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Clouds

Floating Cisterns Affect the Climate

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A Continent Learns Democracy

ORNITHOLOGY
Wire(less)tapping in the Aviary

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Conflicts in the Wake of Catastrophe

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Dear Readers,

“Clouds – a phenomenon remarkable to every man from his youth up – are, in the plain countries, generally looked upon at most as something foreign, something super-terrestrial. People regard them as strangers, as birds of passage, which, hatched under a different climate, visit this or that country for a moment or two in passing — as splendid pieces of tapestry wherewith the gods part off their pomp and splendor from human eyes.” So wrote Johann Wolfgang von Goethe in 1779 in his Letters from Leukerbad. In a similar vein, poets and singers throughout the ages have prized the clouds as heavenly messengers of good and evil.

Neither Goethe nor any other poet before or since could have guessed that clouds would one day be the subject of intense study, and of central significance for science. In every model of the future development of Earth’s climate, they play an exceptionally important role. The connection between cloud formation and the global rise in temperature is, in fact, highly uncertain. It is the lack of knowledge of this association that makes most forecasts of climate change appear unreliable. And yet such forecasts are being applied as a basis for far-reaching international treaties that affect the whole of economic and political life in every region of the Earth.

Against this backdrop, it is clearly the task of science to carefully and responsibly present facts that are based on meticulous measurements and observations. Within the German scientific system, the Max Planck Society is tasked with conducting basic research without restriction in terms of purpose, but with an eye to the needs of the public that sponsors us. Thus, institutes that were established long ago are devoted to issues of future importance – like the Max Planck Institute for Chemistry in Mainz, which has been studying the atmosphere for more than 40 years now.

Given that the formation of clouds is triggered by processes of physical chemistry, and that the events taking place within them affect the climate, the institute in Mainz has assumed a leading international role. The same may be said of the Max Planck Institute for Meteorology in Hamburg, where scientists drew attention at an early stage to the importance of clouds for the development of climate models.

But the role of clouds is not limited to the climate. They also exemplify the origination and effects of turbulent processes on a much-extended scale, comparable with ocean currents and alpine avalanches. It is a question of understanding how minor causes can create vast structures that, in turn, are the cause of other turbulent — that is, non-linear — processes. This is the kind of work conducted at, for example, the Max Planck Institute for Dynamics and Self-Organization in Göttingen.

Former Max Planck Society President Hubert Markl once said that, contrary to widely held belief, the rise in CO₂, with its presumed consequences for the climate, was discovered neither as a result of social scientists’ surveys or the exegesis of political or religious writings, nor even by Greenpeace and its activists. Rather, the relevant data and facts are gathered, ordered and evaluated by large numbers of scientists, the majority of whom are entirely unknown to the public. The Focus topic of this issue provides insight into their work.

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FOCUS

16 Clouds

Water with a Nebulous Effect
How does global warming affect clouds? And what role do clouds play in climate change? To date, climate models have not sufficiently accounted for this important interplay.

The Seeds of Climate
Aerosols are considered to be the salt in our climate soup – and yet they are not easily grasped. That is why researchers are trying to understand just what impact these tiny floating particles have on the atmosphere.

Droplets on a Rollercoaster
Whether clouds form or disperse, whether it rains or snows: turbulent flows play a significant role. Those who research such turbulence ultimately also help meteorologists.

ON THE COVER: Goethe called them "splendid pieces of tapestry wherewith the gods part off their pomp and splendor from human eyes." But clouds are far more than merely the object of poetic observations and romantic rhapsody: they are an object of intensive research aimed at helping us to one day have a better understanding of the global climate.

FOCUS

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Rendezvous on the perch: Here, a tiny radio transmitter transmits what takes place in the brain of a zebra finch.

Robot instructor: Researchers like Jan Peters are trying to teach dumb machines intelligence.

Under water: The tsunami of 2004 caused more than just material damage in the Indonesian province of Aceh.
Mobile Microscopes Look inside the Brain

Tiny laser scanning microscope records brain cell activity in free-roaming animals

With the aid of microscopes and magnetic resonance tomography, scientists and doctors can look inside our brains – but only as long as we keep very still and do not move. Since this is not normal behavior, however, these methods are of limited value in terms of understanding higher brain functions, such as perception and alertness.

Scientists at the Max Planck Institute for Biological Cybernetics in Tübingen have now developed a mobile laser scanning microscope that is so small that it can be mounted on the head of a rat. Very light in weight and only about three centimeters in size, the microscope uses a high-energy pulsed laser and fiber optics in order to observe several fluorescent cells in the brain simultaneously. It also fixes the exact position of the animal, which can move about at will.

For the first time, researchers are now able to track how brain cells behave in an animal exploring its environment. This technology promises to deliver entirely new insights into our understanding of brain functions.

Mini-microscopes facilitate new views in the brains of rats. The tiny devices, weighing just 6 grams and measuring 3 centimeters, can monitor up to 20 nerve cells simultaneously while the animal is free to move around.

Proteins in 3-D

The proteins present in biological membranes play a part in almost all life-critical processes in cells. New investigative methods are providing fascinating insights into their three-dimensional structure. In order to be able to analyze the structure of a protein, tiny amounts must first be converted into crystalline form – only then are the molecules accessible for examination with the aid of X-rays. The Max Planck Institute for Biophysics in Frankfurt am Main recently established an ultramodern Core Center for Membrane Proteins. It comprises a fully automated crystallization unit to manufacture crystals on a nanoliter scale, two mass spectrometers, two X-ray diffractometers and a calorimeter. The crystallization unit will significantly accelerate the manufacture and optimization of crystals and the subsequent structural analysis. “The establishment of the Core Center in Frankfurt also gives a boost to Germany’s status as a research location,” emphasizes Hartmut Michel, Director at the Max Planck Institute for Biophysics. The Center was sponsored by the German Federal Ministry of Education and Research and the EU, as well as receiving support from Max Planck Society central funds. The Max Planck Institute for Biophysics manages the infrastructure and provides personnel to maintain continuous operation.

The Core Center for Membrane Proteins can be used by scientists from throughout Europe.
“In certain research fields, India is one of the key locations”

On February 3, 2010, German Federal President Horst Köhler joined India’s Minister of Research Prithviraj Chavan to inaugurate the Indo-German Max Planck Center for Computer Science at the Indian Institute of Technology in Delhi. In an interview, Max Planck President Peter Gruss explains the Max Planck Society’s interest in developing a partnership with India.

Professor Gruss, why is the Max Planck Society seeking to cooperate with India?

Peter Gruss: There are an increasing number of outstanding Indian institutes working in scientific fields in which Max Planck Institutes are seeking partners the world over. What’s more, I expect India to play an increasingly important role in science in the future. A lot of talented young people are already coming to us from India. In the past five years, the Max Planck Society has seen an increase of more than 80 percent in the number of junior and visiting scientists from India – one out of every ten foreign doctoral students at Max Planck Institutes is from there. And the 120 Indian graduate students at our International Max Planck Research Schools constitute the largest overseas group.

What forms of cooperation already exist?

Peter Gruss: First, we have Max Planck scientists cooperating with their Indian colleagues within the context of specific research projects. There are currently 40 such research projects in such diverse fields as astronomy, cancer research, plant physiology, criminal law and art history. In addition, we help those foreign guest scientists who have proven themselves at our institutes to establish themselves scientifically in their home countries, in an effort to preserve long-term links between them and the Max Planck Institutes. We support these scientists after their return to their home country through the medium of partner groups. There are currently 12 of these groups in India.

What is the newly established Max Planck Center in India expected to achieve?

Peter Gruss: The goal is to create a center of excellence that not only engages in top-level research, but also opens up career opportunities for young scientists in India. India’s universities produce 180,000 IT graduates every year. But the country has room for only about 30 of them to study for doctorates, due to the lack of research institutions of the appropriate caliber. The Center is the result of the cooperation between our Max Planck Institute for Informatics in Saarbrücken and a partner group in India. It will initially comprise six Indo-German research groups, to be joined by four more a year later. The German Federal Ministry of Education and Research (BMBF) and India’s Department of Science and Technology are each funding the Max Planck Center to the tune of 1.1 and 2 million euros, respectively, spread over five years. This form of cooperation has a certain institutional character and is intended to add further momentum to our work with India.

The research work at the Max Planck Center will concentrate on computer sciences – why is that?

Peter Gruss: In certain research fields, India is one of the key locations – and that certainly applies to the computer sciences. Kurt Mehlhorn, Director at the Max Planck Institute in Saarbrücken, who will head the Center in New Delhi together with Naveen Garg, says himself that one of his best works was authored jointly with Indian colleagues. In his field of algorithms, this cooperation has been extremely fruitful. And this is not the only such venture: Saarbrücken is already partnering with Mumbai on database systems and with Chennai in the networks field. We have already gained a lot of positive experience.

In the computer sciences, basic research and application are closely related. During your visit to India you had a meeting with Narayana Murthy, the founder of Infosys Technologies. What did you talk about?

Peter Gruss: Narayana Murthy has distinguished himself not only as an entrepreneur, but as a philanthropist. That is why we talked about how we might expand cooperation between Germany and India with his support – for example through scholarships for doctoral students or the like. Whether we will profit elsewhere from contacts with Infosys – it is, after all, one of the largest IT firms in India, with over 100,000 employees – remains to be seen.
The IPP is in the fortunate position of being able to implement trial concepts at both its locations aimed at optimizing the magnetic field in a future fusion reactor: the Tokamak ASDEX upgrade at the IPP in Garching, near Munich, and the Wendelstein 7-X stellarator at its Greifswald site. “Sophisticated technology demands conceptual diversity,” explained Thomas Klinger, the head scientist in Greifswald. The members of the Federal parliament who visited a week later were also impressed by the scientific and engineering “work of art” that is growing on a daily basis. They promised political support by topping up the project funds for fusion research in Germany’s national budget. Germany’s fusion research institutes intend to use the money to carry out some initial projects in preparation for a demonstration power plant (DEMO) that is due to succeed the ITER trial reactor now under construction and supply fusion-generated power to the national grid for the first time. If everything goes according to plan, the existing coal-fired stations and nuclear power plants could be replaced step by step with clean, safe fusion power stations in the second half of this century. According to forecasts by the Energy Modeling Forum, there could be around 4,000 new power plants supplying a third of the world’s electricity by the year 2100.

Federal Chancellor Visits Greifswald

At the start of the Year of Science that focuses on the theme “The future of energy,” Federal Chancellor Angela Merkel visited the Greifswald branch of the MPI for Plasma Physics (IPP). Commenting on the work in Greifswald, she emphasized that, with this project, Germany is writing a new page in the history of fusion.

First Appointments Accepted in Florida

The Max Planck Florida Institute in Jupiter has filled three scientific posts.

Michael D. Ehlers of Duke University Medical Center will become Scientific Director and CEO. Professor Ehlers currently heads the Department of Neurobiology at Duke University, a private university in Durham, North Carolina. His research is devoted to the structure and connectivity of neurons in the brain. In addition, he is also concerned with the role played by neurons, for example in learning.

Samuel M. Young will head a research group focusing on the cellular and molecular mechanisms of synapse functions. He will be studying the highly specialized contact points in the brain via which neurons exchange electrical and chemical signals. Young most recently headed a research group in the Department of Membrane Biophysics at the Max Planck Institute for Biophysical Chemistry in Göttingen.

Jason Christie will head up a research group devoted to the physiology of synapses. Using electrical recording and imaging methods, he aims to discover how the transfer of information between two cells or within larger groups of cells is altered by temporary activity.

These new fields will complement the research work already achieved by the team headed by Bert Sakmann. The winner of the Nobel Prize for Medicine and his colleagues are working on a program intended to create a three-dimensional map of the brain. The various cell types are identified with special fluorescent markers so that the distribution of neurons can then be mapped and quantified. This work will form the basis for future studies of neurodegenerative diseases, such as Alzheimer’s.
Curiosos Por Las Ciencias – Curious about Science

With the Science Tunnel touring South America, all of the issues of MAX magazine are now available in Spanish.

The official opening of the Science Tunnel took place at the Palacio Pizzurno in Buenos Aires, the headquarters of the Argentine Ministry of Education, on March 8, 2010. In addition to the Argentine Ministers of Foreign Affairs, Science and Education, the ceremony was attended by President Cristina Fernández de Kirchner and Germany’s Foreign Minister Guido Westerwelle. The multimedia exhibition showcasing the latest in science and technology was open to visitors until April 20th. For more detailed background information, our MAX magazines were also made available: with active support from the German Academic Exchange Service DAAD, all of the BIO-, GEO- and TECHMAX issues published to date (a total of 40) were translated into Spanish and printed with the assistance of German businesses and Spanish scientific institutions.

MaxPlanckResearch on FSC Paper

Starting with this issue, the Max Planck Society’s science magazine is being printed on paper certified by the Forest Stewardship Council. The FSC was established in 1993 to promote sustainable forest development. The organization aims to achieve this goal not only through protection orders, but above all through responsible management. The FSC is an international not-for-profit organization based in Bonn with national working parties in 43 countries. It is supported by environmental organizations (including WWF, Greenpeace, NABU, Robin Wood), societies and numerous business enterprises.

On the Net

Lab Log
Science journalist Marcus Anhäuser, who also writes for MaxPlanckResearch, completed a laboratory internship at the Max Planck Institute for Molecular Cell Biology and Genetics in Dresden last year. He recorded his impressions and experiences in a blog (in German). Those wishing to learn more about such subjects as “Men in white coats,” “Meshugge microtubules” or “How to stick fission fungi back together” will find it here – amusement guaranteed:
http://www.scienceblogs.de/labortagebuch/

How Do We Know What We Know?
The Internet exhibition “Evidence” mounted by the Exploratorium in San Francisco offers a graphic explanation of how science works. It focuses on the work of the Max Planck Institute for Evolutionary Anthropology in Leipzig. The Institute studies the origins of mankind, for example by comparing the cognitive abilities of humans and other primates, seeking out the differences in the genomes of Neanderthals and Homo sapiens, and investigating the diversity of human speech. For a fascinating excursion into the working methods and methodologies of scientists, visit:
http://www.exploratorium.edu/evidence/

Expedition into the World of Energy
From May 20th to August 29th the island of Mainau in Lake Constance will offer knowledge hunters the chance to embark on a voyage of discovery. Scientific experiments, simulations and exciting exhibits all about energy will be housed in a total of 20 pavilions, including two designed by the Max Planck Society – one dedicated to material sciences within the field of hydrogen technology, the other devoted to fusion research. The exhibition “Entdeckungen/Discoveries” is a three-year series of events: last year the subject was “Water”. In 2011 the focus will be on research into the field of health.
http://www.mainau-entdeckungen.de/
A Continent Learns Democracy

Conflict, corruption, crime – these negative attributes have become clichés for Africa. The continent seems essentially unable to find peace. For years, the Max Planck Institute for Comparative Public Law and International Law has acted as adviser and intermediary in the process of restoring peace and constitutional rule in the Sudan. The institute is also involved in the constitutional process in Somalia. But how can an institution committed to research on the legal foundations of public authority help bring peace to countries like these? A report on work in progress.

TEXT JOHANNA MANTEL AND RÜDIGER WOLFRUM

Democracy? Dem all crazy!” railed the renowned, late Nigerian musician Fela Kuti once when BBC journalists, reporting on a demonstration in his homeland, asked for his opinion on elections in Africa. German observers, too, tend to shake their heads or resort to cynicism when they hear “democracy” and “Africa” in the same sentence. The public perception of Africa as a continent in crisis stubbornly persists. Whether wars, droughts or coups d’état; the vast majority of reports from the “Heart of Darkness” transmit catastrophes to the German public.

Africa is losing on all development policy fronts – and earning distinctions that are almost exclusively negative: the lowest standard of living, the shortest life expectancy and the highest crime rates, along with corruption, famine and economic paralysis, AIDS and civil war. Not to mention democracy. The annual Freedom in the World report by the American organization Freedom House, which analyzes the status of political rights and civil liberties in 193 countries, reveals a positive global trend. According to the regional report Freedom in Sub-Saharan Africa 2009, however, the continent is headed in the opposite direction.

While 46 percent of countries worldwide are classed as free, 32 percent as partly free and 22 percent as not free, the figures in sub-Saharan Africa are reversed, with just 21 percent described as free, 48 percent as partly free and 31 percent not free. Only 18 out of 53 countries on the African continent have democratically elected governments. Of the 17 countries worldwide classed as the most repressive – the worst of the worst – 8 are in Africa.

But what do these statistics tell us, and how does one actually measure democracy? Governmental and non-governmental agencies cooperating in international development are at pains to come up with meaningful assessment criteria. But these criteria are not without their detractors. One criticism is that the donor countries acknowledge only Western achievements, while ignoring the “unmeasurable” values of conflict, corruption, crime...
Going to the polls doesn’t always mean democracy. The election of Nelson Mandela as South Africa’s head of state in 1994 (center) was without a doubt one of the most successful examples of democratization. Robert Mugabe (right, at the election in the summer of 2008), in contrast, has ruled Zimbabwe as a dictator for years and driven his country into economic ruin. Senegal, on the other hand, is headed in a positive direction under President Abdoulaye Wade (left).
African societies. It thus seems important that appropriate indicators be found that also encompass other social advances.

The criteria by which the rule of law is measured, in contrast, are more straightforward. The Heidelberg-based Max Planck Institute applies concrete standards, such as guaranteed access to courts, the observance of human rights by administrative authorities, and the enforcement of judicial rulings. However, it also takes into account the traditional mechanisms by which disputes are settled without resorting to the courts.

Of course there are also definitive events that can serve as benchmarks for democratization – such as the first democratic elections in the history of South Africa on April 27, 1994. The overthrow of the apartheid regime, the introduction of elections and the establishment of functioning institutions in support of the rule of law make the country at the southern tip of the continent the most prominent example of successful democratization.

Overshadowed by South Africa, other democratic success stories are often forgotten. Zambia, for example, has been a multi-party democracy since the country held its first elections in 1991. Although the opposition parties were subjected to blatant threats at the polls in 1996 and the elections of 2001 suffered from serious administrative problems, the last vote in 2006 gave no cause for complaint.

In neighboring Malawi, the winner of the presidential elections in 2004 succeeded in thwarting his predecessor’s efforts to extend his terms of office, and was again victorious at the polls in 2009. From a democratic perspective, these countries, too, are positive examples. In the mid-1990s, it seemed as though democracy had gained a foothold. In addition to South Africa, the tyrannous regimes in Benin, Ethiopia, Liberia and Mali were brought to an end, and many others saw their supremacy under threat.

Opposition activists in Francophone Africa organized national conferences to call their state leaders and politicians to account for corruption and the use of force. Activists in Ghana and Nigeria intensified their campaigns for democracy. One-party systems, such as in the Ivory Coast, Kenya and Zambia, collapsed.

Today, however, the prospects are less bright again: civil war has split the Ivory Coast in two, and a precarious power-sharing compromise has prevailed since 2007. The president’s nominal term of office expired in 2005 and, after several extensions at the behest of the United Nations, elections were due in March 2010. This deadline was not met, and the country is currently again in the throes of bloody unrest.

Allegations of vote-rigging led to mass riots in Kenya in December 2007 and served to inflame ethnic conflicts. Extensive negotiations and mediation by former UN Secretary General Kofi Annan finally produced a coalition government that is still teetering on the brink of collapse as all sides continue to accuse each other of corruption.

So what is the democratic outlook for Africa? Has democracy failed in Africa? Or is it making slow gains? The question is not easy to answer. Of course there are undisputable successes, as in Ghana, Mali and Senegal, where opposition parties and coalitions with popular support have triumphed in multi-party elections. But there are also still plenty of examples of failed attempts at democratization, like the bloody conflict in the Democratic Republic of Congo, the failure to bring government to Somalia, Mugabe’s tyrannical rule in Zimbabwe, or the conflict in Darfur that constantly threatens to spill over into neighboring states.

Above all, it is a question of differentiating, of considering the entire spectrum of possible developments – from Senegal’s long-established multi-party democracy to the creation of functioning institutions in support of the rule of law in Mali and Benin and the democratic facades in Ethiopia and Guinea to states such as Ivory Coast and DR Congo, which are threatened by war. A thorough analysis of the widely differing processes in different countries is of the
essence. Against this backdrop, the discussion of potential reform of Germany’s development cooperation effort leading to the formation of “focal countries” is to be welcomed.

Irrespective of the answer to the question posed above, the negative cliché of Africa as a continent of crisis and catastrophe is harmful. To take this view is to stigmatize all 53 African nations as one, regardless of their differing cultural traditions and political development; it ignores the fact that the most fundamental conditions vary in the extreme from one country to the next. As a result, the entire continent has come to be seen as an annoyance, and even experts on Africa regard any improvement as impossible.

This image is also widely perceived among political decision makers; there are few votes to be won with policies on Africa. Even at the level of international power politics, there would appear to be no advantage to be gained from a commitment to Africa. The continent has no priority in foreign policy terms. By comparison, countries and regions such as Iraq, Afghanistan, Israel/Palestine and the Balkans are always more pressing.

Many of the fundamental problems of the African countries derive from their division along former colonial lines. The members of the African Union accept the uti possidetis principle (the retention of stable borders in the aftermath of armed conflict), thus preventing many more disputes between states. However, the fact that these borders fail to account of ethnic distributions has led to many violent and bloody civil wars.

The Cold War, too, has left its mark on Africa. Dictatorships were largely the product of the conflict between East and West, which impeded the formation of healthy political and economic nationalism. Most African countries are grappling with the legacy of their former clientelistic structures. Their political systems are generally afflicted by fundamental problems that obstruct the rule of law. Their institutions of state are marked by the dominance of the executive branch. Political power is widely seen as a personal possession unlimited in time or reach.

Institutions that support the rule of law, primarily parliaments, remain largely powerless and often fail to exercise their political control functions simply for lack of material and human resources. In some cases, the lack of control over the executive is compensated for by the extensive jurisdiction of a constitutional or supreme court. However, this leads to the problem of democratic legitimacy.

A definitive increase is required in democratic checks and balances. Parliaments must be enabled to play a stronger role. In Somalia, for example, the Max Planck Institute is supporting the creation of a parliamentary system. In advance of the upcoming elections in the Sudan, the institute is currently providing training in electoral law and is actively advising on legislative issues in both the north and south of the country.

In doing so, the institute team is able to build on existing structures. Customs and traditions should not be ignored. There may not have been such things as constitutions in pre-colonial Africa, but there were social structures that made governing regimes accountable to the people. The kings of the Oyo Empire, which encompassed present-day Benin, Nigeria and Togo, were, for example, obliged to abdicate or commit suicide if the council of elders so decided. The Ashanti rulers, too, whose territory occupied today’s Ghana, could be deposed by their subjects.

Functioning structures based on customary law exist even today in many African countries. In South Africa, for instance, the traditional chiefs are recognized by the constitution and integrated into the country’s legal system. A chief’s decision is legally binding and can be contested in a court of law. The institute thus intensively studies and analyzes structures based on custom, and uses the results of this research in implementing its projects. An administrative system closely based on local structures is expedient for Somalia’s segmented society. In the Sudan, it is a question of integrating the existing web of traditions into the country’s legal system.

> Political power is widely seen as a personal possession
The constitutional commission established for the interim constitution and appointed by the interim government in 2007. The institute is concerned with the integration of the specific social, cultural, political and religious needs, as well as the interests of the Somali participants in the constitutional debate. As co-determination and inclusivity are among the basic prerequisites for any successful constitutional process, it is essential for the Somali people themselves to draft their future constitution. The institute’s Africa team is thus actively supporting the process – without imposing political structures. At the same time, they also advise on the standards of human rights and democratic legitimation that will enhance the sustainability of the constitutional process and its capacity to bring peace.

Particularly in so-called post-conflict countries, it is a matter of the greatest urgency to resolve issues of fairness and justice, the reintegration of refugees and arguments over land. In countries that already possess established governmental structures, it is also important to introduce judicial processes by which citizens can assert their legal rights against the state. Defects and abuses, such as a lack of enforcement mechanisms, vigilantism and the mistreatment of alleged offenders, unfair trials, corruption among the judiciary and other organs of government, are widespread. Solutions to these grievous problems must be sought on various levels.

On the one hand, the structures of the state need to be strengthened – in a process that must necessarily be accompanied by intensive support for the rule of law. German and European development policies often lack concrete goals for this. Issues of good governance are given preference over strengthening democratic institutions and protagonists. The rule of law and the certainty of the law must first exist if human rights are to be observed and populations given the opportunity to participate. In this respect, an evaluation of the support for democracy provided by the EU from 1995 to 1999 also calls for more funds to be devoted to establishing institutions and fighting corruption rather than simply observing elections.

The new guidelines for German foreign aid policies state that “future development projects sponsored by Germany must be more closely oriented toward...
the assertion of human rights.” In reality, however, there is all too often a lack of coherence between mandate and implementation. The intention is that human rights should form the normative foundation of German development cooperation, yet this aim is contradicted by the activities directed by those with an investment interest, such as the Federal Ministry of Economics.

All too often, the decision about whether to grant further development aid is also isolated from the issue of compliance with the principles agreed with partner countries. Sustainable action is needed: the observance of human rights and the success of development cooperation projects are closely intertwined. Commitment in Africa requires an assertive and, above all, patient approach. Most African countries are not lacking in initiative or the ability to innovate. What they do lack are the necessary legal, political and economic conditions to allow their individual powers of innovation to unfold.

This is where the Max Planck Institute for Comparative Public Law and International Law has a part to play. Practical experience over many years proves that – thanks to the institute’s neutrality and acknowledged objectivity – its contribution is in demand. Conversely, this commitment to foreign countries with independent legal cultures of their own enriches the scientific work of the institute.

Incidentally, despite his comment, Fela Kuti, who was quoted earlier in this article, was not disenchanted with politics. On the contrary, he was a dedicated human rights activist whose song lyrics frequently contained direct attacks on African dictatorships and in particular on the military rulers of Nigeria in the 1970s and 1980s. His opinion of democracy did not prevent him from standing as a presidential candidate in 1979 in the first elections Nigeria had seen in a decade.

Above all, commitment in Africa requires patience

THE AUTHORS

Johanna Mantel, born in 1980, has worked at the Max Planck Institute for Comparative Public Law and International Law in Heidelberg since 2008. Originally, she advised the Somali constitutional commission as a member of the institute’s Africa Team, and she has also been involved in the Darfur dialogue. She is currently working on the institute’s Iraq Rule of Law project. In addition to her project work, she is conducting a PhD project on the subject of “The reservations of Islamic states on international human rights treaties,” supervised by Rüdiger Wolfrum.

Rüdiger Wolfrum, born in 1941, is a Director at the Max Planck Institute for Comparative Public Law and International Law in Heidelberg, and served as Vice President of the Max Planck Society from 2002 to 2006. Professor Wolfrum was also a member of the UN Committee on the Elimination of Racial Discrimination for ten years, President of the International Tribunal for the Law of the Sea and Chairman of the German Society of International Law.
Water with a Nebulous Effect

To date, all climate models still suffer from one thing: they are not good at taking into account how global warming affects clouds and, conversely, how changes in different types of clouds inhibit or contribute to the observed warming. **Bjorn Stevens**, Director at the Max Planck Institute for Meteorology, is shedding light on these interactions.
According to René Descartes, they formed God’s throne: clouds. The French philosopher also considered the flowing and temperamental shapes of the fluffy weather phenomena to be the ultimate litmus test for human cognitive powers. Those who understand clouds, wrote the originator of rationalist thinking in the 17th century, would have the means to explain all things wonderful on Earth.

Descartes’ words on the significance of understanding clouds thus remain topical, at least as far as climate research is concerned. For the science that deals with the Earth’s atmosphere, it really does turn out to be a litmus test. The floating mists play a dual role in the Earth’s climate: they cool the surface by reflecting sunlight into space and, at the same time, they warm it by preventing infrared radiation from escaping from the Earth’s surface into space. This two-faced quality makes it more difficult to forecast whether changes to the cloud cover caused by the climate slow down global warming, accelerate it, or do neither. The only thing that is clear so far is that even a small change in the cloud cover can make the forecasts of the climate models obsolete.

“If the cloud cover were to change by a mere five percent or so as a result of climate change, this could cancel out the effect of a doubling of the...
Clouds act to warm the atmosphere. Low-level clouds, on the other hand, emit almost as much heat radiation into space as the Earth’s surface below, which isn’t much warmer. This means that they greatly impact the rate at which the Earth radiatively cools. But low-level clouds are more compact than the veil-like cirrus clouds at that altitude, and they reflect more sunlight into space than would the underlying surface.

“in order to be able to calculate the role clouds play in climate change, we need to know how the occurrence of the high-level and low-level cloud types changes,” says Stevens. The fundamental question is: How do the different types of clouds react to changing conditions in their environment, such as changes in temperature or humidity? If high-level and low-level
Clouds increase equally, the two effects could offset each other, resulting in little net heating or cooling of the surface. If, however, the high-level clouds were to increase and low-level clouds decrease, the temperature of the Earth’s atmosphere would increase more strongly than would be caused by the carbon dioxide increase alone.

Clouds also consist of components of different sizes. The smallest floating cloud droplets just manage to reach a diameter of one hundredth of a millimeter, a falling raindrop measures more than one millimeter, and the air eddies of the turbulences in clouds exhibit diameters ranging from one millimeter to around one hundred meters.

A complete cloud can extend for kilometers; cloud fields can even stretch across hundreds of kilometers. Finally, large-scale moisture cycles cover distances of several thousand kilometers.

“The effect of entrainment can also be global. If clouds over the frequently cloud-covered southeast Pacific Ocean disperse, for example, the Sun’s irradiation on this part of the ocean increases and it becomes warmer – a development that has the potential to contribute to seemingly unrelated phenomena, such as El Niño. “Before we can forecast such climate phenomena as El Niño with certainty, we have to understand many details of cloud physics, including how strongly the entrainment in the southeast Pacific Ocean contributes to the dispersion and evaporation of clouds,” says Stevens.

The task of cloud researchers is made even more difficult by the fact that processes like entrainment are not explaining the difficulties of the undertaking. The trick is to investigate part and whole together by jumping back and forth between them.

The scientist illustrates the link between “very small” and “very large” with turbulent air currents, which are assumed to be decisive for the lifespan of clouds. Aircraft passengers often feel them when the plane shakes. At the edges of a cloud, the turbulence mixes the dry, clear surrounding air with moist cloud air. Atmospheric scientists call this mixing entrainment. The dry air mixed into the cloud affects the water droplets in the cloud. It can change the distribution of their size so that more extremely small or extremely large droplets are formed, which in turn affects the tendency of a cloud to give rise to rain. However, the entrained dry air can also cause the water droplets to evaporate and thus dissipate the cloud.

Entrainment occurs on a practically microscopic scale when compared with the size of clouds: the air eddies involved have diameters of between a few millimeters and a few meters. The effect of entrainment can also be global. If clouds over the frequently cloud-covered southeast Pacific Ocean disperse, for example, the Sun’s irradiation on this part of the ocean increases and it becomes warmer – a development that has the potential to contribute to seemingly unrelated phenomena, such as El Niño. “Before we can forecast such climate phenomena as El Niño with certainty, we have to understand many details of cloud physics, including how strongly the entrainment in the southeast Pacific Ocean contributes to the dispersion and evaporation of clouds,” says Stevens.

The task of cloud researchers is made even more difficult by the fact that processes like entrainment are not

The fundamental question is: How do the different types of clouds react to changing conditions in their environment, such as changes in temperature or humidity?
of equal importance for all cloud types. Each cloud type must therefore be investigated individually.

**CUMULI COVER LARGE PARTS OF THE OCEANS**

Stevens is focusing his efforts on certain types of low-level clouds over the tropical and subtropical oceans. These are widespread and therefore particularly important for the climate. Moreover, Stevens thinks they are relatively easy to understand, as they contain no ice. Ice complicates the cloud problem enormously: depending on the temperature and air humidity, ice crystals form very different structures, ranging from snowflakes, ice needles and platelets to sleet and hailstones. And different ice forms have a different effect on the formation of precipitation.

Stevens has been studying one type of low-level cloud for many years: marine stratocumulus clouds, which cover more than one tenth of the ocean expanse and are thus relevant for the climate. This type of cloud forms over cold sea regions of the subtropics, such as off the Californian and South American Pacific coast and the Atlantic coastline near Namibia. In these regions, there is a layer of cool moist air around 900 meters thick under warm dry air. Directly below the boundary between cold and warm air, a closed blanket of densely packed convective clouds often forms – the stratocumuli.

Stevens has investigated the entrainment of these clouds. For decades, meteorologists wondered whether specific processes could spontaneously break up the marine stratocumuli. They assumed that the entrainment self-amplifies under certain circumstances, like a chemical reaction that produces its own catalyst. This would mean that the dry zone, driven by the entrainment, grows relatively quickly into the cloud from above and thus evaporates it.

Before Stevens’ research, estimates of the efficacy of such a process were very uncertain, with estimated rates of drying varying by an order of magnitude. Stevens therefore decided to recheck the measurements. Eight years ago, when he was still a professor at the University of California in Los Angeles, he used an old military transport plane, equipped with instruments for measuring quantities of meteorological interest, to fly into the stratocumulus clouds off the California coast. The measurements formed the basis for a computer model of the turbulence at the edge of the cloud. This model narrowed the uncertainty by more than a factor of five, and ultimately revealed that the mixing progresses “too slowly for the entrainment to be able to disperse the stratocumuli spontaneously,” explains Stevens.

Even if the entrainment does not suddenly wipe stratocumuli from the sky, satellite images nevertheless show curious “holes” in otherwise solid decks of clouds. The phenomenon is astonishing: seen from above, the clouds form a grainy surface, reminiscent of a multicellular organism. The white cells – the clouds, which can measure 5 to 50 kilometers in one direction – are framed by dark edges where the clouds are thin or absent and the ocean lying below is apparent. At some places, in the center of the blanket of cloud, the pattern is reversed: the cells appear dark with white edges. This is where the clouds in the inside of the cells have disappeared; instead, some have formed at the edges of the cell that had previously been cloud-free – as if one were looking at the negative of a photograph of the original pattern. Measurements from Stevens’ airborne mission showed that the stratocumuli, which normally do not tend to cause heavy rain, rained at the transition to this negative pattern.
Clouds always form when warm, humid air rises. The process explains how fusing water droplets can ultimately reverse kilometer-long air currents.

Stevens explains why they do this as follows: The generally thin stratocumulus cloud layers can thicken due to a local accumulation of moisture, and thicker clouds produce larger drops and thus rain easily. Larger drops fall more effectively through a background of small cloud droplets, as they experience less air resistance relative to their mass.

**RAIN REVERSES UPWARD AND DOWNWARD FLOWS**

These larger cloud drops fall through the cloud, catching up and colliding with smaller droplets below. They coalesce with some of these droplets, become larger and fall even faster. A type of snowball effect occurs, and the droplet grows to a million times its original mass. Sufficiently large drops fall so quickly that they reach the surface of the ocean as raindrops without evaporating again. This is particularly easy in thicker clouds, as they offer the droplets a relatively great height of fall, which gives the proto-raindrops more time to collect cloud droplets on their way down.

The rain from the low-reaching clouds is not without consequences: computer simulations that Stevens undertook with his former doctoral student Verica Savic-Jovcic showed that, when it rains, the circulation of the moist air between the ocean and the cloud layer can change radically. Non-raining clouds are dominated by a strong upward flow in the center of the cell, with weak downward flows at its edges. Afterwards, it reverses: there is a strong downward flow in the center and weak upward flows at the edges. This reversal of the flows causes the original pattern of the cloud blanket to turn into its negative, because clouds form more readily when warm, humid air rises. The process explains how fusing water droplets that cannot be seen with the naked eye can ultimately reverse kilometer-long air currents.

Now that Stevens and his colleagues have gained a better understanding of the stratocumuli, they are taking the next step. “We are currently incorporating the results into the global climate models,” says Stevens. These computer models divide up the atmosphere into grid boxes – pancakes, really, as their length and width measure several hundred kilometers and may be hundreds of meters to a kilometer thick. For each of these boxes, the computer calculates average values of temperature, humidity and other characteristics of the atmosphere.

Since clouds are typically much smaller than a grid box, they slip through this grid, which is to say that the climate models fail to simulate them explicitly. The researchers cannot use smaller grids, as this would increase the computing time to immeasurable proportions. However, when researchers have understood the physical processes in the individual types of clouds, they can make do. They may still not be able to calculate the exact locations in the grid where the individual clouds will form, “But the statistics of the cloud distribution can be calculated on the basis of the average values of parameters like temperature and air humidity, which the computer model computes,” says Stevens. It is then also possible to say what percentage of the grid volume is filled with...
Thus fuse more often and ultimately produce more droplets that are heavy enough to fall; in doing so, they collect more small droplets and finally become drizzle, and then raindrops. Computer simulations have shown that turbulence increases the frequency of droplet collisions by a factor of more than four. “So the cumuli can form rain somewhat more easily than we had thought,” says Stevens.

Stevens doesn’t want to investigate the low-level cumuli only via computer. His office at the Max Planck Institute in Hamburg contains visible evidence that his research rests on two pillars: equations and sketches cover a board on the wall. Directly next to it, on a side table between a group of chairs, is a model of the HALO research aircraft, whose turbulence probe stretches into the sky from its nose. The German Aerospace Center manages this vessel for the German research community (see box, page 27). Stevens uses a combination of theory and fieldwork. On a mission that Stevens is organizing, HALO will soon fly through fair-weather cumuli off the coast of the Caribbean island of Barbados, using various instruments to measure droplet sizes and turbulence.

**THERE IS NO UNIVERSAL FORMULA FOR CLOUDS**

On the island itself, the Max Planck researchers are joining forces with researchers from the Caribbean Institute for Meteorology and Hydrology in Barbados, the University of Miami and the Leipzig Institute for Tropospheric Research, and are in the process of installing remote sensing instruments: radar instruments and a special laser for measuring humidity and aerosol layers. Their purpose is to target the clouds coming in from the open sea. “The data will help us explain the relationships between cloud cover, precipitation, the aerosol and the properties of the air surrounding the clouds,” says Stevens.

The cloud researcher is not only very optimistic about this measurement campaign, but also about the future of cloud research as a whole. "We..."
will learn far more about clouds in the next 25 years than we have learned over the last 25 years,” he says, visibly pleased. The observation techniques were developed during the last quarter of a century. “Now we are using them.” Satellites have since been able to produce three-dimensional images of clouds and their interior with the help of radar and laser beams. In addition, the increasing computing power of computers has been making it easier and easier to simulate physical processes simultaneously on an increasing number of dimensional scales – of course only after the relevant processes were understood.

**CLOUD RESEARCH IS LIKE A JIGSAW PUZZLE**

But Stevens does not believe in a kind of universal cloud formula: “I don’t believe there is such a thing as a general principle that uses a couple of mathematical symbols to explain the complete physics of clouds,” says Stevens. He compares cloud research with cancer research. “Medical researchers used to believe there was a general mechanism that can explain cancer. Now we know that each type of cancer needs to be researched on its own,” says the scientist. It’s a similar situation with clouds: each type of cloud must be understood for itself. The fact that entrainment does not work efficiently for the marine stratocumuli, for example, does not necessarily mean that the same goes for other cloud types. Cloud research thus resembles a jigsaw puzzle: the greater the number of pieces that are filled in, the easier it is to see the whole picture.

Bjorn Stevens agrees with Descartes’ statement that clouds provide the key to understanding the whole world – but with a few reservations. The processes in the Earth’s atmosphere can indeed be understood only by those who penetrate the clouds. But not much more – and he adds: “If I ever succeeded in completely understanding the clouds, I would probably still find it difficult to understand some of the decisions made by politicians.”

**GLOSSARY**

**Low-level cumuli**
Cumuli clouds at altitudes up to 2,000 meters above sea level. These fair-weather clouds cover up to 40 percent of the oceans.

**Marine stratocumuli**
A blanket of low-level cumuli that occur above cold subtropical oceanic regions and cover around one tenth of the oceans.

**Entrainment**
The process by which turbulence at the cloud edge expands into the cloud-free region, mixing moist cloudy air and dry air from the surroundings and evaporating the cloud. This process encompasses scales between millimeters and hectometers.

**El Niño**
Is based on a reversal of the normal ocean circulation between Indonesia and Peru and occurs at irregular intervals around Christmas time (El Niño (Span.) = Christ child). Extremely warm water from Indonesia thus reaches Peru, causing plankton to die off and the food chain to collapse. Since the climate is coupled to the ocean circulations, El Niño influences the weather in many parts of the world.
Aerosols are the salt in our climate soup. Meinrat Andreae and Stephan Borrmann from the Max Planck Institute for Chemistry are studying the impact of aerosols – tiny particles in the atmosphere – on clouds and precipitation.
On the drive to the Max Planck Institute for Chemistry, it feels like something is missing. Not a single cloud is to be seen in the spring sky above the campus in Mainz. The natural phenomenon to which climate scientists Meinrat Andreae and Stephan Borrmann devote their scientific attention is making itself scarce today. Andreae is Managing Director at the institute and head of the Biogeochemistry Department. A chemist by background, Andreae travels around the globe with his research team on a quest to find the last remaining regions with a primordial, pristine atmosphere untouched by the impact of human activity. When he finds one of these places, he studies how fine, naturally occurring particles, known as aerosols, affect clouds and precipitation – in other words rain, sleet, hail and snow. What he is doing is basic research, but a precise knowledge of the untouched climate also helps in understanding whether and how anthropogenic activity is changing it.

With him at the table is Stephan Borrmann, also a Director at the Max Planck Institute in Mainz. As head of the Particle Chemistry Department, he, too, examines the role of aerosols in the climate system. Borrmann’s research department is also an institution of the University of Mainz, where he holds a professorship at the Institute of Atmospheric Physics. His group
has the world’s only wind tunnel in which scientists can study the behavior of individual water drops and ice crystals under the conditions that prevail in clouds. Like Andreae, Bormann also takes his team and equipment on round-the-world trips. Both teams use research aircraft – a kind of flying laboratory for climate scientists. Both groups also cooperate with colleagues from the Max Planck Institute for Meteorology in Hamburg (see “Sahara Dust over Barbados”, page 27).

Andreae’s group is particularly interested in how clouds form in pristine air, such as that above the Amazon rainforest. Members of Bormann’s team, for their part, are looking into the kind of gigantic clouds that churn in the skies above the equator. They thus travel predominantly to the tropical zones of Africa and Australia, where cumulus cloud stacks reach as high as 18 kilometers into the sky, compared with the maximum of 12 kilometers in our latitudes. Enormous weather systems with trade winds and monsoon rain are generated in the wide belt around the Earth’s equatorial girth. “You could say this is where the Sun’s energy comes crashing into our planet,” explains Bormann. “And part of that energy then spreads throughout our atmosphere.”

Clouds still represent big white spots on the meteorological and climatological map. Scientists understand the basics, such as how clouds form and how they create precipitation. However, the enormously complex processes inside them that dominate the weather and, from a long-term perspective, the climate, is something that has thus far defied precise observation. The problem is that scientists and their instruments are unable to get inside many of the most interesting clouds – especially not in aircraft. Severe turbulence with wind speeds well in excess of 200 kilometers per hour and hailstones the size of hens’ eggs would make any such attempt an act of suicide. Even the use of unmanned drones or weather balloons is too expensive due to the high risk of loss. And indirect, remote sensing meth-
ods, particularly those involving radar beams, do not – yet – provide a very precise picture of the swirling drops and ice crystals inside the clouds.

“A small thundercloud measuring ten by ten by five kilometers contains half a million tons of liquid water, finely dispersed in the form of mist,” explains Borrmann. “A lot can happen in the interior and on the surface of a cloud like that.” In addition, there is a huge amount of energy raging inside such a compact thundery cluster – easily the equivalent of a dozen small nuclear bombs. As Borrmann observes: “In my view, clouds represent the largest screw holding the climate system together, but they are also the phenomenon we know the least about.” And this has serious consequences for weather forecasts: today’s computer models are still notoriously inaccurate at predicting where and when precipitation is going to fall.

FLOATING PARTICLES CREATE CLOUDS AND PRECIPITATION

Even models of future climate development consider the effect of clouds only in very rough terms, even though clouds play a crucial role in what goes on. The models have great difficulty predicting how global precipitation distribution will shift as a result of global warming. “These changes will be at least as serious for mankind as the change in mean temperature,” says Andreae.

Clouds are multilayered. The lowest layer of the atmosphere, the troposphere, is where the weather actually brews. Clouds in this layer consist of droplets, a growing quantity of which freeze with rising altitude. Above them there are wispy cirrus clouds consisting of fine crystals of ice. In the next layer up, the stratosphere above 12 to 18 kilometers, there is a huge gap in the clouds. Only between 75 and 90 kilometers into the atmosphere, in the mesopause, do we find clouds again – in an extremely thin veil of ice.

SAHARA DUST OVER BARBADOS

The big cloud systems over the tropics are especially interesting from a climatological perspective. That is why the Max Planck Institute for Meteorology in Hamburg has embarked on a two-year field campaign in Barbados with a group led by Björn Stevens. Their aim is to study the interplay between aerosols, clouds, precipitation and the climate. They are accompanied by the two teams from Mainz headed by Meinrat Andreae and Stephan Borrmann.

Barbados is particularly interesting as it is among the easternmost islands in the Caribbean. When the trade winds blow across the Atlantic from the east in the early summer, they carry almost exclusively natural aerosols with them – above all Sahara dust. At other times of the year, the winds blow in different directions. Then they may carry with them, for instance, soot released by humans burning biomass. Under these circumstances, scientists can use the large-scale weather patterns that vary with the seasons to study how clouds and precipitation behave in their undisturbed state and how mankind influences them.

The measuring instruments have been set up on two peninsulas at the far east of Barbados so that anthropogenic influence is virtually excluded when the weather patterns come from an easterly direction. The remote sensing equipment includes laser systems that screen the atmosphere for water vapor content and aerosols. There is also a cloud radar.

In addition, the HALO research aircraft, operated by the German Aerospace Center (DLR) and partly financed by the Max Planck Society, will fly over Barbados taking measurements. “Spies in the sky” complement the program: the so-called A-Train consisting of six NASA research satellites crosses the skies above Barbados as well. Climate scientists are hopeful that the elaborate system of measurements will deliver precise knowledge about aerosols, clouds and precipitation in the important equatorial region. This should then allow the simulation of more precise computer models of climate development.
All clouds have one thing in common: neither they nor precipitation would exist if there were no dust from natural or anthropogenic sources in the air. Aerosols are the salt in the climate soup, and the Sun is what powers the stove to cook it. The Sun heats the ground and the surface of the water in lakes and oceans, making the water evaporate. The rising vapor would really like to condense into liquid water in the colder air at high altitude – but there is never enough natural humidity to form stable water droplets out of the invisible water vapor. It is only when aerosols come into play that the water molecules have a suitable place to land. Thus, an envelope of water can form around a particle: a little droplet is born. If the temperature falls below about minus 15 degrees Celsius, as it does higher up, the droplet would freeze into an ice crystal.

**THE SIZE OF THE PARTICLES DETERMINES THEIR IMPACT**

Bormann explains what happens in detail. Actually, it is not unusual for several molecules of water to come together accidentally and form a cluster even without the presence of aerosols. However, these tiny structures measuring just a few nanometers – millionths of a millimeter – are at high vapor pressure: they cannot withstand the molecules’ heat-induced urge to move, and they break apart. It is only when droplets get bigger that the forces between the molecules and on the droplet surface are sufficient to bind the clusters of water molecules together. But a cloud droplet in the Earth’s atmosphere does not reach this kind of physically stable size unless it has an aerosol particle as its nucleus.

Human activity is accompanied by soot, dust, organic particles, sulfuric acid droplets and other fine particles. Over densely populated areas, there are at least a hundred times more aerosols in the air than there were before our ancestors learned how to make fire. But even back then, there were clouds and it rained. That is because sea salt is one of the natural aerosols that act as cloud seeds. The wind draws it out of the oceans in droplets of spray and then dries the droplets to form fine salt particles on which vapor can later settle.

Saline particles also reach the atmosphere over land, as do desert dust, sulfuric acid droplets, mineral dust and, occasionally, soot from forest fires caused by lightning bolts and volcanic eruptions. Even plants increase the presence of natural aerosols by releasing organic vapors, such as the terpene molecules from coniferous forests, whose oxidation products stick to fine particles in the air. And even fungal spores can be found among the aerosols.

Instructions for the pilot:
Meinrat Andreae outlines the flight profile for a measurement flight in the Amazon.
Chemical differences have very little impact on whether the particles form clouds, says chemist Meinrat Andreae – which surprised even him: “When I began this research, I was looking for a lot more significant effects from the chemical variability of the aerosols.” What is most important is the size of the particle: from about 60 to 80 nanometers in diameter and larger is the size at which a particle becomes active as a cloud seed. “Interestingly, it turns out that particles from different sources display similar cloud-forming properties if they are the same size,” explains Andreae.

Cloud droplets also do not simply swell into actual rain drops by absorbing water vapor as soon as they have reached a few micrometers – thousandths of a millimeter – in diameter. “The growth of a cloud droplet can be nicely reproduced in the lab,” says Borrmann. “If you spray water on a window pane, you will have a two-dimensional cloud,” explains Borrmann. If you then spray more droplets of water on top of this mist, some of the fine droplets merge into heavier drops. They begin to run down the window pane. “And your two-dimensional cloud is raining,” says Borrmann. It is very similar with real clouds: droplets that become slightly heavier by chance fall downward, colliding with other cloud droplets on the way and assimilating them. That is how they swell to the size of a raindrop.

However, this vivid experiment masks a fundamental difficulty: the exact mathematical description of this collision-coalescence process delivers equations that are solvable only by approximation. Minor errors are unavoidable, and they can have major effects in cloud simulation programs. “Besides the difficulties in describing cloud turbulence mathematically, this is one of the main reasons why computerized clouds still don’t rain correctly,” explains Borrmann: “It is actually very hard to accurately predict just when and how any kind of precipitation is going to fall.”

Things are no less complicated when a raindrop finally does fall, which it does at speeds of up to 35 kilometers per hour. In order to observe exactly what happens here, the scientists would need to plummet downward with the raindrop. Or they could turn the whole thing upside down by blowing against the drop from below with an artificial updraft keeping it suspended against the force of gravity. And that is exactly what the world’s first vertical wind tunnel does. Borrmann’s group operates the tunnel, which can even precool the air to minus 30 degrees Celsius in order to study how cloud ice – in other words sleet, snow and hail – is formed.

A few years ago, the scientists in Mainz were able to use the tunnel to

In a pristine atmosphere (top), large raindrops quickly form and soon rain down. Only a small portion of the cloud droplets rise, whereupon they freeze and drift away. In a polluted atmosphere (bottom), the vapor finds many aerosol particles, which means it forms only very small cloud droplets that rise to high altitudes and freeze while they are up there. Additional vapor then condenses on the ice crystals. This is how energy-filled thunderclouds are formed, which bring heavy precipitation.
The aerosols’ role as condensation seeds is crucial in this atmospheric steam engine. They are what determine when and where it rains.

discover how a raindrop behaves as it falls. The drop is deformed into a kind of mushroom shape in the air stream and begins to oscillate. “This happens as a result of turbulence or collision with other drops or aerosol particles,” explains Borrmann. Eventually the oscillation becomes so strong that the drop bursts apart.

Surprisingly, this always results in two smaller drops, as the Mainz-based scientists demonstrated. They even described in precise mathematical terms how the drops oscillate. As Borrmann says, “Our goal is to enable computer modelers and radar meteorologists to incorporate more precise formulas in their models or measuring instruments and thus improve the accuracy of their forecasts.”

In nature, a raindrop seldom reaches the ground on its first fall. Updrafts send it soaring back into the heights, then it falls again – often freezing and then partially thawing in the process. That is why large hailstones have the internal appearance of onions if you cut them open. Cloud droplets and ice crystals experience similarly rapid ups and downs, too, sometimes even evaporating completely.

Given the complexity of these processes, it is no wonder that scientists have been arguing for years over whether aerosols released by human activity have an effect on clouds and precipitation levels. Recently, Meinrat Andreae and fellow scientists from the University of Jerusalem developed a model that facilitates for the first time a deeper understanding of the aerosol mechanism in clouds.

RAIN FALLS MORE QUICKLY IN PRISTINE AIR

“In our model, we look at a cloud as a kind of steam engine,” explains Andreae, smiling. When the Sun evaporates water from the ground, the vapor carries a large part of the solar energy with it as it rises into the air. When it condenses on a cloud seed in the cooler air at high altitude, the energy stored in the vapor is released as latent heat. Just like in a steam engine, the heat is converted into kinetic energy, in this case air circulation. This drives the updraft and causes the cloud droplets and ice crystals to climb.

In this atmospheric steam engine, the aerosols play a crucial role as condensation seeds. They determine when and where it rains. The pristine air above the Amazon rainforest contains very few particles. The sunlight thus penetrates almost unfiltered right down to ground level and evaporates a great deal of water. However, the vapor finds only a few condensation seeds in the air. Consequently, very large drops form while the vapor is rising, which soon rains down heavily on the virgin forest once again.

However, where air pollution causes increased aerosol concentrations, cloud formation and precipitation distribution can change dramatically. The model developed by Andreae and his Israeli colleagues delivers a convincing picture of this. As air pollution levels grow, the rising vapor finds more aerosols that can act as condensation seeds. As a result, more but smaller cloud droplets form, which slows the formation of raindrops. The cloud thus does not rain down on its point of origin, but continues to rise higher. The falling atmospheric pressure causes the rising air to expand and cool down, as in a cooling aggregate. More water then condenses on the cloud seeds and some of them freeze to form ice crystals. Condensation, for its part, releases energy and drives the atmospheric steam engine even more intensely.

As the aerosol concentration rises, another important attribute of the aerosols comes into play: they screen out more and more of the Sun’s radiation and prevent it from reaching the ground, causing less water to evaporate. In extreme cases, this can even inhibit the formation of clouds and precipitation entirely. The water vapor that remains then drifts away from the cloud’s point of origin rather than raining down upon it.

MORE RAIN, BUT WHERE?

Andreae thus has a scientific explanation for why a thick pall of smog can form over major forest fires or densely populated areas without any rain falling to the ground. “In China there has been a major shift in precipitation frequency, and the cause of this is thought to be the increase in aerosol pollution over northern China,” explains the chemist, adding, “But on a global scale, there is always as much precipitation coming down as there is water evaporating.” It just rains elsewhere. In those places, the clouds, full to overflowing, empty their contents in the form of devastating heavy rainfall, which can cause floods, landslides and mudslides.
Such extreme weather events could well become more frequent as the march of global warming continues. Like a steam engine that runs faster when the fire burns hotter, the movement of the air and the circulation of water would also accelerate in the atmosphere. “A warmer world is also a wetter world,” says Andreae, “But a faster water cycle does not necessarily mean there would be more water available for agricultural use.” After all, water also evaporates out of the ground more quickly when temperatures are higher.

So the role of aerosols in the climate is complex. Despite the breakthrough with the new model, which Andreae helped bring about, scientists are not even close to deciphering all of the precise mechanisms involved in the formation of clouds and precipitation. What is more clear-cut, though, is the impact of aerosols in blocking out sunlight: they have a net cooling effect on Earth’s climate. So would dirtier air be a good thing in the face of impending global warming?

“Some people reason that we should let the chimneys smoke to slow global warming,” says Andreae. “That is not only unethical, it is also complete madness!” As he points out, “With aerosols, we might be able to reduce global warming by a degree or two, but that is as far as it goes.” In contrast, the effects of manmade greenhouse gases, some of which remain in the atmosphere for centuries or longer, add up over the long term. It is impossible for aerosols to counterbalance that, given that they disappear from the air within a week or two anyway. “And the idea of cooling the Earth by injecting aerosols into the stratosphere, a process known as geoengineering, would mean playing a risky and irresponsible game with the future of our children and grandchildren,” says Andreae.

Meinrat Andreae and Stephan Borrmann have a clear message for the politicians. They have no doubt that we have already turned the climate’s heating controls up dangerously high. Andreae believes that current computer models on climate development have probably underestimated the warming effect of greenhouse gases – for lack of good cloud models. “The targets that the scientific world has communicated to politicians are pretty clear,” says the climate scientist. “The only question is how they can be implemented economically and politically.”

GLOSSARY

Vapor pressure
Liquids change to gases below vapor pressure – in other words, liquids, such as water, evaporate. High vapor pressure means that water evaporates easily – even in cold atmospheric layers.

Collision-coalescence process
When two cloud droplets collide, they coalesce into one.

Latent heat
Amount of heat absorbed or released during a phase transition, such as when water evaporates or freezes. The temperature does not change.
Droplets on a Rollercoaster

Whether gases burn, planets form, clouds disperse or it rains – the determining factor is always turbulent flow. Although turbulence is so important, physicists still know very little about it. Eberhard Bodenschatz and his colleagues at the Max Planck Institute for Dynamics and Self-Organization want to change this.
When Eberhard Bodenschatz presents his research, he begins with beauty, showing images of clouds on his notebook: some big and bulky, some rather wispy, but always fluffy – and with a never ending variety of shapes. “This beauty owes to turbulence,” says the Director at the Max Planck Institute for Dynamics and Self-Organization. And in the blink of an eye, turbulence turns the white elephant in the sky into a mouse, and the prince into a frog. Without turbulence there would be only fog, as gray and boring as a dull winter’s day.

So much for the aesthetes. But Bodenschatz also provides numerous practical reasons why it is worth investigating turbulence: Turbulent flows mix the combustion gases in an engine, generate the friction of a ship cutting though the waves, control the formation of stars and planets – and determine the processes in the atmosphere. Since strong wind blows with high velocity, turbulence is generated that moves the air unpredictably with very different speeds and high accelerations. Not only are aircraft shaken about, but wind turbines do not produce electricity as efficiently as they could in a constant flow. And without turbulence, meteorologists might just also have a better understanding of how clouds form and disperse.

But the fact that a turbulent flow is particularly good at mixing particles also helps in some everyday situations. You make use of this when you stir milk into your coffee, during which you can observe the turbulence principle quite well: The stirring swirls the liquid about and supplies it with energy. The large eddy created by the stirring spoon immediately breaks up into ever smaller eddies, until finally the smallest eddies are consumed by friction. In the end, the milk has mixed with the coffee and all energy of motion has transformed into heat.

It is difficult enough in itself for physicists to describe in detail exactly what happens when milk is stirred into coffee. The whole thing becomes much more complicated when small, heavy particles, such as cloud droplets, are swirled by turbulence. Physicists can currently only begin to describe which paths the droplets take.

It is also difficult to investigate the processes in clouds because the strongest turbulence on Earth is in the atmosphere. The stronger the turbulence, the more marked is the difference between the largest and the smallest processes that occur: the largest eddies that are

Helter-skelter in the sky: In the clouds around the Zugspitze, Germany’s highest mountain, the Göttingen-based researchers investigate how droplets of mist are turbulently swirled, and how they accumulate to form raindrops.
involved in the formation of cloud droplets extend for distances of up to 100 meters, while the smallest measure scarcely a millimeter. A unit of measure for the range of the dimensions involved is given by the Reynolds number: the larger it becomes, the broader the range of values – and the stronger the turbulence.

A WIND TUNNEL FOR STRONG TURBULENCE

If atmospheric scientists want to forecast the fate of a cloud, they must know how turbulent the rollercoaster ride of the particles is – in this case the droplets in a cloud. The motions of the particles also decide how often they collide, meaning how quickly the cloud droplets are transformed into raindrops. This is how the cloud finally falls from the sky. Moreover, turbulence mixes dry and wet air, and cold and warm air. “As long as we are unable to realistically describe these processes, the climate models lack the equations needed to make a better forecast of the cloud cover and thus climate development,” says Eberhard Bodenschatz. He and his colleagues are thus working on acquiring a better understanding of turbulence. And since this is a giant undertaking, they need a giant device to complete it.

The laboratory that the researchers have built for this task is easily as big as a school gym. The high-pressure turbulence system extends down the length of the hall – a bright red pipe, taller than a man, which bends to form an elongated closed loop. One of the two 18-meter long main pipes rests in bulky supports just above the floor; the other is about 3 meters higher. Through the loop of the tunnel, the researchers will blow a wind that, at one section, must pass a grille with flaps arranged like a chessboard. “By deliberately closing individual flaps, we generate different turbulent flows,” explains Holger Nobach, the electrical engineer in charge of the construction of the wind tunnel. And at forces that can otherwise be observed only in the atmosphere.
In order for the flows to be swirled as turbulently as in the atmosphere, the researchers send not only air through the wind tunnel, but sulfur hexafluoride as well. Its molecules have a particularly high mass and naturally provide the gas with a high gas density. Moreover, the Göttingen-based physicists can compress it up to 15 times atmospheric pressure. Dense gases make it possible to create the turbulence as it occurs in all weather conditions. They can do this without having to use similarly drastic power to generate the whirling motion, as dense gases have a low effective viscosity—as physicists refer to as kinematic viscosity.

Viscosity indicates how well a gas or a liquid flows. High viscosity thus corresponds to a slow-moving affair. For example, honey has a higher viscosity than air. The kinematic viscosity is needed if accelerations play a role, as is the case with turbulence. The density of the gas or the mass of its molecules then influences the flow behavior. The denser the gas, the more inertia it has, and the larger the force needed to slow it down. This is ultimately how dense gases make it possible to create strong turbulence in a device that is dwarfed by the size of a cloud.

The researchers will chase tiny particles through the wind tunnel with the compressed gas, and film them live as they ride the turbulent flow. This they accomplish by driving three cameras mounted on a carriage along a track. The system is separated from the turbulence by a plate of Plexiglas and stretches over the floor of the upper main pipe. Each of the three cameras will take up to 30,000 images per second of the test particles, thus tracking their path. Eberhard Bodenschatz worked out this measuring principle when he was still at Cornell University in Ithaca, New York—and opened up a completely new perspective on the phenomenon by making it possible to view individual particles on the rollercoaster of the turbulence.

**LIVE RECORDING OF THE SWIRLING PARTICLES**

This approach is named after scientist Joseph-Louis Lagrange, who developed the mathematical tools to turn the results of the measurements of individual particles into a theory. But it is a completely different measuring principle than the one that revealed what physicists currently know about turbulence in clouds. It involves the researchers virtually sitting at one location and measuring the fluctuating speeds with which air or another medium flows past them. This view of turbulence is called Eulerian, again named after the researcher who laid down the mathematical framework. The speed fluctuations are then measured by a red-hot wire through which an electric current flows. Its resistance reacts with extreme sensitivity to the cooling effect of the gas flowing past, and the cooling effect is all the more evident the faster the gas flows.

“Such measurements have enabled many fundamental observations to date, and go back about a hundred years,” says Haitao Xu, who also conducts research into turbulent flows in Eberhard Bodenschatz’s department. Eulerian measurements have provided a good picture of the velocity field that prevails in turbulent flows. However, these experiments have provided no insight into the accelerations that particles experience in the process, because in order to be able to make statements on this, it is not sufficient to measure how fast particles move at a given time and location. The physicists can determine the acceleration of the particles only if they track their flight. And the measurements devised by Eberhard Bodenschatz and his team enable them to do exactly this.

In fact, in the first studies carried out in accordance with the Lagrange principle, the physicists immediately discovered that the particles in a turbu-
lent flow are accelerated much more abruptly than expected. The acceleration of a cloud droplet therefore fluctuates considerably. In a cloud, on average, the acceleration by turbulence is as high as the gravity and can peak at more than 20 times this. “This result shows that the collisions of droplets in clouds, and thus their growth, cannot be forecast with any degree of reliability if we take only the average acceleration into consideration,” explains Eberhard Bodenschatz. How often collisions occur thus depends not only on how the majority of the particles behave; it is determined primarily by the small group of particles that, although rare, are particularly strongly accelerated. They very frequently end up on a collision course.

STRONG ACCELERATIONS LEAD TO MORE COLLISIONS

So the strong fluctuations in the acceleration could also explain why droplets in clouds come together more quickly than the conventional theory allows. In order to test this, the researchers in Göttingen want to conduct the experiment under the extremely rough conditions that prevail in clouds. The first measurements for this will start as early as this year in the high-pressure wind tunnel. In further experiments, the researchers also want to find out whether cloud droplets are able to follow turbulent air flows at all – a daunting task. Compared with the air molecules, even the tiny cloud droplets are gigantic lumps. They are thus easily hurled out of the strongest eddies of the turbulence, just as a truck that moves with the flow on a highway filled with nothing but cars also leaves the lane more easily in a curve.

If the truck is fast – like a cloud droplet that gets caught in the center of a violent eddy – it is pushed into the lanes with opposing traffic. That is why trucks tend to chug along rather leisurely through curves. However, the same applies to a cloud droplet as applies to trucks: The violent eddies with their narrow curves and rapid changes in velocity catapult the cloud droplets out of the area with speedsters and they end up on a collision course. The droplets should thus collide more often and form raindrops in very turbulent clouds than in calmer air. “So far, we have not been able to observe this in clouds and, interestingly, it is the very rare occasions of rapid change in velocity,” says Eberhard Bodenschatz. “It’s like with earthquakes: it’s not the rumbling of the ground, but the very rare major events that matter.”

On another question, which only those who have exact knowledge of turbulent flows can answer correctly, the physicists have already made some progress by observing individual particles – namely the question of how fast two fluids mix in a turbulent flow. The answer to this could contribute to solving many geoscientific and technical problems.
Physicists use the term fluid to describe any substance that is able to flow, and usually mean liquids or gases, but also smoke or solid particles suspended in a fluid. Examples for the mixing of two fluids are moist air in clouds that mixes with the dry air around it, as well as the billows of smoke from a chimney that disperse in the clear atmosphere. How fast this mixing occurs can be estimated by how fast, for example, the paths of two particles separate as they rush through the turbulence. That turbulence is particularly effective at mixing the substances is clear, but how this happens in detail is not.

UP IN THE CLOUDS – RESEARCH ATOP THE ZUGSPITZE

That is why Eberhard Bodenschatz and Haitao Xu also followed the process in a model system with a camera. Accordingly, two or more particles may separate as quickly as the long-accepted theory predicts only if the flow is very turbulent. The physicists usually also have to take the initial distance between the particles into account in order to calculate how fast they drift apart.

The following then applies: The closer the particles were at the beginning, the faster they go their separate ways. This may sound surprising, but there is a simple explanation: The large eddies of the turbulence remain stable longer than the small ones. On the large scale, the particles are guided together in a circle for a long time, but their paths diverge quickly on the small scale when their small shared eddy dissolves.

“To test whether our assumption also holds for the separation of tiny droplets, we still need to conduct our experiments at higher Reynolds numbers,” says Haitao Xu. The experiments in the laboratory assist the researchers in clarifying the laws that very strong turbulence obeys. For this they need conditions that can be very precisely controlled, like in the wind tunnel.

However, these experiments still do not provide the certainty that the droplets in natural clouds behave exactly as the particles in the wind tunnel. They will therefore also use their technique to observe the droplets in real clouds – at the place in Germany where one is probably closest to the clouds: atop the Zugspitze, or more precisely, in the Schneefernerhaus environmental research station.

This is where, in summer, the researchers from Göttingen will install a measurement carriage for the camera in order to look into the clouds. “In order to be able to take 10,000 images per second of the droplets, we need a very strong laser,” says Haitao Xu. He and his colleagues tested the system last year: “And it worked well.”

Eulerian measurements are planned to complete the picture. They have also installed these instruments on the Zugspitze. And colleagues at the Leibniz Institute for Tropospheric Research and Michigan Technical University (USA) are using the most modern instruments available for meteorological investigations on the Zugspitze, and have also packed them into the Actos measuring unit. This is suspended from a rope and dragged through clouds by a helicopter. The researchers ultimately want to use these instruments to make a contribution to more reliable climate forecasts. But not only that: they also want to refute a skeptical statement by British physicist Horace Lamb, who said in the 1930s: “… when I die and go to heaven there are two matters on which I hope for enlightenment. One is quantum electrodynamics, and the other is the turbulent motion of fluids. And about the former I am rather optimistic.”

Clouds under around-the-clock observation: Atop the Zugspitze, partners of the researchers in Göttingen measure such things as particle size and speed, as well as water content and temperature.

GLOSSARY

Reynolds number
Put simply, this is a measure of the intensity of turbulence. It gives the range covered by the values of characteristic parameters, so for example the different dimensions of the eddies. The higher the Reynolds number, the greater the difference between the largest and the smallest eddies.

Kinematic viscosity
Indicates the effective viscous force in a liquid or gas. The viscous force is caused by the friction between particles, the inertial force by the mass or density of the fluid. Kinematic viscosity decreases when density increases. It defines the flow behavior of the fluid when it is accelerated.

Lagrangian measurements
Follow the flight paths of individual particles. They thus permit statements on the speed and acceleration of a particle.

Eulerian measurements
Determine the speed of turbulent flows at one or several points simultaneously. These measurements can be used to obtain the velocity profile of the turbulence.
The Elixir of Life in Space

Scientists find large quantities of water in the disk that surrounds young stars

Water is the elixir of life – and space is full of it. Scientists have now found the substance in a disk surrounding a star of the same type as our Sun. Ewine van Dishoeck from the Max Planck Institute for Extraterrestrial Physics and the Leiden Observatory, and Jes Jørgensen from the University of Bonn’s Arge-lander Institute and the University of Copenhagen used the IRAM interferometer to search for heavy water molecules \( \text{H}_2^{18}\text{O} \) in the vicinity of the young star NGC 1333 IRAS4B, which is between 10,000 and 50,000 years old.

The scientists discovered that most of the water vapor is to be found in the rotating disk at a distance of 25 astronomical units (AU) from the star, roughly equivalent to the distance from the planet Neptune to the Sun (1 AU is the distance from Earth to the Sun).

Earlier observations of NGC 1333 IRAS4B had revealed that the water might be drizzling mainly from the surrounding molecular cloud onto the disk in the form of gas and collecting there. The IRAM data now show that the star’s disk contains 100 times more water than the models of this scenario predicted – equivalent to 100 times the amount of water in the Earth’s oceans.


Mother-of-Pearl Sets the Standard

It sometimes pays to look at nature when searching for the right proportions – and this applies equally to materials scientists. At the Max Planck Institute for Metals Research, scientists found that bivalves (mussels), for example, layer proteins and calcium carbonate in mother-of-pearl in exactly the right proportions of thickness, making the mother-of-pearl particularly strong. Using mother-of-pearl as a model, the scientists created a composite from titanium dioxide and a polymer, and varied the thickness of the layers. But they found it impossible to improve on nature’s ratio: the titanium dioxide/polymer composite proved to be most stable when the inorganic layer was ten times as thick as the organic layer – exactly the proportions in mother-of-pearl.

(Nano Letters, November 6, 2009)

Older Generation With More Entrepreneurial Spirit

In the future, older people will probably take on more risk than the younger generation – at least when it comes to setting themselves up in business. This is the finding of a study into the effects of demographic change on free enterprise, conducted by researchers at the Max Planck Institute for Economics. The study revealed that people born in years with a high birth rate were more likely to start up a company than people born in years when the birth rate was lower. As the baby boom years are receding further into the past, the people who are more likely to venture into self-employment are also older. The Max Planck researchers think that people born in these years are more entrepreneurial because they are supported by a closer social network. The social environment of the succeeding generations, on the other hand, becomes less closely knit as the result of demographic change. Stronger encouragement of entrepreneurial spirit in younger people will thus be needed in the future.
Chimpanzees Help Orphans

In the wild, chimpanzees will adopt young who have lost their parents

What distinguishes humans from animals? For some it is language, for others it is the altruistic willingness to help other members of the species. However, this kind of altruism seems to exist in the animal world, as well. Researchers working with Christophe Boesch at the Max Planck Institute for Evolutionary Anthropology in Leipzig observed that West African chimpanzees adopt orphaned young even though they are not related to them. Several animals lavished care on a juvenile for several years. Surprisingly, half of these adoptive parents were male. This behavior is thought to be encouraged by the presence of leopards with whom the West African chimpanzees share their habitat. The constant threat from the big cats seems to have encouraged cohesion and solidarity within the group. Accordingly, the scientists observed more chimpanzee adoptions in West Africa’s Taï National Park than in East Africa. Wild chimpanzees appear to be more prepared to help than those living in captivity. In zoos, chimpanzees cooperate with other members of the group to only a very limited extent. “Our observations show that altruism in wild chimpanzees is much more widespread than studies of chimpanzees in zoos would suggest,” concludes Christophe Boesch. (PloS ONE, January 26, 2010)

He Who Shoots First Loses

In duels in old Westerns, the cowboy who draws first always comes off worse. This observation intrigued Nobel laureate Niels Bohr and led him to assume that the brain can react faster than it can act. Allegedly, Niels Bohr and a colleague even dueled with toy pistols to prove the theory. Scientists from the Max Planck Institute for Biological Cybernetics in Tübingen have taken a new look at this issue and set up a harmless “shoot-out” in a laboratory. Two research participants were asked to compete to press buttons on a control panel faster than the other. There was no starting signal, so they either had to act on their own initiative or react faster than their opponent. The result confirmed Bohr’s assumption: the reacting participants were 21 milliseconds faster, on average, than those who initiated the duel. The brain can indeed react faster than it can act. This seems to make sense, because fast reaction times can be important for survival, to avoid a rapidly approaching vehicle, for instance. (Proceedings of the Royal Society B., February 3, 2010)
**Genes Working in the Service of Others**

Flu viruses use their host cells for their own reproduction

Our bodies are permanently under siege – viruses and bacteria are constantly trying to get past the defense systems that protect us from infection. Scientists at the Max Planck Institute for Infection Biology in Berlin have now discovered that flu viruses use 287 of the approximately 24,000 human genes to invade the body’s cells and reproduce in them. They benefit from the circumstance that small RNA molecules can inhibit individual genes (RNA interference). In the future, this microRNA could take the form of medications, opening up new opportunities for treating infections. Thomas Meyer, head of the research group at the Max Planck Institute, is convinced that, “The strategy of temporarily switching off certain genes in humans will soon play a key role in fighting infectious disease.” Furthermore, it is very unlikely that viruses could become resistant to such medication. As a next step, the researchers want to examine whether these genes can be blocked in the body without any significant side effects. *(Nature online, January 17, 2010)*

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**Precision Scale for Atomic Nuclei**

The map of our world no longer shows any unexplored islands, but physicists think they might have found one in the periodic table of elements. They suspect that there are stable laboratory-created elements that are heavier than uranium – making them an island of stability among the superheavy artificial elements, which often decay within milliseconds. Help might be at hand in the search for this island in the form of a highly accurate scale for weighing superheavy atomic nuclei. The scale was developed in a project headed by the GSI Helmholtz Centre for Heavy Ion Research, with the collaboration of the Max Planck Institute for Nuclear Physics in Heidelberg. In the apparatus, atomic nuclei run on a helical path that forms a closed ring similar to the end of an electric milk foamer. The mass of the atomic nuclei can be determined from the frequency with which the atomic nuclei move through the spiral and the ring. The mass of a nucleus reveals to physicists how strongly its components – neutrons and protons – are bound to each other, because its mass is less than the sum of the masses of its components. Applying Einstein’s formula $E = mc^2$, the missing amount represents the binding energy of the nucleus, which is released when the nucleus is formed. The physicists can now use the results of these measurements to determine which of the various theories predicting the island of stability for different proton/neutron combinations is the correct one. *(Nature, February 11, 2010)*

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**Help in the Search for Chemical Traces**

It is now easier to identify traces of chemicals. Scientists at the Max Planck Institute of Quantum Optics in Garching, working with colleagues from France and Japan, have developed a device that detects gas traces very quickly and with great accuracy. These gases play a major role in air pollution and climate change, as well as in investigating the atmospheres of other planets. The gas molecules can be identified by their spectra when they absorb light. In order to detect them quickly even when they are present in very small quantities, the new apparatus combines two frequency combs that contain spectral lines positioned at very regular intervals with an amplifying resonator. The researchers use one frequency comb to screen the sample, and use the other like a light ruler to read the absorbed frequencies quickly and accurately. *(Nature Photonics, January 2010)*
Plants Spurn Insects

The flowers of the wild tobacco plant become invisible to moths when they have been attacked by their caterpillars

What happens when a friend becomes an enemy? According to scientists from the Max Planck Institute for Chemical Ecology in Jena, some plants can form new alliances under these circumstances. One of them is the wild tobacco plant in the Great Basin Desert in the western USA. It is pollinated by the night-flying five-spotted hawk moth, which is attracted by the scent of the plant’s flowers. However, the tobacco plant must pay dearly for the moth’s services: the females lay their eggs, from which the voracious caterpillars emerge, on the leaves. But the affected tobacco plants react promptly: alerted by substances in the saliva of the tomato hornworm caterpillars – the hawk moth’s offspring – and in the plant hormone jasmonate, they postpone blooming from night to the early morning, when the flowers attract other, less harmful visitors: hummingbirds, which also feed from the nectar, but otherwise leave the plants alone. Nevertheless, it appears that the wild tobacco plant needs the five-spotted hawk moth in order to reproduce. The scent of the flowers attracts moths that come from many kilometers away, unlike the hummingbirds, and they pollinate a large number of plants in a wide area. It may thus be due to the mobility of the moths that the tobacco plants propagate particularly quickly – for instance as the first plants to colonize large areas of burnt ground after a fire. (Current Biology online, January 21, 2010)

The Black Widow in the Sky

The “Fundamental Physics in Radio Astronomy” team at the Max Planck Institute for Radio Astronomy in Bonn was just set up in 2009, but it already has a reason to celebrate: Just a few weeks after the launch of a pulsar search program using the 100-meter telescope in Effelsberg, the researchers were able to detect the first millisecond pulsar in January of this year. The object, provisionally named PSR J1745+10, was found at the site of a gamma-ray point source discovered with the Fermi space telescope and is interesting for a number of reasons. It is a neutron star with particularly rapid rotation, turning about its own axis once in just 2.65 milliseconds – equivalent to almost 23,000 times per minute. The neutron star, a supernova that was created in the explosion of a massive sun, is also part of a double star system. The companion star seems to be extremely light. This leads the researchers to suspect that highly energetic radiation from the pulsar will eventually cause it to vaporize completely. Astronomers have a fitting name for this kind of neutron star – a “black widow.”

Reading Helps Hearing

Anyone who wants to understand Scottish, Australian or Texan accents better would be well advised to watch films in English – preferably with English subtitles. Researchers from the Max Planck Institute for Psycholinguistics and Radboud University in Nijmegen have shown that it is possible to use films to improve aural understanding of foreign languages if the subtitles reflect the spoken language. They also help listeners become more familiar with accents in the foreign language. Subtitles in the audience’s native language, which are common in some European countries, are not as beneficial because they distract from the dialog. Scientists thus advise watching English films on DVD with English subtitles as often as possible. (PLoS ONE, November 11, 2009)
Atoms in a Quantum Swing

Physicists slow down a single atom using optoelectronic feedback in real time

Reminiscent of many a scene at the playground, researchers at the Max Planck Institute of Quantum Optics manipulate an atom to slow it down in the same way a father uses gentle pushes to propel his child on a swing and then stop it again. The scientists use intense laser beams with innumerable photons to exert a force on the atom. They control the lasers with a very fast feedback mechanism, according to the direction in which the atom is moving, which they determine with a sort of light gate. In this way, they hold the atom up to four times longer than without the feedback in a resonator formed by two mirrors facing each other.

The physicists’ experiment opens up the possibility of bringing an atom to a standstill for as long as the laws of quantum physics permit. Because atoms are subject to Heisenberg’s uncertainty principle, they still oscillate very slightly even at the absolute zero of temperature. (Nature, December 17, 2009)

Enzyme Design with Far-Reaching Effects

Engineers are hardly likely to tinker with the cooling system when they want to increase the size of an engine. Yet chemists at the Max Planck Institute of Coal Research have adopted an approach similar to this in their efforts to optimize an enzyme for practical applications. They substituted two amino acids at a site relatively distant from the biocatalyst’s binding pocket, the location where the chemical reaction takes place. This modification alters the overall structure of the enzyme in such a way that it can now convert a larger number of different chemical compounds. In addition, it preferentially produces one of two possible enantiomers, which occur as what is known as a racemic mixture during traditional synthesis. Although they are chemically identical, the enantiomers differ in terms of their structure in the same way that a right and a left hand differ. Only one of the two versions is usually suitable for use as a pharmacetically active agent. The Max Planck researchers are pointing the way to a new approach that will enable the conversion of enzymes tailored to the needs of the chemical and pharmaceutical industries. (Proceedings of the National Academy of Science, early edition, January 27, 2010)
**Speedy Offroaders**

White blood cells can move with speed and agility

The cell skeleton (marked in color) of an immune cell can form finger-like protuberances to create forward movement.

The analogy is surprisingly apt: like cars, the defense cells in the immune system have an engine, a clutch and wheels, allowing them to penetrate infected tissue and eliminate pathogens. A network of protein chains that pervades the cell and forms the cell skeleton plays an important role in all of this. In order to move around, the cell skeleton creates finger-like extensions that it retracts at another location. Integrins act as wheels – anchors on the cell surface. The link between the cell skeleton and the integrin is equivalent to the clutch, and the connection between the integrins and the external world is like the grip of the wheels,” explains Michael Sixt from the Max Planck Institute of Biochemistry in Martinsried. The immune cells adjust their engine output to the slipperiness or grip of the surface beneath them. If the cell anchors fail to grip on a slippery surface, the engine works harder – the cell skeleton changes more quickly and the cell speed remains the same. (Nature Cell Biology, November 15, 2009)

**The Fruitful Universe**

Stars are created from gigantic gas clouds in galaxies, but their birth rate has changed over time: many more stars were born early on in the life of the universe. Scientists from the Max Planck Institute for Extraterrestrial Physics and colleagues from other institutions now have an explanation for this phenomenon. A few billion years after the Big Bang, normal galaxies contained between five and ten times more gas than galaxies do today, so there was more raw material with which to create stars. The IRAM interferometer allowed the researchers to directly observe the cold gas in young galaxies. They measured its properties spectroscopically in normal, not exceptionally bright galaxies – at a time when the universe was only about 40 percent and 24 percent as old as it is now. Earlier, it was mainly rare, very bright objects that were observed, such as merging galaxies or quasars, which are the nuclei of young, active galaxies. (Nature, February 11, 2010)

Two views of a typical galaxy 5.5 billion years after the Big Bang. On the left, a picture taken by the Hubble Telescope in optical light. On the right, the combination of an IRAM interferometer image (red/yellow) and a photo in the optical range (gray). The galactic disk contains around ten times more cold gas than galaxies today.

**Birth Rates Rising Again**

It appears that the era of low birth rates of less than 1.3 children per woman is over. Scientists from the Max Planck Institute for Demographic Research in Rostock have shown that the trend toward very low and falling birth rates has reversed throughout Europe. This is mainly because the extremely low birth rates are proving to be a transitional effect: parents were not necessarily having fewer children, they were simply having them later. The number of births, which is calculated for a given moment and is generally referred to as the birth rate, thus fell. The average number of children a woman bore in her lifetime, however, was higher. Now that the tendency toward giving birth later is on the wane, the birth rate figures have recovered. The Max Planck researchers expect them to continue to rise. Whether and when parents finally fulfill their postponed wish to have children depends very much on the state of the job market. At least in Spain and Poland, good job prospects manifested themselves in a higher birth rate. In contrast, births fell in eight countries at a time when unemployment was rising. (Population and Development Review, December 2009)

<table>
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<th>Year</th>
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Rising trend: The birth rate is rising throughout Europe; In 2008, it was 0.63 percent above its minimum in Eastern Germany.
A rock that fell from the sky: In April 2002, this meteorite fell to Earth close to the famous castle built by the Bavarian King Ludwig II – hence its name, "Neuschwanstein". The photograph shows a 360° view composed of 20 images.
The Secrets of Cosmic Grains

The end of a meteorite’s journey is abrupt by definition, as the chunk of cosmic material slams into Earth. A celestial rock like this conceals a great many secrets. Ulrich Ott from the Max Planck Institute for Chemistry in Mainz is a scientific detective. He deciphers, for instance, how long the meteorite traveled through space.

On the evening of January 17, 2009, a brilliant light show caused a great deal of excitement. At the same time as the main evening news was being broadcast, a meteor lit up the sky over northern Germany for a few seconds. Coming from the direction of Poland, the ball of fire moved across the Baltic Sea toward Denmark on a westerly trajectory. Close to 600 eye witnesses reported the sight, some even reporting noises like gun shots and rolling thunder. In Sweden, a surveillance camera documented the spectacle, and people in the Netherlands also photographed the fireball. Although the images turned out to be unsuitable for pinpointing a potential impact site with any degree of precision, fragments of the meteorite were already being discovered in early March.

The spectacular find was the result of a systematic search undertaken by the meteorite hunter Thomas Grau from Brandenburg, who was also the first to find a piece of the “Neuschwanstein” meteorite in the Alps back in 2002 (MaxPlanckResearch 1/2003, page 16 ff.). This time, Grau found his treasure on the Danish island of Lolland, where he netted a small piece of rock about the size of a ping-pong ball; it had broken up and was wedged a few centimeters deep in a hole in the ground close to the town of Maribo.

Scientists such as Ulrich Ott from the Max Planck Institute for Chemistry benefit from the instinct of the celestial rock hunter. “This is not the first time we have obtained our samples in this way,” he says. The grain of material the postman delivered this time came from the Museum of Geology in Copenha-
The Max Planck scientists in Mainz have been working with meteorites for decades. The work at the institute is interdisciplinary. The scientific home of the experts is at the interface between astrophysics, chemistry and the geosciences.

A GOOD NOSE FOR NOBLE GASES

It is difficult to investigate the noble gases in meteorites because the concentrations involved are often very low. The noble gas mass spectrometer in Mainz operates essentially like this: The gaseous components of the sample are first heated gradually to vaporize them. Chemical methods remove the gases that are not noble gases from the gas mixture, as they are not important in the extended analysis. Helium and neon enter the measuring apparatus first, while the other noble gases are trapped on the surface of liquid-nitrogen-cooled (minus 196 degrees Celsius) activated carbon. They are released from this “interim storage” by heating, each atomic species at a specific temperature. Argon is freed first, at minus 123 degrees Celsius, followed by krypton. An even higher temperature (about plus 150 degrees Celsius) is applied to release xenon.

The analysis operates on the following principle: A heating filament emits electrons, which collide with the noble gas atoms, causing them to ionize. The high voltage that is then applied ensures that the ions of the individual noble gas isotopes are deflected according to their mass. In contrast to conventional mass spectroscopy, the pumps are closed off during the measurement. These sensitive measurements depend on not a single gas atom being lost.
Ulrich Ott examines the printout of a mass spectrum. This is how the spectra were recorded 20 years ago; now it is done electronically. But the conventional technology is always used in parallel just to be on the safe side.

Weighed – and found to be a lightweight. If you expect to find a large piece of rock in the laboratory, you will be disappointed. A tiny amount of material is sufficient for the analysis. The tiny grain of material from the Maribo meteorite weighed just 115 milligrams.

The samples from the meteorites are stored in Plexiglas bottles like these until they are analyzed in Ott’s laboratory.
1. The meteorites carefully wrapped in nickel foil in the glass sample vessel, where they are freed from adsorbed gases by moderate heating.

2. It looks a little like modern art but is really a cryogenic separation trap. This is a kind of interim storage for the noble gases driven out of the meteorite samples by heating.
high irradiation age, around 20 million years.” But that would indicate that it is not from Mars, because meteorites from Mars manage the space transfer more rapidly, typically within a few million years.

NANODIAMONDS MADE OF A MERE 1,000 CARBON ATOMS

The gas mass spectrometer that helps Ulrich Ott and his fellow scientists decipher the celestial rock is a very sensitive piece of equipment. It has to be, because noble gases are often present in meteorites in low concentrations (see box on page 46). These measurements have nevertheless been routine at the Max Planck Institute for Chemistry for some time, sort of a service that forms part of a standard series of analyses in meteorite research. As the numbers for the noble gases from helium to xenon appear on the screen, Ott talks about his real research field: presolar grains. These phases are embedded in some meteorites and can be investigated separately.

“We are mainly concerned with tiny diamonds that contain a mere 1,000 carbon atoms,” explains the Max Planck scientist. These nanodiamonds are older than the solar system. It was noble gas analyses that identified them as relics from interstellar space, and that first showed that meteorites contain such ancient components.

In addition to the miniature diamonds, the scientists also analyze larger grains, although even these are still on the micrometer scale. They use complex methods to extract the grains from the matrix of the meteoritic rock. Some of the isotopes in these grains exhibit dramatic, distinctive features. Investigations by Peter Hoppe, also from the Max Planck Institute for Chemistry in Mainz, show that, while the isotope ratio of carbon with atomic weights 12 and 13 is around 90 almost everywhere in the solar system, these grains are completely out of the ordinary: some have values two orders of magnitude lower, while others exhibit an isotope ratio almost 100 times higher.

Why is this? It is assumed that stars eject dust at the end of their life. Ancient stellar matter from red giants or exploding supernovae thus reached the primeval solar cloud from which the Sun, the meteorites and the planets formed. The isotope anomalies thus provide insight into the interior of these stars and the synthesis of the chemical elements that occur there – a sort of genetic fingerprint of our stellar ancestors.

NEW MEASURING EQUIPMENT FOR INTERSTELLAR DUST

The Maribo meteorite may also contain the primeval grains; Ott’s measurements indicate a nanodiamond content in the parts per thousand range. An important condition for this is that Maribo was subjected to only relatively mild heating, no more than 200 degrees Celsius, in the four and a half billion years of its existence. There will probably be no detailed search for presolar material, however, because only a small amount – just 30 grams – of Maribo material has been found in Denmark so far.

The institute in Mainz will see a leap in the sensitivity of its noble gas analyses this year, as a new piece of measuring equipment for the analysis of micrometeorites, interstellar dust and individual presolar grains goes into operation. In the meantime, all noble gases from the Maribo sample have been determined in the laboratory and the measurement data evaluated. Ott is not surprised by the result: “Maribo’s radiation age is around one million years,” he explains. This is a very short journey time compared to the ordinary stony meteorites, but not unusual for this class of meteorite. The crumbly material could probably not resist the harsh conditions in space for much longer. And in the end, the heating process in Mainz also proved too much for the grain of cosmic dust: “It vaporized,” says Ott unmoved. “After all, our measurements aren’t a non-destructive technique.”

GLOSSARY

Isotope
Term for various types of atoms of a given chemical element whose nuclei have the same atomic number (number of protons) but different numbers of neutrons and thus also different mass numbers.

Cosmic radiation
High-energy particle radiation from space that consists mainly of protons, electrons and completely ionized atoms. The radiation originates from the Sun, but also from supernovae and neutron stars, as well as extragalactic sources such as active galaxies and quasars.

Meteoroid, meteor, meteorite
These terms are often confused. A meteoroid is a small or large chunk of material that orbits in space. If such a meteoroid enters Earth’s atmosphere, it produces a bright phenomenon called a meteor. A particularly bright meteor is also called a fireball or bolide. Most of the grains are only the size of a speck of dust and burn up, but the larger chunks fall to Earth as meteorites.

Supernova
The sudden bright flare-up of a star, increasing its brightness several million to several billion times. There are several types of supernovae, and two basic mechanisms: the explosion of an individual massive star that has used up all of its nuclear fuel at the end of its life; and the detonation of one of the stars of a binary star system, caused by the transfer of material between two stars (white dwarves).
Wire(less)tapping in the Aviary

Manfred Gahr and his team at the Max Planck Institute for Ornithology in Seewiesen want to find out what goes on in the heads of zebra finches when the males and females engage in a tête-à-tête.

TEXT MARCUS ANHÄUSER
just three more boxes. Manfred Gahr apologizes for the slight disarray. “Just these three and the move is complete,” he says. When they are unpacked, his office – the room in which renowned behavioral physiologist Erich von Holst once lived and worked – will be fully set up and ready for work. The fireplace by the door originates from von Holst’s time, but there is little else that recalls this great era of classical behavioral biology. For the Max Planck Institute for Ornithology in Seewiesen, southwest of Munich, a period of radical change has come to an end.

The institute, formerly known as the Max Planck Institute for Behavioral Physiology and located in a forest between Lakes Starnberg and Ammer, has just emerged from four years of reorganization and renovation. It is steeped in history: many famous behavioral scientists have researched here, the most prominent being Konrad Lorenz. Since his appointment, Gahr, together with fellow Director Bart Kempenaers, has mainly been occupied with the planning and restructuring of the entire institute complex and the simultaneous establishment of a new research department. “Apart from the outer walls, hardly a single stone remains in place,” he says. A fitting celebration in honor of its completion is being planned for next summer.

In the meantime, the 50-year-old scientist, who was born in the Palatinate region of Germany, can once again concentrate on his actual research objective: unlocking the secret of birdsong. With the help of a wide array of methods from the fields of electrophysiology, molecular biology and behavioral biology, Gahr and his team aim to find out what goes on in a bird’s head when it sings or hears the chirping of its conspecifics. Birds do not sing for the fun of it. Behind this activity lie very concrete interests: male birds learn their song to impress females and to enhance their reproductive prospects.

THE SECRET OF BIRDSONG

The researchers in Seewiesen not only focus on the neuroanatomy of the typical areas of the songbird brain, such as the song nuclei, which are located in the forebrain (and include the nucleus robustus archicereali, or RA for short), but even examine individual neurons at work when a male bewitches a female with his song or a young bird learns the basics of social chirping. They also study how both genes and learning behavior influence a bird’s typical song and calls. “We record the activity in the brain so that we can link the molecular mechanisms at the cellular level with the animal’s behavior,” says Gahr.

To do this, the research group headed by his colleague Andries ter Maat uses methods that involve the comprehensive and extensive use of observation technology that would make any secret service proud. Gahr has known ter Maat, an experienced electrophysiologist, since his time at the University of Amsterdam. For the purpose of this
research, the Dutchman with the long silver hair launched what can only be described as large-scale wire(less)tap-ping of the department’s zebra finches: he and his colleagues combine the listen-ing of the calls and songs of the small finches with the telemetric re-cording of their brain waves. Along with video recordings, the acoustic and neuronal recordings are made on an almost continuous basis – total surveil-lance, so to speak. Gahr’s team developed most of the technology needed for this operation themselves. The de-cision to focus on zebra finches, which weigh only ten grams, was no coinci-dence: the zebra finch is the avian spe-cies most commonly kept in laborato ries all over the world.

“They have a few disadvantages, but these are clearly outweighed by their advantages,” says Gahr, who has al-ready worked with other songbirds, chickens and various reptile species in the course of his career. The crucial fac-tor is that, “Because they are colony breeders, we can breed them successful-ly under good conditions in the labora-
tory,” explains the neurobiologist. The little chirpers feel safe and well only in the company of other birds. The re-searchers can thus keep a large number of the birds in a relatively small space. The department has between 800 and 900 zebra finches, and the total kept by the institute is probably around 2,000.

THE ZEBRA FINCH – AN ADVANTAGEOUS AVIAN MODEL

The zebra finches are kept, for example, in House 6b, an elongated building clad with natural timber panels. It is one of the few new buildings on the grounds of the institute, and also its centerpiece. The building can be accessed without getting rained on through a roofed passageway leading from the department’s office building. When someone enters the aviary room, a few of the small balls of feathers flutter nervously to and fro. Others sit huddled close together on the perches. The room is filled with typical chirping sounds that always sound like a rubber duck with a very low squeak. From time to time, complex sequences of notes with repeated syllables can be heard. However, compared with the virtuoso singing of the male blackbird or the European stonechat, the sounds produced are not particularly impres-sive. “But that is an advantage of the zebra finch,” says Gahr. “Its song is easy to decipher.” It consists of just eight to ten individual elements that are nevertheless sufficiently complex. “Animals with more layered songs pose problems for us when it comes to quantification,” says Gahr.

Moreover, the female zebra finches do not sing, which makes them ideal for comparative research. Another ad-vantage of the species is that the ma-ture male does not learn any new song elements. They have thus learned ev erything there is to know by a certain
age. This enables the researchers to establish what a bird learns, and how and when it learned it. “However, this is also one of the disadvantages of this species,” says Gahr. Hormone-sensitive song changes and learning processes in adulthood cannot be studied using this bird model. For this reason, the Max Planck researchers also work with another species, the canary, which is known for its ability to learn new songs throughout its lifecycle.

Andries ter Maat’s observation methods are not identifiable at first glance. In the corner of another room stands an aviary measuring two square meters in area and two meters high. Two plastic trees stand in the middle of the wood-chip strewn floor, and the cage is fitted with perches. “This is our semi-natural habitat,” says ter Maat, who speaks with a slight Dutch accent. “It could also be described as a semi-artificial habitat,” he adds with an ironic grin. The aviary is shielded by two sound-absorbing walls that also provide visual cover. Two stainless steel antennae protrude into the aviary space. The finches live a relatively undisturbed life in this aviary and under controlled environmental conditions – their nutrition is calibrated to the gram and the number of “roommates” is precisely defined.

INNOVATION: MOBILE RECORDING OF NEURONAL ACTIVITY

Two short, thin metal pins, partly covered by the feathers, protrude from the heads of some of the finches. These provide a direct connection to the world inside the birds’ brains. Such an electrode is familiar to anyone who makes electrophysiological recordings of animals, but the one used here is different. “Our recording process is mobile,” explains Manfred Gahr. The pin is usually connected to a cable that transmits the neuronal signals emitted by individual or entire groups of neurons from the brain to a computer.

But cables would not be very useful in an environment like this one, with its perches and artificial trees. “Mobile recording is the only option if we want to study the animals behaving normally under largely natural conditions,” says Gahr. The introduction of a second cabled-up animal to the mix would inevitably result in a jumble of cables. Thus, instead of a cable, the researchers attach to the metal pins a radio transmitter weighing just one gram. This transmits the neuronal activity data to the stainless steel antennae, from which they are forwarded to the computer via the receiver.

Alternatively, the researchers could attach a mobile minicomputer, a data logger, to the birds’ backs. However, in view of the volumes of data produced by the recorded brain area, the mobile memory would quickly become full. “To resolve the neuronal signals, we have to use a very high sampling rate, and that produces enormous volumes of data for just one animal,” says Gahr. The sampling rate is 20 kilohertz. This produces 22 kilobytes of data per second, which is just under 80 megabytes per hour and 800 megabytes over the course of a ten-
Typically, data from up to eight animals is recorded simultaneously, which quickly results in several gigabytes of data every day.

**WANTED: SMALL AND LIGHT ENERGY STORAGE**

The transmission of the data by telemetry is not the problem either. “The crux is the system’s energy supply,” explains the Max Planck Director. As with all mobile devices, whether laptops, cell phones or digital cameras, the technical limits are dictated by battery size. In the case of the bird transmitter, the researchers availed themselves of the smallest commercially available energy storage device they were able to find: a hearing-aid battery. This is the only way they can keep the weight down to around one tenth of the zebra finches’ body weight. The battery provides enough power for five days of constant operation, which is sufficient to produce initial results.

But such telemetric devices cannot simply be purchased at the local electronics store. The transmitter was, in fact, developed by the scientists themselves. “Scientists have been building mobile devices for electrophysiological recordings in animals for around 30 years now,” explains Gahtz. He had already tinkered with just such a system in the 1990s when he worked as the head of a junior research group at the old MPI for Behavioral Psychology in Seewiesen. “But that was more of a sideline.”

Today, he affords himself the luxury of the services of two electronics engineers who focus exclusively on this task. They regularly trawl the market for the latest developments. And their efforts pay off: they will soon complete the development from the analog to the digital age in mobile recording – and thus attain a crucial advantage: Analog technology allows the scientists to record only one location per animal, while the digital equivalent will enable the simultaneous recording of neurons in several locations of the avian brain. Nevertheless, the behavioral physiologists are very pleased with what they have already achieved without the digital technology. “Our current system is a masterpiece of miniaturization,” reports Andries ter Maat with pride. It consists of a measurement amplifier, the transmission unit and the battery. Wrapped in a silicon cover, the entire device weighs just over 1 gram and has a range of 20 meters.

The researchers’ biggest worry is that the device may hinder the animals in their behavior. However, a test showed that, just one to two days after the implantation procedure, the finches behave exactly as before. “The behavioral limitations are mainly caused by the effect of the anesthetic,” says ter Maat. The same reactions would arise if an animal were anesthetized without having a transmitter implanted. The operation is comparable to the fitting of a dental implant and takes around one and a half hours to carry out on the anesthetized bird.
According to Gahr, the time-consuming element of the operation is the precise placement of the electrode in the RA, the neuronal zone involved in the control of birdsong. The operator inserts the electrode, which is just a few hundredths of a millimeter thick, into the brain area until a signal is obtained from the nerve cells. He then locks it in place using a synthetic polymer that dentists also use, and superimposes a pin with the transmitter attached to it. Thanks to the dental adhesive, the electrode sits securely in the skull and can even withstand the hectic activity of the finches.

With their mobile recording device, the Max Planck researchers have the kind of tool at their disposal that the members of their profession have long dreamed of. This device finally makes it possible to examine an animal as small as a ten-gram zebra finch or a mouse while it engages in entirely normal social behavior. It could also be used to study bigger birds. Manfred Gahr has crows in mind here, for instance, which, like zebra finches, are also songbirds but much larger in size. Far bigger batteries could be used on such birds, perhaps enabling the scientists to obtain recordings over several weeks under completely natural living conditions. A doctoral student and an undergraduate are currently studying the sexual and social lives of crows and the associated typical repertore of sounds produced by the birds in their natural environment.

RECORDING DATA AROUND THE CLOCK

Here in the environment of the aviaries, the researchers combine electrophysiological recordings with sound recordings of the calls and songs of individual male and female zebra finches to study the links between acoustic stimuli and neuronal processing. In addition to the mobile recording system, the researchers also use mobile microphone transmitters for this element of their research. The birds being used for this purpose can be identified within the group of zebra finches by the longish antennae running parallel to their backs. This system is another masterpiece of miniaturization and weighs just 1.4 grams.

Ter Maat’s research group uses the mobile devices to make continuous data recordings not only in the aviary, but also in so-called sound boxes. These cozy, soundproof boxes, which are one meter wide and fitted with glass doors, are shared by a male and a female zebra finch for a specific period of time. The song of both birds is recorded using the same non-stop procedure as the neuronal activity of one of the two birds. All of the data is collated in separate rooms on servers. In so doing, Gahr’s researchers generate mountains of information: between 40 and 50 gigabytes of neuronal and acoustic data per day. This means that they produce between 15 and 20 terabytes of data in one year. The data is evaluated using software developed by the scientists themselves. Without this software, the volumes of data produced would be completely unmanageable.
The scientists’ skill and ingenuity lies in their ability to identify patterns and find answers to their research questions within this mountain of data. One of the key questions they would like to clarify concerns the precise activity patterns of song neurons in the socio-sexual context. Up to now, it has not really been possible to answer this question, and this is the very area in which the researchers in Seewiesen have made some very exciting discoveries.

Andries ter Maat sits in his office and points to a graph with two curves: “Above you see the recording from a neuron in the song nucleus of the male, and below it, the acoustic curve of a female making what is known as a ‘tet’ call.” The tet call is one of the most common calls of the zebra finch and is made up to 10,000 times a day. At the beginning, the neuronal signal displays an activity akin to background noise. However, before the female makes its tet call, the activity of the neuron in the male brain declines. When the call has ended, the activity of the neuron surges to a maximum value and then returns to the same level as before the female’s call.

“That’s fascinating,” says ter Maat, “because the male’s song neuron is inhibited.” This shows that the neuron that actually controls motor function reacts in the presence of the female, like a sensory cell to its call. This finding is very exciting but, as is so often the case in research, it immediately raises a lot of other questions. Why does the blockade begin shortly before the female makes the call? Do the male’s song neurons also react to the visually perceived behavior of the female?

In his seminal work on the zebra finch, Richard Zann, the Australian pioneer of field research on zebra finches, who died in a bush fire in early 2008, had the following to say about tet calls: “(...) they are not directed at specific individuals and do not stimulate specific replies.” According to Zann, tet calls form a kind of soft background hum in which other calls are embedded. However, the data produced by ter Maat’s research group suggest otherwise.

Andries ter Maat and his colleagues combine the recording of the calls and songs of the small finches with recordings of their brain waves – almost around the clock and in conjunction with video recordings. As a result, the researchers in Seewiesen produce mountains of information: between 40 and 50 gigabytes of neuronal and, above all, acoustic data. The skill lies in identifying patterns and finding answers to the research questions within the mountain of data.
The recordings reveal a clear connection between the tet calls of female and male finches. The tet calls also highlight the particular advantage of the telemetry microphones. The female’s call occurs exactly between two male tet calls. This happens so often and with such precision that it cannot be a coincidence. “The females and males listen carefully to their partners,” says ter Maat. Such results point the electrophysiologist in a completely different direction: “What we would ultimately like to know, of course, is what all of these tet calls, stack calls, and the entire to-ing and fro-ing mean. This takes us to the field of language,” says the Dutchman. However, before the researchers can go there, a few gigabytes of data remain to be evaluated.

What else they will discover with their telemetric methods is basically a matter for the researchers and their imaginations. No other laboratory in the world can carry out mobile electrophysiological recordings of animals in their normal social environment. Manfred Gahr and his colleagues have a lot more work planned with their tiny recording devices. And now that the renovation of the institute in Seewiesen has elevated it to a new splendor, the Max Planck Director finally has the time to focus on his research. And those last three boxes will soon be unpacked.

**GLOSSARY**

**Song nuclei**
Regions in the avian brain involved in the learning and production of song. The HVC and RA song nuclei in adult male zebra finches are several times larger than the corresponding areas in the adult female brain.

**Habitat**
An organism’s living space.

**Sampling rate**
Sampling is the recording of measurement values at discrete points in time, usually at regular intervals. The number of samples recorded per second is known as the sampling rate.

**Inhibition**
Due to a certain impulse, a nerve cell is not stimulated to form an action potential and the signal transmitted by this neuron is attenuated as a result.
Robots That Learn!

In the world of science fiction, robots are intelligent and adaptive, but reality differs significantly. Robot programming is expensive manual labor, and the resulting programs are inflexible. A key step in making current robots more like their sci-fi counterparts requires endowing them with the capability to learn how to react appropriately and at the right time. Jan Peters is trying to teach exactly this skill to his machines. The computer scientist and mechanical and electrical engineer heads up a research group at the Max Planck Institute of Biological Cybernetics in Tübingen.

TEXT TIM SCHRÖDER

Jan Peters’ laboratory is tightly crammed with equipment – hardly surprising, as the center of the room is occupied by a ping-pong table. The first thing one sees on entering is a heavy industrial robot – an articulated arm, as tall as a man and as thick as a sumo wrestler’s thigh. A second robot arm is suspended from the ceiling next to the ping-pong table, and appears lighter and more dexterous.

Peters and his four students have pushed their desks over to the windows. Unlike the robots, neither the scientists nor their computers require much space. Peters is teaching his robots forehand and backhand, games of skill and how to grasp unfamiliar objects – all things that are still difficult to teach a machine, despite the fact that programmable robots have been around for half a century.

There is no question that modern robots can perform a lot of tasks. They weld auto body parts together with millimeter precision a thousand times a day without getting tired. Robot dogs play football, flick the ball into the goal with their nose and roll yapping onto their backs when they score. Humanoid robots move forward on two legs, offer their hand and say “Hi.” And yet the robot world is still as rigid and inflexible as the stone circle at Stonehenge.

IMPROVED FLEXIBILITY AND APPROPRIATE REACTIONS

Factory robots repeat the same movement a thousand times a day, no more, no less. If a component rolls out of position, they can only report their switch into failure mode. To prevent them from injuring anyone, they are locked away behind bars and light barriers. Football dogs lose all sense of direction when the barriers are removed from the playing field. And electromechanical humanoids stumble when steered to walk over a fleecy velour carpet.

The fact that today’s robots are still dumb is demonstrated by their inability to adapt to the uncertainty in human environments. If you affectionately slap your humanoid companion on the shoulder, you can expect to be knocked to the floor, as the robot is incapable of processing an unexpected slap.

Greater flexibility and the ability to react appropriately and at the right time – this is what robots still have to learn, and precisely what Jan Peters is teaching his machines. Peters is a computer scientist as well as a mechanical and an electrical engineer. He heads a research group on robot learning in the Empirical Inference Department at the Max Planck Institute for Biological Cybernetics in Tübingen. Next door, his colleagues are busy developing theories and calculation specifications for statistical learning. Others employ these methods in brain-computer interfaces, computational photography and bioinformatics.

Jan Peters is the only one here whose laboratory contains massive robots mounted on the wall or suspended from the ceiling on concrete beams as thick as tree trunks. Whatever Peters and his students – computer scientists and engineers – come up with is sent straight to the machine and converted into movement. The Tübingen-based
No child’s play for a robot: In order to catch the ball in the cup (blue), the arm first imitates the movement demonstrated by the scientists in Tübingen, and subsequently improves the behavior by trial and error.
The Tübingen-based scientists are trying to teach robots how to learn. The basic idea is to teach the machines how to accomplish complex tasks by learning flexible motor primitives instead of employing manually programmed movements.

JOINING FORCES: ROBOTICS AND MACHINE LEARNING

Their approach is inspired by human motor learning: babies master the art of grasping things and, over time, learn to change their grip according to need. Grabbing quickly, taking hold of something firmly or gently – eventually, grown-ups master more than 60 types of grasps. But how to make a machine created from cable and steel as smart as an infant? The scientists in Tübingen have chosen to bridge two disciplines that have co-existed for years: robotics and machine learning. In Peters’ lab, the two approaches join forces.

Conventional robotics develops machines that are customized for precisely specified tasks, such as robots in an auto factory. The programmer determines a desired trajectory with high accuracy, as well as how much force is needed to accomplish the task and how it should move its joints. The result is a mechanical servant that strictly carries out the exact same orders. Machine learning is less concerned with heavy robot hardware and is located in the more virtual realm of “data clouds.”

For example, computers learn to identify specific patterns. In mail distribution centers, character recognition programs read addresses in fractions of a second. They have learned what the letter “A” looks like, and can assess very accurately whether an illegible letter is actually an “A” or some other letter. Peters combines the two disciplines to create a teachable robot. “Around 5,000 scientists worldwide are working on machine learning, and 6,000 or so more are engaged in research on robotics,” says Peters. “But only six research groups are really combining both – and we’re one of them.”

A ROBOT LEARNS HOW TO CATCH

Why does machine learning not translate directly into robot learning? The answer becomes obvious when one watches a robot learning to play, for instance, ball-in-the-cup. In this game...
of skill, a string with a ball attached hangs from a small wooden cup in the robot’s hand, and the ball is tossed into the cup by swinging it carefully to and fro.

Trying to teach a robot to play ball-in-the-cup through off-the-shelf machine learning methods would test the patience of a saint! Approaching the problem without domain insights from scratch requires testing thousands of variants, altering arm acceleration, joint rotation and direction of movement. “With this type of robot arm, there are so many permutations that it would take forever to achieve the desired results and catch the ball,” says Jan Peters. Programming the task as in industrial robotics is no alternative due to the complexity and uncertainty of the swing movement. To start with, the ball swings gently to and fro, before being spun around and flipped into the cup. The to and fro motion is very jerky and uneven. “It is precisely these complex movements that are so difficult to program using traditional methods,” explains Peters.

LEARNING FROM IMITATION AND SUBSEQUENT TRIAL AND ERROR

He has therefore developed a robot learning system made up of several components. The learning and retrieval of movements is broken down into several easily digestible stages, using unusual methods such as imitation. First, you have to spell out to the robot what it is actually supposed to do. The quickest way to achieve this is to demonstrate the movement to the ma-
First you have to spell out to the robot what it is actually supposed to do. The quickest way to achieve this is to demonstrate the movement to the machine, in the same way that a tennis coach takes a pupil by the hand to practice his or her forehand.

To play ball-in-the-cup, Peters’ student Katharina Mülling guided the arm of WAM, the laboratory robot, swinging the ball into the cup. This demonstration gave WAM a rough idea of the sequence of movements. It was then followed by a second step: self-improvement. Just like a human learning tennis, WAM had to perfect the movement in order to flip the ball into the cup all by itself. In the language of robot experts, this step is known as reinforcement learning. “Ultimately, the robot’s goal is to reduce the distance between the ball and the cup,” explains Jan Peters. “If the ball ends up in the cup, the distance is minimal.”

The experiment was a success: Once Katharina Mülling had shown WAM what to do, the robot needed only 45 attempts to learn a successful
movement. After around 90 attempts, it now sinks the ball every time. According to Max Planck research scientist Peters, this is no mean feat. “We’ve had visitors here who were totally frustrated after trying unsuccessfully for much longer.”

**MAKING THE ROBOT COMPLIANT**

The robot skill learning system in Tübingen goes even one step further. First, it stores the learned movements, the motor primitives. These are managed by a software module known as the supervisor. The idea is that, according to the situation, the supervisor gives the command to perform specific motor primitives. In most cases, the motor primitives must be adjusted to the new situation, or a series of learned motor primitives can be combined in order to react correctly in a matter of seconds – in the same way that a tennis player constantly has to vary his or her forehand moves: arm outstretched, volleying or diving for the ball. “Humans frequently experience situations in which they suddenly have to adapt a learned behavior,” says Peters. “The first time they strap on a pair of inline skates, for example.”

In the meantime, WAM no longer just plays ball-in-the-cup, but also ping-pong. It still practices using the reinforcement learning strategy. Jan Peters has screwed a ball gun to the ping-pong table, which delivers the balls more uniformly than a human could. WAM parries the shots easily. However, it cannot yet hold its own against a human opponent. After all, ping-pong is an incredibly fast sport, and also an extremely complex one. If a ball smashes onto the table or is whacked to the edge of it, WAM has to move its arm incredibly fast and position it correctly within a fraction of a second in order to hit it.

Unlike conventional robots, WAM robots are fitted with flexible Bowden cables, like those used in automobile brakes, instead of rigid electromechanical gears. These enable a WAM to gently follow trajectories and even give way when it collides with its human training partner – a key criterion in interaction between technology and humans. “If a Bowden cable breaks, we can easily spend a few hours repairing it and fiddling around with screws. But such a compliant robot has huge advantages,” says Peters.

**MOTOR PRIMITIVES PROVIDE REAL TIME FLEXIBILITY**

The scientists and WAM are currently learning what forces are needed and how fast the joints need to be moved for an action-packed game of ping-pong, how quickly the Bowden cables react and how to steer the arm correctly. They are still working on it. One thing is certain – the motor skills learn-
The principle of rewarding when referring to reinforcement learning, as used by Pavlov in his dog experiments. A successful attempt is rewarded with food. “The robot learns how to become a ‘good robot,’” Peters explains. Depending on the robot’s goal, it can then adjust its motor primitives. Accordingly, the stored sequence of movements varies based on the goal function. Peters’ student Jens Kober initially experimented with this virtually, teaching his computer to hit specific segments on an imaginary board with a dart. A few weeks ago he was in Japan and transmitted his commands to the laboratory robot. “Admittedly, it sometimes missed, because the mechanics of the robot hand didn’t always cooperate. However, some darts landed exactly in the right corner,” says Kober.

A supervisor, a motor primitive archive and goal functions are just some components of the robot learning system. Several other factors come into play before the command to move is given.

However, it is clear that all components interact to achieve the movement, and this part is achieved by distributing the task in manageable chunks to these different modules.

**A REWARD FOR A “GOOD ROBOT”**

Six working groups worldwide make for a manageable scientific community. Jan Peters and his students know the other research scientists in the US and Japan well. Peters worked for a long time at the University of Southern California in Los Angeles, where he earned his Ph.D. He uses the principle of rewarding when referring to reinforcement learning, as used by Pavlov in his dog experiments. A successful attempt is rewarded with food. “The robot learns how to become a ‘good robot,’” Peters explains.

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However, it is clear that all components interact to achieve the movement, and this part is achieved by distributing the task in manageable chunks to these different modules.

**FLEXIBILITY IS NOT A REQUIREMENT**

Service robots already exist that can be taught to move by means of instruction. However, they generally act only as a third hand, lifting and holding heavy sheet metal or engine parts. Ultra-fast flexibility is hardly a requirement.
“If service robots are actually going to help us with housework or nursing care in the future, they have to be able to do it properly and adjust quickly to changes in environmental conditions,” explains Peters. There appears to be a big demand for these service robots. Globally, five million iRobot vacuum cleaners are already whirling around people’s homes. But here again, flexibility is not a requirement. Now and then, cleaning robots will buzz through the living room for a half hour before gliding back to their charging stations. WAM would probably just give them a tired smile.

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### GLOSSARY

**Empirical inference**
The Biological Cybernetics Department founded in 2001 at the Max Planck Institute of the same name researches the physical laws underlying empirical data. Scientists develop algorithms and apply them to a wide range of problems, such as computer vision, brain-computer interfaces, bioinformatics ... and robot learning.

**Humanoid robot**
The design of this type of robot mimics the human body. It normally has a head and two arms and legs. Movement sequences and joint positions are also based on those of humans.

**Machine learning**
An artificial system, in this case a robot, does not memorize all examples, but rather gradually acquires the ability to generalize. The system recognizes physical laws in the learning data and is eventually also able to evaluate unknown data or react to new situations.

**Pavlov’s dog**
Russian Nobel Prize winner Ivan Petrovich Pavlov (1849 to 1936) conducted the first empirical experiments to show the effect of classic conditioning: he observed the connection between salivation and digestion. The owner’s footsteps alone sufficed to trigger salivation in kenneled dogs, even when no food was being offered.

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Awash in Aceh: In the northernmost province of the Indonesian island of Sumatra, the tsunami brought death and devastation to more than 800 kilometers of coastline.
Conflicts in the Wake of Catastrophe

Discussions about the relationship between mankind and climate are generally focused on the effects of human activity. Arskal Salim’s field studies in the Indonesian province of Aceh, which was hit by a tsunami in December 2004, reveal how climatic events can impact social and economic order. At the time, the scientist was working at the Max Planck Institute for Social Anthropology in Halle.

TEXT BIRGIT FENZEL
The giant wave that crashed into the coasts bordering the Bay of Bengal at Christmas time in 2004 changed the fates of multitudes on a scale that few natural disasters in recent history have equaled. It is estimated that around 230,000 people perished in the floods. Worst hit of all was Aceh, the northernmost province of the Indonesian island of Sumatra. There, the wave rolled over 800 kilometers of coastline, dragging more than 160,000 of its inhabitants to their deaths and leaving behind a swath of devastation. More than 250,000 houses were totally or partially destroyed.

Some 23,330 hectares of rice paddies and a further 126,806 hectares of arable land were ruined by mud, sand and erosion. An estimated 300,000 plots of land were lost. Many landmarks also disappeared – the paths and trees that had once delineated the boundaries of land holdings in the vicinity of the coast were, like everything else, lost to the floods. Apart from the human dimension, the catastrophe also turned social and economic order into chaos in the areas affected.

“There were frequent disputes,” says Arskal Salim, describing the mood of potential conflict in Aceh after the catastrophe. An expert in law in Muslim contexts, Salim is currently assistant professor at the Institute for the Study of Muslim Civilisations at the Aga Khan University in London. He previously spent three years working at the Max Planck Institute for Social Anthropology in Halle/Saale where, under the auspices of the Project Group Legal Pluralism, he studied the legal system of the island state.

In the course of his studies between 2007 and 2008, Salim, who himself hails from the Indonesian island of Sulawesi, spent a total of ten months in Aceh. During this time, and against the backdrop of the disaster, he authored several works that deal with the tense relationship between the civil and religious courts, and Islam and Adat law, as the customary law is called that predates Islam and that even today is still widely applied by societies in the Indonesian archipelago. “I wanted to find out how people resolve their conflicts in a legal system that permits a large number of competing subsystems, laws, norms and moral concepts,” says Salim.

LANDMARKS AND DOCUMENTS WASHED AWAY

With so many dead or missing, the survivors were suddenly faced with the task of reestablishing issues of ownership. Legal aspects of inheritance took on a new importance. Many of those who survived were orphans below the age of maturity. Now it was a question of establishing who should have custody of them and how to ensure that, when they came of age, they would receive the houses and land to which they were entitled. However, before the reconstruction could begin, the land ownership had to be settled beyond doubt.

As Salim discovered in his research in the post-tsunami region, this proved to be far from easy in practice. “The tsunami had also wiped out landmarks and land boundaries,” says Salim, enumerating one of the big problems that impeded clarification of such legal matters. Since most of the deeds and documents had disappeared in the floods, it was often very difficult to unambiguously attribute parcels of land or identify their boundaries.

“This situation provided an opportunity for many people to claim pieces of land or regain the ownership that previous reforms had deprived them of. Others simply appropriated abandoned plots whose original owners or inheritors were unknown,” explains Salim, describing the post-catastrophe scenario.

After the floods came discord. Neighbors who had previously lived in peace and harmony suddenly began to argue over land boundaries and rights of use. “All of a sudden, people were envious of one another,” says Arskal Salim of the conflicts fomenting within village communities. For example, if one neighbor received more money from the aid funds to rebuild his home than another, resentment seethed behind the freshly re-erected garden fence. For scientists who, like 39-year-old Salim, have an interest in the resolution of conflict in a plural legal sys-

Photos: Arskal Salim (2)
tem, the province in northeastern Sumatra offered a wealth of illustrative material as it struggled to overcome the consequences of disaster.

**CATASTROPHE AS A CATALYST OF PEACE**

“Legal pluralism has a long tradition in Indonesia,” explains Salim, with reference to the history of the legal system in these islands. The way in which the various laws, norms and customs have changed in competition with one another has fascinated him since the very start of his scientific career. When the sultans still held sway in the 16th century, long before the spread of Islam, a customary law was practiced; to this day, there remain regional differences in the Adat interpretation of what is lawful.

Under Dutch colonial rule, after the declaration of independence and in the throes of creating a modern central state, the legal system continued to develop new facets. In the early 2000s, for example, the Indonesian government permitted certain provinces – often with ethnically diverse populations – to have specific laws that applied to them alone. “Paradoxically, this subculture emerged as a product of Indonesia’s efforts to create a standardized structure with a modern, homogeneous legislation,” Salim continues.

However, these attempts to create uniformity out of diversity frequently collided with ethnic differences and regional peculiarities among the traditional legal concepts and religious laws. In the province of Aceh, this led to a bloody civil war that lasted for almost 30 years and claimed the lives of around 1,200 people – though it must be said that the dispute centered mainly on control of the region’s many natural resources of which the central government and the military wished to avail themselves. The conflict was brought to an end eight months after the tsunami with a peace treaty signed in August 2005 in the Finnish capital of Helsinki by representatives of the rebel Free Aceh Movement and the Indonesian government.

“The present system of order is a product of the social and political events that have taken place since the tsunami,” says Arskal Salim, who credits the natural disaster with a role in the process. In his opinion, the catastrophe did not directly inspire the changes that have taken place. Rather, it acted as a catalyst for change. It is questionable whether the peace agreement signed by the Free Aceh Movement and representatives of the Indonesian government would have come about if the fatal wave had not rolled in.

“In an attempt to settle this bloody conflict, the Indonesian government made extensive legal concessions to its rebellious province,” says Salim, explaining the steps intended to ease the way to peace. Officially, Aceh was giv-
en a special autonomous status that not only once again legitimized traditional concepts of Adat law, but also permitted the religious courts to be developed into autonomous institutions under Sharia law. “The latter were given more extensive judicial powers than those of other religious courts outside of Aceh,” says the scientist.

In his mind, the question now arises as to how far the regained authority of Sharia or other religious concepts will influence the legal conflicts occasioned by the tsunami. That was the focus of his sub-project in Aceh, which he carried out as part of the comparative research work undertaken by the project group headed by Keebet and Franz von Benda-Beckmann. He was specifically interested in disputes revolving around land rights.

“One must understand that the relationship between land rights and Islam in Muslim societies is based on the concept that land is something holy, regarded more as a gift from God that is held in trust rather than as a possession or commodity,” explains Salim. It is permitted to use land for productive purposes, but not to waste or over-exploit it. This concept of common property is typical of the Adat systems in Indonesia, which also – in contrast to Islamic law – apply this legal status to defend land as something that is not for sale.

**COMPENSATION PAYMENTS CREATE DISCORD**

In the ten months that Arskal Salim spent doing field studies in Aceh between 2007 and 2008, he came across two cases that illustrated to him how, in case of doubt, the inhabitants of this province deal with crucial issues when the chips are down. It was all a matter of the ownership of some land in one of the worst-affected areas of Aceh, in Lhoknga, some 20 kilometers southwest of the provincial capital of Banda Aceh. The devastation wrought by the earthquake and the tsunami in 2004 was particularly bad there. Several schools, a hospital and many other public buildings were destroyed, along with the principal road serving the area.

The highway connecting the community with the capital was so badly damaged that it seemed a better idea to start from scratch with a new road in a new location. The owners of the properties across which the new road was to be built would receive financial compensation. The money was ready and available, coming from the United States Agency for International Development (USAID). It was the responsibility of the Indonesian government to purchase the parcels of land. However, the community objected in two cases, and the reconstruction of this essential main road was put on ice.

Specifically, it was a matter of two plots of land. One of them, measuring 6,102 square meters, was situated on the right side of the old road and was due to earn its owner a billion rupiahs (about 80,000 euros) in compensation. The other encompassed 7,204 square meters of coastal land for which compensation was to be paid in the amount of 1,440,800,000 rupiahs (about 115,000 euros). These sums were claimed by two men who could even produce documents certifying their rights to the pieces of land in question.
One of the men had a deed confirming his right to the property on a hereditary leasehold basis. He had acquired the right from a Dutch firm that had worked plantations in the region since colonial times. In the early 1960s, the Indonesian government had expropriated colonial property and taken it into state ownership. However, the owner had assumed that his hereditary lease was unaffected – in fact, in 1955, he had had his claims officially confirmed by the Indonesian Minister of Justice as a precaution.

Despite this, he ought to have had his lease renewed after 20 years, because early in the 1960s, during the course of renewed reforms of land ownership, the concept of the hereditary lease in Indonesia had been transmuted into a right to use and enjoy state property for a strictly limited time. The property owner had, however, failed to do this, claiming special extenuating circumstances in his proceedings against the authority responsible for the compensation payments. “He pleaded that, since the late 1950s, the whole area in question had been occupied by the military and that he was therefore unable to renew his land rights,” Salim explains.

CRUCIAL ISSUES IN THE DUEL BETWEEN LEGAL SYSTEMS

As evidence, the owner presented a letter from the then commander of the army in Aceh confirming his statement. When he then also produced a letter from the prevailing military office in Aceh stating that the army had officially returned his property to him, there was no further reason for the authority not to pay the compensation.

However, the community then lodged an objection and claimed the billion rupiahs for itself. Represented by two attorneys, the village elders filed a suit with the civil court. “That enabled them to put a stop on the payment for the time being because, according to the manual covering land purchases for public infrastructure in the tsunami regions, such payments can be made only when ownership is absolutely clear,” Salim says, explaining what happened. At a meeting with representatives of the council of elders, he learned their perspective on the matter. “In the opinion of one of their members, as communal property, the land belonged to everyone in the village, and as such, could not be bought by strangers.”

Thus, when the Dutch planters acquired the land in the colonial era, they could never have received title to it. At best, they would have held it on loan of some kind, or simply seized it from the community as the real owners. “So when the colonial era ended, the land should have been returned to its original owners,” says Salim, illustrating this interpretation of the underlying principles of Adat law as conceived by the community.

The community employed a similar argument to prevent the payment of compensation for the second site. Here, too, the claimant had provided the authority with official documents. He had a certificate from the Indonesian land bureau dating from 1991 that confirmed him as the owner of the parcel in question. “From a legal perspective, he had a much stronger claim to ownership than the other claimant, because...
his title was granted by an official procedure under Indonesia’s new land laws,” says Salim.

Despite this, the community’s objection was enough to prevent the money from being paid. As a result, the case came to be heard by the civil court in Jantho, where the two disputes with the community were dealt with jointly. As part of his research, Arskal Salim met with the judge who presided over the case. From her he learned that the matter was settled peaceably after three short hearings. As she explained to him, she did little more than suggest a compromise solution – just as the law prescribes in such cases.

GOING TO COURT IN LARGE NUMBERS

The three court hearings themselves were anything but quiet and peaceful. By this time, the community had mobilized a large number of its members to attend the court where they faced a crowd recruited by the son of the leaseholder from among the ranks of former resistance fighters who were there to support his father. The second landowner also brought a sizeable body of his own supporters to attend the hearings.

The solution was essentially due to the efforts of an attorney appointed by four of the village elders and a representative of the district authority. “In his view, in terms of their rights to the land, none of the parties was in a particularly strong position,” Salim recalls from his discussions with the lawyer. As such, none of the parties were entitled to the compensation payments either. And that did not sit well with the lawyer, believes Salim: “At the end of the day, he was concerned about where the community would find the money to pay his fee.”

Since it was certainly not the lawyer’s intention to provide his services for nothing, he left no stone unturned to bring the parties to the negotiating table. In the end, it was the leaseholder who opened the way for a compromise. “He offered to donate a part of his compensation to rebuild the mosque that was destroyed by the tsunami,” says Salim, describing the first step toward resolving these land disputes. After that, the parties haggled for a while over the amounts to be donated before finally agreeing that the men would each pay the community 300 million rupiahs to rebuild the mosque.

1 | Peace at last: Eight months after the tsunami, the Indonesian Minister of Justice Hamid Awaluddin, former President of Finland Martti Ahtisaari, and Malik Mahmood of the Free Aceh Movement (from left) signed a treaty between the rebel organization and the Indonesian government.
2 | Gates of justice: The civil courts offer one of many ways for people to settle legal issues of land ownership.
The procedures adopted by the parties in this dispute are characteristic of the skills displayed by the people of Aceh in maneuvering their way through a pluralistic legal system to assert their rights. According to Salim: “It should be noted how different interpretations of facts, norms, rules, institutions, actors, motivations and interests culminate in claims that translate into passionate disputes, and how these, in turn, lead to a solution.”

A SECULAR BATTLE FOUGHT ON PAPER

The competing norms applied by the parties to protest their rights to the properties in this particular dispute are just a few of a whole range of alternatives that the pluralist legal system in Aceh has to offer: Adat law, land law dating from the Dutch colonial era, national land tenure law at various stages of reform, and Islamic law. From this perspective, the behavior of the people in this part of the Indonesian archipelago calls to mind the advertising slogan employed by a Swedish furniture store chain: “Discover the possibilities.” Salim continues: “The way in which the people of Aceh pick out the arguments that offer the best prospect of success from among the plethora of rules and norms that the pluralist system in their region has to offer is like shopping around for justification.”

The case also offers some interesting clues to the importance of religious concepts in the resolution of land disputes. “Given the large role that religion plays in the daily lives of the people in Aceh and the view of land as a gift from God, one really ought to expect these factors to play a role in this context as well,” says the scientist. In fact, at first sight, the sequence followed by the attempts at mediation is reminiscent of the traditional Islamic process of conflict resolution, the musyawarah. “Freely translated, it means something like ‘consultation to reach a solution.’”

Typically, this procedure is embedded in a religious-cultural setting. It begins with a shared prayer, and at the end of the procedure, the parties to the dispute present their mutual apologies and share a meal in celebration. The whole proceedings take place in a mosque or at least in a communal building. However, all these circumstances that lend the procedure a religious character were absent from the dispute over the two plots of land. “The initiative emerged from the civil court, the whole process was driven by a lawyer, there were no prayers or celebratory feasts, and the parties met in a room adjoining the civil court,” Salim says, describing the secular character of the mediation in this case.

Likewise, in terms of the arguments employed, any religiously inspired ideas were conspicuous by their absence. Instead, the two landowners fought a paper battle with official documents and deeds according to the rules of secular legal artifice, whereas their opponents sought recourse in Adat law. “The fact is that, in these proceedings, religion made an appearance only in the final result, with the parties agreeing to apply a part of the compensation payments to rebuild the mosque destroyed by the tsunami,” concludes Salim in his role as a specialist in ethnography and law. Moreover, in the end, the parties were not particularly strict in following through, as Arskal Salim noticed on another visit to the province in mid-2008. “The mosque was only partially renovated, with the work paid for with money from the national fund for reconstruction.” One of the village elders eventually told Salim what had become of the donations from the two landowners: The money had been spent on enlarging the car park in front of the mosque.

GLOSSARY

Legal pluralism
The coexistence of multiple concepts of legal order within one socio-political space (be it a village, a province such as Aceh, a state, or in the world as a whole). The term global legal pluralism is now also used.

Sharia
The religious rules of conduct of Islam and Islamic law.

Adat
An all-embracing term that refers to the morals, customs, traditions, social organization, law and partially pre-Islamic beliefs practiced in most ethnic societies in Indonesia. Large parts of the legal aspects of Adat were treated as Adat law in the colonial era and recognized by the law of the land as the prevailing system of law. Even beyond this degree of recognition, many Adat institutions still prevail as village or tribal law. Adat law is sometimes translated as custom or customary law. This can lead to misunderstandings, as the rules of Adat law are flexible and have, to a large extent, been adapted to changing economic, social and political circumstances.
Aristotle observed it, and Karl von Frisch was awarded the Nobel Prize for explaining it: the waggle dance – a dance used by honeybees to communicate the location of food sources.
Dancing with Bees

With his lederhosen and white hair, the elderly man looked well groomed. Countless generations of pupils were shown the educational films in which zoologist Karl von Frisch explained the dances of honeybees. His research on these insects and their behaviors earned him fame and renown throughout the world. Tania Munz from the Max Planck Institute for the History of Science in Berlin is researching von Frisch’s life as part of a project on scientific observation.

TEXT TINA HEIDBORN

The man whistled and the fish swam over to him: fish were among Karl von Frisch’s favorite experimental animals – particularly a blind bullhead catfish called Xaverl. Von Frisch had Xaverl so well trained that he swam over to the scientist when he whistled softly, proving that fish can hear. But even more than fish, von Frisch liked bees. “The waggle dance looks comical. But it is not really comical, it is incredibly interesting. It is one of the most amazing occurrences in the insect world. And that’s saying a lot,” he once commented, looking back on his work.

The decoding of the waggle dance of the honeybee earned the behavioral biologist the Nobel Prize in 1973, along with a huge amount of general interest. “The hype was enormous,” says historian of science Tania Munz, who is currently working on a book about Karl von Frisch.

What von Frisch discovered in the mid-1940s was a source of fascination, and not only to his fellow researchers. “Von Frisch gave many public lectures in schools and other educational institutions. For example, I found a letter in the archive from a school asking the scientist to come and give a lecture. He had already visited the school the previous year. Von Frisch wrote in response to the renewed invitation that he’d already presented on the bees and now could give a lecture on fish – also a fascinating topic. The school replied that that would, no doubt, be very interesting, but could he please speak about the bees,” reports Tania Munz.

The American researcher, who also holds Swiss citizenship, arrived at the topic of her book through von Frisch’s Nobel Prize acceptance speech. “I found the experiments fascinating. Von Frisch worked with great care, precision and creativity. He simply conducted good research – and this is demonstrated by the fact that his studies are still cited today,” she says. As a sensory physiologist, von Frisch had been focusing since the 1920s on questions concerning sensory perception in animals, such as: Can fish or bees hear sounds? Can bees distinguish between colors, smells, and tastes?

TAIL WAGGLING AS A DISTANCE INDICATOR

For his experiments, Karl von Frisch developed an ingenious marking system with which he was able to track individual bees within a swarm. This enabled him to explore the meaning and purpose of the so-called bee dances that had already been noted by Aristotle. Von Frisch postulated that honeybees convey information about food sources to their fellow bees with the help of certain round and waggle dances.
When they return from an abundant food source that is no more than 100 meters away, they inform the other bees with a round dance. If the food is further away, the successful bee waggles for hive mates in the shape of a figure of eight: starting with a straight line, followed by a semicircle, another straight line and a semicircle in the opposite direction. The angle the bee assumes in the hive in relation to gravity corresponds to the angle to the sun that the bee flew on its path to the feeding place. The speed at which the bee shakes its hindquarters back and forth (“waggles”) indicates the distance to the food source.

**THE FOURTH INSULT TO HUMANITY?**

“The discovery that animals could communicate in such detail and, moreover, symbolically caused a sensation,” says Munz. “However, von Frisch’s discovery also brought up some serious questions about the self-image of humans. If even such lowly animals as insects can communicate so brilliantly, what were the implications for the perceived difference between animals and humans? For centuries, language had been the sole preserve of humans (at least as far as humans were concerned). It was seen as the boundary that divided *homo sapiens* from the other living organisms on earth. Von Frisch’s findings eroded this self-image.

But Karl von Frisch’s research did not meet with universal acceptance. Criticism was expressed even before he was awarded the Nobel Prize, in particular by American biologist Adrian Wenner. Wenner firmly believed that the bees conveyed information in their dances, but he questioned the significance of this information. According to Wenner, the smell of a food source was the sole factor in determining whether a bee would find it or not. The information conveyed by the dances was not used, and even ignored.

“Karl von Frisch was over 80 when this debate began,” says Tania Munz. “He had produced enormous volumes of data and studies, he had a lot of students, and was no longer actively involved in empirical research at the time.” But thanks to his extensive and
rigorous studies and the support of numerous international colleagues, he was able to hold his own in the dispute. And of course the awarding of the Nobel Prize also gave von Frisch’s cause a huge boost.

The debate concerning the information content of the honeybee dances is still ongoing today. A perennial source of controversy among the bee research fraternity, it has remained a focus of debate for decades. Just late last year, a scientist revisited the topic in an article in the German newspaper Süddeutsche Zeitung: Jürgen Tautz, a biologist from Würzburg, explained that bees cannot locate a non-smelling food source with the help of the waggle dance alone, and that Karl von Frisch overestimated the significance of location information in the waggle dances.

AN EXCHANGE OF SCIENTIFIC BLOWS

With this article, Tautz joined the endless ranks of von Frisch critics – and promptly garnered strong disagreement from his own sphere. For example, Randolph Menzel, a colleague from Berlin, immediately insisted that the bee dances contain an abundance of important information and fulfill a significant motivational and instructive function. In this recently kindled exchange of blows, the focus of the debate involves the human interpretation of the animal dance.

Historian Tania Munz observes the dispute with scholarly interest, but without taking sides. “I am not a bee researcher and I cannot settle the argument,” she stresses. What is certain is that bee communication is extremely complex and the last word in this debate has not yet been heard. Munz can, however, appreciate the dispute in the context of the developments that have taken place in recent decades. As a historian of science, she sees the current debate as an interesting replay of the dispute between Wenner and von Frisch in the 1960s and 1970s.

Nevertheless, Munz vehemently defends von Frisch on one point of criticism originally raised by Adrian Wenner and currently being brought into play: she deems the claim made by Wenner and his successors to the effect that von Frisch himself was clearly more cautious in the statements he made in the 1920s and 1930s to be unfair. Karl von Frisch did not assemble his final theory until the mid-1940s. At that time, he recanted his earlier findings and developed what would become his final version of the meaning of the bee dances.

The Max Planck researcher is also able to position von Frisch’s interest in bees in a broader historical context. “During the National Socialist era, it was discovered that von Frisch had a Jewish grandmother. As a result, the Nazis wanted to force him out of the university system. However, many people expressed their support for him. And von Frisch himself argued that his research could help in fighting the Nosema infestation that posed a threat to the bee populations in the early 1940s,” says Munz. As the bees were the most important crop pollinators, the Nazis viewed von Frisch’s work as making an important contribution to maintaining the German population’s food supply.
The examination of the core questions underlying serious research intensified as a result of von Frisch’s work: How does one carry out research without becoming personally involved? How can animals be observed with maximum objectivity? And is this even possible or, indeed, desirable? How can scientists avoid the traps of anthropocentrism and anthropomorphism? These questions, too, must be understood in their specific historical contexts.

Consequently, he was allowed to continue researching and even received official state funding for his work. Von Frisch’s work in a different field, that of communication science, would take on a significance that outweighed that of the German Reich’s honey production. His insights and experiments inspired other scientists to engage with questions concerning animal communication. By way of background information, Tania Munz mentions that, from the perspective of the history of science, research on communication became a prominent global trend after the Second World War. Computer scientists and cyberneticists studied it in the context of artificial intelligence, and a short time later, Noam Chomsky’s deep grammar theories revolutionized the world of linguistics.

In laboratories all over the world, scientists started to hang on the lips and mandibles of bees, monkeys, birds, whales and dolphins in an attempt to study their languages. The chimpanzee Washoe, who learned over 30 symbols from a sign language, emerged as the star of this research circus. However, it was not exclusively the fascination with Karl von Frisch’s work that inspired emulation. Tania Munz sees in the enormous interest shown in this field a countermovement to the dominance of behaviorism. “People had had enough of behaviorism. It had forbidden them from commenting on anything that went beyond what was strictly observable behavior,” she says. At the same time, the examination of the core questions underlying serious research intensified as a result of von Frisch’s work: How does one carry out research without becoming personally involved? How can animals be observed with maximum objectivity? And is this even possible or, indeed, desirable? How can scientists avoid the traps of anthropocentrism and anthropomorphism?

FOCUS ON THE HISTORY OF OBSERVATION

The fact that research is also subject to trends and occasionally undergoes changes in direction is one of the phenomena historians of science study. Tania Munz’s work on Karl von Frisch is part of a larger project entitled “The History of Scientific Observation” that Munz and her colleagues at the Max Planck Institute for the History of Science are currently working on. Doctoral student Nils Güttler, for example, is working on the development of plant geography starting in the 18th century. “The main question the project addresses concerns how scientists identify and stabilize an object of investigation,” he explains. The question as to how plants are distributed across the earth encompasses a vast, almost impenetrable study area: the entire globe. The question came into focus with explorers and their explorations during the 19th century, in particular with Alexander von Humboldt. A form of representation that would influence the discipline thereafter, the geographical map, developed as a result.

“The field of observation could now be organized with the help of maps,” explains Güttler. As a result, reports the scientist, the object of scientific observation was molded into a particular form – a form that was not freely invented, but that emerged from the observations and became increasingly established as a kind of yardstick.

However, the maps that Alexander von Humboldt developed are now obsolete: they are too abstract and extensive. Today we know that the distribution of plants is influenced by more factors than those that von Humboldt identified: temperature and soil conditions are not the only factors that play a role here, as he claimed. After von Humboldt’s death, the theories of evolution altered the view of the maps. The occurrence of plants and plant communities observed at the time was increasingly viewed as a result of historical processes, such as migration.

“The perspective from which I consider an object is crucial,” says Güttler. And this changes frequently during the course of the history of science. Science historians refer to the “period eye,” the particular perspective of a certain historical research generation or epoch. Accordingly, Alexander von Humboldt had a different perspective on plant geography than that of today’s scientists.

Tania Munz has been aware of this historicist dimension of scientific research since her work on Charles Darwin, the subject of her master’s thesis. Today’s scientists would no longer work
the way Darwin did, she says. “Darwin not only used different methods, he also amassed information from widely differing sources. For example, he used information he obtained from colleagues who he viewed as reliable. These would probably be described as anecdotes today and could not be presented as scientific sources. That standard did not exist at the time.”

The importance of changing and often evolving possibilities for observation can also be demonstrated on the basis of Karl von Frisch’s work. The marking system he devised for bees created completely new possibilities for observation: it made it possible for the first time to identify individual bees in the hive and at the different food sources. However, thanks to the development of new technologies, today’s bee researchers are far more advanced in their methods. They can also track bees in flight, for example with the help of radio transmitters.

SUCCESS BASED ON A SIMPLE PROCESS

Technology now also enables the use of programmable robot bees – a step forward compared with the artificial wooden bees developed by one of Frisch’s colleagues. “However, Karl von Frisch’s bee research also shows that innovation and new ways of thinking and looking at things do not depend on advanced technology,” says Munz. The marking of the bees by hand would have to be classified as a low-tech procedure, and yet it yielded an immense gain in knowledge.

Von Frisch, who was born in Vienna in 1886, was completely open to new technologies and processes. For example, he made use of film recordings, particularly in the presentation of his research. “Von Frisch was the first scientist to show a film at the 1924 meeting of the German Society of Naturalists and Physicians. This meant that he could present the bees in the conference hall, even in winter when the ground outside was covered in snow.
By a happy stroke of fate, I was born with a love of the animal world. This was a source of some discomfit to my parents."

Karl von Frisch felt at home with animals, even as a child. Even at a ripe old age, the zoologist, behavioral scientist and sensory physiologist inspected the bee hive constructed specially for his research.

and the bees were dozing in the hive. Needless to say, that made quite an impression,” reports Tania Munz.

For Karl von Frisch, the observation of bee dances and other animal phenomena was a lifelong preoccupation. The love of different animal species was something he acquired in his childhood home. As a child, he kept an entire zoo, reportedly consisting of 170 wide-ranging animal species that he observed with passion. His father, a renowned surgeon, would have preferred his son to have followed in his professional footsteps. Frisch thus first studied medicine before switching to zoology.

As the scientist himself put it, observing animals was something he simply could not resist. "Every frog interested me more than my school work," he once reminisced. "By a happy stroke of fate, I was born with a love of the animal world and a delight in the observation of their living impulses. This was a source of some discomfit to my parents. The fact that, despite this, they fostered my inclination in every way was decisive in terms of my future profession."

He continued: "Animals of all kinds – bought, as gifts, caught by me – were permanent guests in my nursery. My mother also liked to have a cheerful bird, usually a blue tit, around during the bleak winter months. It was allowed to fly around the room, giving it its freedom in the spring. I quickly learned from my mother to see animals as sentient beings."

GLOSSARY

Anthropocentrism
The view whereby humans see themselves as the focus of worldly reality.

Anthropomorphism
The assignment of human characteristics to animals, gods or natural elements.

Behaviorism
A theoretical position that assumes that the behavior of humans and animals can be studied using a scientific method that focuses only on external manifestations and behaviors. Behaviorism was established in the early 20th century and became popular in the 1950s, in particular through the work of B. F. Skinner.

Nosema
Nosema disease (also known as nosemosis) is a disease of the honeybee caused by the zygomycete species Nosema apis and Nosema ceranae. Nosema is the most common disease of mature bees and is highly contagious.

Mandibles
The typical mouthparts of the arthropods belonging to the Mandibulata clade. They consist mainly of a strong lower jaw and are suited to the biting and chewing of plant and animal foods or as a gripping device for the transport or manipulation of objects.

Sensory physiology
The study of seeing, hearing, feeling, smelling, tasting, and the sense of balance. The main focus of the science is on the different mechanisms that convert physical stimuli, such as light or sound waves or chemical signals, into electrical signals.
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So Much Life

Demographics must be biological and political, says James Vaupel. This approach makes him a rule-breaker – and not just in Germany. For the Director at the Max Planck Institute for Demographic Research in Rostock, going against the norm is the norm.

A PORTRAIT BY BJÖRN SCHWENTKER

James Vaupel can't take it any longer. The ideas want out. He had patiently spooned up the beetroot soup with chocolate ice cream, but now he pushes the plate with the nicely browned steak medallions aside, half uneaten. He needs room to write. Vaupel, who prefers to be called “just Jim,” hastily rummages through his jacket for a pen. He can’t find a piece of paper. No matter, the napkin will have to do. Then Jim starts drawing. Survival lines, mortality rates, one diagram after the next takes form on the soft paper.

While he draws, he lectures, speaking quickly, sometimes hastily – and always aggressively. The demographer is used to having to convince people, even today, 20 years after his greatest discovery: life expectancy is increasing, and there is no discernible limit. “People simply don’t want to believe it,” says Vaupel and draws a line upward so vigorously that he accidentally extends it onto the table. The napkin is too small for life.

The wait staff at “Goodfellas” – Jim’s favorite restaurant in Rostock due to its bold and unusual taste creations – has grown accustomed to the lively American with the white hair and round face, who always orders his meals in this funny mixture of German and English. He comes here once a month to eat with staff members, junior scientists and research colleagues from around the world. It is hard to imagine him not winning them over, or them not pushing their plates aside just as quickly in order to launch a new research project with Jim, preferably starting yesterday.

A MAJOR CHANGE IN AGING RESEARCH

It is this mixture of determined con-viviality, keen intellect and an uner-ring feel for research topics with the potential to offend that has already made James Vaupel one of the great demographers of our time. Even before he moved to Rostock in 1996 to make the Max Planck Institute for Demographic Research, of which he is the founding Director, one of the world’s leading demography institutions within a matter of years, Vaupel had already radically changed the face of his field. And with it, that of aging itself.

Today, his research is highly topical – everyone is talking about demographic change. But the driving force behind it, as James Vaupel has shown, is much older than the current commo-nation about it: lifespans in industrialized countries have been steadily increasing for the last 200 years. Demographers have repeatedly defined upper limits for life expectancy, but every one of these limits has been surpassed – some even by the time they were published. Through meticulous data analysis, Vaupel proved that the maximum age is increasing by two and a half years each decade. It was this finding that led him to remark: “Live nine months and you get three additional months free.”

People haven’t yet grasped just what this means. It seems so logical: those who live longer are old longer. But being old is not good. “Old age” is still considered to be a period in life that is filled with disease and infirmity. Unjustly so, Vaupel stresses: as life expectancy increases, so, in fact, does the share of healthy years. On the whole, people have more health, more vitality and more time to work.

James Vaupel is a prime example of this. Flashing a boyish smile while brushing off the suggestion of retirement, few people would guess that he will soon be 65. “I was never more productive than I am now,” he says. And: “My best ideas are still ahead of me.” Sixty-five? That’s not old. Retirement? Thanks to new German regulations on extending service periods, he’s allowed to continue working as a Director at the Max Planck Institute for Demographic Research until he...
Taking the ferry to the institute: James Vaupel lives in Denmark and works in Rostock. This makes the ferry the vehicle of choice.
turns 70. After that, he’s assured of a professorship in Denmark, where his family lives. He says he is in top form, especially intellectually. No one would doubt him. The man is pure life.

TURNING NUMBERS AND DATA INTO A MATHEMATICAL THEORY

And yet it was death that brought him to demographics. He was already 30 years old and actually on his way to a professorship in public policy at Duke University in Durham, North Carolina, when suddenly three of his relatives died unexpectedly. This hit Vaupel hard. “I resolved to give some thought to how untimely death might be prevented.” He read everything he could get his hands on about premature death. Data series were particularly revealing, as they showed that his compatriots’ chances of survival were miserable. Many died young, most before the age of 65. Those who did grow older, however, lived very long. Why? Vaupel discovered how much the mortality rate varied from one person to the next. He excitedly wrote down what the numbers were telling him. His text was accepted as an article in the journal Demography – and immediately cited extensively. “I really hit something,” says Vaupel today.

He had discovered the heterogeneity of demographics and began to expand his ideas into a mathematical theory. This work later garnered him the prestigious Population Association of America award for mathematical demography.

James Vaupel was 39 when he finally became a professor of demography at the University of Minnesota. He was

Keen intellect, determined conviviality and an unerring feel for research topics: James Vaupel, who goes by Jim, is one of the great demographers of our time.
His parents had a small optical shop. It didn’t earn a lot, and they had no money for Jim’s education. Jim, however, had plenty of curiosity. His parents had a small optical shop in Islip, New York (USA). It didn’t earn a lot, and they had no money for Jim’s education. Jim, however, had plenty of curiosity. He earned top grades in school. Jim would never say that he had always been a bright student, or an innovator. But he was, even if he tells the story differently.

At the small table in “Goodfellas,” he leans back contentedly, sipping on his dry Riesling, and relates the tale of how he more or less stumbled upon the world of academia. Having graduated from high school at the top of his class, he received a scholarship for college: Harvard was his ticket to the temple of science. He later received additional scholarships, and even earned his Ph.D. But his path to demography was anything but “straight.”

Vaupel studied business for a while at Harvard Business School, but he didn’t like it there: “My classmates were only interested in money. I was interested in ideas.” He transferred to the Kennedy School of Government with the intention of going to work for the government. He thought that government officials were the ones who had the real power to change the world. Vaupel had already joined the Harvard Republican Club while still in college, and was very interested in politics. At that time he was still oblivious to what would eventually become his current passion, demography.

Jim had been taking statistics courses ever since his college days. He first registered for them because he knew the professor from television. As a teenager, he had loved the 6:30 a.m. show with the professor lecturing on mathematics. The world of numbers has not released its grip on him since. Regardless of what field Vaupel happened to be drawn to in his early years at the university, he always studied it from a mathematical standpoint. It would be many years before he would realize just how much his later success benefited from this approach.

THE DEDICATED DEMOGRAPHERS SOCIETY

When he finally arrived in Minnesota, and thus in the field of demographic research, the first thing Jim did was consult the telephone book. He had combed through citation lists and come up with 180 scientific authors in Minnesota who had published papers on population. He called every one of them, arranged to have lunch with 100 of them, and formed a scientific demography research club with 35: mathematicians, physicians, economists, psychologists. Vaupel had always considered population research to be an interdisciplinary field.

All of these researchers had one thing in common: they felt it was time for a new paradigm in aging research. It quickly became clear to Vaupel who his scientific opponent was: medical expert James Fries. Fries had published an article a few years earlier that had received much attention. In it, he summarized the established notion of how life ends: every person has a natural lifespan that is determined by genetic makeup. It cannot be changed. Even
Old age is being delayed – people are staying young longer. And it has nothing to do with genes.

Aristotle believed something similar, 2,500 years ago. James Vaupel didn’t believe it. He wanted to refute Fries – and thus the impossibility of postponing death.

He devised an action plan: He needed to verify whether, based on the population average, people who had nearly made it to the supposed maximum age always died after the same number of years, or whether the probability of dying might not change over the course of history. But it wasn’t very easy to make this determination. There was no data on the aged. Vaupel began his search, surveyed statisticians and combed through archives around the world. He found what he needed in Sweden. There, reliable data on citizens’ ages and death dates has been recorded since 1860. This statistical goldmine was designed to ensure that the King of Sweden always had enough tax revenues and soldiers. For Vaupel, it ensured a scientific breakthrough.

**NO SUCH THING AS AN INNATE LIFESPAN**

Vaupel also found out that life expectancy is not increasing as a result of a slowdown in the aging process. Rather, the aging process is being postponed. Old age is being delayed – people are staying young longer. And it has nothing to do with genes. So there is no such thing as an innate and immutable lifespan. Studies on twins demonstrated this. Aging, as Vaupel found, is anything but set in stone. It is pliable.

None of Vaupel’s scientific successes would have been possible if he had not always had excellent datasets to work with. In most cases, he had to generate them himself. He tracked down the twin data in the files of the Danish statistical office; a student entered the data into the computer. Now he has established large-scale data collection at the Max Planck Institute in Rostock. The data lab at the institute maintains the “Human Mortality Database,” the world’s largest list of mortality figures from around the globe.

However, James Vaupel wasn’t content to hoard measured data on just humans. After all, man is not the only organism that ages and dies. Do different creatures have different survival strategies? Or are they similar? Right after the study with the Danish twins, Vaupel investigated fruit flies. He was able to breed thousands of “twins” simultaneously in their population. Vaupel was the first demographer to establish a database that doesn’t archive human mortality figures – something that was almost unheard of in his discipline. Many peo-
people therefore consider Vaupel to be the revolutionary of demography.

He delights in breaching the methodological limits of his field: for instance when he screwed hundreds of small light bulbs into a board and wired them to measure their service life. Or when he analyzed the “mortality” of cars in his search for universal patterns of mortality. They could, in fact, exist: the life and death of insects appears to obey similar mathematical laws as that of light bulbs.

For James Vaupel, there is method to the madness of such deviation from the norm. Of course his staff is surprised when their boss shows up at the office wearing bright red socks again, or with flowers on his lapel or a particularly odd tie. But it isn’t absent-mindedness – it is intentional. When Jim, at 18 years of age, read the works of John Stuart Mill, he decided that he would do something unusual every day: utter a particular thought, tell an interesting story – or just wear red socks. Like the British Mill, a liberal free-thinker of the 19th century, Vaupel believes in the need for personal individuality: the only progress is that against the tyranny of convention.

**HIS CREDO: TRANSPARENT KNOWLEDGE FOR ALL**

Today, he experiments with persistent polyps in the service of research in the basement laboratory at the Max Planck Institute. A couple of floors up, the staff in the research group on the evolutionary theory of demographics recently set up their workspace. Ultimately, believes Vaupel, what determines aging and life expectancy can be understood only with the aid of biology. “I am proud to have ushered in the renaissance of biodemography,” says Vaupel – and considers himself to be following in a fine tradition: in the early 20th century, it was normal to understand demographics as the population science of all living beings. This approach was lost during the Second World War – just like demographic research in Germany. After Hitler, there were only a handful of population researchers left, spread throughout the German Republic. Teaching and education were nearly dead.

In a sense, Vaupel revived them. He established a world-class demographic research facility at the Max Planck Institute. Its reputation made it easy to re-establish education, as well: one can now study demography at the University of Rostock. And Vaupel founded, sponsored and continues to sponsor multiple post-doc programs, such as the Max Planck Research School for Demography or, at the European level, the European Doctoral School of Demography.
It’s a matter of course that the Director keeps coming back to participate here. “I actually consider myself first and foremost a teacher,” he says. He wants his findings to benefit mankind. His unconventional approach also extends to his communication: when the Internet journal Demographic Research that Vaupel established in 1999 went online, it was one of the first open access journals ever created. His credo: Transparent knowledge for all.

THE DISTRIBUTION OF LABOR

In “Goodfellas,” Jim hunches over his napkin. He has since switched from white wine to red, and taken off his jacket. He writes “Demography” on a blank corner of the white scrap. Above it, he draws a fat circle. That’s politics. That’s what gives the whole thing meaning. In the end, only politics can ensure the quality of life he so loves. Research, Vaupel believes, must aid politicians in making decisions, and can do so only through knowledge transfer. That is why, at the institute in Rostock, there is a research group on population and politics. And that is why the Director is always prepared to openly disseminate his knowledge, for example in the media. But take note: “I want to convey facts,” says James Vaupel, “not a political opinion.”

With one exception: When it comes to retirement age, the American doesn’t understand the Germans. If it were up to him, there would be no such limit. Everybody would be allowed to work as long as he or she wants. He himself wants to continue doing research until he is no longer able. He doesn’t consider this a hindrance to simultaneously enjoying leisure time, be it as an enthusiastic amateur chef or as a passionate equestrian. Vaupel once worked it out in the journal Science: If older people were to work just a few years longer, it would take only a few hours per day to make demographic change less daunting. The feared shortage of workers would be alleviated just as quickly as the problem of financing pension funds.

Our modern life will undergo a revolution, believes Vaupel: “The 20th century was the century of distribution of wealth. The 21st will be that of distribution of labor.” If work were organized more cleverly, there would even be more free time for the young generation. Time to have children, for instance.

Politically speaking, for Vaupel, family is not something the government should force. Personally speaking, family is his greatest joy. The younger of his two daughters just recently bore him a grandson. He hopes to watch him grow for a couple of decades yet. And if his gut feeling is right, he will. Jim has never calculated his own life expectancy – although he could. He relies on his inner voice, which tells him that he has another 30 years yet. Or more. So much life!
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Finally, on the evening of September 3, 1938, the moment had arrived: the Hamburg-Süd line passenger steamer *Monte Rosa* slipped her moorings and departed her home port en route to the New World. Among those on board was 28-year-old zoologist Harald Sioli who was traveling to Brazil where, at the Instituto Biológico in São Paulo, he was to study the physiology of estivation in toads. His return ticket was undated – but he never dreamed that it would be 19 years before he was to see his homeland again.

In his youth, Harald Sioli had devoured the accounts related by the great scientific explorers. In 1934, shortly after completing his doctorate, an opportunity finally presented itself for him to follow in their footsteps. As an assistant at the Kaiser Wilhelm Society Institute of Hydrobiology in Plön, he was invited to accompany an expedition to Brazil to investigate the reservoirs in the dry northeast of the country with the scientist Friedrich Lenz.

It was on this occasion that Sioli became acquainted with the amphibian species *Bufo marinus*, the South American cane toad. In a rock fissure, he and his companion came upon estivating toads that were barely able to move. This strange phenomenon aroused his curiosity: How did the cold-blooded creatures manage, despite the high ambient temperature, to so reduce their energy consumption as to be able to survive the dry season by sleeping through it?

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TEXT ELKE MAIER

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Finally, on the evening of September 3, 1938, the moment had arrived: the Hamburg-Süd line passenger steamer *Monte Rosa* slipped her moorings and departed her home port en route to the New World. Among those on board was 28-year-old zoologist Harald Sioli who was traveling to Brazil where, at the Instituto Biológico in São Paulo, he was to study the physiology of estivation in toads. His return ticket was undated – but he never dreamed that it would be 19 years before he was to see his homeland again.

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It was this engrossing question that the zoologist aimed to pursue on his second journey to Brazil. In the laboratory in São Paulo, he set about artificially inducing estivation in order to compare the toads’ basic metabolic rate with that of their wide-awake conspecifics. But the objects of his research let him down: “The toads that I ‘dried out’ preferred to desiccate and die rather than estivate,” Sioli complained. To resolve the problem, the young scientist decided to study sleeping toads, not in the laboratory, but in their natural habitat. And in any case, with the outbreak of war, his return to Germany was postponed indefinitely.

With a suitcase full of equipment, Harald Sioli boarded a coastal steamer in November 1939 and, for a second time, headed for the dry lands in the northeast of Brazil – where he was astonished to find that, against all the rules of climatology, it had rained. As a result, “The otherwise leafless vegetation was green, and the toads were unwilling to sleep while there was life-giving water to enjoy, leaping about and chanting their mating songs (...)”.

After this further setback, Sioli gave up researching toads. Instead, he traveled northward: “I wanted to at least have seen the Amazon, the object of desire for so many naturalists,” he wrote. In Belém, he encountered Swiss zoologist Gottfried Hagmann and journeyed with him for 900 kilometers along the Amazon onboard an old river steamer – a trip that was to shape his future: “When I saw the vast river with its shallow shorelines and endless forests, I suddenly knew: this is my country.” And so he resolved, upon expiration of his contract with the Instituto Biológico in São Paulo, to return to the Amazon to study the limnology of the Earth’s largest river system, which at that time was largely unknown.

In the years that followed, Harald Sioli journeyed throughout Amazonia. He observed, collected, took pictures and analyzed water samples. He also kept a meticulous journal to record his impressions. Neither the damp tropical heat nor the swarms of mosquitoes, malaria or dysentery could dissuade him from researching the natural history of this vast stretch of land. His interests rapidly extended beyond the waters to include the land-based flora and fauna, the geology and the climate.

Brazil’s entry into the War in the fall of 1942 had a sudden and dramatic effect on Sioli’s work. One night he was arrested, and af-
After his retirement in 1978, Harald Sioli continued to travel to Brazil, on one occasion inaugurating a floating field station that was named after him. Research into tropical ecology continued at the Max Planck Institute for Limnology under the leadership of Wolfgang J. Junk. Harald Sioli, who would have celebrated his 100th birthday in August this year, died in 2004. With his holistic view of the Amazon region as a unified whole comprised of water, forest, soil and climate, he made a fundamental contribution to our understanding of tropical ecosystems. His life of adventure is documented in his extensive memoirs published in German under the title Gelebtes, geliebtes Amazonien (Amazonia lived and loved). His research work was punctuated by numerous publications and awards. Only one thing eluded him: the secret of the summer-sleeping toads.
How can we improve our relationship with our Polish neighbors, which has been seriously impaired over the past 200 years? In the view of Klaus Hahlbrock, former Vice President of the MPS and co-initiator of the “Science & Art in Europe,” science and art offer fertile ground for understanding one another.

Polish and German scientists and artists met for the first time in November 2002 at the “Science & Art in Europe” event. In the course of numerous scientific symposia, an art exhibition, concert and receptions held in Warsaw, Krakow and Poznan, participants were able to meet and exchange ideas.

The success of this event inspired the organizers in 2005 to attempt a second round, this time in Berlin, Dresden and Jena. This year “Science & Art in Europe” returned to Warsaw. The lion’s share of the organization was undertaken by the Foundation for Polish Science, supported by two partners in Poland, the Polish Academy of Science and the Academy of Arts and Sciences, and three in Germany, the European Academy of Otzenhausen, the MPS and the Volkswagen Foundation. The main focus was on ecology, energy and climate, with public lectures delivered by Max Planck scientists Peter Berthold and Günther Hasinger along with Stefan Rahmsdorf of the Potsdam Institute for Climate Impact Research and Polish colleagues working in these specialist fields. A symposium entitled “Trade-offs as a response to energetic bottle-necks” prompted an exchange of ideas between scientists from institutions including the Max Planck Institute for Ornithology, the Mammal Research Institute of the Polish Academy of Science and the Leibniz Institute of Freshwater Ecology and Inland Fisheries.

The meeting also brought together artists from both countries. Poland’s Meccorre String Quartet and German students from the Musikhochschule Freiburg gave a joint performance of Mendelssohn’s octet for strings. And there was a surprise in store for Klaus Hahlbrock, who ever since his days as Vice President of the Max Planck Society has been committed to good relations and fruitful exchanges with our Eastern European neighbors, especially Poland. The Foundation for Polish Science awarded him an Honorary Distinction for his outstanding services in support of cooperation between Poland and Germany in the field of science.

Delighted about the award from the Foundation for Polish Science: Klaus Hahlbrock (right), with Maciej Żylicz, President of the Foundation (left) and Andrzej Członkowsky, Chairman of the Foundation Council.

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“How and Axolotl goes to…”

Dresden MPI presents first internal award for public relations

The MPI for Molecular Cell Biology and Genetics is always at the forefront when it comes to successful public relations. Now the institute even has its own internal award for employees with the brightest ideas: the Golden Axolotl.

“I certainly can’t complain – at my institute, public relations is viewed less as a necessary evil than as something to be supported with energy and imagination,” says Florian Frisch, who has headed the PR department at the Max Planck Institute for Molecular Cell Biology and Genetics in Dresden since 2003. The staff at the institute have put their heart and soul into a variety of events, and “it was time to really say a thank-you for their wonderful support.” Frisch knew at once that something special was called for. The idea quickly developed of an internal PR award, and in next to no time it came to fruition: “One morning while showering, in my mind’s eye I saw the Golden Axolotl,” the press spokesperson recalls.

After years of media publicity, the Mexican salamander has become something of a mascot for the institute and therefore makes an ideal trophy – Carolyn the salamander is one of the most popular attractions for the approximately 3,000 people who visit the institute every year. “It’s all the more appropriate because the axolotl is such a cuddly-looking creature,” Florian adds. The award is, after all, intended to emphasize the lighter side of things. The Directors liked the idea “that the whole thing is meant to be serious, but not too serious, and that such an award not only emphasizes what we do, but also acts as an incentive for others to join in.”

Florian Frisch invited the entire workforce to submit nominations and assembled a jury: besides himself, it comprises Stephan Schön, the science editor of the Sächsische Zeitung, and Susann Pfeiffer, who coordinates “Network Dresden – the
Advances in 3-D

Inter-institute workshop on applications in science

A reasonably powerful computer is all it takes to view objects of scientific study in lifelike reality in the comfort of one’s own home – however, the 3-D software involved often has limitations. A workshop hosted jointly in Jena by the MPI for the History of Science, the Kunsthistorisches Institut in Florenz and the Hilprecht Collection of Middle Eastern Antiquities at the Friedrich Schiller University aimed to jointly overcome these limits.

Imagine you are an art historian standing in a monastery in southern Italy. Above you, in the semi-darkness, the capitals of the columns are inscribed with fantastic figures. Wouldn’t it be nice to view them on your monitor at home with virtual lamps illuminating every detail?

Or perhaps you’re in a museum, staring at a 4,000-year-old clay tablet on which a schoolchild once wrote out tiny sums. How useful it would be to enlarge and rotate them on-screen in three-dimensional form.

Or perhaps as a biologist you need to measure the skulls of small rodents without piercing the objects with your measuring instruments. Wouldn’t it be helpful to call up images of the skulls on-screen and measure every aspect with a virtual ruler?

In fact, you can do all of these things! Scientists representing a wide range of disciplines attended a workshop at the end of last year to explore the possibilities. They contributed their experiences with computer-generated 3-D models and techniques and considered whether and where there are advantages in jointly developing new technologies and software.

Three methods are currently in use in scientific applications. Firstly, there are the models and virtual worlds created using “classic” computer-aided design (CAD) techniques; secondly, there are models calculated on the basis of tomographic sections, and thirdly, there are scanners that record stereographic images from which virtual grids can be created by triangulating the measuring points. These provide models of surface areas to which textures can be added as required.

Matteo Dellepiane (of the Istituto di Scienza e Tecnologia dell’Informazione “A. Faedo” in Pisa) introduced 3D-COFORM, a working environment in which to document and display 3-D models and virtual worlds created using “classic” computer-aided design (CAD) techniques; Christiane Bathow, who described an expedition to Inner Mongolia.

The team of scientists who look after the Hilprecht Collection and their colleagues from the MPI for the History of Science demonstrated the scanners currently being used to record mathematical cuneiform tablets. Ute Dercks of the Kunsthistorisches Institut in Florenz introduced the Cenobium project that aims to create a multimedia record of Romanesque cloister capitals in the Mediterranean area. The scientists at the MPI for Evolutionary Anthropology are also well equipped with 3-D technology, as research coordinator Jörg Noack described in a presentation entitled “Bits, Bytes and Neanderthals.” The Department of Human Evolution has an ultra-modern virtual reality laboratory used to reconstruct fossil fragments and fossils that have become deformed, as well as to conduct virtual explorations of archaeological sites.
Sometimes it’s not so much the intellectual issues that pose problems for scientists. For many of them, especially when spending time abroad, the first priority is to find a suitable home for the family or a good kindergarten. Visiting scientists at German universities and Max Planck Institutes receive help in matters like these from the International Centers (IBZs) and Guest Houses. Representatives of these organizations met in Munich in December to exchange ideas.

This was their fourth meeting since 2002, and it prompted considerable interest. Some 28 IBZs and Guest Houses were represented, even though there has so far been little networking between them. So when the participants met for a Bavarian sausage breakfast, they were not short of things to talk about. Items on the agenda ranged from integrating different cultures to financing and administrative matters, through to “meet-and-greet lounges” and operating instructions for washing machines in Chinese.

The IBZs and Guest Houses are united by an underlying sense of purpose that one representative from Berlin described as the “philosophy of academic coexistence.” The goal is for scientists from abroad to feel at home in Germany. On the one hand, this means finding suitable accommodation without undue difficulty. On the other hand, many visitors feel the need for personal contacts in a foreign land. Therefore, the Centers offer scientific lectures, discussion groups, concert evenings and other leisure encounters. One is even affiliated with a kindergarten and a school.

Due to the different ways in which they are organized, however, the Centers often find themselves dealing with problems on their own. Audit offices, for instance, dispute whether operating a guest house should even be one of the tasks of a scientific institution. Some participants were concerned that as funds become scarcer in the coming years these problems will intensify. And yet, in an age of increasing globalization, paralleled by a growing skepticism toward foreigners, the IBZs and Guest Houses are now more important than ever. In order to present a more united front in the future, the representatives attending the meeting agreed to reinforce their “brand” by forming an alliance.

The meeting was also an opportunity to exchange practical experiences. On a guided tour of the newly renovated Munich IBZ, the female participants – the IBZs are mostly operated by women – drew inspiration from the interior design features. With utility costs included in the rents charged by most Centers, it is often a challenge to persuade residents to be economical in their use of electricity and water.

Working at the IBZs and Guest Houses also requires extensive interpersonal skills to strengthen communal life. The atmosphere is also aided by the requirement written into the rental agreements for residents to give presentations of their own work. The participants from Munich in particular were concerned that intercultural exchanges at the IBZs might suffer from being too dependent on the work of volunteer program planners – one reason being that many of the female scientists who previously gave generously of their time now have professional commitments of their own.
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