lattice, as can be found in terrestrial solids. However, the atomic nuclei of the iron here are very rich in neutrons; for every 50 protons there are more than ten times as many neutrons. In deeper layers, the high pressure squeezes them out of the atomic nuclei and they can then move freely in the crystal lattice. Electrons also whizz around in the entire crust.

Toward open space, the outer layer is probably formed by a thin atmosphere of hot plasma a few micrometers thick. Below it, the experts suspect there is a thin ocean of liquid matter only a couple of centimeters thick. It consists of hydrogen or of all sorts of elements that the neutron star sucks in from an accompanying star, if it has one, and that collect on the surface. Solely the strong gravitational force holds the atmosphere and ocean in place. In the light of neutron stars, the astronomers have observed tiny oscillations that indicate that the ocean may slosh to and fro. However, the experts aren’t sure whether magnetars have an ocean at all.

On the other hand, every neutron star does have a magnetic field in which particles such as electrons and their positively charged antiparticles, the positrons, move. The magnetic field is bound to the star and rotates with it – the greater the distance, the faster the rotation. At a distance of a few thousand kilometers, the magnetic field practically reaches the speed of light. Beyond this so-called light cylinder radius, the magnetic field lines open up, and electrons and positrons can escape.

“But the external magnetic field not only rotates with the star – one of our models describes how it is coupled to the magnetic field in the star’s interior,” says Michael Gabler. His conclusion: “During starquakes, the external magnetic field oscillates, as well, giving rise to very strong electric currents in the magnetosphere.” The photons released during a gamma flare are scattered by the charge carriers of these currents – electrons and positrons. “This scattering can explain the observed frequencies in the hard X-rays,” says the Max Planck scientist.

This example in particular shows that the theory on the composition and structure of neutron stars can’t be all that wrong. Quite a few questions remain unanswered, though. Magnetars will continue to attract researchers like Michael Gabler in the future.

TO THE POINT

- Neutron stars are the inconceivably dense remnants of supernovas.
- With a diameter of a mere 20 kilometers, they rotate rapidly about their axes, emitting cones of radiation into space in the process, and thus become visible as pulsars.
- About 10 percent of all neutron stars have strong magnetic fields; these stars are therefore known as magnetars.
- Magnetars occasionally exhibit violent radiation outbursts that originate from the catastrophic collapse and reorganization of the outer magnetic field.
- The neutron stars oscillate during the explosions. These oscillations can be observed indirectly, and ultimately provide information on the structure and composition of the star.

GLOSSARY

Binary system: It is thought that more than half of all the stars in the Milky Way exist in binary or multi-body systems. In a binary star system, for example, two stars orbit a common center of gravity. The masses of the two partners can be determined from the orbital data.

Dipole: Two spatially separate poles, each having a different polarity (+, −). They can be electric charges or magnetic poles of the same size. A simple example of a dipole and its field is a bar magnet.

Dynamo effect: The generation of a magnetic field in the interior of a celestial body (planet or star) through electromagnetic induction. This is caused by the interaction between the motion of a substance (convection) in electrically conductive matter and the rapid rotation.
Magnetic fields spanning 100,000 light-years permeate entire galaxies and envelop their central black holes. Researchers working together with Rainer Beck, Silke Britzen and Sui Ann Mao at the Max Planck Institute for Radio Astronomy in Bonn are teasing the secrets out of these invisible force fields.

Forces that Rule in Galaxies

Moreover, M 51 – also called the Whirlpool Galaxy – is a very good example of how magnetic fields are influenced by external effects. The gravity of a close companion galaxy produces strong density waves in the gas of M 51, with the consequence that the spiral arms are particularly pronounced and stand out clearly. At the same time, the waves also compress the magnetic field at the inner edges of the spiral arms.

“Here we see a clear connection between the gas density and the strength of the magnetic field,” explains Beck. This is also interesting because new stars can form in these compacted regions. For decades, astronomers have been discussing what effect the magnetic fields have on the gas clouds and star formation.

FIELD LINES FOLLOW THE SPIRAL ARMS

To date, the group working with Beck and Marita Krause has studied many galaxies in the radio range – now including M 51, as well. Magnetic maps show that the lines of the ordered field follow the course of the spiral arms, snuggling up to their curves, as it were. On the most accurate maps, it’s possible to see that the magnetic field strength is often strongest at the inner edges of the arms, but ordered fields also exist between them.

Moreover, M 51 – also called the Whirlpool Galaxy – is a very good example of how magnetic fields are influenced by external effects. The gravity of a close companion galaxy produces strong density waves in the gas of M 51, with the consequence that the spiral arms are particularly pronounced and stand out clearly. At the same time, the waves also compress the magnetic field at the inner edges of the spiral arms.

“Here we see a clear connection between the gas density and the strength of the magnetic field,” says the scientist. But he didn’t let this deter him.
which electrically charged particles – primarily protons and electrons – whiz about. These react to the magnetic field, pull at it like dough in a mixer, and decelerate the rotational motion of the whole cloud. The centrifugal force decreases and the cloud can contract further. In this manner, magnetic field brakes could assist in star formation.

“Despite many decades of research, we still know relatively little about the effect of magnetic fields on the events in the interior of galaxies, such as the formation of spiral arms or active galactic centers,” says the Max Planck researcher. They absolutely can’t be neglected, as most astronomers believed when Beck first started his research.

While the gas and the stars in a galaxy can be seen, magnetic fields remain invisible. So how can we detect them at all? “They have to be illuminated,” says Rainer Beck, “and this is what the electrons do.”

These particles, which exist in the space between the stars, are forced onto helical trajectories in a magnetic field and thus emit radio waves in their direction of motion, like minute headlights. Furthermore, the radio waves are linearly polarized: they have a tendency to oscillate in one plane, namely the one vertical to the magnetic field orientation. The strength and structure of the magnetic field can be derived from the intensity and polarization of the radio emissions.

ASTRONOMERS USE AN EFFECT FROM NATURE

The Effelsberg radio telescope is uniquely suited to accomplish this: Despite having reached the ripe old age of 43, continual technical improvements mean it is still the most sensitive instrument in the world for detecting polarized radio waves.

Our Milky Way, too, is a disk-like spiral galaxy. Since our solar system is within the disk, radio telescopes receive the radiation from all directions. This makes the detection of the spatial structure more difficult. Then again, the Milky Way is the nearest spiral galaxy to us, and thus reveals a great many details.

In order to find out about the spatial structure of the magnetic field, astronomers use a further method here. They observe pulsars and distant galaxies that emit radio waves. When this radiation passes through a magnetic field, the plane of polarization rotates. This effect is named after Michael Faraday, who discovered it in laboratory experiments even back in 1845.

The researchers derive the strength and direction of the magnetic field traversed from the value of the Faraday rotation. Furthermore, the average strength of the field found in between is given by the distance of a pulsar. “For us, the Faraday rotation is like a cosmic compass,” says Beck. But it doesn’t work quite as simply as its counterpart on Earth.

One problem is that, although a specific polarization plane of the radio waves is measured, the plane in which the radio source originally emitted the waves is unknown. Here, astronomers are assisted by the fact that the wave rotates to a greater degree the greater the wavelength of the radio emissions and the field strength are. Observations at several wavelengths therefore provide the strength and direction of the field.
Sui Ann Mao has collaborated on what is so far the most precise magnetic field chart of the Milky Way. The radio astronomer, who was born in Hong Kong, spent several years as a researcher at Harvard University in Cambridge (USA); since the beginning of 2014, she has been working at the Max Planck Institute in Bonn. Here, she was awarded a five-year fixed-term position within the framework of the Minerva program.

For Mao, this program, which promotes the careers of female scientists, was one of the key reasons for moving to Germany. “In addition, the scientific environment here in Bonn is very good, and I can set up my own research group,” she says.

Together with colleagues, Mao measured the Faraday rotation of the radio waves with the help of pulsars and distant radio galaxies. To do this, she used the Very Large Array (VLA), a system consisting of 27 radio dishes in New Mexico. The result of the magnetic field survey isn’t easy to interpret. Nevertheless, the data best fits a model in which the magnetic fields in the interior of the Milky Way – as with Messier 51 – follow the spiral arms and are symmetric about the disk plane. Here, they have a strength of up to two microgauss. For comparison, the Earth’s magnetic field is around one hundred thousand times stronger at middle latitudes.

The further one moves away from the center of the Milky Way, the more the field changes. In the outer region, it is nearly azimuthal, meaning the field lines are almost circular. Astronomers had long been in the dark about how such a structure, which can be found in a very similar configuration in almost every spiral galaxy, can form.

“We now assume that this takes place in a multi-step process,” says Rainier Beck. In an electromagnet, a wire carrying a current generates a magnetic field. In space, this role is assumed by turbulent plasmas, which are formed, for example, when stars explode. The stars then shed hot gaseous envelopes that propagate at high speeds. Initially, chaotic magnetic fields form inside these envelopes, and then the envelopes get caught up in the rotation of the galaxy and dragged along.

As this happens, the field lines gradually rearrange until they produce the pattern observed today, following the spiral arms. “This galactic dynamo creates order from chaos,” is how Beck’s colleague Mao summarizes this process, which takes place on scales of tens of thousands of light-years. “Dynamo” because kinetic energy is converted into magnetic energy here – remotely comparable to a bicycle dynamo.

Most of the galaxies investigated are undisturbed lone wolves, but astronomers know that the stellar systems can also come dangerously close to each
other or even collide. Gas and dust clouds then swirl around, densify locally and become the birthplaces of large numbers of new stars. What happens to the magnetic fields in these cases?

Beck and his colleagues have used the VLA to investigate the most prominent example of two merging stellar systems, the Antennae Galaxy, 90 million light-years away. A special property of this array came to their aid here: its overall size can be varied by moving the 27 telescopes mounted on tracks backwards and forwards. “In this way, we can realize a kind of zoom lens for the radio range,” explains Beck.

In fact, this is how he determined that the magnetic fields are stronger than in normal spiral galaxies, especially in the “crumple zone” of the cosmic crash. The causes are probably the increased turbulence in the gas and intensive star formation. The ordered magnetic field structure is destroyed there and makes way for a chaotic one. Sui Ann Mao recently used the now considerably improved VLA to carry out new measurements that will hopefully explain the magnetic chaos.

An ear to space: The 100-meter diameter dish of the Effelsberg radio telescope (top) also strains its ears for signals from quasars. A jet emanates from the object 3C 279 (diagram below). Two densifications (C5 and C10) move away from the quasar. They apparently have different birthplaces (red squares). Modeling (red solid line) these different trajectories makes it possible to determine the parameters of a binary system of two supermassive black holes.

Cosmic collisions: Magnetic fields play a key role in the formation and focusing of jets (right-hand page, left). In the merging stellar system – known as the Antennae Galaxy – the ordered magnetic field structure is destroyed (right-hand page, right).
It would be exciting to investigate these fields locally with greater resolution of detail, but today’s telescopes come up against their limits here. The radio astronomers place great hope in the future Square Kilometre Array (SKA). This is an international project in which thousands of radio antennas with a total collection area of one square kilometer will be installed in Australia and South Africa. This gigantic installation is expected to be completed during the coming decade, and to dominate this research for a long time to come.

**BLACK HOLES AT THE HEARTS OF THE GALAXIES**

“With the SKA, the number of pulsars that we use for the magnetic field survey of the Milky Way would increase to 10,000,” enthuses Mao. But to the great surprise and dismay of all German radio astronomers, the German Federal Minister for Education and Research, Johanna Wanka, announced Germany’s exit from this pioneering project in June 2014.

The SKA would also be ideal to study a further aspect of galaxies: the activity of supermassive black holes at their centers. According to what is known today, at the heart of almost every galaxy is a black hole that contains matter amounting to several million to billions of solar masses. It is likely that each of these invisible bodies is surrounded by a hot, rotating gas disk that can shine very brightly depending on the conditions.

In some cases, matter breaks away from the disk and flows toward the black hole. While a large part of it disappears into the cosmic maelstrom never to be seen again, another part is redirected and shoots into space in two opposite directions perpendicular to the plane of the disk at almost the speed of light. Such a jet can extend over a distance of several million light-years; it is presumably held together by magnetic fields. Silke Britzen is trying to discover how these plasma flows form.

“There is now hardly any doubt that magnetic fields play an important – maybe even the key – role in this,” says the astrophysicist. They could decelerate the gas in the disk – a process that is crucially important in order to allow the gas to approach the black hole on a spiral trajectory and ultimately plunge into the massive monster. However, what really happens in its immediate vicinity is still largely unclear.

The researchers don’t know, for example, whether a dynamo similar to the one in the spiral galaxy is at work in the gas disk on much smaller scales. It would also be conceivable that mag-
Magnetic field lines with opposite polarity suddenly connect and release energy that goes into accelerating the jet particles. Researchers are familiar with these magnetic short-circuits from the Sun, where they trigger outbursts of radiation and gas.

Einstein’s theory of general relativity should also have an impact on the formation of jets. This theory predicts that space is entrained by a rapidly rotating black hole, and whirls around the central body like a whirlpool in the drain of a wash basin. This rotation of space carries everything along with it, including the inner region of the gas disk.

What causes the jet to accelerate? The rotation of the black hole or the rotation of the disk? “This question can be addressed using computer models only by solving the physics of the theory of general relativity and magnetohydrodynamics together,” explains Silke Britzen. An extremely complicated undertaking – and actually a problem that science hasn’t yet been able to solve.

“Naturally, we would prefer to observe the region in the immediate vicinity of the black hole directly using radio telescopes,” says the Bonn-based researcher. Perhaps this will be possible one day with very long baseline inter-

Antennas on the field: The Low-Frequency Array (LOFAR) station in Effelsberg. Some of the 96 dipole antennas for low frequencies can be seen in the lower half of the image, while the upper half shows panels that conceal dipoles for higher frequencies. LOFAR is an array of many radio telescopes, spread all over Europe, whose signals are combined into a single signal. The system currently consists of 46 stations.
The “wobble” at the bottom of the gas jet could be caused by two black holes orbiting each other at close proximity, causing the gas disk of one partner to oscillate at the bottom of the jet.

In order to be able to explain her observation data with the aid of models, Britzen is collaborating with theoreticians. Recently, they were able to explain the jet structures of two galaxies. In one case, two black holes could orbit each other at a separation of one and a half light-years; in the other, of nine light-years. For two giants – estimated to have a mass of one billion solar masses each – this distance is downright tiny. The enormous distances of several billion light-years will make it impossible to observe the central regions of these two galaxies directly, but according to the model, the bright base of the jets should also wobble to and fro. Silke Britzen wants to look for these variations. She puts her faith not only in increasingly precise radio telescopes, but also in the European Space Agency’s (ESA) recently launched astrometry satellite Gaia. The researcher in Bonn will have to wait a few more years yet for its results, though. But astronomers need a lot of patience anyway.

Glossary

Charles Messier: The French astronomer (1730 to 1817) compiled a catalog with more than 100 celestial objects such as galaxies, gas nebulae and star clusters. The numbers from this Messier catalog are still used today.

Gaia: The Gaia space probe of the European Space Agency (ESA) was launched on December 19, 2013. It is expected to produce a survey of the complete sky in the visible range and chart around one billion stars astronomically, photometrically and spectroscopically.

Ionization: A process whereby an atom or molecule loses one or more electrons. This leaves a positively charged ion behind.

Michael Faraday: The English natural scientist (1791 to 1867) was one of the most important experimental physicists of the 19th century. His discoveries include electromagnetic induction. The farad, the unit of electrical capacitance, is named after him.

Polarization: Light or radio waves usually oscillate along all possible directions. A wave is polarized when it oscillates along one particular direction only.
Micro-Scallops for Medical Applications

Tiny swimmers can be propelled through media resembling bodily fluids

Micro- or even nano-robots could someday perform medical tasks in the human body. A team of researchers, including members from a group led by Peer Fischer from the Max Planck Institute for Intelligent Systems in Stuttgart, have now taken a first step toward this goal. They have succeeded in constructing a type of artificial scallop measuring just a few hundred micrometers in diameter. The scientists navigate the tiny vehicle through biological fluids by using a magnetic field to rapidly open and close the device. This kind of locomotion is possible only because the viscosity of the model fluids – like that of bodily fluids – changes with the device’s speed of movement. The micro-shell can be propelled not only by a magnetic actuator, but also by one that responds, for example, to temperature changes. Previously, the Stuttgart-based researchers presented a corkscrew-shaped nano-vehicle that moves like a propeller through a liquid medium. (Nature Communications, November 4, 2014, & ACS Nano, published online on June 9, 2014)

Scallop-shaped micro-swimmers: Basing their design on the operating principle of this shellfish species, a team of Max Planck researchers in Stuttgart has built a tiny submarine, shown in this image on the right. Small magnets, shown here as red and blue cylinders, open and close the two halves (shells) of the device.

Magnetic Fields as Midwives for Stars

Astronomers observe polarized dust emission of two dark clouds in the Milky Way

Stellar heavyweights in the universe, with eight or more times the mass of the Sun, form from very dense and massive gaseous cores deeply embedded within interstellar clouds. In fact, the high mass of these cores has long puzzled researchers: due to their own gravity, the cores should – in theory – quickly collapse and self-destruct before telescopes on Earth can detect them. So what prevents them from collapsing? A team headed by researchers from the Max Planck Institute for Radio Astronomy in Bonn has now found the answer: the experts observed polarized dust emissions from two of the most massive clouds in our Milky Way, the “Brick” and the “Snake.” They discovered that strong magnetic fields hold the clouds together and help stabilize the region while it gets ready to form high-mass stars. (Astrophysical Journal, vol. 799, 2015)
The catalogs of celestial objects list a galaxy cluster called “Abell 4067.” However, recent observations using the XMM-Newton space observatory indicate that this object actually constitutes a merger of two separate clusters. The smaller system appears to be losing the majority of its gas. The data analyzed by scientists at the Max Planck Institute for Extraterrestrial Physics also shows that the compact core of the infalling cluster has thus far survived this encounter. The core cuts right through the central region of the larger galaxy cluster like a bullet, without being destroyed in the process. The layers outside of the core, however, are stripped away. Further observations are scheduled in the near future to examine this process in detail and study how the gases of the two components mix. From this, the researchers hope to gain new insights into the growth of galaxy clusters in general. (Astronomy & Astrophysics, January 10, 2015)

Collision of Two Galaxy Clusters

The Sun is constantly bubbling, and in this process, finger-like plasma structures lasting several minutes form in the Sun’s gaseous envelope, the corona. These structures appear whenever gas masses are ejected from the Sun’s surface at extremely high velocities. Ever since they were discovered around 15 years ago, researchers have been trying to unravel the mystery surrounding the forces that create these dark structures known as “tadpoles”; they form a clear contrast to the bright plasma in which they are embedded and which is visible in ultraviolet light. A German-American team of scientists headed by the Max Planck Institute for Solar System Research has now succeeded in finding an explanation for these filigree shapes. The scientists analyzed images of the Sun, but also created computer models that simulate the formation of these plasma structures. Their findings show that the driving force behind this phenomenon is a fundamental process in fluid physics known as the Rayleigh-Taylor instability. The RTI can occur when plasmas of different densities come together. (Astrophysical Journal Letters, December 1, 2014)

Don’t Be an Outsider!

Toddlers imitate their peers to fit in – great apes stay true to themselves

From the playground to the boardroom – people often adapt their behavior to those around them in order to fit in with a particular group. Even children as young as two years of age give in to peer pressure: a study conducted by the Max Planck Institute for Evolutionary Anthropology in Leipzig has shown that, even at such a young age, children forego a reward if it means having to behave differently from their peers. Chimpanzees and orangutans, on the other hand, mostly ignore the actions of their peers, even after reaching adulthood, and instead stay true to themselves. Conformity is thus a typically human trait, and a very useful one at that, as it delimits different groups. By adapting their behavior, humans can coordinate joint activities. Furthermore, conformity stabilizes and fosters cultural diversity. (Psychological Science, October 29, 2014)

A witch’s cauldron in the solar atmosphere: This image originates from the AIA instrument of the American SDO satellite and shows the ultraviolet radiation emitted from part of the corona on October 22, 2011. It was taken at a wavelength of 13.1 nanometers (turquoise) and 9.4 nanometers (red). The dark, finger-like structures of the Rayleigh-Taylor instability at the top of the image stand out clearly from the bright plasma.

Photos: MPI for Evolutionary Anthropology/R. Barr (bottom); NASA/SDO/MPS (top)
More Daycare Centers Doesn’t Always Mean More Children

Stable cultural influences can hinder family policy programs

In Germany, the birth rate is around 1.39 children per woman – on average. Because in reality, the birth rate varies significantly from region to region, and this has been going on for decades: there is no unified trend among couples across the country deciding for or against children. The conclusion “more daycare centers = more children” or “more money = more children” doesn’t automatically hold true in all parts of Germany. In fact, as Barbara Fulda from the Max Planck Institute for the Study of Societies discovered, gender roles and model families are perceived differently in different regions, which might explain the varying success of sociopolitical programs designed to incentivize couples to start a family and have more children. These cultural influences became apparent in a field study conducted as part of her dissertation, in which she compared two regions in the German states of Baden-Wuerttemberg and Bavaria, which have similar sociocultural backgrounds. These influences supplemented factors that are commonly studied in fertility research, like the number of available places in kindergartens and the financial conditions related to starting a family. Cultural influences, however, change very slowly. This could explain why the regional differences in birth rate remain so stable, and why these discrepancies lead to the fact that family policy incentives – such as parental allowances for fathers – aren’t as widely accepted in all parts of the country as policy makers would like them to be.

Duality in the Human Genome

Our genomes are extraordinarily individual – a challenge for personalized medicine

Humans don’t like being alone, and neither do their genes, which prefer instead to occur in pairs. However, conventional analytical methods can detect only a mix of the maternal and paternal forms of a gene. Scientists at the Max Planck Institute for Molecular Genetics in Berlin analyzed the genetic makeup of several hundred people and decoded the genetic information on the two sets of chromosomes separately. A sample of this size contains an average of 250 different forms of each gene. In larger sample sizes, the number of possible forms increases accordingly. Changes in a gene form that cause an amino acid in a protein to be exchanged for another are known as mutations. When several mutations occur in a single gene, these mutations aren’t randomly distributed between the parental chromosomes, as the researchers discovered: in 60 percent of the cases, all of a gene’s mutations occur in just one of the parental chromosomes, while in 40 percent of the cases, they occur in both. The diversity decreases at the protein level, yet in 372 test subjects, most of the genes and their numerous forms still produce at least 5 to 20 different protein forms – a major challenge for scientists seeking to develop customized treatment methods that target individual proteins.

(Nature Communications, November 26, 2014)
Look First
Visual perceptions dominate conversations

When people converse with each other, they often speak about what they hear, smell, taste or feel. First and foremost, however, they talk about their visual perceptions. Sight is the most important of the five senses, and the respective verbs dominate the conversations. This is the conclusion reached by a team headed by researchers from the Max Planck Institute for Psycholinguistics after conducting a study involving 13 languages from around the world. The scientists analyzed audio and video recordings of typical everyday conversations. However, they found no evidence of a fixed hierarchy of the other four senses in the speakers’ linguistic usage. Hearing ranked second in most of the languages studied, but in Semai, for example, which is spoken on the Malay Peninsula, verbal references to olfactory impressions occur more frequently than allusions to hearing. Why we most frequently talk about sight and visual perceptions may be because of the specific biology of the human sensory apparatus, and because there are simply more opportunities for visual experiences than, say, taste experiences. After all, you can look at many things, but you can’t go around tasting everything. (Cognitive Linguistics, December 23, 2014)

Choreography of an Electron Pair

The motion of the two particles in a helium atom can be imaged and controlled with precisely timed laser flashes

Physicists are continuously advancing the control they can exert over matter. A German-Spanish team headed by researchers from the Max Planck Institute for Nuclear Physics in Heidelberg filmed the motion of the two electrons in a helium atom for the first time, and even controlled this electronic partner dance. The scientists managed to do this using a series of different, precisely timed laser pulses. For this, they employed a combination of visible flashes of light and ultraviolet pulses that lasted just a few hundred attoseconds. One attosecond is one billionth of a billionth of a second. One of the reasons physicists aim to specifically influence the motion of electron pairs is because they want to revolutionize the field of chemistry: if they can steer the paired bonding electrons in molecules using laser pulses, they could potentially create substances that can’t be produced using conventional chemical means. (Nature, December 18, 2014)
Smiling Builds Trust

Smiles perceived as genuine promote cooperation

“A smile gains more friends than a long face.” This Chinese proverb holds true, however, only if the smile is sincere and genuine. Researchers at the Max Planck Institute for Evolutionary Biology in Plön conducted a behavioral experiment that proves that such a Duchenne smile creates trust. A Duchenne smile is formed subconsciously and is considered to be outside of our voluntary control. The study carried out by the researchers from Plön shows that a smile rated as honest and genuine induces trust, and rightly so: on average, those individuals are more cooperative. The study also shows that a person is more likely to produce a genuine smile when the stakes are high and the matter at hand is important to that individual. It therefore seems that flashing a Duchenne smile is costly, and the associated effort is made only if it is deemed worthwhile. (Evolution and Human Behavior, January 2015)

Obesity – Like Father, Like Son

A parent’s diet can lead to epigenetic changes that affect their offspring’s bodyweight

Our genes are a major factor in determining our weight. At the same time, however, environmental influences can also affect bodyweight through what are known as epigenetic changes. These modifications can be inherited, although they don’t change the genetic code. Scientists at the Max Planck Institute of Immunobiology and Epigenetics in Freiburg discovered that the diet of male fruit flies can influence the bodyweight of their sons in this way. The offspring whose fathers were fed food with a very low or very high sugar content two days before mating tended to be overweight – but only if they themselves also consumed large amounts of sugar. The fathers’ diet had no impact on sons that consumed a balanced diet. The offspring of fathers that weren’t conditioned by a very low- or high-sugar diet, on the other hand, maintained a normal bodyweight even if they consumed large amounts of sugar. The researchers believe that if fathers are fed a high-sugar diet, the packaging of the DNA in their sons is loosened, allowing fat metabolism genes to be expressed more easily. A similar mechanism may also exist in humans: the evaluation of data from tests on North American Pima Indians, who frequently suffer from obesity, shows that obese humans have the same gene signature as the fruit flies. (Cell, December 4, 2014)

Researchers can identify the obese flies by their red eyes: Due to the particularly sugary diet of their fathers, the genes for a red dye in the eyes, as well as for other metabolic factors, can be detected in the sons.
"Train your brain by playing games." That sounds too good to be true – and in fact, it probably is just that. This advertising slogan wants us to believe that we can enhance our cognitive abilities and even prevent dementia by playing certain "brain games." Yet there is no scientific evidence to support these claims, as 70 internationally renowned cognitive psychologists and neuroscientists have now clarified in a joint statement. There aren't enough research findings to suggest whether and how these games affect the brain and cognitive performance, or help individuals cope with day-to-day activities. Yet the human brain and behavior can be trained well into old age even without computer games: people who remain physically active, take part in social activities and lead intellectually stimulating lives stand a better chance of staying mentally fit as they age.

Superconductivity without Cooling

The electrical resistance of some materials can be removed not only by means of extremely low temperatures, but also – albeit for a very short time only – by using intense infrared laser pulses. An international team, to which physicists from the Max Planck Institute for the Structure and Dynamics of Matter in Hamburg made crucial contributions, has now explained how the light makes a ceramic called yttrium barium copper oxide superconducting even at around 20 degrees Celsius. According to the team, the laser pulses cause individual atoms in the crystal lattice to briefly shift, thus enabling superconductivity. These findings could help scientists develop materials that become superconducting at significantly higher temperatures, and that would therefore be of interest for new applications. (Nature, December 4, 2014)

No resistance at room temperature: Short light pulses excite oxygen atoms (red) in the copper oxide ceramic, causing them to briefly oscillate (blurred). As a result, the distance within each copper oxide double layer increases (copper – yellow-orange), while the distance between the double layers simultaneously decreases. It is highly probable that this effect enhances the superconductivity.

Computer-Based Brain Games Fail to Deliver on Their Promise

Researchers at the Max Planck Institute for Solid State Research first coat a gold surface with a layer of spherical carbon molecules and then place a single dye molecule (shown here in magenta) on it. Next they apply a voltage between the prepared surface and the tip of a scanning tunneling microscope, creating an electric field (indicated by the gray lines in the diagram). At a specific field strength, the dye molecule converts the electrical energy into light (shown here as a yellow wave).

A Nano-Lamp with a Lightning-Fast Switch

A light source and its transistor-operated brightness control shrink to the size of a single molecule

Information is processed and transmitted by ever-smaller components, sometimes using electrons and sometimes using light. Scientists at the Max Planck Institute for Solid State Research in Stuttgart have now developed a light source that converts an electrical voltage pulse into a light pulse by means of a single organic dye molecule. In this process, the molecule generates light and also functions as a transistor-controlled light switch, which can even be used to regulate the light intensity by means of the voltage that is applied. Since the molecular switch allows the light to be switched on and off extremely quickly, this light source could serve as a blueprint for nano-components that convert electrical signals with gigahertz frequencies into optical signals. (Nano Letters, published online on September 2, 2014)

No resistance at room temperature: Short light pulses excite oxygen atoms (red) in the copper oxide ceramic, causing them to briefly oscillate (blurred). As a result, the distance within each copper oxide double layer increases (copper – yellow-orange), while the distance between the double layers simultaneously decreases. It is highly probable that this effect enhances the superconductivity.
Architect in the Cellular Cosmos

Elena Conti used to entertain the notion of becoming an architect. The fact that she decided to study chemistry in the end detracted nothing from her passion for the subject. As Director at the Max Planck Institute of Biochemistry in Martinsried, she studies the architecture of molecular machines in the cell – and is fascinated by the sophisticated structures in miniature.

Text: Elke Maier

Ordered structures: Elena Conti is interested in the structure and function of molecular machines that are vital to a cell’s survival. Investigating these structures requires sophisticated laboratory work.
from Collegio Ghislieri, a renowned institution founded in the 16th century that supports highly talented students. She actually wanted to specialize in organic chemistry, but then discovered that theory, especially the theory of molecular structures, was far more exciting to her than laboratory work.

Her faculty included a young professor who was investigating the structure of macromolecules, and Elena Conti completed her undergraduate work with him. Only then did the idea of going into science take shape. Coincidentally, the professor, Martino Bolognesi, had studied under Nobel laureate Robert Huber in Martinsried. At the time, Conti had no inkling that fate would one day land her there, as well.

For her doctoral work, Elena Conti traveled to the Imperial College of Science, Technology and Medicine in London, where she devoted herself to studying the enzyme that is responsible for the symphony of blinking lights we enjoy in gardens on sultry summer evenings. The title of her dissertation was *The Structure of the Glow-Worm Luciferase*, a somewhat arcane topic: “Because it’s a niche field without much competitive pressure, I had enough time to learn the methods thoroughly,” she recalls. To this day, her doctoral supervisor Peter Brick is one of her closest friends, as well as being her most exacting critic: “My research group loves it when he appears at one of our conferences and makes my life difficult,” Conti says.

**SCIENCE THAT RAISES THE ADRENALIN LEVEL**

She acquired the biochemical tools for her later work while doing a postdoc at Rockefeller University in New York. There, she studied how proteins are transported from cellular plasma to the nucleus. “The time I spent at Rockefeller University opened my eyes,” she recalls. “I moved from a small research group with leisurely tea breaks and Wimbledon games playing on the TV to a big, busy laboratory with exciting biology going on all around me. My adrenalin level was correspondingly high. It was quite normal to work during Christmas and Easter.”

The hard work paid off: she discovered how a certain identifying pattern that occurs in many proteins in the cell nucleus is recognized by matching receptors – a key piece of the puzzle to better understand processes by which proteins are transported from the nucleus to the cell plasma.

After this accomplishment, Elena Conti was fully captivated by biochemistry. When she saw an ad for a position at the European Molecular Biology Laboratory (EMBL) in Heidelberg, she jumped at the chance and moved to Germany in 1999. It wasn’t easy to leave New York after two and a half years. “New York has so much energy,” she rhapsodizes. “But I knew that the EMBL is one of the best institutions for setting up my own working group.”

With a small team, she set out to investigate how RNA molecules are transported from the nucleus to the plasma and, in the process, are inspected for errors – a topic that still fascinates her to this day.
RNAs are a family of thread-like molecules that carry out vital functions in the cell. The so-called messenger RNAs – a special class of RNA molecules – act simultaneously as copiers and couriers. They are responsible for copying the blueprints for proteins that are coded in the nuclear DNA and for conveying the information to ribosomes, protein factories in the cell that then build the proteins according to the blueprints.

During this process, reliable quality control is vital for the cell, as any of the steps can result in errors. Errors lead to defective RNA molecules and incorrect blueprints with potentially fatal consequences for the cell and the body as a whole. It would be equally disastrous if blueprints that are no longer required were allowed to accumulate uncontrollably in the cell.

Elena Conti wasn’t the only person at the EMBL who was active in this research field. Elisa Izaurralde, now Director at the Max Planck Institute for Developmental Biology in Tübingen, also focused on RNA transport in Heidelberg. Not only did the two scientists have the same research interests, they also complemented each other in their methodologies. “Whereas Elisa looked at the biological side, I sought to answer the structural questions,” Elena Conti says.

The two became good friends outside of work, and twice a week, their agendas included a joint visit to a fitness studio. “After a workout, we used to discuss science and experiments in the sauna,” Conti recalls, laughing. “People must have thought we were crazy!”

But it was definitely worthwhile: the two researchers characterized a number of factors that are involved in the transport and quality control of RNAs. In 2008, the two women shared the Leibniz Prize.

Elena Conti had already moved to the Max Planck Institute two years before. She was increasingly intrigued by the question of what happens when the cellular quality-assurance mechanism identifies defective or superfluous RNAs: How does the cell manage to get rid of such molecules? Together with her team, she began to research how the elaborate machinery picks out RNA molecules and destroys them, similar to a paper shredder.

A PRIMORDIAL MICROBE IN THE RESEARCH SPOTLIGHT

One focus of her work is to decipher the mechanism of action of the exosome, a molecular complex whose job is to break down RNAs. The exosome occurs in all eukaryotes, or organisms whose cells possess a nucleus. It is also present in simplified form in prokaryotes, organisms that lack a nucleus. At first, Elena Conti and her colleagues concentrated on the exosome of Sulfolobus solfataricus, a prokaryote.

This primordial microbe belonging to the Archaea group of organisms was discovered by Wolfram Zillig, then Director at the Max Planck Institute of Biochemistry. He discovered the heat-loving microbes in sulfurous pools around Mount Vesuvius, near Naples. In comparison with higher organisms, its exosome consists of just a few proteins. And because they are adapted to the harsh environment in which the microbes thrive, they are particularly robust. This makes them easier to handle for research purposes.

Conti’s team showed that the exosome of S. solfataricus has a hollow cylindrical structure. Inside it is the heart of the mechanism: the active centers at which RNA breakdown takes place. The eukaryote exosome is similar in
A weakness for design: Elena Conti’s flair for esthetics and clean lines is reflected in the decor of her office. She abandoned her original notion of studying architecture in favor of chemistry.

structure. It, too, comprises nine protein subunits that form a barrel-like structure, but without the active centers. Instead, a tenth subunit that is absent in *Sulfolobus* is responsible for the shredding work.

**THROUGH THE JAWS OF THE SHREDDER**

The result is astonishing: Why has such a complicated structure been conserved over billions of years, from prokaryotes to eukaryotes? And why is it so vital that the cell would perish without it? “At that point, it was clear that we would have to tackle the more complicated eukaryote exosome,” Conti says.

With the help of sophisticated biochemical methods, the researchers finally succeeded in visualizing the complex in action. “Isn’t it beautiful?” asks Elena Conti, as she points to the three dimensional atomic model of a eukaryote exosome on the computer screen. It was captured precisely at the moment when an RNA molecule docked and was about to disappear into the jaws of the shredder.

“The RNA is transported through the central cavity of the barrel structure and finally lands at the subunit responsible for breakdown,” the scientist explains, as she rotates the model with a click of the mouse. “Even though the barrel has lost its enzymatic function over the course of evolution, the RNA binding sites and the mechanism that transports the RNA through the complex are essentially still the same.”

For the RNA to fit through the channel, it first has to be unfolded and pass through a narrow opening. What initially appears to be very complex turns out to be a stroke of genius. In this way, only those RNA molecules that are actually supposed to be broken down enter the shredder. This prevents a potentially dangerous machine like the exosome from indiscriminately chopping up RNA molecules in the cell.

But how does the cell recognize which RNA molecules are destined for the molecular garbage can? And how does it ensure that defective molecules are reliably destroyed before they can cause harm? The Max Planck researcher is currently addressing these questions. One thing is certain, though: The exosome must cooperate and communicate with many other molecular machines in the cell.

This ensures, for example, that messenger RNAs can’t be broken down until other machines have snipped off a characteristic structure at one end of the thread-like molecule. Conti and her colleagues are investigating how the entire process works. “You can think of it as a sort of assembly line,” the scientist explains. “Each machine carries out a highly specific task before passing the workpiece on to the next. It all has to be finely orchestrated. We want to understand the information flow in the process.”

The fact that problems with RNA metabolism are also implicated in many diseases shows just how important these processes are. In recognition of her work
in this field, Elena Conti was awarded the 2014 Louis-Jeantet Prize for Medicine, one of the most prestigious distinctions in biomedical research.

Elena Conti no longer works alone at her laboratory bench. She therefore looks forward all the more to her daily tour of the laboratory and takes the opportunity to chat with her colleagues and find out what has and hasn’t worked. “That’s the most exciting part of the day,” she says. “I’ve got a great lab team! When I suggest an experiment, more often than not, it turns out that they already thought of it long ago and the experiment is already half complete.”

Does she also think of other things with so much enthusiasm when she leaves the institute in the evening? “It’s difficult to switch off,” she admits. As Maria Callas said in a famous quote: “An opera begins before the curtain goes up and first ends long after it has come down!” This sentence rings particularly true if your partner is also a scientist, as in Elena Conti’s case: Jürg Müller leads a research group at the Max Planck Institute in Martinsried that is investigating chromatin, the material of chromosomes, and how genes are read.

A ROUTINE FAMILY DAY WITH GENES AND MOLECULES

Not surprisingly, genes, RNAs and molecular complexes are often part of life at home. “It’s a bit of a challenge as far as family life is concerned,” says Elena Conti. But her partner’s critical opinion is very important to her: “As you get older, your colleagues become younger and younger, and sometimes you don’t feel able to speak your mind frankly,” she muses.

Elena Conti and Jürg Müller met at the EMBL in Heidelberg. When their daughter was six months old, he also moved to Munich. During Lucia’s first year, a nanny helped out with childcare. Since then, Lucia goes to the institute’s nursery. When Elena Conti and Jürg Müller attend different conferences at the same time, the grandparents are happy to lend a hand and look after Lucia. “I would like my daughter to have as close a relationship with her grandparents as I had with mine,” she says. Elena Conti knows precisely where her priorities lie: “The two most important things are my family and my work. Even if my day had more than 24 hours, I would still divide the time between the two.” Elena Conti and her family live in the western part of Munich. They have annual passes to the Botanical Garden, Hellabrunn Zoo and Lenbachhaus art museum, where the three can often be found on weekends. The fact that Conti suddenly also remembers a little chocolate shop behind Munich’s Viktualienmarkt (“You really must go there!”) shows that art isn’t the only thing she appreciates.

Otherwise, there’s not much time left over for leisure activities, and she manages to make it to the fitness studio only once a week now. “My work is my hobby,” she says – almost apologizing. But it’s a privilege when one’s work is also one’s passion. Or in Elena Conti’s case, two passions: architecture and chemistry.
In the event of an impending global flu pandemic, vaccine production could quickly reach its limits, as flu vaccines are still largely produced in embryonated chicken eggs. Udo Reichl, Director at the Max Planck Institute for Dynamics of Complex Technical Systems, and his colleagues have therefore been working on a fully automated method for production in cell cultures that could yield vaccines in large quantities in a crisis.

**TEXT TIM SCHRÖDER**

The weapons against influenza include the egg – the plain old chicken egg. The egg is, after all, a biotechnology laboratory in miniature. In 1931, pathologist Ernest W. Goodpasture at Vanderbilt University in Nashville made a momentous discovery. He pricked an incubated egg with a fine needle and infected it with influenza viruses. The viruses reproduced prodigiously in the egg. When Goodpasture drew a bit of liquid out of the egg and examined it a few days later, he found that the number of viruses had skyrocketed. Goodpasture immediately realized that eggs are an ideal host for growing influenza viruses and, since vaccines require viruses, the perfect tool for producing vaccines.

The trick is to carefully inoculate the body with viruses without making it ill. The immune system then learns to recognize the pathogen and is able to mount a defense against it. Medicine uses three basic immunization methods for this. The first is to inject a large number of killed viruses; the second is to inject smaller numbers of attenuated and therefore non-infective viruses; and the third is to inject fragments of the virus shell or individual viral proteins. In any case, all three methods require viruses.

**VACCINE PRODUCTION NEEDS TO BECOME MORE EFFICIENT**

Goodpasture’s method is now 80 years old and has been continuously refined. Nevertheless, the egg remains the method of choice for manufacturing flu vaccines. Ninety-five percent of all flu vaccine doses still contain egg-grown viruses. However, this method is nearing its limits: for a single vaccine dose, one or two eggs have to be embryonated in a temperature-controlled cabinet, and many millions of eggs are needed to produce enough vaccine to supply an entire country.

The biologist and process engineer has been working with his team on developing alternatives to vaccine production in eggs. Like vaccine manufacturers and other research groups around the world, he is pinning his hopes on animal cells cultivated in laboratory vessels and bioreactors. However, it is expensive to replace an established method of pharmaceutical production, and the industry is very reluctant to do so. Udo Reichl is therefore seeking to make the production of vaccines in cell cultures so efficient that companies will see it as a viable alternative.

The cells that come into question for virus production were, for the most part, extracted from various animals and organs many years or even decades ago – from monkeys, hamsters and...
Mutable virus: The influenza virus mutates constantly. Therefore, for every impending epidemic, scientists must rapidly develop a new vaccine, and pharmaceutical companies must be quick in producing it in large quantities.
dogs, for example. Many of these cell lines are immortal, meaning that they can propagate indefinitely. There are also some new cell lines that research institutions and biotech companies have rendered genetically immortal. These, too, would be suitable for use in pharmaceutical production.

Udo Reichl’s team has identified several such cell lines that are particularly suitable for growing viruses. “It’s ironic,” says Reichl. “Other scientists are busy fighting viruses and keeping their numbers as low as possible, while we’re trying to stimulate a cell to produce as many viruses as possible. Our work isn’t anti-, but pro-viral.”

It is both fascinating and frightening how a virus infects a cell and reprograms it to release thousands of copies of itself. An influenza virus resembles a spiked ball. The spikes consist of the proteins hemagglutinin and neuraminidase. At the tip of the hemagglutinin spike is a lock-like structure that enables the virus to bond to the surface of animal or human cells. The fine structure of this site determines whether the structures on the cell surface fit the viral hemagglutinin like lock and key, thus allowing the virus to enter the cell.

THE FIGHT AGAINST INFLUENZA IS A RACE AGAINST TIME

If the lock on the virus surface finds a corresponding key on the cell surface, the influenza infection begins to run its fateful course. The membrane of the host cell opens up, and the virus penetrates into the cell and releases its genome inside the nucleus. The viral RNA then reprograms the cell to act as a virus factory. The cell blithely synthesizes viral components, which are then assembled into hundreds or even thousands of new viruses. The assembled viruses bud off from the cell surface, a process that requires the viral protein neuraminidase. For humans and other animals, it is disastrous when the viruses start to replicate so prolifically – that’s when influenza really takes hold. For vaccine production, however, it is ideal.

While influenza viruses are, for the most part, still being produced in eggs, other types of viruses have long been grown in cell cultures. But the aim of vaccine developers in both cases is the same: to produce large quantities of viruses in a short time so as to have sufficient vaccine on hand in the event of an epidemic or global pandemic. Unfortunately, it is pointless to stockpile some vaccines because many viruses – particularly the influenza virus – readily mutate, giving rise to new pathogens against which the available vaccine is useless.
The fight against influenza viruses is thus a race against time. Will scientists be able to identify a new virus variant and adapt the composition of vaccines before the pathogen is able to trigger a flu epidemic? More often than not, pharmaceutical manufacturers and researchers win the race. But all too often, the viruses are quicker. Things then get tricky, because the virus may spread rapidly and trigger a pandemic. In such cases, it would be good to have a fully automated breeding machine for influenza viruses that could be ramped up quickly and churn out the viruses in large quantities – a production line such as Reichl is hoping to develop.

The basic technology for growing viruses on a large scale is already available. It uses a type of cultivation vessel known as a bioreactor. However, there are obstacles to achieving optimum virus yield. The first is that the cells used for growing viruses – such as those in embryonated chicken eggs – have to reproduce rapidly. Afterwards, they have to be washed, provided with fresh nutrient medium and then inoculated with virus seed to replicate progeny viruses.

Several cell cultivation methods are currently available. For instance, there are cells that grow and replicate only if they are able to attach to surfaces – so-called adherent cells. With these cells, the maximum quantity is severely limited, because eventually the surface available for cell attachment becomes densely covered, at which point cell division stops. By contrast, some cells grow only if they are floating freely in nutrient solution, a cell suspension. Typically, much higher cell concentrations can be reached in a suspension than with adherent cells. However, cells in suspension have a tendency to clump together, which can impede the process. In addition, clarifying the cells from the medium is a more elaborate process. A third method, a middle road, has therefore been developed for bioreactors: a kind of pseudosuspension for adherent cells in which the cells are grown on microcarriers. The microcarriers, in turn, float freely in the liquid medium.

“On average, concentrations of around two to three million cells per milliliter of medium can be achieved with this method. With the type of cultivation strategy we envision, we hope to reach concentrations that are ten to a hundred times greater. We call the method high-cell-density cultivation,” says Yvonne Genzel, team leader in Udo Reichl’s department. That is an ambitious goal, but the researchers are able to tweak the process in many ways. Being highly sensitive, cells require the right medium with the ideal composition of nutrients, including vitamins, minerals and sugars. The temperature
must be set exactly right, just like the pH value and the oxygen content of the medium. A stirring mechanism is required to keep the cells or microcarriers in suspension, to prevent clumping and to distribute the nutrients and oxygen evenly.

HOLLOW FIBERS EXPECTED TO BOOST CELL YIELD

Few research groups in the world have the ability of the Magdeburg-based biotech researchers to manipulate all the many factors involved in the cultivation of viruses and cells – from the type of the reactor to subsequent modification of a vaccine. Reichl’s team, for example, is able to study the process in all its complexity and analyze the effects of every change in detail, allowing them to control and fine-tune the process. The laboratory in Magdeburg is equipped with a variety of glass reactors in which tiny propellers spin. “These mixers must have the right shape and run at the right speed so that we don’t damage the cells,” says Yvonne Genzel. She opens the steel door of an incubation cabinet. Inside is a vibrating platform, and fastened to it are small glass flasks containing floating cells. She removes one of the flasks and holds the brownish, cloudy solution against the light. “Quite a high cell concentration,” she notes.

For high-cell-density cultivation, the nutrient medium must initially be changed every few days, and then more and more frequently to ensure that the cells are sufficiently supplied with nutrients. Only then can they divide frequently and reach high concentrations in the solution. At this point, the oxygen supply becomes the limiting factor. The more cells there are floating in the solution, the more oxygen they consume. The researchers therefore pump pure oxygen into the vessels to supply the cells. But even this approach has limitations, as the stirrer cannot be run at a sufficient speed to distribute the oxygen uniformly throughout the highly concentrated cell culture. Nevertheless, Reichl, Genzel and their colleagues have already achieved remarkable cell concentrations. With the process considered for influenza virus production, they have already attained a concentration of 50 million cells per milliliter. In the future, they hope to raise that figure to 500 million.

A very recent, promising technique may help to further boost the cell density. Yvonne Genzel reaches for a glass tube containing a thick bundle of thin white hollow fibers. The membrane of these fibers allows oxygen and nutrients to pass through, but is impermeable to viruses and cells. With the help of the hollow fiber bundle, cells can be cultivated in a continuous flow. In this process, the cavities between the fine hollow fibers are filled with cells. Nutrient medium is then pumped through the fibers. Like arteries in the body, the nutrients and oxygen diffuse through the fiber membrane to the cells. “In this way, we’re able to achieve better distribution of nutrients and improved cell growth compared with conventional bioreactors,” says Genzel. One advantage is that it isn’t necessary to separate the spent nutrient medium from the...
cells and replace it – a very tedious process. All that is required is to pump fresh nutrient medium through the hollow fiber unit.

However, the scientists are still a long way from perfecting the process, because the number of virus-producing cells isn’t the only consideration. It’s also important for the cells in high-density cultures to be in good physiological condition, as only then can they produce viruses in large quantities. A high virus yield depends not only on the cell count, but also on the number of viruses each cell produces. This varies between several hundred and tens of thousands of viruses per cell.

A key factor is finding the right time to infect the cells in the culture with viruses: on the one hand, the cell count should be as high as possible; on the other hand, the cells must be fit. “It takes a lot of experience to identify the right conditions,” says Genzel. If the conditions are right, the researchers inoculate the cells with seed viruses. Seed viruses must also be in good condition and highly infectious so that each one successfully initiates intracellular virus replication. After six to eight hours, the infected cells start to release the first viruses, which, in turn, infect new cells. As the cells slowly die, billions of fresh viruses accumulate in the nutrient medium. The time at which the viruses are harvested is also critical for obtaining a high virus yield. This is particularly true for vaccines containing live viruses. The longer the virus harvest is delayed, the more likely it is that inactive, non-infectious viruses will accumulate in the reactor. The key is to determine the harvesting time at which the reactor contains a maximum number of infectious viruses. The process is less time-critical for vaccines that use inactivated viruses, because the viruses don’t have to be active. Virus cultivation in Magdeburg isn’t just a matter of process engineering, though. “We also want to gain insights into the cells and try to modify them so that they produce more viruses,” says Reichl. To do this, he has established a large array of analytical tools – a high-performance liquid chromatography system, for example, that can measure the cells’ metabolic products during viral infection and production.

CONVENTIONAL METHODS ARE USUALLY SET IN STONE

“I would have expected the cells to crank up their metabolism while they’re producing viruses,” says Reichl, “but they act just like healthy cells. Following an infection, not much changes in the cells until most of the viruses have been released and the cell dies.” Reichl can do more than measure the cells’ metabolic products. Using flow cytometry, for instance, where one cell after another zips through a tiny glass tube, he can also count and analyze the cells. The unit can count tens of thousands of cells per second. In addition, a laser beam aimed at the cells measures, for example, which viral proteins a cell is producing at the moment and whether the proteins are located in the cytoplasm or the nucleus of the cell. It still isn’t entirely clear how Reichl and Genzel can use this knowledge to improve virus production in cells, but one thing is certain: “Few researchers are looking as closely as we are at the fundamental processes that are critical for the growth of viruses in cell cultures for vaccine production,” says Genzel. The same can be said of vaccine manufacturers. “Companies usually can’t afford basic research. Furthermore, very few companies are experimenting with the established virus cultivation processes, as it is very expensive to modify and optimize production methods.”

Preparing for an emergency: Three vaccination methods have become established for priming the immune system to defend the body against viral infection. In the first method, live but attenuated viruses are administered, for example in the form of a nasal spray (left). For this, the viruses are grown so that they can still reproduce, but are no longer able to cause infection. In the second method, killed viruses are administered by injection. In the third method, only fragments of the viral shell or proteins are injected.
Because of very tight regulations, established methods are usually set in stone. Some manufacturers are even still using conventional adherent cells – that is, cells that require a solid surface to grow on – for cultivating viruses. However, when one considers that the development of a new vaccine production method costs several hundred million euros, it’s clear why the industry is relatively conservative in its approach.

THE MARKET FOR VACCINES HAS GROWN ENORMOUSLY

Genzel and Reichl are working not only with influenza viruses, but also with a long established virus type, the modified Vaccinia Ankara Virus (MVA), which is derived from the smallpox virus. This virus was produced over a period of many years by one of the pioneers of immune research, Munich-based veterinarian Anton Mayr. This vaccination virus is very well tolerated and non-infectious, making it highly suitable for work in simple laboratories. In contrast, any researcher wanting to work with the Ebola virus, for example, would have to meet extremely high safety standards, including the use of air locks, negative pressure systems and air filtration systems.

MVA is interesting particularly because it is a suitable transporter of genes. Such transport viruses are called vectors and are used, for example, in medicine to treat diseases caused by genetic defects. For instance, some individuals have a defect in the gene containing information for the synthesis of a metabolically important protein. Using a vector, it is possible to insert the intact
working it with the information it needs to synthesize the protein.

Moreover, vectors can also be used to immunize the body against dangerous diseases. Researchers hope that this can also be achieved for diseases such as Ebola and HIV/AIDS. For immunization purposes, MVA would be coated with the surface proteins of a dangerous virus, for example the AIDS virus. Because MVA is harmless, the safety risk for the patient is low. The immune system, however, learns in this gentle way to recognize the surface of the dangerous virus and is then able to develop immunity against it.

During the Ebola epidemic last fall, researchers published the results of an experiment in which they vaccinated macaque monkeys with an MVA vector carrying an Ebola protein. The study results caused quite a stir, as a positive test in macaques evidently means that immunity against Ebola can be achieved in apes.

Ebola is a disease that repeatedly makes headlines despite the fact that its death toll pales in significance to that of influenza, malaria and tuberculosis. “Consequently, the industry has little interest in the costly process of developing Ebola vaccines,” says Genzel. She hopes to be able to contribute to the development of inexpensive vaccine production with the help of an efficient technical process. That is certainly conceivable, because the market for vaccines has grown enormously in recent years, not least due to the frequent occurrence of bird and swine flu.

In 2009, that figure grew to USD 25.2 billion, and for 2015, it is expected to reach USD 56 to 64.2 billion.

Nevertheless, the researchers in Magdeburg still have a lot of work to do. “A virus looks simple, but it is extraordinarily adaptable and, to a certain extent, unpredictable,” says Reichl. “An influenza virus has only eight gene units that code for a dozen or so proteins. I used to think that it must be easy to understand such a virus, but that’s not the case.”

One uncertainty stems from sugar structures on the surface of hemagglutinin, which are key factors in determining the virulence of the virus. For instance, it has been known for some years that many proteins travel through the body, not in pure form, but with attached sugar groups. Experts call this phenomenon glycosylation.

For Reichl, this means: “If we want to better understand the replication of viruses and the effects of vaccines, we also have to investigate the glycosylation of their proteins.” And glycosylation means delving down to the molecular level. “Fortunately, we have the equipment and expertise at the institute to analyze the structure and composition of these sugars.”

Reichl knows that the fight against viruses will never be won. “There are too many viruses around the corner. But if we can manage to produce the right vaccine in large quantities, we will already have achieved a great deal.” As far as the influenza virus is concerned, he has another reason for exploring new technological processes and finding alternatives to the egg: If a bird flu spirals into a pandemic, things could get tricky. “If we have to slaughter the stock of poultry to stop the virus, how in the world are we supposed to obtain eggs to produce vaccines?”

TO THE POINT

- Established production methods for vaccines that use embryonated chicken eggs would probably be unable to meet demand during a global flu pandemic.
- Researchers from the Max Planck Institute for Complex Technical Systems are therefore looking at ways to produce large quantities of influenza vaccines, for example in animal cell cultures.
- In order to increase the concentration of animal cells in a nutrient solution and obtain as many viruses for vaccine production as possible, the Magdeburg-based scientists are systematically varying all the factors involved in cell cultivation. They are also looking for the optimum time to harvest the viruses from the infected cell culture so as to ensure maximum yield.
- Max Planck researchers are able to produce not only influenza viruses, but also MVA viruses, making the method interesting for vaccines against Ebola and HIV, as well.

GLOSSARY

Adherent cells: Animal cells that have to colonize a surface to reproduce.

Glycosylation: Many proteins are glycosylated, meaning that they have attached sugars that impact the function of these proteins and their effects in vaccines.

Hemagglutinin: A protein on the surface of an influenza virus that enables the influenza virus to bind to and penetrate a host cell.

High-cell-density cultivation: A cell culture with a concentration of tens to hundreds of millions of cells per milliliter of nutrient solution.

Neuraminidase: Another protein that resides on the surface of the influenza virus and that is required for the release of newly synthesized viruses from an infected cell.
November is not a pleasant month in Germany. It is usually chilly and damp, gray and dismal. The trees lose the last of their leaves, shrubs wither, and many animals seek out a place to hibernate for the winter. In late autumn 2014, however, nature perked up again: forsythia blossomed luxuriously, hedgehogs trotted perkily through gardens, and strawberry plants grew new buds.

What had gone awry? “The unusually mild temperatures sent the wrong signal to the plants,” says George Wang. Last year’s late autumn had a very spring-like feel to it – possibly indicating that the temperature differences between the seasons are diminishing. In temperate climate zones, however, the temperature is an important indicator for plants when it comes to which season currently prevails. If the thermometer rises above 20 degrees Celsius, the plants assume that spring has arrived, and form blossoms or new shoots, even in November. This is, of course, a poor investment: as soon as the next night frost arrives, the small delicate leaves die. Wang, a biologist at the Max Planck Institute for Developmental Biology in Tübingen, sees the impacts of the weather quirks in late 2014 as indicative of a possible trend that he recently discovered: “We could experience similar events more often in the future,” he says.

The correlation between the weather and the physiology of living organisms is George Wang’s specialization. He is interested in how climate change affects animals and plants, and what impact it has on evolution. “All physiological processes depend on the temperature,” says the American-born researcher with Taiwanese roots. He has been working in Tübingen for four years.

Biochemical processes unfold faster at higher temperatures, so the metabolism of cold-blooded, or poikilothermic, animals accelerates. Populations of

Day and night in the context of global change: Daily temperature variations are rising throughout the world due to climate change. This can have wide-ranging ecological consequences, also for forests.
some insects reproduce considerably faster when it is warmer. Other animals don’t tolerate high heat at all. As a result, when temperatures change, ecological relations also change – for example, the food available to birds in particular months, or which insect can pollinate a particular flower. Wang discovered an example of this kind of correlation four years ago. With his American colleagues Michael Dillon from the University of Wyoming and Raymond Huey from the University of Washington in Seattle, he calculated how climate change affects the metabolism of poikilothermic animals in the tropics. Their surprising finding: Although temperatures in the tropics have scarcely risen since 1980 – they increased by just a few tenths of a degree Celsius – this small change was sufficient to cause a significant rise in the metabolic rate of reptiles, amphibians and invertebrates. According to the scientists’ calculations, it increases just as much as that of animals in moderate climate zones where increases in temperature have been considerably higher. “This is due to the fact that the metabolic rate is exponentially dependent on the temperature,” reports Wang. For tropical lizards, amphibians and insects, this means that, as temperatures rise, they need considerably more food and may have less energy available for reproduction.

**TEMPERATURE CYCLES IN GLOBAL CLIMATE CHANGE**

Dillon and Wang would also like to have studied the future development of the tropical animals’ metabolic rate. However, during their work they encountered a typical problem: because the influence of the temperature is non-linear, it is not sufficient to rely on mean temperature forecasts. “If you want to study questions relating to ecology, you must also take tempera-
ture variations into account,” stresses Wang. Such studies, however, were rare up to now.

“Some colleagues have studied changes in the case of extreme temperatures, but in that case, too, the values were mostly averaged out,” he says. Yet the lives of most animals and plants are influenced mainly by short-term variations, such as the change in temperatures from day to night. The seasons also play an important role for flora and fauna – particularly in the lives of the numerous organisms that exist for only a couple of days or weeks.

To date, very little was known about how these cycles have changed over the course of the global change that has unfolded in recent decades. “Such high-frequency climate variability is difficult to characterize as, in many cases, the resolution of the available data is insufficient, and there is also a lack of suitable analysis techniques,” explains Wang.

He had already encountered this problem back in 2007, during his doctoral research at the University of Washington. At the time, he was studying a favorite model animal of biologists, the fruit fly Drosophila melanogaster. He wanted to find out how the insect reacts to heat stress – and to predict how its behavior will change as a result of climate change. “But it wasn’t possible because the corresponding climate data wasn’t available,” he reports. Together with Michael Dillon, Wang found a solution to this problem.

The mathematical method of choice for identifying periodic changes in larger volumes of data is the Fourier transformation. “But it only really functions with perfectly sampled data,” says Wang. Climate data is notoriously incomplete and inconsistent: one weather station may measure the temperature on an hourly basis, while another may do it only every four hours. In addition, gaps constantly arise in the data because sensors fail or are undergoing maintenance.

Because similar problems also occur in astrophysics, Wang and Dillon made use of a mathematical model that was previously used mainly in that field to identify the high-frequency cycles in climate data. They presented their findings in the journal Nature Climate Change in September 2014.

DATA FROM ALMOST 8,000 WEATHER STATIONS

The fact that biologists must be able to handle large volumes of data and program them themselves is something that Wang takes entirely for granted: “There is no way around this today.” For their study, he and Dillon amassed over one billion temperature measurements. The data originated from almost 8,000 weather stations throughout the world, and had been recorded between 1926 and 2009.

Due to the enormous volumes of data involved in their study, the two researchers had to monopolize several supercomputers in Germany and the US. They started by extrapolating the mean temperatures from the measurements, along with the daily and seasonal temperature variations at different latitudes. The mean temperatures they calculated reflected the Earth’s climatic zones: In all of the tropics – that is, between the latitudes of 23 degrees north and south of the equator – averaged over the year, the same temperature of around 25 degrees Celsius prevails. The further north or south one moves, the colder the annual mean temperature becomes.

However, the daily temperature variability doesn’t follow a clear trend from the equator to the poles: Averaged over the entire period for which the researchers analyzed the weather data, the daily temperature fluctuations were lowest at higher latitudes. In the temperate zones, they reach peak values of up to 15 degrees Celsius. In the tropics, the difference is consistent in all locations, at around 6 degrees.

The seasonal fluctuations, in contrast, follow a completely different pattern than the daily variability: they are strongest at high latitudes and barely noticeable around the equator. In individual locations in Siberia and Canada, for example, summer and winter temperatures can differ by over 60 degrees Celsius. In the southern hemisphere, temperatures generally fluctuate less between summer and winter – presumably because the land masses there are smaller and the influence of the oceans therefore greater.

In order to identify the latitudes at which the daily and seasonal variability is more significant, Wang and Dillon created a new mathematical parameter that correlates the variability of the two cycles with each other.

As their evaluation showed, the tropics, moderate zones and high latitudes can be differentiated from each other not only on the basis of their mean temperatures, but also through the relationship between their seasonal and daily temperature cycles: the dif-
ference in temperature between day and night in the tropics is greater than that between summer and winter. The seasons thus play a subordinate role for nature here. Plants flourish and blossom all year round, and animals don’t undertake any major migrations.

Nevertheless, the calculations revealed that, when considered for an entire year, the temperatures don’t follow such a smooth course throughout the tropics as was previously assumed. It is only within a few degrees latitude north and south of the equator that seasonal variability is practically nonexistent.

The further one moves away from zero degrees latitude, the greater the influence summer and winter exert – even if the mean temperature remains as high as it is at the equator. “Our analysis reveals that the seasonal temperature variability within the tropics is changing considerably depending on the latitude – with unknown ecological consequences,” says Wang.

**FLORA AND FAUNA IN THE RHYTHM OF THE SEASONS**

The ratio between seasonal and daily temperature variability is almost exactly reversed at the tropical boundaries: Within the tropics, the variations are more or less equal. In the temperate zones, in contrast, temperatures vary over twice as much over a year than over the course of a day. “In Germany, it’s maybe 10 degrees colder at night on average than it is during the day, while the temperature difference between summer and winter is around 25 degrees,” reports George Wang. As a result, the animal and plant worlds are subject to distinct seasonal rhythms.

Wang and Dillon then examined how the temperature cycles changed globally between 1975 and 2013. Their data confirmed the already-known global temperature rise: During this period, the greatest temperature increase, 1.2 degrees Celsius, occurred at the poles. Temperatures in moderate climate zones increased by 0.7 degrees, and in the tropics, by just 0.4 degrees.

To the researchers’ surprise, daily temperature variability also changed significantly over this period – and it followed the same pattern: The strongest variation also arose at the poles, with the difference between night and day temperatures there having increased by 1.4 degrees Celsius. The cor-

A bonus for pests: Some animals found at higher latitudes, like the mountain pine beetle, adapt to the rising temperature differences between day and night. They can then tolerate lower temperatures, too. Accordingly, these bark beetles now produce two generations of pests in America each year and damage considerably more trees. To stem the losses, infested forest areas are destroyed in controlled fires.
responding increases in the temperate zones and tropics were 1 degree and 0.3 degrees, respectively. In contrast, the seasonal temperature variations at the poles and temperate zones declined until around 2010, and moreover by 1.4 and 0.3 degrees Celsius, respectively. In the last three years of the analysis, the values rose again slightly, while there were few changes in the tropics.

According to Wang and Dillon, their data indicates a shift in the climate zones: “Daily and annual variability at higher latitudes have converged – the temperature variations have become more tropical, as it were,” explains Wang. However, this doesn’t necessarily mean that the seasons are disappearing, he emphasizes. Overall, the global temperature distribution is flatter – the differences between the different climate zones are diminishing.

The two biologists don’t have an explanation for this phenomenon. “We aren’t climate researchers,” stresses Wang. Whether or not these changes can be explained by global warming thus remains unclear. Long-term shifts in the atmospheric air flows may play a role here, as may a phenomenon known as global dimming. Measurements show that, between 1960 and 1990, there was a progressive decline in the amount of direct solar radiation reaching the soil surface, possibly due to the increase in air pollution.

However, this trend has been reversed since 1990, and more sunlight is reaching the soil surface, particularly at higher latitudes. In a comment published in Nature Climate Change, climate researcher Alexander Stine from San Francisco State University suggests that this may have contributed to stronger variations in the daily temperature course.

George Wang is interested in the ecological consequences of these changes. They could be wide-ranging – for mankind, nature and agriculture. For example, it’s possible that short-lived insects that emerged only in moderate zones in the warm season could, in the future, thrive throughout the year. “Increasing temperature differences between day and night creates an evolutionary pressure that forces the animals to endure greater temperature variations,” explains Wang. “As a result, their physiology could also adapt to the winter weather.” In the US, for example, the mountain pine beetle can now produce two generations per year rather than just one, as was previously the case. Consequently, these insects are infesting considerably more trees, and have left a veritable trail of destruction in parts of the Rocky Mountains in recent years.

A profile of the climate zones: Based on over 7,900 weather records, the scientists examined how the variations in temperature correlate with geographical location. The diagrams on the left present the results per weather station in color. The mean temperature, which declines in the direction of the poles (a, b), was established. In terms of the long-term mean, the temperature variations between day and night are the lowest at the poles and highest at temperate latitudes; they are around six degrees on average in the tropics (c, d). The differences in seasonal variability decline toward the tropics (e, f).
Climate change documents: Temperature measurements between 1975 and 2013 reveal different changes in three climate zones: polar region (gray), temperate latitudes (blue) and the tropics (red). The diagrams on the right show the differences between the first and last records in the series. According to the study, the greatest increase in mean temperature (a, b) occurred at the poles, while it scarcely rose at all in the tropics. The rise in the temperature variability between day and night is also highest at the poles and lowest in the tropics (c, d). In contrast, the temperature difference between summer and winter (e, f) at high latitudes has declined considerably since 1975 and remained unchanged in the tropics. The trend at temperate latitudes is not yet clear.

The transmission of the malaria pathogen is also dependent on daily variations in the temperature, as a study carried out in 2010 revealed. Another study demonstrated that the movements of migratory birds are influenced mainly by the weather, and less by long-term climate trends. Research has also revealed that the wintering strategy of thale cress, an important model plant studied by biologists, depends on both environmental signals and genetic factors. Thus, greater temperature variability could also generate evolutionary pressure for plants.

Most of the department to which George Wang belongs focuses on the molecular mechanisms that control plant adaptation: “We examine genetic variations at the boundaries of genetics, genomics and ecology,” explains Detlef Weigel, Director of the Molecular Biology Department at the Max Planck Institute in Tübingen. In terms of his research topics, George Wang is something of an exotic species within the group.

The fact that he ended up in Tübingen at all was due to personal reasons: Detlef Weigel brought Wang’s wife, molecular biologist Beth Rowan, to Tübingen in 2009. Wang followed her from Seattle a year later and also found a position in the department. “It’s a large and diverse group. You have a lot of freedom here and can work together with great people,” says Wang.

The biologist, who grew up in Los Angeles, has no regrets about moving from the US West Coast to tranquil Swabia. “Tübingen is wonderful,” he says – and singles out the childcare available in the university town for particular praise. The fact that the temperatures in Germany aren’t as pleasant as those in California – and that winter here sometimes brings snow and double-digit sub-zero temperatures – isn’t a major issue for him.

TO THE POINT

- Climate change has wide-ranging ecological consequences, not only due to the rise in mean temperatures, but also because of changes in the temperature variability between day and night and between the seasons. This can affect the metabolic rate of poikilothermic animals.
- To be able to study the future influence of climate change on flora and fauna in more detail, George Wang from the Max Planck Institute for Developmental Biology and Michael Dillon from the University of Wyoming used climate data to analyze high-frequency temperature variability between day and night and summer and winter.
- The different climate zones, namely the tropical, temperate and high latitudes, can differ in terms of both mean temperatures and short-period temperature variations. The influence of the day-night cycle dominates in the tropics, while the influence of the seasons is more important at temperate latitudes and the poles.
- It is assumed that the short-term temperature variability is changing due to climate change: As with mean temperatures, since 1975 the greatest increases in daily temperature variations have been recorded at the poles, and the smallest in the tropics. In contrast, seasonal variability has presumably decreased especially at high, but also at temperate latitudes. Consequently, short-period temperature variations at higher latitudes are converging with the patterns that prevail in the tropics.
Finding a job does not have to be rocket science ... 

... even if your work is.

academics brings together the brightest jobseekers and leading employers from the world of research.

Find up-to-the-minute job opportunities and relevant information for your scientific career in Germany on academics.de/maxplanck

academics.de/maxplanck

Your smarter choice for jobs

You would like to launch an advert? The academics team is looking forward to your call: +49 (0)40/320 273-50 // Email: anzeigen@academics.de
The Max Planck Institute for the Study of Societies (MPIfG) has been looking at the issue of “illegal markets” since 2012, and it has proven far from easy to draw any clear lines of demarcation. After all, the cycle of manufacture, distribution and consumption isn’t always as uniformly criminal as in the case of drugs or child pornography. Academic staff and doctoral students headed by Director Jens Beckert are researching counterfeiting in Argentina, the mining and trade in diamonds in Sierra Leone, the trade in rhinoceros horn and financial market crime – a look at an innovative project in economic sociology.
No trading in the marketplace is exclusively illegal; never is it entirely separated from the legal economy. Jens Beckert, Director at the Max Planck Institute for the Study of Societies, finds the interfaces between illegal markets particularly interesting.

Why are you at the MPIfG concerned with illegal markets?

**Jens Beckert:** In my area of research, we are concerned primarily with the sociology of markets. Up to now we have worked on the tacit assumption that trading in the market takes place largely within the framework of the law. But in this new research field, we want to test the extent to which previous methods and approaches can be extended to study illegal markets.

What new findings are you hoping for?

To begin with, illegal markets are interesting because they are of substantial economic and social importance. Studying them also indirectly gives us insight into the conditions that allow legal markets to flourish. For example, the consequences are clear to see when certain supporting structures, such as the protection usually afforded to property rights, cease to apply. The participants in illegal markets must cooperate with one another without recourse to the legal protection granted by the state. This has an enormous impact on the way these markets are organized.

What are the consequences?

The relationships between those who do business in illegal markets are almost entirely restricted to personal networks within which it is possible to develop close bonds of trust, but where misdemeanors can also be rapidly punished. This, in turn, has consequences for the organizational form: businesses are unable to expand as widely as in the legal economy. You might say that illegal markets never mature.

What issues are you researching?

We are interested in how cooperation between market participants functions in the absence of the protection afforded by law. How is competition organized? How can buyers of illegal goods recognize the value of a product? Whether we’re talking about counterfeit branded products or drugs, there’s no advertising to promote illegal goods, no seal of quality or unbiased consumer tests. For example, even among imitation brand-name clothing items, the quality varies – and the knowledge needed to tell the difference is widespread. This is something we discovered when researching online forums. Interestingly, however, we’ve noticed that many consumers who specifically buy counterfeit goods still never quite escape the feeling of having bought a fake. Even if they successfully deceive the world around them. Because in their hearts, these consumers are brand fans. This phenomenon might also explain why industry is often halfhearted in tackling brand piracy: because, to some extent, the trade in imitations helps bolster the brand value.

Will your research results also be of relevance to the advice you give to politicians?

Our interest is primarily systematic. So when we began the project, we also carried out an extensive study in which we attempted to differentiate between the various forms of illegal markets. Nevertheless, the results of individual research projects also have direct practical relevance. For example, when our scientists were investigating the trade in rhinoceros horn in southern Africa, they discovered that the poachers who supply the horns regard conservation as a continuation of colonial disenfranchisement. This is something that will have to be taken into account when action is taken to protect the rhinos.

Isn’t it very difficult for scientists to gain access to information about illegal markets?

In other cases, investigative journalism proved to be an informative source. All of our researchers have been in the field where they had direct contact with market participants, most of whom were willing to talk to us. Fortunately, none of our scientists ever found themselves in a really dangerous situation.

What other surprises have you experienced so far?

It was a genuine surprise to discover how close the links often are between legal and illegal market segments – especially in areas in which the unlawful practices of the market participants aren’t instantly categorized as morally reprehensible. The fluid nature of the interface between legality and illegality is also evident in a field in which we have just begun a new project: financial market crime. In this field, illegal acts take place within the context of entirely legal organizational and market structures. It has become clear to us that the interconnection between legal structures and illegal acts is one of the most interesting research topics in our investigation of illegal markets.

Interview: Ralf Grötker

---

**Photo:** Matthias Jung for the MPI for the Study of Societies
During the years in which the civil war raged, rebels terrorized the civilian population of Sierra Leone in their search for “blood diamonds,” which in turn were traded for weapons from Liberia. After the war ended, the diamond sector underwent a thorough reform, both within the country and at the international level. The goal: to bring the entire value chain and trading process under state control. This has been only partially successful, as doctoral student Nina Engwicht discovered.

During the years in which the civil war raged, rebels terrorized the civilian population of Sierra Leone in their search for “blood diamonds,” which in turn were traded for weapons from Liberia. After the war ended, the diamond sector underwent a thorough reform, both within the country and at the international level. The goal: to bring the entire value chain and trading process under state control. This has been only partially successful, as doctoral student Nina Engwicht discovered.

During the years of civil war in Sierra Leone between 1991 and 2002, diamonds mined without a permit and traded in defiance of licensing and customs regulations played an important role both as an illegal currency and as a means of money laundering. Both uses are commonly considered to support criminality and terrorist structures, and are thus thought to pose a risk to the stability of post-war society. In my study, I take a look at the illegal diamond market in the Sierra-Leonean post-war society. I am interested in how this market functions under the different contextual conditions in present-day Sierra Leone, how widespread illegal diamond production and trading still are today, and how the illegal diamond market stands in relation to the legal market and the state.

Between the end of 2012 and June 2013, I spent six months in the country conducting interviews and participant observation. What impressed me most was the absence of violence and the high degree of social integration, and how closely the legal and illegal diamond markets are linked. Among other things, I visited the major marketplaces in which diamonds are illegally traded. They are well organized, with each market having a “chairman.” In fact, in addition to the chairman, one of the markets I studied also had a council of elders, a secretary and deputy secretary, a treasurer, auditor, PR officer and other posts. Anyone wishing to become a trader in one of these markets first has to register.

Everything that happens in the marketplace is dominated by participants who collaborate astonishingly well, working together without friction.

Under the scorching sun, searching for the one big stone that could change their lives: Diamond miners in the Kono region of eastern Sierra Leone.
The merchants not only sell to dealers higher up in the value chain, but they also trade among themselves. In this way, many dealers profit from the sale of the same diamond. When conflicts do arise, they are resolved through the mediation of the chairman. There is also a kind of social fund to which all of the traders contribute, and from which benefits are paid to members faced with a wedding, a death in the family or a child’s naming ceremony. After the civil war, the government initially launched numerous raids on illegal markets, and some of the illegal merchants were arrested. The traders then turned to the chairman of the legal diamond merchants, who put pressure on the authorities to end the raids.

Apart from these considerations, there is no state welfare system in Sierra Leone. The illegal market sectors provide work for many young men who would otherwise constitute a potential source of unrest. For this reason, from the authorities’ perspective, these effectively interwoven trading relationships are a good reason to tolerate a certain degree of illegality. Of course, the illegal diamond trade is also attractive to criminal organizations. But the consequences of its existence aren’t as serious as they were during wartime. What’s more, criminal organizations have plenty of different sources from which to finance themselves, and aren’t dependent on the illegal diamond trade.

The high degree of collaboration among the market participants has to do with the nature of the good and social structure of the market. Most of the diamonds mined in non-industrial mining operations in the country are what are termed melee goods: stones of the smallest category. When a stone of this kind changes hands, no individual receipt is issued, making it easy to circumvent the rules that apply. In addition, many traders have licenses of their own to mine diamonds. They are then able to buy stones from illegal diggers and then sell them as their own legal goods, and even legally export them. From the point of view of the state, however, this is still better than if the diamonds were to be smuggled.

Apart from these considerations, there is no state welfare system in Sierra Leone. The illegal market sectors provide work for many young men who would otherwise constitute a potential source of unrest. For this reason, from the authorities’ perspective, these effectively interwoven trading relationships are a good reason to tolerate a certain degree of illegality. Of course, the illegal diamond trade is also attractive to criminal organizations. But the consequences of its existence aren’t as serious as they were during wartime. What’s more, criminal organizations have plenty of different sources from which to finance themselves, and aren’t dependent on the illegal diamond trade.

CULTURE & SOCIETY
Illegal Markets

A Status Symbol to Die For

Annette Hübschle/Transcript: Ralf Grötker

Three rhinoceroses are killed in South Africa each day, their horns chopped off and sold illegally on international markets. Kruger National Park and other public and private game reserves have become battlefields where state security forces and game wardens fight for the rhinos’ survival. Despite their efforts, conservative estimates give rhinos another seven years before they go extinct in the wild. The number of animals killed by poachers has risen in the space of two years from 668 (2012) to 1,215 (2014). Doctoral researcher Annette Hübschle is investigating why efforts to protect the rhinoceros aren’t succeeding.

My local roots – I grew up in Namibia – and professional networks that I groomed over a decade while working as a researcher on organized crime issues for a South African research institute proved extremely valuable for the purposes of data collection. During twelve months of fieldwork in southern Africa and Southeast Asia, I conducted more than 420 ethnographic interviews and focus groups. Among those interviewed were poachers and their bosses – so-called kingpins, most of whom come from Mozambique – convicted rhino poachers in South African jails, rogue wildlife professionals, rhino farmers, prosecutors and game wardens, community members living in Mozambican villages bordering Kruger National Park, representatives of conservation NGOs, and activists, traders, smugglers and Asian consumers. The large sample size and the use of other qualitative data such as police charge sheets and court files enabled data triangulation and verification. This is particularly important when studying illegal markets.

My goal was to understand and record the market in its entirety, from the “production” of horn – poaching, hunting or theft – to the international trade and consumption of rhinoceros horn. In light of the obstacles presented by the illegal and transnational nature of the market, the question arises as to how the various market participants achieve social order and how they re-
solve the coordination problems of cooperation, competition and valuation.

One principal finding is that important actors along the value chain simply don’t accept the ban on the trade of rhino horn. I call this mechanism “contested illegality”, and it serves as a strategy to legitimize illegal economic activities. It starts with the poachers who are individuals that have lost their ancestral lands and the associated hunting rights as a result either of colonial expropriation or of the establishment of protected areas and transfrontier conservation parks. Unsurprisingly, they don’t accept the land tenure system or the trade ban imposed by the Washington Convention on the International Trade in Endangered Species (CITES) of 1973, which came into force under the old apartheid regime.

However, some poachers are merely the foot soldiers for professional big game hunters and farmers, most of them white Afrikaners, who have their own personal networks and sell rhino horn as far away as Asia. Many of them own game reserves or farms, while others are vets or helicopter pilots. These actors claim the moral high ground and believe that the trade ban lacks legitimacy and relevance to the African case. They share the belief that the rhinoceros can be effectively protected only if private rhino owners are provided with economic incentives to breed rhinos, such as trophy hunting and the sale of rhino horn. According to this narrative, both the private sector and the state would obtain the necessary funding for environmental protection and conservation through legalization of the trade. However, this approach hasn’t shown the desired effects – the domestic trade in rhino horn was permitted in South Africa until 2009 – and this led to an interface between legal and illegal economic activities – a gray channel of sorts. The prominent involvement of state officials in corrupt activities shouldn’t be discounted, either, with such corrupt activities ranging from CITES permit fraud to active participation of police officers and game wardens in poaching groups.

Among end consumers, the illegal nature of the trade would appear to be of little or no concern. Rhinoceros horn is one of the most expensive commodities in the world, with a kilogram costing more than EUR 50,000. The horn was frequently used in powder form as a medicine in traditional Asian pharmacopoeia, but it is also popular as a status symbol, a gift to consolidate business relationships, or an investment commodity. In fact, anyone who buys horn as an investment tool is counting on the extinction of the wild animal.

Many of the political measures taken to date have, in my view, served only to make the problem worse. The securitization of the fight against rhino poaching and the permission for game wardens to resort to the use of firearms (should there be an immediate threat to their lives) has led to the deaths of around fifty rhino poachers in the past year in Kruger National Park alone. These deaths have further alienated communities living next to parks, as they perceive the lives of wild animals
A Big Chance

Matías Dewey/Transcript: Ralf Grötker

In recent years, La Salada, on the outskirts of Buenos Aires, has developed into an important marketplace for inexpensive clothing in Argentina. There are more than 7,800 stalls manned by traders selling T-shirts, jeans, jackets, shoes, underwear and children’s clothes. A large portion of the “brand-name” goods are counterfeit. Many of the stallholders also own sweatshops where the garments are designed and the materials purchased and tailored. Matías Dewey, a senior researcher at the Max Planck Institute for the Study of Societies, has discovered why the people here are facing the future with confidence.

My brother works as a sociologist with an NGO that provides conflict resolution seminars for young women in Argentina. As an additional incentive to take part in the seminars, the NGO also offers hockey courses. Because I myself once used to be a professional hockey player, I was involved as a hockey teacher. It struck me at the time that the parents of many of these young women worked in La Salada. That’s how I made my first contacts for my field research.

There are various aspects of illegality that come together in La Salada. A large proportion of the garments sold to be valued more highly than those of their fallen community members.

Social injustice and the colonial legacy further encourage the locals to turn to poaching, which at least offers the opportunity for social mobility, a chance at socio-economic upliftment. Some poachers have started to form their own poaching groups and sell the horns themselves to intermediaries or Asian buyers. For villagers living next to Kruger National Park, there are few other avenues for income generation. As the park continues to expand to include conservation areas in neighboring Mozambique and Zimbabwe, more villagers have been resettled from their ancestral grounds in recent months. I think the time has come to consider the use of social impact bonds – structural aid and direct investment in land rights, schools and hospitals as a reward for village communities that support the fight against poaching.
The sun low in the sky gives a false impression of idyllic charm. In fact, the area surrounding La Salada is littered with garbage, and the adjacent Riachuelo River is heavily polluted. On market days, the local buses avoid the teeming district.

Here are counterfeit copies of brand-name goods. Also, the settlement itself is comprised of buildings erected without permits. And lastly, a large part of the work done in La Salada is illegal, as the workshops pay no taxes, the occupational health and safety rules are ignored, and none of the workers are employed on official terms and conditions. Most of the workers in the sweatshops have an immigrant background.

What fascinates me most is the optimism of the people who work in La Salada. The majority of them are aware that what they are doing isn’t entirely legal. But no one here aspires to become a mafia boss or make big money through serious crime. They themselves define their activities above all as work – physical work that often involves the use of learned skills. Work also means an income and a daily routine. Many of the vendors have previously worked as street traders, always in informal and extremely short-term employment. For them, La Salada is their first real job. Suddenly, they see a future before them: they can afford a television and maybe a car, even pay for Internet access. One man who I got to know there had previously sold drinks. Now he pushes a cart in La Salada. In the last eight years he has changed cars five times.

Even though the peacekeeping powers of the state are completely absent in La Salada, outbreaks of violence are surprisingly rare. Maybe that’s simply attributable to the fact that what we’re dealing with here isn’t serious organized crime. The people are, for the most part, “law-abiding” – if one may use that term. That is, the traders in La Salada pay taxes. Not in the usual sense – they pay to ensure that the law isn’t enforced, enabling them to do business undisturbed. Some of this money actually ends up in the state coffers illegally. And it’s rare for anyone to not comply with their informal payment obligations. Paradoxically, this is also due to the fact that there are no rules: people simply don’t know what consequences they might face if they refused to pay.

Even though La Salada is illegal, the market presents a win-win situation for all concerned. The traders have their livelihood, and their customers in the lower and middle income groups can buy the clothing they need in La Salada – they don’t have the money to pay the high prices that legal products are sold for in Argentina. From the politicians’ point of view, cheap clothing and job creation are a welcome alternative to welfare benefits. This dynamic strengthens not only relations in the marketplace, but also client networks and existing power structures.
Research in the loop

youtube.com/maxplanck­society
A Palace Pond in a Beaker

When the use of detergents increased after the Second World War, every year, thousands of tons of phosphates ended up in streams, rivers and lakes. Hans Jürgen Overbeck, who later became Director at the Max Planck Institute for Limnology in Plön, carried out research in the 1950s on how bacteria and algae reacted to this. A pond in Sanssouci Palace Park in Potsdam provided him with some crucial insights.

TEXT ELKE MAIER

The artificial pond on the garden side of Orangery Palace was a constant thorn in the side of the park management of Sanssouci: The pond, which forms part of the terrace complex, contained a thick green algal soup and exuded an odor that was not quite in keeping with the royal setting. And yet the water in the 1,000-square-meter and approximately 70-centimeter-deep pond was changed regularly. A fountain fed it with water drawn directly from the Havel River once a week. However, this failed to bring about any improvement – on the contrary. Like many inland waters, the Havel had been oversaturated with nutrients, and above all phosphorus, since the 1950s. This was caused by the rapid increase in the use of detergents after the War. The phosphates, which acted as softeners, entered rivers and lakes directly with the wastewater. Another contributory factor was artificial phosphorus-based fertilizer, which was generously spread on fields and meadows and flushed directly from them into rivers and lakes, where it also stimulated the growth of algae. Thus, the unattractive green soup had become a familiar sight in many places.

The over-fertilization of water bodies – referred to scientifically as eutrophication – is far from a mere aesthetic problem. When they die, the masses of algae are decomposed by myriad bacteria. This process consumes oxygen, allowing ammonium ions, methane and, soon after, toxic substances like hydrogen sulfide and ammonia to accumulate in the deep, oxygen-free waters. In short: the river or lake “collapses.” The process also reinforces itself, as, due to the oxygen deficiency, the insoluble phosphate, which is bound with iron in the sediment of the water bodies, is dissolved again and causes renewed algal growth. Although the detergent industry denied the link, it was already obvious at the time that eutrophication was directly related to phosphate inputs. What was unclear was the precise biological and chemical processes at work here. The pond in the Sanssouci Palace gardens therefore provided a very promising research area for an ambitious young scientist like Hans Jürgen Overbeck.

Overbeck was born in 1923 in Schwerin, also renowned as the “city of seven lakes.” As a young boy, he was fascinated by the unspoiled nature of Mecklenburg’s lake-studded landscape and its Baltic coast. In 1940, he embarked on his studies of biology and chemistry in Rostock. He first encountered the topic of phosphates during his work at the Hiddensee Biological Research Institute: a project on “sea fertilization” carried out there aimed to establish whether it would be possible to increase fish production in the Rügen lagoon through phosphorus fertilization. It was hoped that it would be possible to accelerate the growth of algae through the addition of phosphate, and in this way to create a nutrient basis for the zooplankton – small, crab-like organisms that drift in oceans and seas and provide food for the fish. “More phytoplankton = more zooplankton = more fish” was the self-evident conclusion to be tested.

However, Overbeck and his fellow scientists were quickly forced to acknowledge that the calculation wasn’t quite so simple: “We were surprised to discover that the question regarding phosphorus and the nutrient chain was far more complicated than we expected,” writes Overbeck in his autobiographical novel Insel der Kraniche (Island of the Cranes).

On the one hand, the researchers had overlooked the smallest cells that formed the first link in the chain. On the other hand, like oxygen, hydrogen sulfide, the temperature and the salt content, iron and manganese compounds dissolved in the seawater also affected the availability of the phosphorus. “Big surprises emerged in the early days of the testing. What we were dealing with was a vast, complex ecosystem,” concluded Overbeck.

When the young scientist accepted a position at the Botanical Institute of the University of Potsdam upon completing his doctorate, the pond in the Sanssouci Palace gardens provided him with an excellent opportunity to revisit the “phosphorus problem” – this time using a more contained research object – with the aim of answering some fundamental questions.

It was, for example, a mystery why the algae in the pond proliferated so luxuriously, despite the fact that it was almost impossible to detect any dissolved phosphate in the water – free phosphate being the only form in which the algae can absorb phosphorus. Over-
Overbeck discovered that 90 percent of the phosphorus was stored in biomass and dead organic matter and bound in complex chemical compounds. But how were the algae able to absorb it and use it?

To answer this question, Hans Jürgen Overbeck and his colleagues started to breed the algae from Orangery pond in the laboratory. As was easily identified from their characteristic cell shape, the organisms in question were mainly green algae of the species *Scenedesmus quadricauda*; moreover, large volumes of bacteria were also present in the pond.

To eliminate the bacteria, the researchers filtered their samples and established a pure *Scenedesmus* culture in a nutrient solution. To their astonishment, this did not agree with the algae whatsoever: they wasted away and stopped reproducing in the bacteria-free water. Yet when the scientists added bacteria again, they started to grow robustly. The bacteria were clearly important for the algae’s nutrient supply.

But what was their precise role in this process? Further tests provided the answer. They showed that the bacteria excrete special enzymes known as phosphatases. These dissolve the phosphate from the organic compounds so that the algae can absorb the phosphorus. Having isolated the phosphatases in a pure form, the researchers put their discovery to the test. They added the enzymes to a bacteria-free algal solution: the algae thrived – even when the phosphorus was available only in compounds.

Hans Jürgen Overbeck succeeded in demonstrating that algal growth was not dependent on the currently quantifiable concentration of phosphorus in the water. What is far more important is the rapid transformation of the bound phosphorus. Even a body of water the size of Orangery pond is a highly dynamic system that is subject to a very rapid cycle. Overbeck and his colleague Hans-Dieter Babenzien later also proved that other enzymes – amylases and saccharases – control the decomposition of carbohydrates.

“It later emerged that this principle of the linking of the metabolisms of different organisms in ecosystems through free enzymes is a universal phenomenon that applies not only to aquatic ecosystems, but also to terrestrial ones,” writes Overbeck in his novel. The studies on the grounds of Sanssouci Palace not only contributed to the explanation of the phosphorus cycle, but also brought a fundamental ecological principle to light.

After the success of his work on Orangery pond, Overbeck soon turned his attention again to a “real” body of water: Lake Plüßsee near Plön, in the hilly area known as the Holstein Switzerland. At the time, he was troubled not only by the travel restrictions and lack of technical resources available to him in the GDR, but also by the lack of intellectual freedom there. Thus, he and his family moved to the West in 1961 – shortly before the construction of the Berlin Wall.

His new place of work was the Hydrobiological Institute of the Max Planck Society in Plön. He quickly made a name for himself internationally with his comprehensive studies on Lake Plüßsee. In 1966 – the Hydrobiological Institute had since become the Max Planck Institute for Limnology – he became Director of a new department called the Department of General Limnology.

The aim of the Plüßsee project was not only to explain the complicated metabolic cycles in the lake, but also to measure the plant, bacterial and animal production, study the population dynamics of the plankton, and clarify various climate effects. Scientists from very different disciplines were involved in the study. They came from fields as wide-ranging as hydrophysics, chemistry, biochemistry, microbiology, planktology, zoology, paleontology and mathematical modeling. Today, this small lake in its idyllic forest setting is one of the most studied lakes in the world.

Throughout his life, Overbeck’s passion remained the bacteria found in bodies of water and the biochemical processes they control. For this reason, the scientist, who died in March 2013, shortly before his 90th birthday, is feted as the pioneer of “aquatic microbial ecology.” The fact that he never neglected the environmental perspective was typical of his approach. For example, he and his colleagues investigated the microbiological processes behind the production and use of methane in water bodies. Their research provided an important basis for our understanding of the role of methane in climate change.

Overbeck’s insights into the phosphorus cycle were used when solutions were being sought for overcoming the eutrophication of waters. In the 1970s, the Max Planck Institute built one of the first German pilot sites for a so-called third or chemical stage in water treatment in Lütjenburg, near Plön. It was so successful in eliminating the phosphate content of the water using iron salts, and functioned so well, that 90 percent of the phosphate was removed from the water from the outset. The process prevailed: today, a mechanical, biological and chemical treatment stage is standard at water treatment plants in Germany.
High Tech at a Lofty Height

A 325-meter-high climate research tower is being built in the Amazon rainforest.

Construction of the steel structure, which will be taller than the Eiffel Tower, is set for completion in early summer. Scientists from the MPI for Chemistry are closely involved in its development and will also coordinate the research there.

When Jürgen Kesselmeier wants to travel to the building site of the Amazonian Tall Tower Observatory (ATTO), he faces a day and a half’s journey from the Brazilian metropolis of Manaus. He starts out by car, heading north, then turns east to the Balbina Dam, continuing along the Uatumã River. Following a boat trip, the final leg of the journey is made by jeep down a jungle track. “Apart from the measurement station with two smaller 80-meter-high towers, there is nothing here but forest,” says the project leader from the MPI for Chemistry in Mainz.

Now the ATTO is being added to the location. Since the laying of the foundation stone in August 2014, the tower has already reached a height of 270 meters. Construction will continue when the rainy season is over, and the gigantic structure is due to be inaugurated in June 2015. Behind the work of the builders, technicians and scientists lies a logistical feat that could be achieved only through their concerted efforts. For example, a Brazilian company transported the steel struts over land and river to the protected area and provided around 30 workers. They alternated in three-week shifts at the site, sleeping on hammocks in the camp near the tower, complete with its own kitchen, shower and WCs.

Technicians and scientists from the National Institute of Research in the Amazon (INPA), the Universidade do Estado do Amazonas and the MPI for Chemistry will equip the gigantic structure with sensors, probes and pumps. Air will be sucked in from different levels and the proportion of aerosols it contains will be measured. The scientists also plan to study the processes involved in the transport of air masses – processes that take place over several hundred kilometers. “We want to understand where and why greenhouse gases such as carbon dioxide, methane, nitrous oxide and other reactive trace gases form and accumulate,” explains Kesselmeier, whose team includes ten MPI staff members. He fondly recalls the first time he climbed to a height of 120 meters to take lunch to three colleagues. “I’m not exactly unafraid of heights, but there were plenty of places on the structure that provided a secure hold,” he explains. Moreover, his efforts were rewarded with a “magnificent view.” Nevertheless, Kesselmeier has a lot of respect for those who work at this height. He isn’t yet sure whether he will climb the 325 meters to the top of the tower, but he definitely wants to give it a try.

It isn’t just the height that makes the ATTO so special. Climate measurement stations already exist at 800 meters, on the roofs of skyscrapers in
Open Access Needs the Young Generation

The Max Planck Society offers junior scientists targeted seminars on free scientific research knowledge, and sponsors the world’s largest specialist conference.

More research findings in Open Access journals – since the Berlin Declaration in 2003, this desire is increasingly becoming a reality, also in the Max Planck Society. This became evident, for instance, at the Open Access Week 2014 events.

In the transition to freely available research findings, particularly junior scientists in the Max Planck Society play a special role. After all, they face considerable pressure to publish in highly respected journals in order to advance their career opportunities.

To this end, the Max Planck Digital Library and PhDnet initiated the “Open Access Ambassadors” format, a network of ambassadors for free research knowledge. The first researchers just embarking on their careers arrived at the MPI of Psychiatry in early December to meet with leading Open Access advocates. There, more than 60 Max Planck doctoral students, postdocs and group leaders learned a lot not only about the advantages of digital Open Access journals, such as short and transparent review processes, but also about how they can promote the expansion of the Open Access concept at their institutes.

The trend is also becoming noticeable worldwide: “In a changing culture, the old guard is sometimes reluctant to make room for a new generation. In the Open Access movement, it’s different. Here, the old ones are hungry for you to climb the throne!” – these were the words with which co-founder and Chairman of the Board of PLoS, Patrick Brown, opened OpenCon 2014, the largest Open Access conference for junior scientists from all over the world. With financial support from numerous Open Access journals and research institutions, including the Max Planck Society, they assembled in mid-November for a two-day conference in Washington, DC.

Dubai. What is unique about ATTO is the valuable ecosystem in which the scientists take their measurements: It is the largest continuous forest area on Earth, and it is constantly shrinking due to such operations as slash-and-burn clearing and the expansion of soya plantations. As a CO₂ sink and freshwater reservoir, the Amazon rainforest has a huge influence on global weather, and it is enormously rich in species diversity.

The cost of constructing the measurement tower is around 8.4 million euros, which is being funded approximately equally by the German Federal Ministry of Education and Research and the Brazilian partners. However, the cost and effort are worth it, as Kesselmeier firmly believes that the ATTO will help answer questions about climate change and complement established climate models. It is said that around 390 billion trees still stand in the world’s largest tropical forest. ATTO will tower above them all.

Career Conference for Postdocs in Garching

The Max Planck Society and the Technische Universität München (TUM) have committed themselves to actively fostering post-doctorate career paths. Postdocs from Munich are invited to attend the joint conference “Careersteps for Postdocs in Academia and Industry” on May 7, where they can learn about the diverse array of professional prospects within the context of practical workshops. The opening lecture will be held by Ijad Madisch (pictured left), co-founder and CEO of ResearchGate. A further highlight is a podium discussion with top-class representatives from the political, scientific and business arenas. The conference will take place at the TUM Institute for Advanced Study in Garching.
Science Is International and Colorful

Researchers in Saxony advocate tolerance and cultural coexistence

In view of the marches by members of Pegida (from the German acronym for “Patriotic Europeans against the Islamization of the West”) in Dresden and Legida in Leipzig, scientists at Max Planck Institutes in Saxony are taking a stand for tolerance and cultural openness. President Martin Stratmann supports these initiatives, as he made clear at a meeting with Saxony’s Minister President Stanislaw Tillich.

People are laughing, and later dancing in time to feel-good brass-band music. Science is having fun, science is fun – this is what the two-minute video clip conveys. And more importantly: science is at home in Dresden, with researchers from all over the world whose work is also important for the economy, and thus for the entire region. That’s the message spoken by American biochemist Elly Tanaka in a close-up shot, and then she likewise states in German: “We’re sure that the majority wants a culturally open and colorful Dresden.”

In the video, this is simultaneously the cue to join the group dance: dozens of scientists in white lab coats hop around, waving their national flags. Whether USA, Spain, Croatia, India, Egypt, Iran – no one counted them, but the diversity of flags is impressive.

The clip is now available on YouTube. It was recorded by the Public Outreach team at the MPI of Molecular Cell Biology and Genetics (MPI-CBG), but for the big tolerance event in late January in Dresden. Not only some 250 artists – including Herbert Grönemeyer, Sarah Connor and Adel Tawil – but also citizens took to the stage to speak out before more than 22,000 people. Among the speakers were Kai Simons, Founding Director Emeritus of the MPI-CBG. And to underpin his message, this video clip was shown – in which, incidentally, scientists not only from this MPI, but also from other Dresden-based research institutions also played a part. “We wanted to make it very clear that Dresden is cosmopolitan and that, as scientists, we need this cosmopolitan atmosphere,” says Simons.

Even if the administrations of other MPIs are reluctant to take such a public stance on the Pegida and Legida demonstrations, everyone is concerned that Saxony’s good reputation as an internationally established location for science could suffer in the long term. Furthermore, in letters to the President of the MPG, scientists also cautioned against a change in the cultural climate. Against this backdrop, in early February, Martin Stratmann met with Minister President Stanislaw Tillich in Dresden. “It is disastrous if, in view of the latest developments in Dresden and Leipzig, employees are inhibited in moving around the city, or are even afraid,” said Stratmann during this meeting. He stressed that, “Minorities like the international scientists and their guests must be certain of the particular support of the state government.” Tillich emphasized: “We firmly oppose those who incite and stir up public opinion against foreigners. Dialogue is needed for Saxony to be able to continue its positive development, as is a climate of openness and tolerance. This is important for science, too.”

The two agreed to stay in contact and to initiate specific measures – actively involving the local institutes. Stratmann further highlighted that he “supports all initiatives in politics and society aimed at peaceful coexistence of cultures, and at tolerance and openness.” He additionally pointed out that the MPI in Saxony has, independently of the current polarization, for years been engaged in encouraging practical communication and coexistence. This may take the form of open house days or school projects like at the MPI for Evolutionary Anthropology in Leipzig, or that of the MPI-CBG. International doctoral students at the institute in Dresden then address students – in German and English – under the motto “Science Goes to School” and show how they work: the DNA extraction from bananas that was also featured at the recent container festival is popular there, as well.

The video: www.mpg.de/weltoffen
Research Establishments
Research doesn’t have to be heavy.

Go paperless!
The Max Planck Society’s magazine is now available as ePaper: www.mpg.de/mpr-mobile

Internet: www.mpg.de/mpresearch