

Max Planck RESEARCH

The Science Magazine of the Max Planck Society I.2011



FOCUS India

A Subcontinent in Scientific Focus

ASTRONOMY

The Warped
Ways of Light

SPECIES PROTECTION

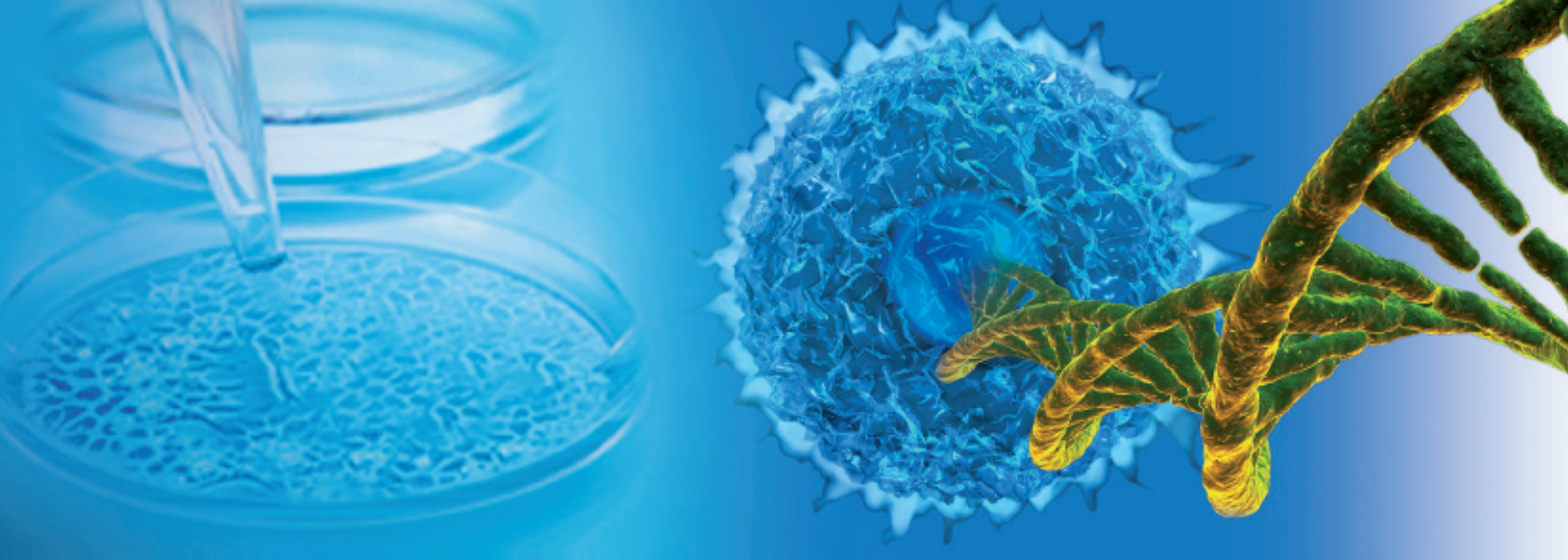
Biodiversity Must
Be Restored

SOCIAL MEDIA

The Echo of
Digital Tweets

2011

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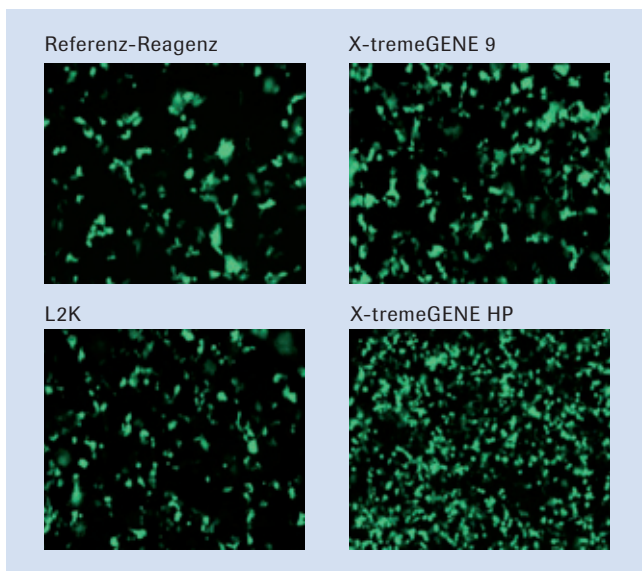


Abb. 1 Geringe Toxizität nach Transfektion mit X-tremeGENE Reagenzien. COS-7 (Ref. Reagenz, X-tremeGENE 9, L2K) bzw. HeLa Zellen (X-tremeGENE HP) wurden mit dem jeweiligen Reagenz transfiziert und die GFP-Expression im Cellavista System analysiert.

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**Nur für Forschungszwecke.
Nicht für diagnostische Anwendungen geeignet.**



Photo: MPI for the Study of Religious and Ethnic Diversity – Reza Masoudi Nejad

Waiting for His Holiness

The stereotype of the isolated researcher – that doesn't apply here at all: Peter van der Veer and Reza Masoudi Nejad, both from the Max Planck Institute for the Study of Religious and Ethnic Diversity in Göttingen, are studying the religious diversity of India. Their approach involves plunging themselves into the tumult, as here in the streets of Mumbai. Thousands of Shiite Muslims from the Dawudi Bohra community crowd into the Bhindi Bazaar to catch a glimpse of their spiritual leader. This faith originated in Fatimid Egypt in the 11th century. Despite the long tradition, the faithful registered to attend a sermon by His Holiness via e-mail.



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India

20 Breathless in the Megacity

Megacities are attractive: They offer the enticing prospect of employment and the benefits of an urban infrastructure. But megacities are also dangerous: they expose their inhabitants to high levels of air pollution.

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Climate change affects people both globally and regionally. In India, for example, scientists are investigating the interplay of dry season and monsoon.

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In India, those who fall ill can choose from among many therapeutic methods. They can rely on the skill of a surgeon or that of a spiritual healer. And it seems that the supposed contradictions aren't really all that incompatible in practice.

42 Early Globalization of Art

Art history has traditionally been focused on the study of European artifacts. The links and interactions between artifacts in Central Asia, India and the Mediterranean were largely ignored – reason enough to break down these boundaries.

50 Do Emotions Make History?

Emotions are universal and are valid in every country on earth – or so we might think. Scholars beg to differ. Taking India as an example, they are exploring how the cultural environment has shaped emotions over the course of history.

ON THE COVER: Mumbai in the morning fog: With nearly 14 million inhabitants, the metropolis is one of the world's most populated urban centers. The development of this megacity, India's principal port city, is representative of the transformation the subcontinent is currently undergoing – also in the academic arena.

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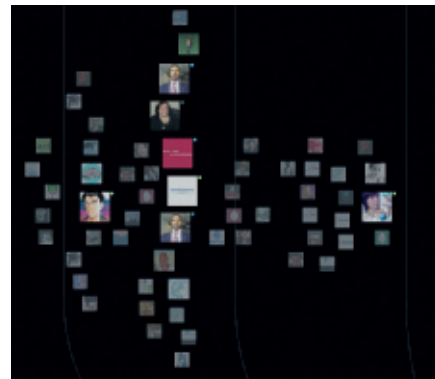
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Dear Readers,



President Peter Gruss,
Max Planck Society

Ever since I first explored India in the early 1970s in an orange VW beetle, the country has held a greater fascination for me than any other. Undemanding in terms of comfort but rich in time, I discovered a land steeped in the magnificent culture of ages passed, yet equally overshadowed by extreme poverty.

Today, not only are my travels confined to a different timescale, but – and more importantly – India, too, has changed immensely. The nation is experiencing an economic miracle and is now one of the world's most attractive growth markets. At the same time, research centers are emerging that are of international importance. I was able to visit some of them on my last trip to India in February last year. The National Center for Biological Sciences (NCBS) deeply impressed me. This institute would rank among the best even in Germany and elsewhere. That is why we are currently exploring the option of setting up a Max Planck Center there.

What's more, a whole series of other high-caliber research institutions populate the Indian scientific landscape, including the Indian Institute of Science in Bangalore, the five Indian Institutes of Science Education and Research, and some of the Indian Institutes of Technology (IITs). Their graduates are among the reasons that computer and pharmaceutical companies are booming, with growth rates commonly in the double-digit range.

Yet India remains a conundrum. Outside the gates of these ultra-modern research and business centers, 40 percent of the population lives below the poverty line. One child in two is malnourished. While the Indian Space Research Organization is preparing a mission to Mars, for which it received seed money of USD 2.2 million from the government, 35 percent of Indians are still un-

able to read or write. The children, particularly those born into the poorer echelons of society, frequently have no opportunity to complete even an elementary education.

In pursuing its innovation policy, the Indian government is treading an unusual path of which we may well be critical. But let us not forget that poverty cannot be eliminated without investment in science and technology. As the magazine *NewScientist* recently commented, the hope is "that India can short-cut the established path of industrial development and move straight to a knowledge economy." Numerous studies have found that investments in basic research boost a country's economy in the long term. In the short term, experience has shown that particularly information technology and biotechnology are essential to India's industry, and thus also for govern-

Investments in basic research boost a country's economy in the long term

ment revenues. That is the only way that India will be able to invest more money in the country's development.

I am struck by the efforts being made by India's politicians to catapult the burgeoning country to the forefront of research and development. Measured against gross domestic product, India is already investing more in R&D than Germany is. Furthermore, Prime Minister Manmohan Singh has proclaimed 2010-2020 to be India's Decade of Innovation. India's future program as a center of education and science is an ambitious one.

The Indian government, for example, is founding numerous new universities in order to meet the huge demand from young people for higher education. For many of them, an academic qualification is the only escape route from poverty. Last year alone, almost half a million young people from every corner of society sat the joint entrance examination for the IITs. The test is considered to be one of the hardest in the world. I admire the enthusiasm and ambition displayed by these hundreds of thousands of young Indians: they study for months from early until late, yet in the end, only 2 out of every 100 applicants are awarded one of the coveted places.

The potential scale of young talent in India is vast. The Max Planck Society must thus be particularly concerned to support these gifted young people through its various programs. Our first task has been to arouse the interest of Indian students and graduates in Germany in general and in the Max Planck Society in particular. Until just a few years ago, young people in India had their sights set on Great Britain and the US to study or work. Things have since changed, at least for the Max Planck Society.

India now accounts for the second highest proportion of foreign Ph.D. students at the Max Planck Society. At our International Max Planck Research Schools, Indian students actually make up the largest group. Numerous Indian scientists are now receiving postdoctoral training at a Max Planck institute. To support these young colleagues after they return to India, the Max Planck Society is financing continued cooperation between them and their former institute. For a fixed period of up to five years, the Max Planck Partner Groups provide group leaders and their teams with favorable conditions under which they can continue to develop their research. The Partner

Groups in India have met with an outstanding response: 17 have been set up since 2005, and 7 more will join them in 2011 alone. We have also been offering special grants – the Max Planck India Fellowships – for some years now to enable Indian scientists to spend a little time in Germany.

We have had a local presence since February 2010, in the form of a Max Planck Center at the IIT Delhi, sponsored by India's De-

.....
**I am certain: the world
will continue to be
amazed by India in the
years ahead**

partment of Science and Technology and the German Federal Ministry of Research. Incidentally, the starting point for the Center was a former Partner Group attached to the Max Planck Institute for Informatics.


Through all these activities, the Max Planck Society is attempting to make a small contribution to the development of India as a knowledge society. There are many signs that India's population shares this ambition. India is the world's largest democracy. The policies pursued by Prime Minister Manmohan Singh and his coalition of parties evidently have so much backing that, in the parliamentary elections in 2009, the government increased its majority. Furthermore, science enjoys a high status in Indian society. That made a deep impression on us when the Max Planck Society's Science Express – an exhibition on board a train – toured India. Five million visitors have seen the exhibition since it set out in 2007, often forming lengthy queues just to get in. The train was an excellent op-

portunity to raise awareness in India, both of Germany's research profile and of the Max Planck Society itself.

No doubt there are still challenges that India must overcome if it is to maintain its economic and scientific momentum in the long term. For example, there is still much to be done to improve basic education and reduce the number of children who are forced to leave school early. Another important task is to develop the country's infrastructure, especially in the rapidly growing megacities.

Such aspects of urban development will take center stage in the German Year in India this autumn, with a theme of "City Spaces." To mark the start of the German Year, the Max Planck Society, in concert with Siemens AG, is planning a third forum in New Delhi in the international series of "Future Dialogue" conferences. The presentations, plenary discussions and panels of experts will focus on the options and opportunities for "Sustainable Cities." Business leaders, top politicians and scientists from all over the world are invited to attend this high-profile conference to discuss how economic growth can be encouraged in major conurbations while at the same time minimizing the impact on society and the environment.

Millions of people worldwide are being drawn to cities. The urban planning challenges are huge, especially in India. The process of change on the subcontinent continues apace. Of one thing I am certain: the world will continue to be amazed by India in the years ahead.



Peter Gruss,
President of the Max Planck Society

New Website Marks Anniversary



al Chancellor Helmut Schmidt delivered an hour-long speech in which he reminded the audience of the responsibility of science to the common good. Overpopulation, the globalized economy, nuclear weapons, climate change and the clash between Western culture and the Islamic world were among the challenges Schmidt cited as opportunities for science to meet the onus upon it. Sociologist J. Rogers Hollingsworth of the University of Wisconsin described the development of the Max Planck Society following the collapse of the Kaiser Wilhelm Society as “astonishing”: when the MPS was founded in 1948, “no one would have believed it possible.” The event was chaired by ZDF journalist Petra Gerster. To mark the occasion, the new website now of-

The Max Planck Society website at www.mpg.de has been completely redesigned to offer a new, user-friendly experience. The site went live on January 11, 2011 with a lead article to accompany the official celebration of the 100th anniversary of the establishment of the Kaiser Wilhelm Society at the Berlin Academy of Arts. Former German Feder-

fers for the first time a detailed portrayal in words and pictures of the history of the two research organizations. The range of information available has been considerably expanded over the previous website. The primary objective is to provide users with fast and intuitive access – it shouldn’t take more than three clicks to find the desired information.

Continuity and Disruption

The book *LOOKING BACK TOWARDS THE FUTURE* presents a whole host of buildings in use now or in the past where science was or still is being done, and looks at the people involved. Published to mark the 100th anniversary of the establishment of the Kaiser Wilhelm Society, the book describes the history of the two institutions through more than 300 pages of photographs, essays and interviews. The work showcases the legacy and the fading traces of the Kaiser Wilhelm Society in the modern-day Max Planck Society, grouped into the three categories continuity, disruption and change: institutes of the Max Planck Society that grew out of a Kaiser Wilhelm institute in the same location; Kaiser Wilhelm institutes that were closed or integrated into other institutions; and Max Planck institutes

that distanced themselves geographically from their founding KWI, but that still retain a recognizable link in terms of structure and research topics. In a nutshell, the book takes readers through a number of milestones in the recent history of science and illustrates their importance for science today – from the nuclear physics of Otto Hahn and Lise Meitner to the Bibliotheca Hertziana, the Max Planck Institute for Art History by the Spanish Steps in Rome. Yet it also exemplifies the darker side of the history of the Kaiser Wilhelm Society, some of whose scientists were only too compliant in allowing themselves to be used by a criminal regime. The list of authors also includes historians who, in the 1990s, sat on the Presidential Committee on the History of the KWS under National Socialism.



Max Planck Society (editor): *LOOKING BACK TOWARDS THE FUTURE*. Max Planck Society and Kaiser Wilhelm Society, Sandstein Verlag, 38 euros

First Exploratory Round Table Conference

A series of conferences held jointly by the Max Planck Society and the Chinese Academy of Sciences has been launched in Shanghai

The first Exploratory Round Table Conference entitled “Synthetic Biology” took place on October 19-21, 2010 at the *Shanghai Institute of Advanced Studies*. The goal of this series of conferences, which will be held once a year, is to discuss the development status of new and emerging areas of research, as well as to outline the current situation in written summaries and subject the work to critical analysis.

Scientists from the Max Planck Society and the Chinese Academy of Sciences met with leading international experts in Shanghai to share current ideas and concepts, and discuss the future prospects for synthetic biology. The goal of this discipline is to analyze and describe complex biological systems from an engineering perspective and translate these systems into synthetic control loops or functional

units. The ultimate aim is to create “minimal life forms” that are able to support quasi-natural, optimized and artificial processes such as photosynthesis. The Exploratory Round Table Conference offers an additional means of establishing priorities in the ongoing development of both organizations’ research portfolios. The subject on this year’s agenda will be quantum physics.

Postcolonial Megacities Double As Research Laboratories

How do megacity dwellers envisage the lifestyle they aspire to?

Under the leadership of Peter van der Veer, scientists from the Max Planck Institute for the Study of Religious and Ethnic Diversity, together with colleagues from New York University and India’s Tata Institute of Social Sciences (TISS) and Partners for Urban Knowledge (PUKAR), intend to investigate how the urban environment in rapidly growing megacities impacts the development of ethnic and religious ambitions. The memorandum of understanding signed on the TISS campus in Mumbai on December 13, 2010 marked the official launch of the “Urban Aspirations in Global Cities” project. Over the next five years, the researchers will apply various scientific approaches to a study of the world’s megacities and their inhabitants. The chosen cities include Mumbai, Shanghai, Singapore and New York. These are not just important financial centers; they also each possess a unique ethnicity, from New York’s diversity to the exciting youth culture of Mumbai. Parts of the project will examine how the social aspirations of migrants make their mark and help shape a city, whether content-



Nearly 14 million people live in Mumbai, the financial hub of India.

ment or a propensity to violence predominate, and how texting is becoming the preferred medium of expression and communication in a new youth

culture. The team also intends to investigate the paradox of why megacity modernization does not automatically promote secularization.

“Good relations with the Ministry of Environmental Affairs”



Jochen Schöngart

Whitewater swamp forests – várzeas – are regularly flooded with nutrient-rich water from rivers such as the Amazon, and stretch up to 30 kilometers inland on either bank. Jochen Schöngart of the Max Planck Institute for Chemistry, and his colleagues Florian Wittmann and Maria Teresa Fernandez Piedade of Brazil's National Institute of Amazonian Research (INPA) in Manaus – with which the MPS has been cooperating since the 1950s – have put knowledge of these forests on a scientific footing. This, in turn, provided the basis for new legal controls over the logging industry in the várzea forests of the Amazon.

Mr. Schöngart, how will the logging industry in the swamp forests be regulated in the future?

Jochen Schöngart: The frequency with which trees can be cut down after reaching a given size will soon be dependent on their growth rates. We call this a GOL concept – growth-oriented logging. Fast-growing softwoods can be felled every 12 years, whereas slow-growing hardwoods can only be logged every 24 years. The current logging cycle is 25 years, irrespective of species and location, and the minimum diameter at which trees can be felled is 50 centimeters.

Which specific research findings have influenced the legislation?

In the 1980s, my Ph.D. supervisor Martin Worbes discovered, as part of his standard basic research, that trees in the tropical swamp forests form annual rings as they adapt their growth to the annual cycles of inundation. In the past, biologists had assumed that annual growth rings occur only where trees are exposed to the changing seasons. We then developed a method by which to reliably determine the growth rates of trees on the basis of these annual rings. With this information, we were then able to create models that show how rapidly the individual economically useful timber species grow in different locations. The resulting cycles of exploitation for the various tree species in the várzea vary between 3 and 30 years.

Are two defined cycles of exploitation sufficient for sustainable logging?

To put in place cycles for each individual species, the environmental authorities in the state of Amazonas, together with the beneficial owners in the várzea, would have to make an inventory of tree populations that extend over vast areas. They don't have the capacities for such an endeavor. That is why we worked with the State Ministry of Sustainable Development and the Environment to establish logging cycles of 12 and 24 years.

Will the new regulations be obeyed?

As far as the bulk of the area is concerned, I am optimistic. Other than in some isolated corners, the state environmental authorities exercise very effective controls. What's more, the people who live along the rivers accept the new rules because, from now on, they can actually fell a number of softwood species more frequently than in the past.

So, in the future, the amount of timber extracted from the swamp areas will not exceed what the tree populations can stand?

To answer the question with absolute certainty, we would have to know more about the population dynamics of the individual

species: How do they rejuvenate themselves? At what age do they begin to reproduce, and at what rate? And so on. My colleague Florian Wittmann is studying these correlations. We will probably have some reliable results in a few years' time.

So regulations based on growth rates don't achieve that much ...

Growth rates provide a fairly good criterion for sustainable logging.

Will the state authorities go along if new research shows that sustainable logging requires other regulations?

I think so. Following our initial success, we have very good relations with the Environment Ministry. That's also something we are relying on when it comes to location-specific regulations. In blackwater swamp forests that are flooded with water that is low in nutrients, the trees, for example, grow much more slowly than in the várzea. We are studying the growth rates now, and we will have precise results in about four years. Of course we hope that there will then be new rules for these locations.

Does your work have an impact on the logging industry outside of the swamp forests?

Our growth models are at least transferable to economically exploited tree species in other tropical forest ecosystems, given that it has since been proven that many tropical trees form annual rings. For example, we have developed growth models for four tree species in the forests of central Amazonia that are not subject to flooding, and we have also established species-specific management criteria such as logging cycles and minimum felling diameters. We have already achieved a lot through our research. The várzea forests alone cover around 200,000 square kilometers, and they are highly ecologically sensitive. The blackwater forests account for another 100,000 square kilometers, making a total area the size of Germany. Interview: Peter Hergersberg

Max Planck Innovation Licenses New Analytical Technology

TagFinder permits the identification of several hundred metabolic products in a biological sample



The quality of biological products such as fruit and vegetables is highly dependent on internal metabolic processes. Metabolites, such as sugars, amino acids, hormones, etc., are responsible for such properties as taste and nutritional value. For this reason, they are the subject of great interest to researchers in the food and agricultural industries. After all, optimizing quality requires an understanding of the material composition of various plant products. Metabolites also play a major role in industrial biotechnology. They are an important starting point for fine chemicals, enzymes, vaccines and recombinant proteins that are manufactured with the aid of micro-organisms

and cell cultures in bioreactors. Optimizing these production processes by analyzing the metabolic processes and identifying bottlenecks allows the desired substances to be manufactured with greater speed and efficiency. Biochemical research service provider Metabolomic Discoveries GmbH has acquired an exclusive license from Max Planck Innovation to the TagFinder analytical software. This software, developed at the Max Planck Institute for Molecular Plant Physiology in Golm, is part of an innovative testing procedure that, unlike conventional methods, allows not just a few but several hundred metabolic products to be identified in a biological sample.

Research Matters for the Future

The Max Planck Society publishes RESEARCH PERSPECTIVES 2010+

With more than 120 Max Planck Directors as co-authors, RESEARCH PERSPECTIVES 2010+ is a science-based collaboration. The Perspective Commissions of the individual sections of the Max Planck Society have identified a total of 36 topics on which the scientists have written extensive articles. The RESEARCH PERSPECTIVES indicate which fields the Max Planck Society perceives as being of particular importance for the future: "Our task is to conduct research at the frontiers of knowledge, so we keep a keen eye on areas of research that are developing dynamically and raising new scientific

challenges," explained President Peter Gruss. The objective is to identify areas that are particularly promising, where dynamic breakthroughs and paradigm shifts are to be expected – and ultimately where the greatest scientific yields are likely to be achieved. The extended articles have been condensed by journalists for inclusion in a handy brochure that can be ordered in German or English from the Press Office at presse@gv.mpg.de. The full English texts and the informative summaries are available as PDF documents at www.mpg.de/perspektiven.



New Director for Florida



David Fitzpatrick (left) and President Peter Gruss signing contracts at the Berlin offices of the Max Planck Society in November 2010.

With the start of 2011, the Max Planck Florida Institute has a new Director, neuroscientist Dr. David Fitzpatrick. Dr. Fitzpatrick comes from Duke University, Durham, NC, where he held the James B. Duke chair of neurobiology at the School of Medicine. The main emphasis of his research work is on the functional organization and development of neuronal circuits in the cerebral cortex. This is the largest and most complex part of the human brain and is tasked with sensory perception, motor control and cognition.

"This is one of the most exciting steps in my career as a scientist," declared Dr. Fitzpatrick on signing his contract with the Max Planck Society in November in Berlin. Pointing to the wealth of new techniques now emerging, he continued: "It is no exaggeration to say that we are at the dawn of a new era in our understanding of brain functions and diseases." His wife, Dr. McLean Bolton, who was previously Research Assistant Professor in the neurology section of Duke's Department of Pediatrics, is also moving to the Max Planck Florida Institute, where she will head a Junior Research Group focusing on functional disorders in neuronal circuits.

On the Net



Finding women who can lead

The Robert Bosch Foundation and publishing company Spektrum der Wissenschaft are seeking to support the advancement of top female scientists by exposing their profiles to both science and industry via the career portal "AcademiaNet." Journalists and conference organizers, too, will find it easier to find female experts by searching the lists of disciplines. Of course, exposure on the Internet also facilitates successful networking.

www.academia-net.de

Noblesse oblige: New series of podcasts

The new series of podcasts devoted to the Max Planck Society's Nobel Prize winners kicks off with the awards presented to Karl Ziegler, Manfred Eigen and Paul Crutzen. Each month through the end of the year, a new episode will be published online on the new website, introducing all 14 Nobel laureates. Tune in at:

www.mpg.de/278082/Karl_Ziegler

Welcome to Galaxy Zoo

The human brain is very good at recognizing patterns – a fact that "Galaxy Zoo" exploits for the benefit of science. Volunteers study images of galaxies on the project website and answer questions on their shape and form. The professional astronomers running the project are then able to use this information in their work. The latest version of the web portal entitled "Galaxy Zoo: Hubble" is evaluating images of hundreds of thousands of remote galaxies recorded by the space telescope.

www.galaxyzoo.org

Max Planck tweets

The Max Planck Society recently began publishing up-to-date news items on social networking site Twitter. The tweets issued by the Press Office are currently available only in English, but the number of followers is growing steadily. Due to this initial positive experience, a German Twitter feed will soon be available, too.

<http://twitter.com/maxplanckpress>




International Max Planck Research Schools (IMPRS), jointly conducted by Max Planck Institutes and Universities, form educational centers of excellence in vibrant, innovative and interdisciplinary research environments. The IMPRS offer outstanding graduate students from all over the world the opportunity to earn their doctoral degree in structured programs providing excellent research conditions. To date, 56 Research Schools have been established, covering a wide range of disciplines and topics:

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- Heart and Lung Research, Bad Nauheim
- Human Origins, Leipzig
- Infectious Diseases and Immunology, Berlin
- Marine Microbiology, Bremen
- Molecular Basis of Plant Development and Environmental Interactions, Cologne
- Molecular Biology, Göttingen
- Molecular Cell Biology and Bioengineering, Dresden
- Molecular and Cellular Biology, Freiburg
- Molecular and Cellular Life Sciences: From Biology to Medicine, Munich
- Neural and Behavioural Sciences, Tübingen
- Neurosciences, Göttingen
- Physics of Biological and Complex Systems, Göttingen
- Primary Metabolism and Plant Growth, Potsdam-Golm
- Structure and Function of Biological Membranes, Frankfurt

➤ **Social Sciences, Humanities & Law**



- Adapting Behaviour in a Fundamentally Uncertain World, Jena
- Comparative Criminal Law, Freiburg
- Comparative Legal History, Frankfurt
- IMPRS for Competition and Innovation - Legal and Economic Determinants, Munich
- Demography, Rostock
- Human Origins, Leipzig
- The Life Course: Evolutionary and Ontogenetic Dynamics (LIFE), Berlin
- Maritime Affairs, Hamburg
- Retaliation, Mediation and Punishment, Freiburg
- Social and Political Constitution of the Economy, Cologne

➤ **Chemistry, Physics & Technology**



- Advanced Materials, Stuttgart
- Advanced Photon Science, Munich-Garching
- Analysis, Design and Optimization in Chemical and Biochemical Process Engineering, Magdeburg
- Astronomy and Cosmic Physics, Heidelberg
- Astronomy and Astrophysics, Bonn
- Astrophysics, Munich-Garching
- Atmospheric Physics and Chemistry, Mainz
- Biomimetic Systems, Potsdam-Golm
- Bounded Plasmas, Greifswald
- Complex Surfaces in Material Science, Berlin
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- Earth System Modelling, Hamburg
- Elementary Particle Physics, Munich
- Geometric Analysis, Gravitation and String Theory, Potsdam-Golm
- Gravitational Wave Astronomy, Hannover
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- Optics and Imaging, Erlangen-Nürnberg
- Physical Processes in the Solar System and Beyond, Braunschweig, Göttingen, Katlenburg-Lindau
- Polymer Materials Science, Mainz
- Quantum Dynamics in Physics, Chemistry and Biology, Heidelberg
- Science and Technology of Nanostructures, Halle
- Surface and Interface Engineering in Advanced Materials, Düsseldorf, Mülheim a. d. Ruhr, Bochum, Beijing, Shanghai, Xiamen

Biodiversity Must Be Restored

The global extinction of species is rapidly accelerating. We still have a chance to stop it – at least in Germany. But time is of the essence. A simple strategy based on the biotope network model at Lake Constance (*Biotopverbund Bodensee*) shows a way out of the biodiversity crisis. The German federal government and the individual states must now set the right political course.

TEXT **PETER BERTHOLD**

Recent decades have seen an accelerated extinction of wild plants and animals throughout the world, the scope and speed of which is unprecedented. We are bombarded with bad news about this on a daily basis across all media. One day, we are asked not to eat tuna or cod. The next, the focus shifts to who will pollinate our fruit trees if the world's bee population dies out. How

and warming seas. The Living Planet Index 2008, produced by the World Wide Fund for Nature (WWF) and based on trends in 4,000 populations of 1,500 known species, shows an overall decline of 27 percent in the world's biodiversity between 1970 and 2005. The decline is most noticeable in the Asia-Pacific region.

The Red Lists of endangered species published by the International Union for the Conservation of Nature (IUCN) provides the most accurate information on the global decline in the diversity of species. The figures in the 2009 report give cause for alarm: 17,291 species – more than one third of the 47,677 species that were studied – are threatened with extinction. Among vertebrates, for example, one in eight birds, one in five mammals and one in three amphibian species were considered at risk; 277 known species (excluding fish) have already disappeared in the last few hundred years, but not one single new species has emerged.

Seventy percent of plants are at risk. The fact that the number of endangered species has increased by almost 55 percent since the 2002 IUCN list is partic-

Among vertebrates, one in eight birds, one in five mammals and one in three amphibian species are endangered

will we make our furniture in the future if climate change wipes out all of our spruce trees? And where can we enjoy some recreational snorkeling if entire coral reefs are transformed into dead haunted castles?

This loss of biodiversity is not a natural catastrophe; it has been caused by a single, massively dominant species of mammal: humankind. More than 10 million plant and animal species currently inhabit our planet. Each year, thousands of them disappear even before biologists have a chance to name them. The global causes of this mass extinction include the deforestation of large areas of rainforest, pollution

Successful ecological restoration: The Heinz Sielmann pond at Lake Constance, which covers an area measuring 10 hectares, is currently home to 40 percent more bird species than five years ago, including rare species such as the stonechat and the red-crested pochard. Residents in nearby Owingen-Billafingen are also delighted to see the first pair of storks in living memory nesting in the area.



ularly worrying. Given this “galloping consumption,” biologists predict that one fifth of all known species could be extinct by 2030 – a figure that could even rise to one third by 2050.

The current decline in the diversity of species takes two forms: the extinction of mainly rare species with mostly smaller habitats, and the dwindling of even more abundant species, some of which inhabit vast habitats. The latter are a priority in the Red Lists,

More than 350 Red Lists currently exist and are practically impossible to grasp

whose purpose is to draw attention to endangered species, specify the causes of the threat and contribute to protective measures.

Although they were not published in Germany until the early 1970s, the country currently has more than 350 Red Lists, and they are practically impossible to grasp. They provide the federal government and the individual states with information about 25,000 species in approximately 30 systematic groups, ranging from algae, fungi and lichens to flowering plants, and from snails, spiders and insect groups to vertebrates. In Europe, Germany leads the field with an average of 50 percent endangered species across all plant and animal groups. This proves that extinction isn’t restricted to distant, exotic locations, but is also occurring right here, in a country that has a long tradition of nature conservation.

Two more examples with a geographical context deserve mention: BirdLife International reveals some interesting facts about birds, a species group that is particularly well studied, in 35 European countries. Of the more than 100 species studied, no fewer than 56 of them declined between 1980 and 2005 alone; just 29 increased, and 27 remained stable. The decline was most evident among farmland birds. The new EU countries initially had fewer losses, but they are increasingly reaching a par with the old EU members.

One of the best-studied ornithological communities in Germany is at Möggingen on Lake Constance, where the Department of Migration and Immunology (formerly known as the Vogelwarte Radolfzell

ornithological division) is based. Since the institute was re-established there in 1946, bird populations have been recorded over an area measuring four square kilometers. Results obtained over slightly more than 50 years – from 1947 to 2002 – make for grim reading: of a previous figure of 110 breeding bird species, 35 percent have disappeared altogether or nest only sporadically; 20 percent have declined in the population; 10 percent have increased or are new arrivals; and 35 percent can be considered to be stable. In addition, the number of individual birds also fell dramatically, from an original figure of 3,300 to the current figure of roughly 2,100. The biomass has also declined, from an earlier weight of 240 kilograms to 150 kilograms today. Similar scenarios prevail in areas in Bavaria, Schleswig-Holstein, England and Switzerland.

The species listed for our region are by no means just rare birds, but also include such ubiquitous species as the house and tree sparrow, starling and skylark. The populations of the first three “pests” mentioned above, whose roosting places in Germany were exploded using dynamite even into the 1960s – like those of the skylark – have reduced in number from a former 10 million breeding pairs to less than half that figure. This would be considered genocide if our conspecifics were reduced in number in this way.

The second example relates to insects. On average, more than 50 percent of insect species are on our Red List. Our more senior readers will easily remember how anyone who drove a car in the 1950s frequently had to clean their windshields as, despite low driving speeds, countless dead insects obscured the driver’s vision. Today, however, we have no such problem – most insects have disappeared.

Nevertheless, we hear time and again about the biodiversity paradox. Politicians are particularly prone to using the term, misleadingly and cynically, and we should not fall for it. The “paradox” is that, even though our plant and animal populations are continuously declining, species lists for large areas like the whole of Germany are getting longer. How can this be? Quite simply, if most, but not all, of the individuals in a particular species have died out, the species remains on the federal list, even if it has disappeared from many regional lists.

If, for example, parrots make a run for it, as it were, and settle in Cologne or Stuttgart, or runaway rheas settle in Mecklenburg, these invasive species are added to our lists even if, as “spots of color,” they replace only a fraction of the estimated 75 million



individual birds that we have lost since 1800. We need to exercise caution if the lists are getting longer, but the habitats populated by the species are getting emptier.

When we see the efforts that are being made – ranging from amateurish to helpless – to put a stop to the extinction of species, of all places in a country with a long tradition of nature conservation, one could think that it had happened very suddenly, like a plague descending upon the unprepared. Not at all! Ornithologists warned of this 150 years ago. *Illuminating the case: on the reduction in birds in central Germany (Beleuchtung der Klage: über Verminderung der Vögel in der Mitte von Deutschland)* is the name of a work published in 1849 by Johann Friedrich Naumann, the father of ornithology in Central Europe.

Naumann's work made it clear that the peak in bird populations that developed magnificently in the mosaic cultural landscape of the Middle Ages, when habitats and food were abundant, had been passed. The increasingly intensive use of land meant that animals and plants were driven back. Consequently, the first real measure was taken in 1888 and resulted in the Reich Bird Protection Act. At the same time, the term "conservation" was coined. However, this Act did nothing to achieve its actual goal – to permanently stabilize bird populations.

And that is symptomatic of the practically endless chain of subsequent measures, only a fraction of which are mentioned here: establishing private conservation associations (beginning in 1899); setting up an ornithological station (Rossitten) with bird conservation programs (1901); establishing the State Agency for Natural Heritage Preservation (1906); the Reich Law for the Protection of Nature, which designated a number of conservation areas (1935); the Federal Nature Conservation Act (1976); the EU Directive on the Conservation of Wild Birds (1979); the EU Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (also known as the Habitats Directive, 1992).

These ordinances led to a surge in activity that, in Germany alone, resulted in the establishment of 21,402 protected areas in 13 different categories, some of which overlapped significantly. In the end, this huge raft of measures turned out to be nothing more than a paper tiger: the destruction of habitats and the depletion of species continue as before, the Red Lists are getting longer – perhaps even being sugarcared, for instance by changing the evaluation cri-

teria. Analysis shows that, despite the great number of protected areas, only a small percentage of the land area really fulfills the intended purpose of protection.

The causes of the extinction of species have been well researched: human overpopulation and the destruction of habitats by increasingly intensive farming combined with urban sprawl, the disturbance of natural environments and overconsumption of resources. Nevertheless, we do very little to protect our existing species. Instead, we adopt a firefighting approach: limiting the damage by trying to extinguish the fire when it is already burning. And then sitting on the fence when there's no fire burning.

A new dimension to the ludicrous conservation strategy that prevails revealed itself in 1992. As part of its Convention on Biological Diversity (CBD), the UN proclaimed 2010 to be the International Year of Biodiversity and set out to significantly reduce the loss of biodiversity – a mission that failed completely. A sustainability indicator for species diversity was developed for Germany. The aim is to achieve a value that is higher than the 1975 value by 2015. In 2007, in a best-case scenario, the data showed a stagnation of 69 percent of the target value. Trying to achieve an improvement of 31 percent in the eight remaining years is utopian, frighteningly naïve and, given the measures currently in place, about as promising as illuminating the far side of the moon by then.

Still, one thing has had an effect on the decline of the diversity of species: EU regulations have become much more strict. When Germany didn't implement the above-mentioned Habitats Directive

A huge raft of measures proved to be nothing more than a paper tiger

promptly, the country was threatened with a fine of 1.5 million Deutschmarks per day in 1998. Improvements were subsequently made and the threat is currently off the table. However, there is still a fear, particularly among authorities that grant permits, that species protection requirements, which are now rigorously enforced, will be violated. And, for the first time, conservation organizations have the tools that



allow them to do their work effectively: delay, examine in detail, push through protective measures and, if necessary, derail projects.

Politicians, on the other hand, continue to railroad through projects as much as possible before “dangerous” species are discovered. This wrangling over biodiversity resulted in the recent publication of an article in the business section of the German daily FRANKFURTER ALLGEMEINE ZEITUNG, whose headline exclaimed: “Millions for newts – biodiversity gone

Dense network of high-quality habitats as “living spaces” for plants and animals

mad.” We can understand how conservationists, who have always had their backs to the wall in these power struggles, highlight species for which the necessary protective measures are, in some cases, useless or absurdly expensive. Conversely, only a reliable biodiversity and conservation strategy would help – something that we in Germany have been waiting in vain for for 150 years.

As more than six billion people now inhabit the Earth and we can neither stop the population explosion nor adequately feed the masses and are thus reliant on every resource, we must seriously ask ourselves how much biodiversity we actually need. Apart from crop plants and domestic animals, are other species necessary, or are they merely parasites, competitors or even pests?

Many agriculture technocrats seem to be aiming for increasingly simplified, reduced ecosystems. In the East, such an ecosystem looks like it would consist of humans/rice/poultry/freshwater fish, plus some fruit and vegetables; for us in Germany, it could be humans/wheat/corn/pork/beef and a few additional products and luxuries. We now know that such mini-systems are not sustainable in the long term. Avian influenza (bird flu), a pesticide-resistant corn rootworm or some type of grain AIDS could break a link in this short chain and suddenly wipe out millions of people. This is one area where we should learn from history: when a potato blight ravaged the potato crop, the staple diet of the Irish population,

one million people died of starvation in the country in 1845. We also know that the more diverse ecosystems are, the more stable they are.

For this reason alone, we should ensure that as many species as possible are preserved. There are also a number of other reasons to preserve biodiversity. To date, we have used only a fraction of the above-mentioned 10 million species. But even among these, certain species have proved themselves to be trendsetters for almost every advance. So practically every species could play a key role at some stage in important areas of our life. We therefore need to preserve as many species as possible as a precautionary measure.

The more drastically our environment changes, the more the various species that inhabit it have to continuously adapt – through selection and micro-evolution. This is predicated on sufficient genetic diversity, a hallmark of large, stable populations. Yet another reason to safeguard not only different species, but also large populations with high evolutionary potential. The current threat of extinction facing the world’s bee population is probably one consequence of genetic impoverishment (resulting from breeding).

Genetic engineering promises great advances in many areas of life, including food, disease and pest control, and even the prolongation of life. Its continued progress will depend more and more on finding the correct genes and gene combinations. These can be sourced from many different species, each of them a benchmark for successful evolution. One important objective would thus be to maintain their entire gene pool as much as possible.

Finally, there is an important aesthetic and ethical aspect to be considered. Many people find it difficult to live without beautiful wildlife, or to be partly to blame for its extinction. (Unfortunately, this argument loses weight if we look at the millions of people who live quite happily in degraded ecosystems in places like China, for instance.)

Since the plethora of measures implemented over the past more than 100 years has certainly slowed down – but not stopped – the decline in the diversity of species in some places in Germany, my colleagues and I called for, and also formulated, a new and sustainable conservation strategy in 1988.

This strategy envisaged the ecological restoration of between 10 and 15 percent of the land area that can be spared by establishing restored “living spaces” for plants and animals in every municipality.

This would produce a dense network of high-quality habitats that all species could reach through natural distribution.

Following my retirement in 2004, I was able to initiate this kind of ecological restoration project with the help of the Heinz Sielmann Foundation. The Lake Constance Biotope Network is a major experiment consisting of more than 100 modules on a generous 500 square kilometers. At a cost of 3.5 million euros, the first 11 projects have been completed and the next 15 are in progress. Wetlands are a priority – located in the cleared cultural landscape, they produce the greatest biodiversity.

The results are astonishingly positive. The pioneering module, the “Heinz Sielmann pond” with adjoining wet biotope mosaic (measuring around 10 hectares), was created in a valley that had been subject to intensive farming. Bird populations had been recorded here for three decades and showed similar signs of decline as those in Möggingen, mentioned at the beginning of this article. Once the wetland was set up, the number of bird species observed increased from 115 to 165 in just five years, an increase of 43 percent; 10 species settled in the wetland as new breeding birds during the period. Of the 75 dragonfly species living in Germany, 33 of them have immigrated; 215 flowering plant species are developing abundant populations and providing a home for myriads of insects; five amphibian species are depositing several hundredweight of spawn each spring.

The most important finding is that Germany is extremely capable of regenerating itself in terms of biodiversity. We were also surprised by the virtually

THE AUTHOR



Peter Berthold, born in 1939, studied biology, chemistry and geography. In 1972, he qualified as a university lecturer at the University of Konstanz. In 1998, he was appointed Director at the Max Planck Institute for Ornithology and, until his retirement in 2004, was head of the Department of Migration and Immuno-ecology. In 2005, he was accepted onto the foundation council of the Heinz Sielmann Foundation. Berthold is committed to nature conservation and is a leading researcher on bird migration.

350,000 euros each. This new biotope network would come to just one billion euros, which works out to around 65,000 euros per municipality. This seems absolutely feasible.

In a second step, expert groups worked with the local authorities to determine what exactly would be restored in each municipality. The necessary funding could be obtained from foundations holding private assets. The roughly two billion euros in bequest wealth lying in the accounts of well-to-do Germans could be a good source; more funding will emerge when the initial success becomes apparent. And other countries would follow this type of good example.

In addition, a moderate rise in the “greening” of all agricultural land would be necessary, in particular by increasing the diversity of species and varieties of crop plants. The toleration of roughly 5 percent wild herbs is also on our wish list. We want to see an end to the annihilation of as many “non-plants” and “non-herbs” as possible, as the non-words of the plant “protection” services state. This would herald the return of our insects, birds and bats, and we would once again be able to enjoy the pleasure of walking through fields and open countryside. ◀

Each municipality in Germany should receive its own biotope

euphoric acceptance among the general public – more areas are being offered than we can ecologically restore. The project was also generously supported by donations.

We therefore suggest that every municipality in Germany should receive its own pond or biotope through ecological restoration. A new wetlands biotope located every ten kilometers would mean around 3,000 modules in Germany, at a cost of

Breathless in the Megacity

Megacities offer the enticing prospect of employment and the benefits of an urban infrastructure – but they also expose their inhabitants to high levels of air pollution. Together with an Indian Partner Group of the **Max Planck Institute for Chemistry** in Mainz, **Bhola Ram Gurjar** is analyzing this pollution and how badly it is affecting the health of city dwellers.

TEXT **GANAPATI MUDUR**


Bhola Ram Gurjar is always fascinated to observe the object of his research from a plane. An environmental engineer by trade, he grew up on a farm where millet was cultivated and sheep were raised. The farm was in a village with no electricity, near Ranthambore forest, a tiger reserve in Western India. Today, Gurjar's interest lies in megacities – cities with ten million inhabitants or more. Whenever he approaches Delhi, Tokyo or New York by air, time and again, he is amazed by the sprawling extent of these conurbations, the tightly packed buildings, traffic arteries, industrial areas and patches of green.

“Modern cities are among mankind's greatest achievements,” says Gurjar. But for all the advantages that cities offer, they also have serious disadvantages. The air in some of these vast hubs of human activity is extreme-

ly polluted. “Cities are great habitats,” Gurjar continues, “but they can be better still if we get a grip on problems like this.” As an environmental engineer and associate professor at the Indian Institute of Technology in Roorkee, he would like to do his part.

POINTERS TO IMPROVE AIR QUALITY

At first glance, Roorkee doesn't really seem the ideal place to study air pollution and its consequences for megacities. Situated in the foothills of the Himalayas, the town has less than 150,000 inhabitants – tiny, by Indian standards. Nor is there much industry here to pollute the environment. Bhola Ram Gurjar's desktop, however, is brimming over with air quality data – data that provides tangible evidence of the air pollution in Beijing, New Delhi, Los Angeles and 15 other megacities. >



Smog over Mumbai: The air in some megacities contains enough contaminants to cause thousands of extra deaths. Air pollution in India's capital alone claims around 10,000 lives each year.



» At first glance, Roorkee doesn't really seem the ideal place to study air pollution and its consequences for megacities.

To improve the quality of the air in megacities, Gurjar has teamed up with Jos Lelieveld, Director at the Max Planck Institute for Chemistry in Mainz. Together they developed Ri-MAP (Risk of Mortality-Morbidity due to Air Pollution), a mathematical model that estimates how many additional lives a given degree of air pollution will claim, relative to a clean atmosphere. The computer program can help the authorities in megacities around the world to clean up their polluted air. It enables them to take tar-

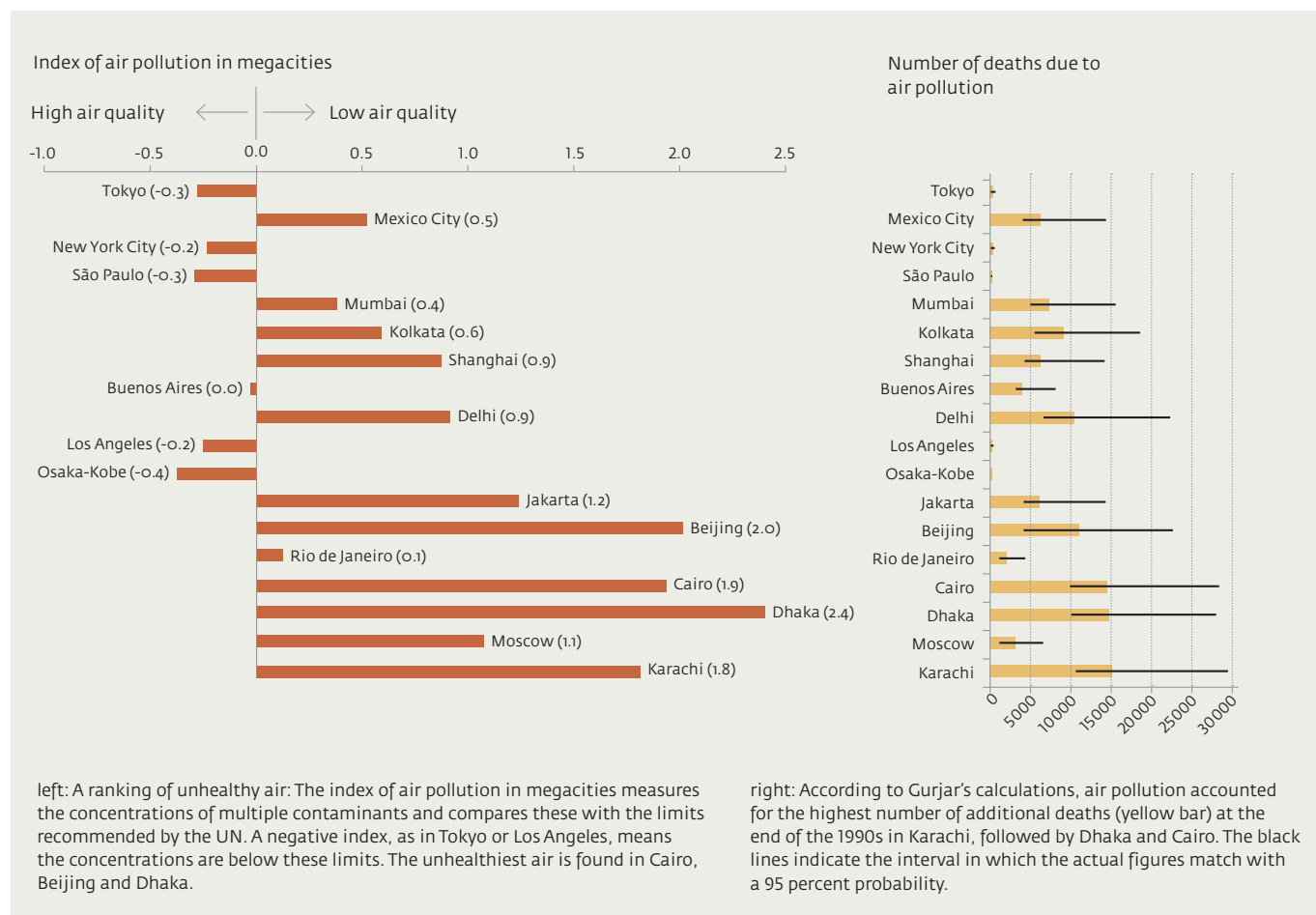
geted action based on reliable data, rather than mere supposition, to reduce the levels of particularly harmful contaminants.

OVERSHADOWED BY THE DISASTER IN BHOPAL

Gurjar arrived at the analysis of air quality and its effects on health by a somewhat circuitous route. Almost 30 years ago, he received a government grant that enabled him to enroll at a school of engineering in Jodhpur. He

still remembers studying by the light of a kerosene lamp in his village of Daulatpura in Rajasthan. His decision to specialize in civil engineering was prompted largely by chance. "I was so delighted by the idea of studying engineering that it didn't seem to matter which branch I chose. The boy sitting next to me filling out his form chose civil engineering, so I did too," Gurjar recalls.

His first job after receiving his engineering degree was on a construction site in Western India, building a run-



way. However, he found the task of co-operating with construction firms and the bureaucracy involved in public sector building projects so frustrating that he returned almost immediately to the academic world. He first completed a master's degree at his college, then a Ph.D. at the IIT in New Delhi.

It was while studying at the IIT in the 1990s that he began to specialize in the evaluation of environmental risks. He was interested in air pollutants even back then, not least because memories were still fresh in India of what at the time was the worst industrial disaster in history: in December 1984, a leaking storage tank in Bhopal had allowed toxic methyl isocyanate gas to escape, killing at least 2,500 people.

MEGACITIES ARE BECOMING INCREASINGLY RELEVANT

The accident sensitized Gurjar, too, to the dangers of airborne contaminants. He thus set up a risk assessment study in which he compared the cancer rates in certain Indian states with the levels of potentially carcinogenic substances recorded by the local environmental authorities.

On the very day on which he was awarded his doctorate from the IIT in New Delhi, Gurjar learned from a scientist from the US that Jos Lelieveld was recruiting postdoctoral researchers for his department. The group specialized in atmospheric chemistry, and Lelieveld himself had studied the inter-relationship between atmospheric chemistry and climate. He investigated the effects of the Indian monsoon on pollution transports and the capacity of the atmosphere to clean itself and remove the contaminants.

Gurjar applied and was accepted for a three-year postdoctoral research scientist's position – but he encountered



top | Bhola R. Gurjar (center) and his colleagues, here Pralhad Walvekar (right) and Ajay S. Nagpure, hope to make a contribution toward improving the air quality in megacities.

bottom | One of the offices occupied by the Max Planck Partner Group on "Megacities and Global Change" with (left to right) Tapeshe Mishra, Pralhad Walvekar, Shweta Saxena and Vandana Tyagi.

a dilemma. He simultaneously had an offer for a Ford Foundation fellowship for studies at the Harvard School of Public Health. Gurjar recalls that Lelieveld sent him a single-page analysis in a leading scientific journal that pointed out that the Max Planck Society had more publications in the field of atmospheric chemistry than Harvard. He now admits that there was another reason he picked Germany over Harvard. The Ford Foundation fellow-

ship was just enough for him to travel alone to the US. The pay as a post doc at the Max Planck Institute for Chemistry was also sufficient to bring his wife along to Germany.

When he arrived in Mainz, Lelieveld offered him the chance to choose any research topic he liked. "That was something of a surprise," says Gurjar. In India, it is usual for a mentor to tactfully but firmly direct his protégés toward a particular subject. "I decided to



left | Nitin Bhargava, Simerpreet Singh and Mandeep Sidhu analyze data on urban air pollution.
center | The researchers in Bhola Gurjar's team use these solutions and chemicals to determine the concentration of pollutants, such as oxides of nitrogen and sulfur dioxide.

study the air pollution in megacities, and Lelieveld evidently shared my enthusiasm for the topic.”

The importance of megacities, they both believed, would steadily increase, not least in research. And indeed the number of conurbations with more than ten million inhabitants has risen from just 2 in 1950, when only Tokyo and New York passed this threshold, to 20 at the beginning of the 21st century. According to some forecasts, the number of city dwellers worldwide will reach five billion by 2030, by which time 8 out of 10 megacities will be found in Asia and Africa.

AIRBORNE POLLUTANTS TRIGGER MANY DISEASES

As a consequence of this development, more and more people will be breathing air that is hazardous to their health. The problems vary from city to city. Every megacity is shrouded in its own characteristic air pollution, generated by high traffic densities and various industrial activities. In varying proportions, the air contains considerable

quantities of carbon monoxide, sulfur dioxide, oxides of nitrogen, particulates – such as soot – and organic compounds such as those released in the combustion of fossil fuels. Some megacities generate more exhaust fumes than entire countries. In Beijing, for example, a total of 2.7 million tons of carbon monoxide are released into the air – more than Portugal – yet Beijing occupies only a fifth of the area covered by Portugal.

The resulting concentrations of exhaust fumes are certainly not conducive to good health. They have long been associated with respiratory diseases such as asthma, but in recent years, links have been established between air pollution and other illnesses ranging from cardiovascular diseases to breast cancer.

Five years ago, researchers at the University of New York, Mount Sinai School of Medicine and the University of Michigan produced results indicating that particulates with a diameter of 2.5 micrometers can cause arteriosclerosis, which in turn is a risk factor for heart disease. Scientists at the Fritz Hab-

er Institute of the Max Planck Society reported two years ago that particulates less than 20 nanometers in size can provoke even greater inflammation than larger micro-particles. And just recently, experts at the Institute for Cancer Epidemiology in Copenhagen showed that long-term exposure to even low levels of air pollution increases the risk of serious chronic obstructive pulmonary disease, an affliction that makes it hard to breathe.

It is becoming steadily clearer that there is a risk associated not just with highly polluted air, to which even short-term exposure can be harmful. Even low concentrations of contaminants can cause damage if individuals are exposed to them over long periods. As an analogy, one could compare this with the passive smoking of cigarettes.

The airborne contaminants that people breathe in with their city air and how these affect their health is a natural extension of what Bhola Ram Gurjar focused on during his three-year stay in Mainz. During this period, he compiled an emissions inventory for the Indian capital of New Delhi, where



right | Precision work in the laboratory: Simerpreet Singh pipettes precisely measured amounts of chemicals into a flask to measure the concentration of airborne pollutants.

the number of vehicles on the roads has burgeoned in recent decades, while the city's infrastructure has failed to keep pace. Between 1971 and 2001, the overall length of the road network grew by a factor of 3.5, from 8,380 kilometers to 28,508 kilometers. Yet over the same timescale, the number of vehicles on the roads increased 20-fold: from 180,000 to almost 3.5 million.

"The inventory helped us to eliminate some false interpretations regarding the sources of the air pollution," says Gurjar. In the 1990s, public transportation and private traffic were regarded as the main cause of the contaminants in Delhi's air. However, Gurjar's analysis showed that up to 80 percent of sulfur dioxide and particulate emissions in the city were contributed by coal-fired power stations.

The results made it clear that what the megacities needed was an emissions inventory. In an article in the journal *ATMOSPHERIC ENVIRONMENT*, Gurjar and Lelieveld thus called for an international program to gather data on air pollution emissions and estimate their local and global effects.

The two researchers also practiced what they preached: Shortly after the article was published, Bhola Ram Gurjar returned to India and took up a position at the Indian Institute of Technology in Roorkee. There, he and Lelieveld established a Max Planck Partner Group to study air quality in megacities. Such Partner Groups enable scientists from abroad, when they return home, to continue with the joint research and existing projects first initiated at a Max Planck institute.

AN ADDITIONAL 15,000 DEATHS IN KARACHI

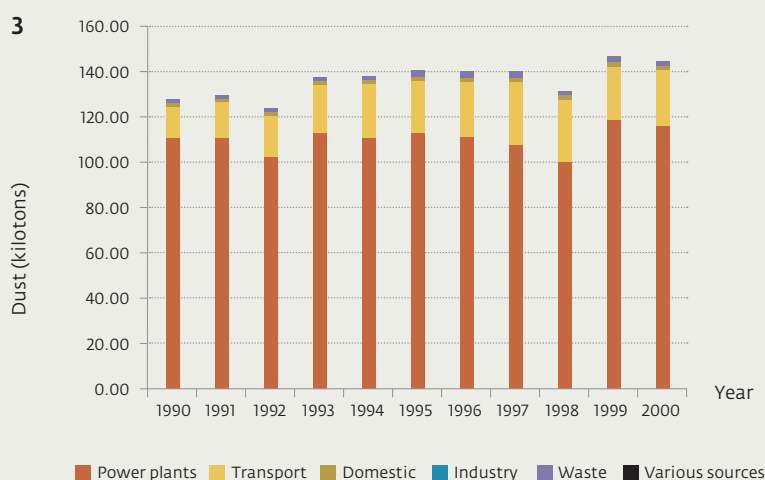
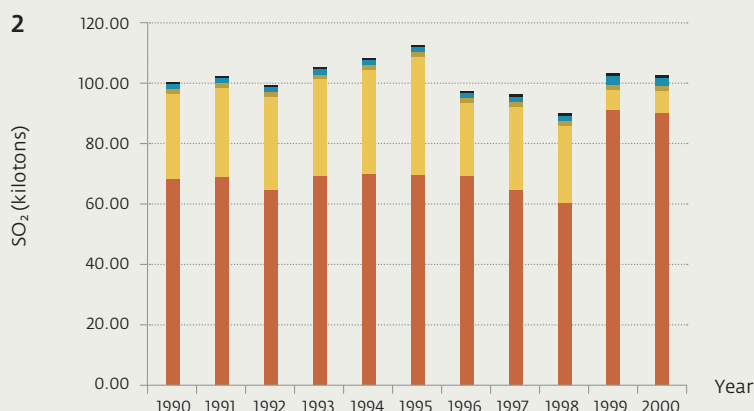
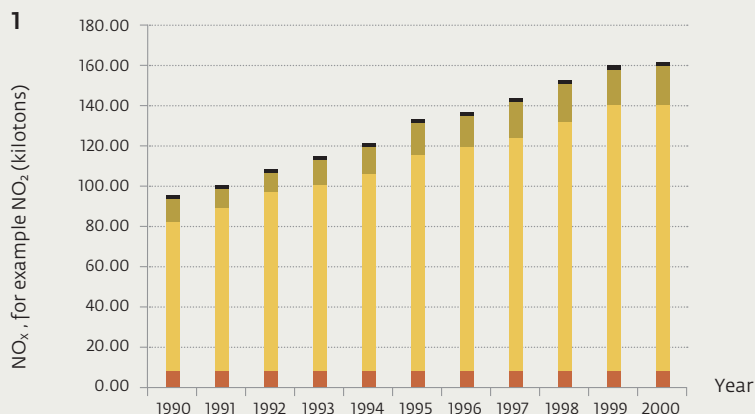
The scientists first studied the emissions in the world's 18 largest megacities and ranked them in order of air quality. The figures measured in 2000 showed that Tokyo, Beijing, and Shanghai had the highest emissions of carbon monoxide, while Beijing, Shanghai and Los Angeles recorded the highest emissions per inhabitant.

The highest concentration of sulfur dioxide was found in Dhaka, followed by Beijing and Shanghai. The levels in

each of these three megacities exceeded the standards recommended by the World Health Organization (WHO). Moscow, Beijing and Jakarta claimed the dubious record for the highest concentrations of nitrogen dioxide, while the inhabitants of Karachi, Cairo, Dhaka and Delhi suffered the worst particulate pollution.

But Gurjar and Lelieveld were not satisfied simply with drawing up a pollution ranking table. They wanted to rank these megacities by the actual impact of these contaminants on the health of their populations. Ri-MAP is the result of their continuous research collaboration – a model that combines various data: the population of a megacity, the air quality and the risk to human health presented by each hazardous substance in the air. Based on a set of ratios of concentration to effect, the model predicts the number of additional deaths in each city that can be attributed to individual airborne contaminants.

The resulting table for the 18 megacities in which the researchers analyzed the quality of the air shows where



Sources of pollution in Delhi: Bhola Ram Gurjar and his colleagues have investigated the emissions given off by power stations, traffic, domestic households, industry, agriculture and garbage. Oxides of nitrogen, such as NO₂, originate mainly from the steadily growing volume of traffic (1). The narrow black bars represent a combination of sources not depicted individually (1 and 2). Most sulfur dioxide is emitted by power stations (2). Between 1996 and 1998, emissions declined with the introduction of low-sulfur diesel, and because in 1998 the power stations burned less fuel. Meanwhile, however, the growing volume of traffic has cancelled out the improvements. Power stations are the main source of particulates (3). Reduced capacity utilization, as occurred in 1992 and 1998, noticeably reduces the concentration of particulates.

the air is most dangerous to breathe. Karachi has the highest number of additional deaths due to air pollution, almost 15,000 per year. Some 14,700 people die each year as a consequence of Dhaka's polluted air, 14,100 in Cairo, 11,500 in Beijing and 10,500 in New Delhi.

WHICH POLLUTANT MUST BE REDUCED FIRST?

In Los Angeles, New York and Tokyo, in contrast, the effects of air pollution have long since ceased to be so drastic. Here, the number of additional deaths is less than 500 per year. "The analysis shows a clear trend: the health risk presented by air pollution is greater in the megacities of the developing world than in the industrialized countries," says Bhola Ram Gurjar.

The researchers admit that the figures do not reflect any absolute certainties. The current model assumes that the entire population of a megacity is exposed to the same degree of airborne pollution. Furthermore, the model also uses annual averages of individual pollutants. In the future, however, the researchers intend to take account of monthly, weekly or even daily fluctuations in the concentrations of contaminants, as well as the number of people who are directly exposed to these substances.

"The estimates of risk may not be perfect, but we believe that they can be helpful in establishing guidelines for pollution control," says Gurjar. The model breaks down the health risks in order of pollutants: it considers the relative risk – that is, the probability of disease or death – if the concentration



Delhi's power stations release the bulk of various pollutants into the air. To reduce the number of power outages, more stations are planned, for example here on the undeveloped land in the foreground.

of one contaminant rises by one point on the Ri-MAP scale. The resulting figures show for each contaminant how steeply it increases the mortality rate due to respiratory or cardiovascular diseases, or how many hospitalizations it prompts due to chronic obstructive pulmonary disease. In both Karachi and Dhaka, around 2,100 deaths are attributable to respiratory diseases. "The city authorities could even use such approximate values as a basis for decisions on which pollutant to reduce first."

ANALYSIS TO INCLUDE HEAVY METALS AND OZONE

New Delhi became a test city for the Ri-MAP model. Analysis revealed that the number of additional deaths due to air pollution rose steeply between 1998 and 2002. Then, in 2003, the rate suddenly declined, remained constant for a few years, and is now once again rising steadily.

"The steep decline in 2003 could be attributable to the fact that that was the year in which the city authorities con-

verted all of their public transport service buses from diesel to run on compressed natural gas," Gurjar explains. "Since then, however, the steep growth in the overall number of vehicles has cancelled out this improvement."

Gurjar and Lelieveld are now keen to broaden their research to include other pollutants, such as heavy metals, ozone and minute particulates that can penetrate the human lung. At some point, Gurjar continues, the estimates of risk generated by the model should be compared against epidemiological data from the megacities. "Correlating the Ri-MAP figures directly like that with actual death statistics is the toughest test of such a model," says Gurjar.

If the model's predictions were to be confirmed by such a comparison, it is likely that city administrators would have faith in the forecasts. The results of the model calculations would then demonstrably offer a reliable basis on which to plan the measures needed to make the air healthier to breathe. Not only would there be health benefits:

the fantastic views of these megacities, seen from above from an approaching aircraft, would also be less clouded by smog – perhaps even to the point where they could be enjoyed in awe-inspiring clarity. ◀

GLOSSARY

Ri-MAP

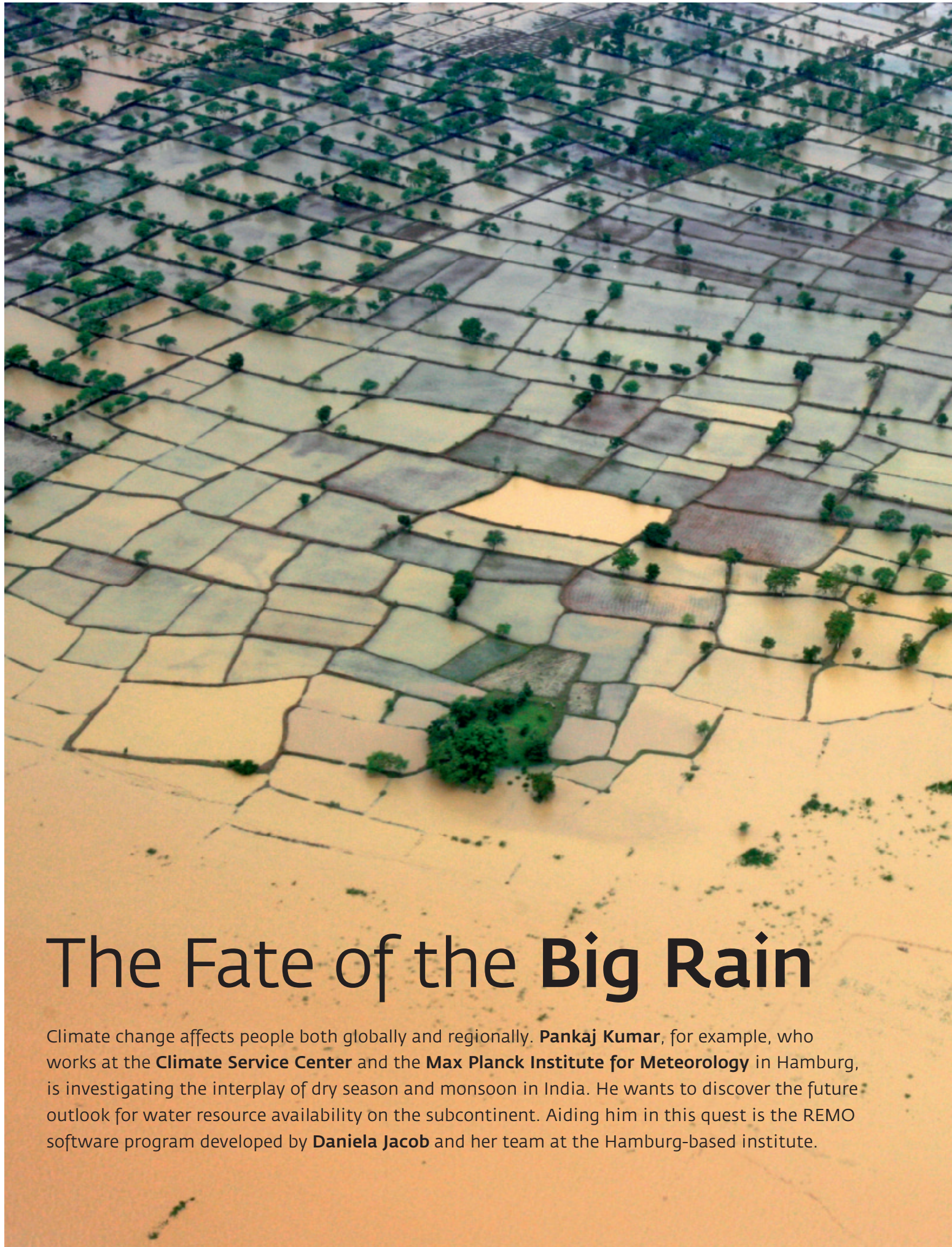
This model allows estimates to be made of the number of additional deaths and hospitalizations attributable both to specific air pollutants individually and to overall air pollution in total.

Ratio of concentration to effect

The statistical relationship between a specific contaminant concentration and its physiological effect. Thus, when exposed to a specific concentration of particulates, a certain proportion of the population will contract arteriosclerosis.

Relative risk

Indicates the probability of contracting a certain illness (such as a heart attack) for persons at particular risk (such as smokers) relative to persons not subject to the same risk.



The Fate of the **Big Rain**

Climate change affects people both globally and regionally. **Pankaj Kumar**, for example, who works at the **Climate Service Center** and the **Max Planck Institute for Meteorology** in Hamburg, is investigating the interplay of dry season and monsoon in India. He wants to discover the future outlook for water resource availability on the subcontinent. Aiding him in this quest is the REMO software program developed by **Daniela Jacob** and her team at the Hamburg-based institute.



Photo: Corbis

Waterworld: This aerial photo shows a flooded region near the city of Raipur, in central India. The annual monsoon season claims thousands of lives in southern Asia each year.

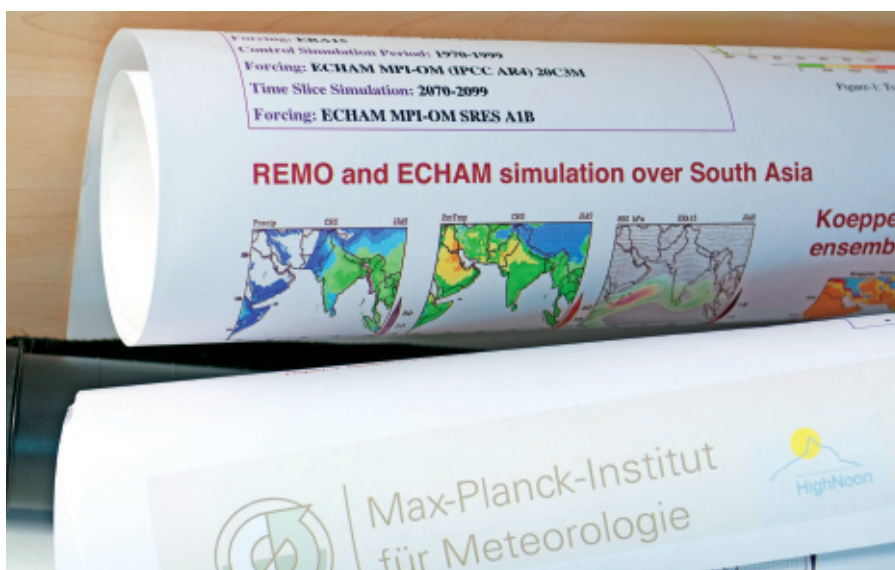
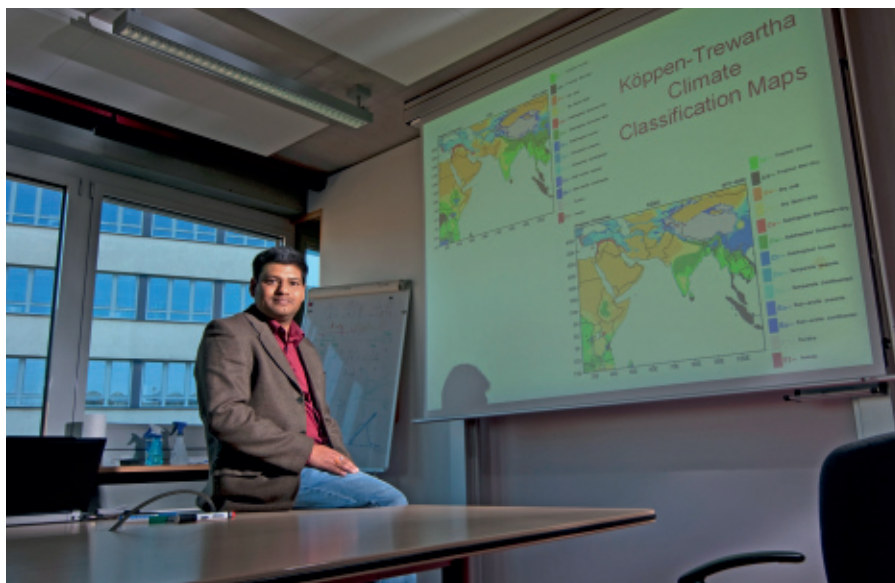
TEXT **TIM SCHRÖDER**

The air in May is hot and humid as it moves to the southwest after crossing the equator over the Indian subcontinent. It has traveled thousands of kilometers across the Indian Ocean, becoming saturated with water vapor. The clouds trail along with their fat, rain-laden bellies, and it takes very little to tear them open: an obstacle, perhaps a few mountains. As soon as they reach the southwestern tip of India and chafe against the mountains of Kerala, the clouds are forced upward and burst. It rains for weeks: the monsoon has arrived.

LIFE IS REAWAKENED BY THE MONSOON

The leaden mass of clouds navigates around the mountain slopes and finally spreads over all of India as far as the Himalayas. The rain falls on parched ground, fills creeks and rivers. Trickles swell to streams. The water engulfs paths, fields and villages. People wade along, knee-deep in water, while cars create small bow waves in the flooded streets. Yet for the Indians, this is no catastrophe: it has been dry for months. Now, life is reawakened by the monsoon.

The monsoon brings almost enough rain for an entire year – drinking water and water for fields and plantations. It's been that way for centuries. India's population is 1.2 billion and growing. As it grows, so, too, does the amount of food the subcontinent must produce if it is to feed all of its people. At the same time, there is increasing anxiety that climate change could throw the interplay of dry season and monsoon downfalls out of kilter in just a few decades. What if the rain comes late or early? What if it changes its duration? What if it doesn't come at all? >



Max Planck scientist Pankaj Kumar (above) examines India's climate as if with a magnifying glass. Using the simulation programs REMO and ECHAM (below), he zooms in on valleys, mountain forests and big cities.

When the Intergovernmental Panel on Climate Change (IPCC) warns that the writing is on the wall and the average global temperature could rise by more than 2 degrees Celsius, it really means nothing at all – because the real effects of climate change are seen on the ground: in the countryside, on the coasts, in cities. Change comes in many forms. The global climate model grid is too coarse to gauge what will happen at the local level.

Pankaj Kumar is one of the scientists studying the finer details. Working at the Climate Service Center and the Max Planck Institute for Meteorology in Hamburg, he is investigating the future outlook for water resource availability in India. To do this, he uses the REMO regional model, an elaborate software program that took meteorologist Daniela Jacob and her team at the Hamburg-based institute years to develop.

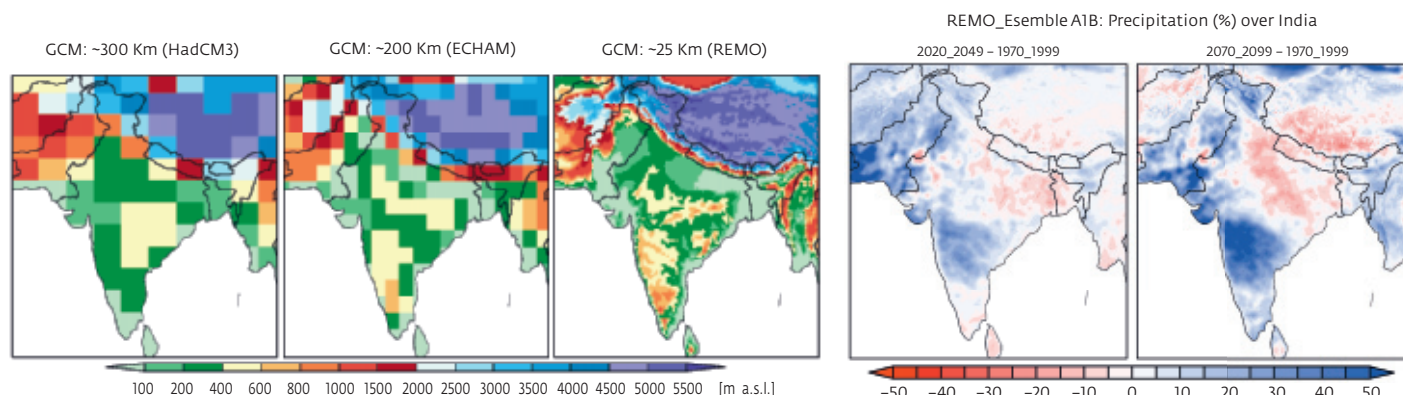
Kumar is the only Indian researcher in Jacob's group. REMO is a kind of magnifying glass that assesses the climate outlook on a small scale. It zooms into the regions, into valleys, mountain forests and big cities.

The global climate models (GCMs) the IPCC uses are rather coarse in comparison. They divide up the entire globe into a grid of weather squares measuring approximately 200 x 200 kilometers each. Only for a very small number of studies do they go down to 100 x 100 kilometers. They analyze airflows, air pressures, temperatures and winds. Above all, however, they simplify. By human standards, 200 kilometers is a long distance. A lot happens in 200 kilometers – the landscape changes, the weather changes. The average data for a 200-kilometer square gives no real indication of the peculiarities of a region.

The narrow boot of Italy, for example, falls right through the global climate grid: Italy = sea. Unfortunately, there is as yet no computer powerful enough to calculate worldwide climate for decades for each square kilometer of the Earth's surface.

That is why REMO picks out smaller areas and analyzes climate in finer grids with squares measuring 10 x 10 or 25 x 25 kilometers. It links data from the GCM – the major air currents, areas of low pressure and important seasonal fluctuations – with details of the region – the vegetation, type of terrain, heights, depths, valleys and mountain ridges. It calculates the amount of rainfall, and whether the ground can absorb the water.

India itself is a rather large area for the REMO system to handle, so Pankaj Kumar has broken it down into a grid of 25-kilometer squares. He smiles with a certain amount of pride as he explains that his REMO simulations, linked with ECHAM (GCM of MPI) and HadCM3 (GCM of Hadley Centre) simulations under the IPCC A1B scenario, are the first to run through India's climate and the consequences for the monsoon for the entire 21st century. Previously, only two detailed climate change studies had been carried out for India, and both covered only the



The difference is in the detail: The global climate models of the intergovernmental Panel on Climate Change are rather coarse, and break the globe down into a grid of weather squares measuring around 200 x 200 kilometers each. REMO, on the other hand, achieves a resolution of just 25 kilometers for the Indian subcontinent (third graphic from left). This is then reflected in the precision of the data used for climate projections, as the two graphics on the right show.

last 30 years of this century, or the decades when climate change issues look set to become really big.

Kumar set the computer to calculate 15 decades – from 1950 to 2100. He ran through several different simulations in order to check the individual findings, and came up with striking results: “We now have to assume that annual precipitation will decrease by 5 to 20 percent by the middle of the century over central India and the plains of north India,” says the researcher.

This applies particularly to the most productive agricultural region, the plains of northern India, which is watered by the Ganges River. Many hectares of land on the Ganges plain are irrigated by the waters of the great river and the rainfall from the monsoon. For now, Kumar can only provide numbers. What his Indian compatriots will be able to do in the future is still open.

When Daniela Jacob began developing REMO in the mid-1990s, she was interested only in the Baltic Sea. How would its climate change? In time, though, the Baltic Sea became too small for her. “We wanted to create a tool to discover what climate change really means,” she explains. “We are doing in-depth fundamental research, but what I have really always wanted is to create something of practical relevance.” While writing her diploma thesis at the Technische Universität Darmstadt, Jacob modeled the transport of acid rain. She simulated and analyzed cloud formation in land-sea breeze systems

for her dissertation, then simulated the blustering behavior of snowstorms during her stay in the US. Then she moved on to the climate of the Baltic Sea.

Jacob came to grips with the simulation of regional climate phenomena by a long, in-depth process. Then REMO went into operation in 2006. Along with Guy Brasseur, former head of the Max Planck Institute for Meteorology, Jacob was strongly involved in the foundation of the Climate Service Center, an independent institute in close proximity to the Max Planck institute that provides regional climate simulations as a service.

TWO DECADES OF MENTAL EFFORT HAVE GONE INTO REMO

“We get lots of inquiries”, says Jacob. “Museum curators who want to know how the climate in their city is changing so that they can protect their works of art from excessive humidity, as well as shipping offices and power plant operators, for example.” How often will the water levels in rivers be low? How many weeks per year will the Rhine and Moselle be impassable? When will power plant operations have to be curtailed because of a lack of cooling water? Forestry officials ask where in Germany the common beech will die out, and farmers want to know if there will be enough frosty nights for curly kale to develop its flavor.

“We don’t give weather forecasts, of course. What we do is calculate probabilities about how the climate might

develop at our doorsteps,” says Jacob. It sounds so simple, yet almost two decades of mental effort have gone into REMO. The challenge was to link a number of parameters in such a way that they generated a true image at the end of the process. The researchers use “re-analysis” to check whether the model works. They set the software to calculate past events and use real measurements to ascertain whether the simulation matches the real-world data. REMO’s usefulness is evident from the fact that more than 40 institutions around the world are already using it.

Of course, there are other regional models, such as that of the renowned Met Office Hadley Centre in Exeter, UK. Pankaj Kumar used this model data for some of his Indian studies, and the results showed almost the same trend: the level of monsoon precipitation is decreasing. For India, the question that remains is how to respond to this change. The international project High-Noon, involving Kumar and Daniela Jacob’s research group, is seeking to provide an answer. The project will try to clarify how water resource availability will change in northern India, and how much water will flow through the Ganges, which is used by millions of Indians for drinking water and to irrigate millions of hectares of land.

Kumar has outlined the future of the monsoon, but there is a whole range of other influencing factors that the international research team plans to investigate – such as the influence of

» Our REMO analyses have shown that the irrigation of fields in the warm Indian climate directly influences precipitation in the Ganges region.«

human activity. “Our REMO analyses have shown that the irrigation of fields in the warm Indian climate directly influences precipitation in the Ganges region – heavy irrigation leads to high evaporation and thus to heavy rainfall,” says Jacob. “It is factors such as these that make the use of regional models so challenging.”

It is fully unclear as yet to what extent the snow and glaciers of the Himalayas influence water resource availability in the lowlands. The high mountain glaciers are an unknown variable; nobody has ever really calculated how

much water they release. Two years ago, however, one of Jacob’s doctoral students developed a kind of “glacier module,” a software component for REMO that simulated the behavior of glaciers in the Swiss Alps. There was plenty of data available for the researcher to feed into the model. That data showed that only a small percentage of water in the Rhine comes from glaciers. Now the glacier module is to be coupled up for the India simulation.

The situation in the Himalayas is different. Fahad Saeed, one of Kumar’s colleagues at the Max Planck institute, is fa-

miliar with the data for his homeland of Pakistan. “About 70 to 80 percent of the water that flows through the Indus comes from the mountain glaciers,” explains the scientist, whose research focus is the western Himalayas. Kumar is concentrating on the central region.

NO ONE GLACIER IS LIKE THE NEXT

The relevant data is not yet available for India. Pankaj Kumar intends to prepare initial estimates by next year, when the HighNoon project winds up. “The size of the glacier’s surface and its thickness are important to us”, says Kumar. “Of course, it is hard to determine the thickness, but mathematical approximations are sufficient for now.”

Devoted glaciologists would tear their hair out in the face of such simplifications, because no one glacier is like the next. Their structures are different, as are their densities. Some are full of clefts and fissures, while others are dense and lie heavily on the crags. For REMO, though, it is enough for now to make a rough estimate of their thickness. Then there is the reflecting power, the albedo. Dark glaciers absorb more heat, melt more easily and release more water, while glistening white snow on the ice crust throws solar radiation back like a mirror.

Consequently, mass and albedo are important factors in predicting the future of glaciers. The HighNoon team includes Indian hydrologists who use this data to calculate how much water flows from the mountains – a vital piece of information for those who live around the Ganges.

HighNoon also aims to discover how the population can adjust to possible changes. Indian agricultural scien-

The Himalayas as a climate factor – and simultaneously an unknown variable: It is fully unclear to what extent the snow masses in the high mountains influence water resource availability in the lowlands. And so far, nobody has calculated how much water the glaciers release. One fact is known: there is regularly something brewing over India – in the lower image, a rain cloud over Nariman Point, Mumbai.





Talking shop in the corridor: Team members Fahad Saeed, Daniela Jacob and Pankaj Kumar (from left) have a discussion at the Max Planck Institute for Meteorology in Hamburg.

tists and other experts are speaking with people on the ground. In recent weeks, they took the first step of meeting with local politicians and farmers in the villages and cities along the Ganges – in the northern district of Udham Singh Nagar, practically at the foot of the mountains, in the central Ganges plain around the holy city of Allahabad and in the West Midnapore district of the lower Ganges.

“SIMULATIONS ARE ALWAYS FRAUGHT WITH UNCERTAINTIES”

“Obviously, climate simulations are always fraught with uncertainties,” points out HighNoon project leader Eddy Moors of Wageningen University in the Netherlands. “So we have to come up with measures against the consequences of climate change that are somewhat flexible.” This could include building smaller, cheaper dams or infiltration basins using natural materials to store rainwater from the monsoon, so that sinking groundwater levels could be topped up in many places. In other cases, farmers could switch to hardier plants or different irrigation techniques.

The researchers are also interested in the Tehri Dam in northern India, an enormous and highly controversial

structure that has stored water for the city of New Delhi in recent years and generates hundreds of megawatts of power through its powerful turbines. “We want to find out how the dam should be managed if the climate changes,” says Moors. How should the outflow be regulated in order to prevent flooding and flash floods after heavy rain, or to manage water availability in periods of drought? What will happen to power supplies if the glacial melt pattern changes?

The HighNoon project has reached the halfway mark. It is still carrying on with older international projects, but many questions remain unanswered. Moors and Kumar hope to make significant progress over the coming year. Kumar is confident that his work will be fruitful. “The project lays important scientific foundations that are needed before many other measures can be taken.” Then he smiles again, glances over at his colleague Fahad and adds, “And then there’s the fact that you have an Indian and a Pakistani sitting here together, working on a detailed regional simulation for both India and Pakistan that is quite unique and even includes glacial water in its calculations. We’ll find the answers to lots of questions.”

GLOSSARY

Monsoon

The monsoon is a large and continuous air current in the tropics and subtropics. It changes direction twice a year and is driven by the position of the Sun, which changes during the course of the year. The high altitude of the Sun in the equatorial region causes the land and sea to heat up to different temperatures, and this leads to marked differences in pressure, generating winds. When the monsoon current blows after crossing the equator in the westerly to southwesterly direction, it carries large amounts of water that it then discharges as heavy rainfall. This sometimes causes major flooding. In India, the main monsoon rains fall during the months of June through September.

REMO

REMO stands for Regional Climate Model or Regional Climate Modeling. The REMO software was developed at the Max Planck Institute for Meteorology in Hamburg and calculates future climate for individual regions. Its underlying data grid is set to 10 x 10 kilometers or 25 x 25 kilometers, a scale that enables predictions to be made about possible climate change even for specific rural districts or conurbations. Global climate models have a much coarser spatial resolution, since calculating the world’s climate on a small scale would exceed the capacity of today’s supercomputers. Global models work with 100- or even 200-kilometer grids.

HighNoon project

The HighNoon project is an EU project funded under the 7th European Framework Programme for Research. The project aims to clarify how water resource availability will change in northern India. It brings European researchers together with their colleagues from a number of Indian research institutions, including meteorologists, hydrologists and agricultural scientists. (www.eu-highnoon.org)

Healing with Amulets and Antibiotics

Although **Gabriele Alex** and **Vibha Joshi** belong to different departments at the **Max Planck Institute for the Study of Religious and Ethnic Diversity** in Göttingen, both scientists are studying the wide range of healing methods used and traditions followed in Indian society. Here they show from different perspectives how the supposed contradictions aren't really all that incompatible in practice.

TEXT **BIRGIT FENZEL**

In India, those who fall ill can choose between Western biomedicine and a vast array of indigenous healing methods. They can ease their pain with Ayurvedic oils, nasal douches or enemas, or try their luck with conventional homeopathic granules or naturopathic plant salves. They can also realign their body's unbalanced energies with the help of a therapy prescribed by a Siddha doctor, involving vomiting, purging or hot compresses.

Patients can also consult a Unani specialist working according to the Greek four humor principles to restore the correct balance of blood, phlegm, and black

and yellow bile. In particularly acute cases, specialists even offer services that stray into the realms of metaphysics.

According to Gabriele Alex's observations, whether a patient with a broken leg consults a surgeon or relies on the exorcism skills of a spiritual healer very much depends on the presumed cause of the illness, the distance from the patient's home to the health services available and, above all, his or her socioeconomic status. "It's basically the same as it is for us – we try to cure certain ailments using home remedies and visit the doctor only for more serious illnesses." >



Photo: MPI for the Study of Religious and Ethnic Diversity – Gabriele Alex



In India, people who fall ill can choose from a vast array of therapies, trusting the skills of a qualified doctor or a healer.



Anthropologist Vibha Joshi has carried out research into the flexibility with which many Indians combine elements from different religions with modern and traditional medicine to treat illnesses, based on her study of the Angami in Northeast India. According to local custom, they mix Christian, animistic and other religious elements when treating illness. Unlike Gabriele Alex, who, as a member of Steven Vertovec's team, is concerned mainly with socio-cultural diversity, Joshi belongs to Peter van de Veer's department, which focuses on aspects of religious diversity.

STUDYING CAUSES THROUGH DREAMS AND TRANCES

In her recently completed book *Christianity and Healing: the Angami Naga of Northeast India*, Joshi describes the relationship between Christian belief and healing among the Angami Naga in Nagaland, more than 85 percent of whom are converts to Baptism, Catholicism or other Christian denominations. "In some cases going back three generations," says the Max Planck researcher.

Although Christianity is a long-established religion in this region, it has not totally superseded the indigenous spiritual world of the Angami. Even today, they still have mediums and shamans who are reputedly able to make contact with the ancient guardian spir-

The methods practiced by spiritual healers stray into the realms of metaphysics. They are supposedly called by dreams and visions to use their powers to help people.

» The Christian churches in the federal province of Nagaland still foster the culture of prayer and healing, and belief in miracle cures is widespread.

its. Some predict the future, while others enter dream or trance states to identify the causes of illnesses and how to cure them.

In a case study in her book, Joshi describes the matter-of-fact way in which people mix the different healing services offered by biomedicine or folk medicine, Christianity and the traditional spiritual world. The study concerns the illness of a young woman from a Baptist family whose affliction priests declared to be caused by possession. After a febrile illness and initial asthma attacks, aggressive behavioral changes suddenly appeared in the patient, directed at everything and everyone. On a visit, the researcher was told about all the different efforts to find the correct diagnosis and therapy. First the family had turned to local healers, at the same time calling in the head of a nearby prayer center who also practiced as a folk healer. He diagnosed an evil spirit as the cause of her blackouts. The family also sought advice from biomedicine and took the girl to the local hospital for blood tests, but the doctors there failed to come up with an explanation for the patient's condition. A doctor from Assam finally did manage to treat the young woman's asthma.

The family then sought Christian assistance in the form of a pastor who tried to drive out the evil spirit with prayers. Still the fits of rage persisted, and other priests consulted concluded that a really large evil spirit must have lodged in the girl's body for so long that it was extremely difficult to separate it.

The family received a second diagnosis from another preacher, who attributed the girl's fits of rage to a sin committed by her great-grandfather. A third theory, finally, explained her condition as the result of the patient's refusal to accept a divine gift when she was a child. The Angami believe that shamans and spiritual healers are called by dreams and visions to use their powers to help people. Refusing such a call puts both body and soul in jeopardy.

BIBLE QUOTATIONS HELP THE TREATMENT

At the time of the researcher's visit, the girl was still not cured despite all the therapies that had been tried. The anthropologist, however, was not interested in the success or failure of the different treatment methods. To her, this patient history was a clear example of the undogmatic flexibility of the Angami's attitude to the broad spectrum of secular and spiritual medicine and treatment traditions. It is by no means exceptional for priests to be consulted on health problems. Joshi believes that this close link between Christian belief and healing has to do with the history of the mission in Nagaland.

The first Christian missionaries who arrived in the region at the end of the 19th century tried to spread their message among Angami society through education and medical assistance. "At that time, it was common for treatment to be linked to bible quotations, in order to bring the compassionate side of the Christian God clos-



A selection of drugs is available at a primary health care center, which includes a consulting room and a pharmacy.

er to the people," says Joshi. And this is still the case, as she discovered during her field research in Nagaland. "In some primary health clinics, I saw bible verses hanging over the entrance or in the treatment rooms." In addition, the Christian churches in the region still foster the culture of prayer and healing, and belief in miracle cures is widespread. As an example of these Christian establishments whose treatment methods follow in the footsteps of the Lord, she names the Revival Church of Nagaland, whose specialties include healing through the laying on of hands, and which runs healing camps specifically for this purpose.

The healing offered by other churches concentrates more on the power of prayer. "These are mainly groups of women and people who are believed to

» These improvements in the biomedical services available even in rural areas have come about on the back of the Indian government's development programs.

have unusual powers, who say special prayers for the sick," explains Joshi. Her observations confirm the link that still exists between Christianity and medicine. "Now the church's role is to reconcile the various warring factions of the Naga nationalists and thereby heal the Naga community."

Joshi's colleague, ethnologist Gabriele Alex, also came across images with Christian overtones while conducting research in the folk-medicine-based healer shops of the Vagri in Tamil Nadu. The Vagri are one of the three population groups chosen by Alex for her study on healing systems and traditions in Tamil Nadu. "I was particularly interested in how low-status castes perceive medical therapies and what methods they use to treat illnesses," she said as she talked about her project.

In fact, the inhabitants of India's most southerly federal province have access to a wide choice of healthcare systems. For one, there is traditional folk medicine with its extremely comprehensive and varied arsenal of remedies and prescriptions against illnesses of all kinds. "These include grandma's household remedies based on healing herb teas, root mixtures and soups, and professional healers who run their own practices or even clinics and treat broken bones, animal bites and skin diseases," says Gabriele Alex, enumerating some of the specialties of the *nattu maruntu* tradition.

The common factor in all these treatments is that they stem from knowledge of medicinal recipes and healing plants from the local natural

environment, handed down from one generation to the next. The tradition clearly includes an ideological element. "This type of medicine is strongly associated with India's romantic past and an image of nature and naturalness that is at odds with the modern world," says Alex. For another, the people living in rural areas also now have access to basic biomedical services. Like everywhere else in India, the range of public healthcare services in Tamil Nadu has been visibly improved by the introduction of basic healthcare establishments.

HEALTH IS LINKED TO PROGRESS

"Besides this, the Indian government has also integrated traditional medical traditions and knowledge systems into governmental health policy," says the ethnologist. As a result, Ayurveda, Yoga, Unani, Siddha, homeopathy and natural healing have been standardized and incorporated into government training, research and healthcare provision. According to Gabriele Alex, "There are also more private doctors than there used to be 20 years ago. When I began my initial research in 1998 in Madukottai, only one doctor was based there – and he wasn't a real doctor, just a quack who had worked as an assistant to a biomedical doctor for many years before eventually setting up on his own."

Eleven years later, the village boasted three private doctors, a government health center where a doctor, a nurse and a laboratory assistant were available

on weekday mornings, and a primary health subcenter with a pharmacist, birthing room and consulting room.

These improvements in biomedical services, available even in rural areas, have come about on the back of the Indian government's development programs. "Health is a major theme in this discourse, and is directly linked to economic growth and progress," says the researcher. As part of her study, she wanted to find out whether improved access to public biomedical clinics is actually displacing traditional healing systems. The fact that no or only very low costs are charged for the government service would seem to support this.

"But despite government interest in the topic of healthcare provision, hardly any studies have been conducted on this," says Alex. "It is still assumed that providing a good service means that people will use it." In addition to the Vagri, she also chose for her study the Mutturaja and the Paraiyar, who represent the traditional lower castes, both of which live from agriculture. The Vagri, in contrast, who do not practice as peripatetic healers or run healer shops but sometimes offer treatment from their homes, are traveling salesmen like their forefathers, selling cosmetics at the roadside. Others live from hunting and setting traps for small animals.

"Vagri healers are known for their special folk medicine and miracle cures against aging, impotence and infertility," says Alex. Their medical repertoire includes oils for external application, as well as powders and pastes, for which the healing plants used are



above: Modern medical services play an increasingly important role in India – as here in a clinic, where mothers wait with their children for vaccinations.

below: Explanations are a key element in the modern Indian health system, as these posters directed at young mothers show.





top: The population may make only limited use of public health institutions, but Indian women prefer to give birth in a government hospital.

bottom: Hidden but popular: Many patients put their faith in natural remedies, such as those offered by Siddha pharmacies.



mostly standard folk medicine remedies. On her visits to healer shops, she also saw how these folk medicine practitioners stir and pulverize very special ingredients in pots and pans. "But they also use animal fats, snakes and meat as ingredients in medicine, and this differentiates them from the other folk medicine healers." Other Vagri specialties include fortune telling and protective medicine, for which unusual items are sometimes used. "For instance, they buy amulets containing fox horn," explains the scientist, describing another specialism of the healer's art. "This small horn supposedly comes from the skull of the fox and transfers the animal's potency and strength to its wearer."

Among the Hindu Paraiyar in Madukottai, too, the cami (lords) are responsible for ritual healing. "The members of this caste worship mainly deities to

which animals are sacrificed and that project a certain wildness and danger, such as Kaliyaman and Karuppa, as well as Muni, who is both a deity and a spirit," Alex explains. These beings are apparently responsible both for causing illnesses and for healing them. The ritual specialists of the Paraiyar thus also play a healing role.

WOMEN PREFER GIVING BIRTH IN THE HOSPITAL

So, when they fall ill, how do these people choose from the many treatments on offer, ranging from folk healing traditions to biomedical institutions? This was one of the core questions in Gabriele Alex's study. To find the answers, she worked in the field using qualitative and quantitative methods for collecting ethnological data. She recorded the medical histo-

» The most commonly reported ailments are fevers, colds and flu infections and diseases of the digestive tract. Illnesses associated with modern civilization, in contrast, play almost no role.

ries of her interviewees in one-on-one conversations, in order to identify examples of, and changes in, health behavior. The scientist also used standard questionnaires to record the types of illnesses and their assumed causes, and the choice of healers and doctors, relating them to factors such as age, gender, education level, caste and place of residence. This methodology produced illuminating data on the medical options actually available to members of these castes and how they perceive and use these options. Analyzing the data she had collected gave Alex insight into the main causes of illness in this region. "The most common ailments reported are fevers, colds and flu infections, as well as diseases of the digestive tract," she summed up. Illnesses associated with modern civilization, in contrast, play almost no role.

The researcher was also the first person to document the fact that at least some sections of the population confound the assumptions of health policymakers. "Public health clinics are visited to a limited extent only," she says. "State hospitals are preferred only for births, because there, Cesearean sections are not performed unnecessarily – instead, babies are brought into the world slowly."

On the other hand, most survey respondents said that they preferred visiting private hospitals for fever. "Because antibiotics are often prescribed there and the drugs are considered to be more effective," the researcher explained. She also discovered that pa-

tients seeking a cure combine the various treatment methods or alternate biomedical methods with home remedies or traditional healing arts.

MALNUTRITION IS THE BIGGEST PROBLEM

A key factor in the choice of therapy direction is the assumed root cause of the patient's ailment. "People there have a clearly differentiated concept of the causes of illness," says Alex, "they distinguish between natural and supernatural causes." Biomedical doctors are competent to deal with the former, spiritual specialists with the latter.

As the scientist also discovered, the castes differ in their preferences for certain healthcare institutions. Paraiyar and Mutturaja clearly prefer government doctors and clinics or go to pharmacies and medical shops, which Gabriele Alex attributes to the socioeconomic status of these castes. "These people are day laborers and simply cannot afford hospital visits, because that would mean losing a day's work," she says. "Medical advice from pharmacies is normally free of charge and vaccinations cost just five to ten rupees."

On analyzing her questionnaires, Alex also discovered an interesting paradox: of all people, the Vagri, whose response to public healthcare institutions was the most positive in the questionnaires, use them the least of the three groups. "They feel private hospitals provide better and more effective treatment. This has to do with

the discrimination experienced by the members of low-status groups in public hospitals."

The researcher finds it particularly interesting that, when asked for suggestions on how to improve the healthcare system, most of the participants in her study cited optimization of nutrition as the most important measure, and especially improved protein intake. "All the government programs are aimed at expanding the healthcare system – yet the people in the countryside see malnutrition as their biggest health problem." ◀

GLOSSARY

Siddha

Scholastic medicine tradition developed in southern Asia. The main Siddha influences are rooted in yoga philosophy, Tantric theories and practices, and alchemical and Ayurvedic concepts.

Unani

Scholastic medicine tradition, originating in Greece and further developed in the Arab region. The current form incorporates traditional healing arts from Egypt, Syria, Iraq, Iran, India, China and the Middle East. Unani probably reached India in the 12th century.

Nattu Maruntu

"Folk medicine," a collective term embracing countless healing and folk medicine practices, refers to medical healing traditions that are based on drugs of plant and animal origin and that cannot be ascribed to the scholastic traditions (Siddha, Ayurveda).

Early Globalization of Art

Art history has traditionally been focused on the study of European artifacts. The links and interactions between artifacts in Central Asia, India and the Mediterranean were largely ignored. Researchers working with **Gerhard Wolf**, **Hannah Baader** and **Avinoam Shalem** at the **Art History Institute** in Florence (Kunsthistorisches Institut in Florenz, MPI) are seeking to break down these boundaries and open up new, global research perspectives.

TEXT **GUIDO HINTERKEUSER**

The horizons of this project, which responds to the challenges of globalization, are broad. Its full title is “Art, Space and Mobility in Early Ages of Globalization: The Mediterranean, Central Asia and the Indian Subcontinent 400 – 1650.” Nevertheless, there are concrete starting points, for instance the Museo degli Argenti in Florence, which keeps parts of the former treasury of the Grand Dukes of Tuscany.

Gerhard Wolf, Director of the Art History Institute, and Hannah Baader, Head of a Minerva Research Group, are two of the three initiators of “Art, Space and Mobility.” They happily give visitors a guided tour of the Medici collection, to provide a vivid explanation of one of the most challenging projects currently running at their institution.

Here, on the ground floor of the Palazzo Pitti, away from the crowds of tourists, are objects frequently dismissed with the label “handicrafts,” even though they appear to have been specifically predestined to demonstrate the mobility of works of art in the pre-

modern era. In this context, Islamic and Mexican artifacts encounter and coexist with works of art from the northern Alpine region and Italy.

A EWER TAKES ON A NEW IDENTITY

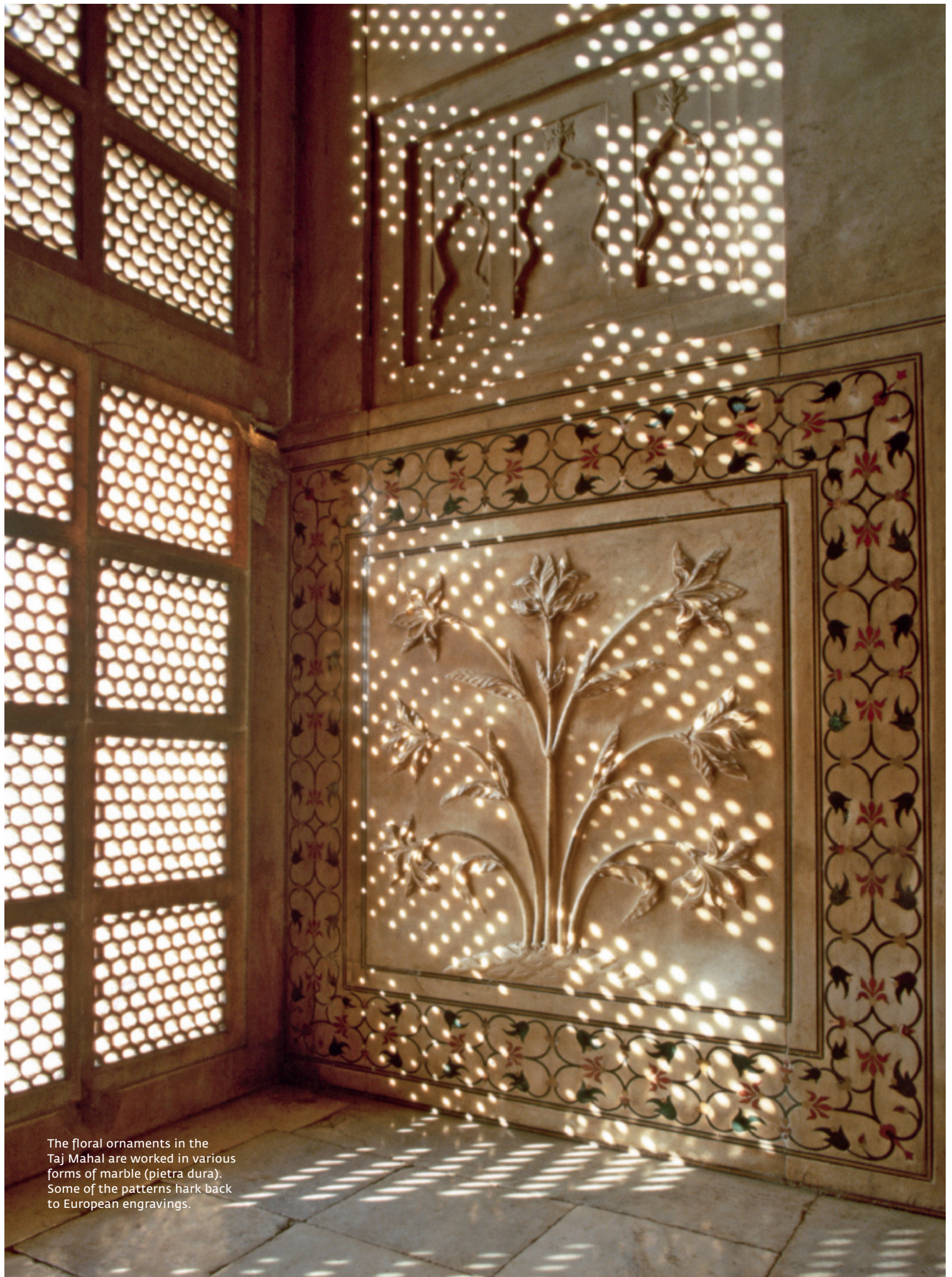
Baader and Wolf approach a display case containing a rock crystal ewer that may already have been in the art collection of Lorenzo ‘il Magnifico’ de’ Medici. Decorated with ornamental plant forms and waterfowl, it bears the Arabic inscription ‘*li-qa’id al, quw-wad khassatan*’ which, translated freely, means “for the Commander of Commanders in person.” These words may identify Husayn, one of the founders of the Fatimid Dynasty, who held this title from 1000 to 1008, and then again from 1010 to 1011.

We have in front of us an object that has traveled far and taken on a new identity. Once it came into the possession of the Medici family, it evolved new effects and meanings, winding around its original core rather like the growth

rings of a tree. Conventional Islamic art history – the ewer would probably be classified under this heading – would attempt to reconstruct its original context. Who commissioned it? Were he or she and the recipient one and the same person? Is the artist or the workshop known? Where did the material come from? Of course, questions like these still remain important.

During our conversation, however, Avinoam Shalem, the third of the project’s leaders, draws attention to the dialectics of scientific discovery and classification processes: a hundred years ago, the construction of Islamic art in its own right was a great step forward. However, it meant that other connecting lines were cut off, and must now be painstakingly knotted back together again.

Shalem cites two major art history initiatives: the founding of the Islamic Collection in Berlin in 1904 at the prompting of Wilhelm von Bodes, and the 1910 Munich exhibition “Masterpieces of Mohammedan Art.” Both were of paramount importance in de-



The floral ornaments in the Taj Mahal are worked in various forms of marble (pietra dura). Some of the patterns hark back to European engravings.

- top | This Fatimid rock crystal ewer was made in around 1000 AD and may come from Cairo. Today, it is at the Museo degli Argenti in the Palazzo Pitti in Florence.
- bottom | This miter from the first half of the 16th century shows New Testament scenes – not painted, but made with feathers.



veloping an awareness of Islamic art, which had, in the past, generally led a rather marginal existence in various departments.

But the danger of apparently unambiguous labeling is never far away. Shalem wrote an article for a collected volume published by the Kunsthistorische Institut on the transfer and circulation of Islamic objects in the medieval Mediterranean region. The title: *The Otherness in the Focus of Interest*. Here, the researcher explores how migrating artifacts, much like people, take on new identities when they end up in a different context. These migrations come more naturally to crafted objects in particular: the valuable materials and skilled work that go into their manufacture, together with their functionality, mean that they are usually immediately understood, even in foreign cultural circles.

IMAGES MADE FROM THE FEATHERS OF EXOTIC BIRDS

On the upper floor of the Museo degli Argenti, one comes upon artifacts from Mexico, which came into contact with the Mediterranean and Europe as a result of the Spanish conquest and hegemony. When examining a bishop's miter, it is only at second glance that we see that all the depictions of New Testament scenes on it are not painted, but made up of the colorful feathers of exotic birds. These feathers still possess their original brilliance and luminosity.

On the front of the miter, in the center, the crucifixion of Christ is depicted, and below it, the Flagellation, the bearing of the Cross and the crowning of Jesus with the Crown of Thorns, together with the Mass of St. Gregory. Running along the base, we see the Last

Supper, flanked by the washing of the disciples' feet on the left and Christ on the Mount of Olives on the right. The unusually woven interlacing that frames these scenes is formed by the initials of Jesus and Mary – IHS and MA – and as such can be found in engravings from the period around 1500. Prints of this sort were sent to Mexico, where they initiated indigenous artists into what were, for them, the new realms of Christian iconography.

So models migrated across the ocean to the West, where they were adopted and transformed, to finally make their way back to Europe in a new interpretation – possibly as gifts. So the artifact made in Mexico served less as a missionary tool to convert the local inhabitants than as a document of how successful the mission had already become.

The "Art, Space and Mobility" project is a highly ambitious one, as it aims to open up new, global research perspectives. It wants to break up the narrow view of traditional art history, with its focus on the Western world, and broaden it, not only chronologically but, above all, spatially. With this in mind, the researchers are seeking to create greater permeability in the dividing lines, still extant today, between general European art history and the art history of Byzantium, Egypt, Islam, India and East Asia, as well as between art history and various archaeological disciplines.

Furthermore, it is necessary to look beyond present national borders, as modern boundaries often have little to do with former constructs of rule and domination. Thus, national historical narratives are constructions that are often easy to unmask over a longer period of time – especially from the years 400 to 1650. Conflicts gave rise to new



empires, while old ones were driven back. The effects of the resultant sparks on the arts were sometimes destructive, but sometimes also creative.

A CRITICAL VIEW OF NATIONAL ART HISTORIES

As with art history's most fundamental method, the analysis of style and form, "Art, Space and Mobility" aims to achieve a critical evaluation of national narratives in the discipline, which may not easily stand up successfully against a more global background. Using a geographical approach, the researchers want to conduct an impartial survey of the MeCAIS (the Mediterranean, Central Asia and the Indian Subcontinent) area, which they have chosen for their study. "However, unlike the geopolitical studies of the pre-war era, this does not in any way involve an attempt to create new, present-day hegemonies," says Gerhard Wolf.

The project's leaders are particularly keen to illustrate the possibilities of "Art, Space and Mobility" using concise examples. One of these is the famous

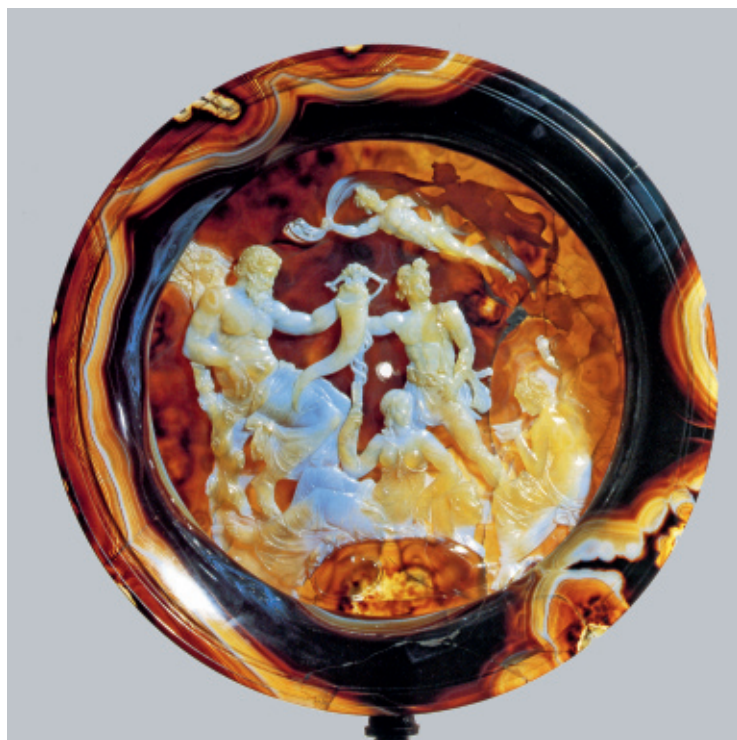
Taj Mahal in Agra, built between 1631 and 1648 and lying at the eastern boundary of the region under study. It was commissioned by Shah Jahan, who ordered it to be built as a mausoleum for his principal wife Mumtaz Mahal, who died in 1631. Upon his death in 1666, he, too, was laid to rest here. Inside the mausoleum are various depictions of flowers, symbols of the anticipation of paradise.

Particularly striking are the flowers worked in *pietra dura*, or marble inlay, some of which hark back to European engravings. It is notable that the Mogul botanists referred to European engravings even for plants that were indigenous to their region: they saw a worthy example in the way these were depicted, usually with front and side views of the whole plant and its flowers, togeth-

top: Shah Jahan commissioned the Taj Mahal in Agra as a mausoleum for his principal wife Mumtaz Mahal, who died in 1631. He was also laid to rest there following his death in 1666.

bottom: Inside the Taj Mahal, various depictions of flowers, symbols of the anticipation of paradise, are found. The copper engraving of a Turk's cap lily by the French artist Pierre Vallet (left) served a Mogul painter as a model for his drawing.





- left | The *Tazza Farnese*, made of sardonyx, shows an allegorical representation from Egyptian Hellenistic mythology and may have been created in the 1st century B.C. in Alexandria.
- right | In the early 15th century, Muhammad al-Khayyam produced this brush drawing from the *Tazza Farnese*.

er with images showing various stages of development. These European engravings found considerable resonance in the Mogul culture, as the latter was very familiar with the depicted subject matter. One example that is cited is Pierre Vallet's engraving of the Turk's cap lily (*Lilium martagon*), which must have eventually reached India, where a Mogul painter used it as a model for his drawing.

CREATING A MULTINATIONAL NETWORK OF RESEARCHERS

The project, approved by the Getty Foundation in March 2009, will initially run for two years, but has been set up for a six-year period. The fact that the Getty Foundation opted for "Art, Space and Mobility" despite tight resources fills Institute Director Gerhard Wolf with pride. But this collaborative project was a logical move for the Getty Foundation, which counts "Art History as a Global Discipline" among its leading themes. "Art, Space and Mobility" was in the air, its subject matter a direct out-

come of the research efforts of the project's three principal investigators.

For a long time now, Wolf has been devoting himself to the art history of the Mediterranean basin and of early colonial Mexico. Hannah Baader, who has been working at the Art History Institute in Florence since 2004 and now heads the project "Art, the Sea and the Cultivation of Nature 1200 – 1650," is involved in the art and cultural history of the sea and its role as a link and a mediator. The most recent work to emerge from this project is the book *Das Meer, der Tausch und die Grenzen der Repräsentation* (The Sea, Trade and the Limits of Representation). Finally, Avinoam Shalem is a professor for the History of Islamic Art at Munich University's Kunsthistorische Institut (Art History Institute), as well as a Max Planck Fellow in Florence. For centuries, Islam has played a highly influential role in the region extending from Gibraltar to India, the project's chosen area of study.

One of the project's key concerns is to involve young scholars from many countries – with top priority being given

en to fellowships – in order to interconnect national art histories. Individual research projects, such as doctorates at an advanced stage, will initially be funded for one year. At the same time, the researchers will be encouraged to communicate with colleagues from other countries who share their field of expertise. This will ensure that they are brought out of the isolation of nation-centered art history research.

One of the most exciting and impressive objects, whose fate provides a particularly good illustration of the methodological guidelines of "Art, Space and Mobility," is the *Tazza Farnese* (the Farnese Cup) from the National Archeological Museum in Naples. Indeed, its varied ties and references could make it the leitmotif for the project.

It journeys across the region taken on by "Art, Space and Mobility" no fewer than three times: as its raw material sardonyx from India to Egypt, as the end product to Persia at some point in time, and then eventually westward again to Italy. Various dating attempts place it from the third to

» The *Tazza* could be an allegory for the Golden Age proclaimed by the Emperor Caesar Augustus, which was global and not restricted to Egypt.

the first century B.C., and there are a number of different interpretations for the subject it depicts.

While a Gorgonian (Medusa's head) can be seen on its reverse and bottom side, the base is occupied with a scene of eight figures, which requires elucidation. One convincing interpretation sees in it an allegory for the fertility of the Nile. Accordingly, the sitting bearded figure bearing the cornucopia is Neilos, god of the Nile, who nourishes Egypt, where the scene is clearly located, as suggested by the pharaonic sphinx at his feet. Seated on the sphinx is a fertility goddess, while the standing figure behind her could be the Greek hero Triptolemos, who represents farming and cultivation. The scene is rounded off by two winds, to whose influence the fruitful floods of the Nile are attributed, and two Horae, which symbolize the seasons.

The suggested time of its creation is the last seven centuries of the Ptolemaic court in Alexandria, which came

to an end in 30 B.C. with the suicide of Cleopatra and Egypt's degradation into a Roman protectorate. However, the fall of the Ptolemaic empire did not mean an end to its artistic workshops and traditions.

THE MYSTERIOUS TRAVELS OF AN ORNATE CUP

Therefore, the other possibility is that the *Tazza Farnese* was not made until between 30 and 10 B.C., also by an Alexandrian artist, but already under – or perhaps even for – the emperor Caesar Augustus. The *Tazza* could thus be an allegory for the Golden Age proclaimed by him, which was global and not restricted to Egypt. Accordingly, the scene-in-the-round would symbolize the world, and the rim of the vessel the ocean that surrounds it.

“Art, Space and Mobility” is not content with merely placing an object within the context of its creation, but also investigates its more far-reaching

effects, which are often associated with migrations. The *Tazza* is a paradigmatic example of this: Its whereabouts for many centuries after its creation are unknown. At the beginning of the 15th century, however, it must have been in Persia at the court of the Timurids, either in Herat or in Samarkand. Evidence of this is provided by a brush drawing executed by the painter Mohammed al Khayyam and kept at the Berlin State Library.

We know as little about the object's travels to Persia as we do about the circumstances of its relocation to Italy, which occurred soon afterward. Following stops in Naples and Rome in the collections of King Alfonso I and Pope Paul II, the aforementioned Lorenzo ‘il Magnifico’ de’ Medici moved it to his Florentine collections in 1471 after a visit to Rome. In Florence, it was admired by Sandro Botticelli: the two winds were probably the inspiration for the wind deities, the *zefiri amorosi*, in his famous *Birth of Venus*. >

THE TEMPLE AND THE MUSEUM

The foundation of the art museum was one of the hallmarks in the development of the secular state. Both temples and museums offer a narrative of the past, be it interpreted as secular or divine, showing history in an aesthetically organized framework. Studied from a comparative and interreligious perspective, the processes involved prove to be extremely complex. The Partner Group investigates this new field of research, focusing on the following questions: How are art and the museum considered in societies that have different experiences with modernity than is typical in European societies? What was the impact of the colonial experience in this regard? What is the function of art in Hindu, Buddhist, Islamic or pluri-religious societies like India? How do the visual practices and concepts of space in Hindu, Christian and Islamic temples differ from one another, and when and how do they relate to one another? How can art – today and in the past – interfere with religious conflicts or overcome them? The Partner Group investigates these problems by means of fellowships, workshops and conferences that involve a strong cooperation and

exchange with the Kunsthistorisches Institut in Florence within the scope of the research project entitled “The Temple and the Museum. Considering the Places of Art and Religion in a Comparative Perspective: The Mediterranean, Europe and India 1200 – 2012.”

Kavita Singh is Professor for Art History at the School of Arts and Aesthetics, Jawaharlal Nerhu University, Delhi. Her research interests include the history and politics of museum collections, the social history of Indian painting, and the application of narrative theory to art. Kavita Singh has been a Guest Curator at the San Diego Museum of Art. She was co-curator of *Power and Desire: Indian Paintings from the Binney collection*, an exhibition of Indian miniature paintings that traveled through the US, Europe and Asia, and of *Where in the World*, an exhibition examining contemporary Indian art in the era of globalization. She has received grants and fellowships from the Getty Foundation, the Clark Art Institute, the Victoria and Albert Museum, London, and the Asia Society, New York.



The coronation mantle of the Holy Roman Empire. Made of red silk interwoven with gold thread and embroidered with pearls and enamel, it was produced in 1133/1134 for King Roger II of Sicily in an Arabic-Norman workshop in Palermo.

But Florence was not to be its last stop. Through Lorenzo's great-nephew, Alessandro de' Medici, the *Tazza* ended up in the hands of his wife Margaret of Austria, who married Ottavio Farnese a year later and took the valuable object with her to Rome. Here, it was seen in the 17th century by Nicolas Poussin who, like Botticelli before him, was influenced by it, resulting in the Egyptian coloration of his painting *The Exposition of Moses*, now at the Ashmolean Museum in Oxford.

COMMUNICATION IN THE MONGOL EMPIRE

Borrowing directly from the *Tazza*, whose coloring is determined by the nature of the stone, Poussin also painted his sphinx with a dark body and a pale face. In 1731, the piece was inherited by Carlos, Infante of Spain, who became King of Naples and Sicily in 1735, who then moved the cup to the Palazzo di Capodimonte. At this point it must be clear that justice cannot be done to an artwork like the *Tazza Farnese* within a single discipline.

While the *Tazza Farnese* may be a special case, once the multilayered complexity associated with it has been

grasped, other works of art can also be approached with similar questions in mind. The individual fellows who will do the actual field research will also be encouraged in this direction. Their task will be to examine their material for such multiple layers and to take a critical approach to any apparent definitudes.

Satenik Chookaszian, for example, from Yerevan in Armenia, is using the 13th century medieval manuscripts created in the Armenian Kingdom of Cilicia to investigate the impulses of neighboring artistic languages. Irene Giviashali, post-doc from Tbilisi, Georgia, is looking into how medieval Georgia was positioned, in the artistic sense, between Byzantium and the Islamic dynasties. At the University of Ulan Bator in Mongolia, Dorjjugder Purevjav is working on a doctorate concerned with verbal and written communication forms and pathways within the Mongol Empire. Finally, Pushkar Sohoni at the University of Pennsylvania is investigating the spread of architectural knowledge in the early modern Deccan (the southerly part of the Indian subcontinent) and the mediating role played by the Indian Ocean.

While these four fellowship holders are staying at their home institutions, two post-doc projects have been established in Florence: Mattia Guidetti is researching the art of sacred construction in Syria between 600 and 1300, and is particularly interested in the sites where Christian and Muslim holy cities existed not only alongside, but also sometimes within each other. Simon O'Meara from the American University of Kuwait is using the examples of the Kaaba in Mecca and the Dome of the Rock in Jerusalem to investigate the dialectics between the "seen" and the "unseen" in Islamic theology and aesthetics.

WORKSHOPS FOR FELLOWS AROUND THE WORLD

"Art, Space and Mobility" has developed a differentiated structure to facilitate networking between the widely scattered fellowship holders. All project participants meet several times a year to exchange views. Two thematic workshops in Florence and at the Berlin State Museums are complemented by a site-specific workshop that takes place at different locations each time. In addition, there are sym-

posia and an annual Summer School that is also open to outside applicants.

The first Summer School took place in Tunisia in May 2010. Participants devoted themselves to Ifriqiya as a cultural meeting place and visited late-Roman sites such as the Amphitheater of El Djem, the Aghlabid dynasty's city of Al-Qayrawan and Mahdiyya, the first capital of the Fatimids. Ifriqiya is identical to the former Roman province of Africa, which comprised the eastern regions of Algeria, Tunisia and parts of Libya, and was conquered by Muslim Arabs in 663. Under the Aghlabid dynasty, Ifriqiya experienced an age of cultural flourishing from 800 to 909.

The legacy of the region's ancient Roman and Byzantine masters was integrated into an artistic language that was deemed appropriate by the new Islamic rulers. From the year 827 onward, they began their bid to conquer Sicily, only a hundred kilometers away – a process that led to a further transfer of art and learning in both directions. In this context, it becomes clear that the sea was not an agent of separation, but of connection. Products could be transported by sea, something that could have been accomplished over land only with great difficulty, less speed and less scope.

The links to the West extended as far as Andalusia, and those to the East up to the centers of Islam, such as the Caliphs of Baghdad, on whom these rulers depended. In Qayrawan (Kairouan), which today is a UNESCO World Heritage Site, the workshop participants visited the Great Mosque, which was extensively reconstructed by the Aghlabids starting in 836 A.D. The inner hall, with its 17 naves and the transept in front of the Qibla Wall, dates from this period. Spolia from Carthage were already used in a new building that was started around 703 A.D.; the Aghlabids also liked to use antique building components, "islamizing" the material, as it were, with verses from the Koran and professions of their faith.

Here, it also became clear that the boundaries of academic disciplines can

often obscure the view of connections. There is thus no doubt that the coronation mantle of the Kaiser of the Holy Roman Empire of the German Nation, which is kept in Vienna, also has some connection with Ifriqiya. Like the Fatimid rock crystal ewer at the Museo degli Argenti in Florence, the coronation mantle also bears an Arabic inscription in Kufic script, betraying its origins in the royal embroidery workshops (tiraz) in Palermo in 1133/34. This semi-circular, floor-length cloak, made of a shimmering silk fabric, is embroidered with pearls, gold and silver thread; on the back, the embroidery depicts a stylized palm tree flanked on each side by a lion prevailing over a fallen camel.

The mantle, made for the Norman King Roger II of Sicily, came through his daughter's marriage to the Hohenstaufen Kaiser Heinrich IV, and so made its way into the coronation insignia.

THE PROJECT HAS AN OPEN FRAMEWORK

Christian re-conquest by the Normans didn't occur until 1061. This, however, did not mean the end of the then well-established royal court workshops of Islamic artists who, in turn, had encountered the traditions of the Byzantine craftsmen in the preceding centuries. On the contrary: the new rulers were not only keen to use their services, they also carefully observed the royal courts of the Mediterranean and brought both Greek and Arabic artists to Sicily. The new rulers, needing to achieve legitimization, regarded Arabic writing as a ceremonial, holy script, standing for monarchic identity or symbolizing the mythical glamour of the Fatimid court.

In view of the infinite number of themes that are possible for research within "Art, Space and Mobility," anything is suitable except a highly selective approach. Unlike other major projects in the past, this one does not define a set framework that must then be filled with years of painstaking

detail work. Instead, it is all about developing and implementing new methodological approaches for surveying visual arts over an intercontinental area.

Success will be measured particularly by whether the project generates not only collected works and conference proceedings issuing directly from "Art, Space and Mobility," but also, increasingly, studies that take a globalized view of artworks that appear to be narrowly and clearly demarcated. In doing so, the project lays the foundations for the research of visual arts in a globalized world. ◀

GLOSSARY

Fatimids

A Shiite-Isma'ili dynasty that ruled in North Africa – in Maghreb and Egypt – as well as in Syria, from 909 to 1171.

Iconography

An art historical method involving the identification and interpretation of motifs and meaning in visual artworks. The research and interpretation of the subject of images taking into account contemporary literary sources, such as works of philosophy, poetry and theology, that influenced the relevant motifs and their depiction is also known as iconology. Art historians Aby Warburg and Erwin Panofsky introduced the first systematic teachings of this method.

Spolia

Structural components and other remains, such as parts of reliefs or sculptures, friezes and architrave stones, and remnants of columns or capitals, that originate from the structures of older cultures and are reused in new buildings. Antique intaglios, cameos and reliefs on medieval book covers and reliquaries are also referred to as spolia.

Holy Roman Empire

Official name for the realm of the Roman-German Kaiser from the Middle Ages until 1806. The name of the Empire is taken from the medieval rulers' claim of upholding the tradition of the ancient Roman Empire and legitimizing their rule as God's holy will in the Christian sense. It is also known as the Old Reich, to distinguish it from the German Reich that was established in 1871.

Splendid colors and calligraphy: Advice books for Muslims (here in Urdu, the official language of Pakistan) are beautifully presented – and serve as important sources for research on emotions.



Do Emotions Make History?

One might presume that feelings are universal. Scholars working with **Margrit Pernau** at Berlin's **Max Planck Institute for Human Development** would probably beg to differ. Taking India as an example, the group is exploring how the cultural environment has shaped emotions over the course of history.

TEXT **TINA HEIDBORN**

The expert in difficult-to-decipher texts sits behind the first door. A brief glance at a manuscript that drives others to despair is often all he needs. "It's great to have someone on the team with a native command of Arabic, Persian and Urdu. Even handwritten texts pose no problem for him," says project leader Margrit Pernau. Her doctoral student Mohammad Sajjad smiles modestly when the subject of his language skills comes up.

When Sajjad told his friends at home that he was going to Germany on a scholarship to complete his Ph.D., they were more than a little surprised: an Indian doing a doctorate on an Indian subject in Germany, and working as part of an international research group – is that even possible? But India is a common topic at the Max Planck Institute for Human Development, where the country is the focus of research into the history of emotions.

In January 2008, historians working with Director Ute Frevert began investigating whether emotions actually make history. Their work traces emotions and how they change over the course of history, and explores the importance attached to them. "We all like to believe that our own emotions are universal," says Margrit Pernau. Yet she and her fellow researchers set out to question this very assumption. Their core hypothesis is that emotions are shaped by culture. It is through their environment that people learn which emotions they are supposed to or are allowed to have, and how they are permitted or, indeed, expected to express them.

The rules of emotions can thus change over the course of time, as can the ways in which feelings are expressed. Consequently, emotions are also embedded in a specific cultural setting. "We needed a region where the rules were different than those in

» For a long time, the core of an Indian family did not consist of father, mother and child. Instead, sons stayed on at home with their parents and brought their wives to live with them.

Western Europe,” says Pernau. That is how India came to be part of the research scope.

On the one hand, the Indian subcontinent is far enough away from Europe to be really different. And unlike South America, which is also geographically distant from Europe, India has never been significantly shaped by European immigrants. On the other hand, India has historical connections with Europe, particularly as a result of British colonial rule. “Relations between India and Europe have been close for 300 years, and have been both mutual and reciprocal,” points out Margrit Pernau.

Consequently, from a European perspective, India is less different than China. For the scholars, the subcontinent was thus an ideal addition to the scope of their project aimed at exploring emotions over the course of time. At the same time, it provided a means of investigating the entanglement between South Asian and Western European cultures.

This modern publication on how to bring up girls warns against excessive consumerism (left). In contrast, prayer mats and hand mills are recommended (right).

But India also represents quite a challenging field of research, even just in terms of its languages. Historians of emotions take the same approach as all historians: they search for sources, then read and analyze them. Project leader Margrit Pernau has three shelves crammed full of books in her office. Elegantly shaped letters stretch across colorful bindings, graceful calligraphy, beautifully presented: Indian advice books, including “How to be a good wife,” “How to raise your daughter to be a good wife” and “A husband’s rights with respect to his parents-in-law.”

For Margrit Pernau, these are important sources that she can use to learn about the “emotional rules” in certain situations: How do I need to behave as a wife, a husband, a mother-in-law? Emotional norms, as outlined in literature such as these advice books, are one way for historians to access the world of feelings. Looking at these books, it didn’t take the scholars long to realize that different emotional rules are often underpinned by different social structures.

How do I become the perfect wife and daughter-in-law? Indian and German advice books each approach such subjects from the perspective of very different contextual backgrounds: “In large families where the sexes are segregated, as is the case in the Indian model, the hierarchies are completely different than in the European model of the nuclear family,” explains Pernau. For a long time, the core of an Indian family did not consist of father, mother and child. Instead, the sons stayed on at home with their parents and brought their wives to live with them.

PEOPLE FELT DIFFERENT IN THE PAST

In this situation, conflict quite often arose between the sisters-in-law, in other words the women who had married into the household. “The husbands, that is to say the brothers of the family, also would frequently play out their own conflicts with each other through the women,” explains Margrit Pernau. “That was a completely different framework for emotional management within the family,” she says.

Photos: Norbert Michalke (2)





A Muslim family at the large camel and cattle market in Pushkar, India. Muslims make up just over 13 percent of the Indian population.

However, advice books like these are not the only sources of information on the values and emotional standards of days gone by. Schoolbooks are also useful: what were women to learn, what were men to learn? What values do schoolbooks communicate? Schooling always involves emotional education, too. Then there are texts that deal explicitly with emotions, such as scientific works that explain the origin of emotions, or philosophical and theological treatises. Prohibitions, morals, ethical behavior – these were and continue to be burning issues throughout history.

The Max Planck scholars are tracing not only the rules that apply to feelings through different times and cultures, but also the ways in which emotions are expressed. Writers often express emotions: their own or the feelings of others. In addition to the literature written by men, India was another of the nations that saw increasing numbers of texts published by female authors from the 19th century onward, as women began to write novels, autobiographies and letters.

On the surface, emotions appear to be a rather unusual subject for historians to tackle. But on closer inspection, there are vast amounts of very differ-

ent sources out there. In the case of India, these sources come in many different languages: Hindi, Urdu, Persian, Arabic; English did not appear until much later. Margrit Pernau admits that this poses huge challenges. Her team currently includes four doctoral students: two Germans and two Indians. “I would never have given a purely Indian topic to someone who could read only sources in English. You need a command of at least one of the common languages,” says Pernau. The two German doctoral students, both women, studied Indology, and one is currently completing her doctorate in advice literature in Hindi. She has just traveled to India to begin a two-month research residency.

A TALENTED LINGUIST FROM DELHI JOINS THE PROJECT IN BERLIN

Mohammad Sajjad set out in the opposite direction in October 2008. A full-bearded man in his mid-thirties, Sajjad applied to join the Berlin-based project from his home in Delhi. Originally from Dinajpur, a district in the north-west of the state of West Bengal, his native language is a local dialect – a mixture of standard Bengali, Urdu and

Hindi. He attended a madrasa (Muslim religious school) in Uttar Pradesh for six years – so he spent six years learning how to read not only printed texts, but also hand-written documents in three important languages: Urdu, Persian and Arabic.

Persian, long the language of the Mogul courts, is very important for historians concerned with India. Sajjad’s talent did not go unnoticed at the madrasa, and they sent him to study at one of the universities in Delhi. There, he added another new language to his repertoire: English, the language of instruction at all Indian universities. It was at the university in Delhi that Sajjad heard from one of his professors about the call for applications by the Max Planck Institute for Human Development in Berlin.

Mohammad Sajjad’s field of research fits seamlessly into the historiography of emotions: he is analyzing the relationship between teachers and students in Sufism, the most important mystical current in Islam. In Sufism, Sufi teachers show their students the path to Allah. A very detailed code of



Islam arrived in the 8th and 11th centuries, after India was conquered by Muslim forces from Afghanistan. Missionaries then made sure that the new faith spread.

conduct (*adab*) for this had already emerged in the 13th century – a code that specified what form the spiritual relationship between teacher and student should take.

It stipulated that a student must place himself completely in the hands of his teacher and reinforce his submission by swearing an oath of obedience (*bay'ah*). The code also spelled out how the student should feel about the master: he must feel *hayba* for his teacher – reverence, fear and respect. Over the years, the great Sufi masters and their schools established religious practices and traditions. The love of students for their Sufi masters did not even end at death, as students would often continue to worship the masters in rituals at their shrines.

In the 18th century, however, a time when India saw a great flourishing of Islam and its religious literature, criticism grew: “Muslim reformist legal scholars (*ulama*) sparked a debate about which were appropriate emotions to feel for a Sufi master and which were not,” says Sajjad. “They

even accused the Sufis of polytheism, the worst and most unforgivable of all sins in Islam.”

Sajjad’s research is examining significant players, individuals and emotional communities among Muslim reformists and Sufis in North India between 1750 and 1830, along with the theological disputes they initiated. The range of sources the scholar is drawing on in his research is diverse: speeches by masters that were written down by their students (*malfuzat*), as well as hagiographic descriptions of masters as penned by the students (*tazkirahs*). He is also studying hand-written documents, correspondence (*maktubat*) and mystical poetry. All of them testify to one thing: that very specific emotions were cultivated within this mystical religious practice.

BOTH SIDES SHOULD LEARN FROM ONE ANOTHER

Although the significance of emotions may be clear in the religious context, Mohammad Sajjad had not been aware that it was possible to study historiography explicitly from the perspective of emotional research until he joined the Berlin project. He had to systemat-

ically familiarize himself with the methods and schools of European historiography for his project work. “It is very helpful to be in such close proximity to fellow researchers here,” he says. “For instance, I have a colleague I always go to when I need help on discourse analysis.” His fellow scholars, for their part, come to Sajjad when they need his assistance with sources written in Urdu, Arabic or Persian. “It truly is a dialogue between us. And it’s definitely reciprocal,” says Mohammad Sajjad.

The way things work there on a small scale, between the scholars, is also how the project is meant to work on a broader scale: it should not be a one-way street between Germany and India, with information flowing in one direction only. Cooperation should be mutually enriching. That is why Margrit Pernau insisted that all European scholars working in the “History of Emotions” research center should actually learn about India, its culture and its language. “People were a little nervous at first, but that eventually gave way to a great deal of openness and willingness. And the realization that the Indian culture is really not all that alien to them. It worked wonderfully well.”

» In the mercantile world of these entrepreneurs, honor, prestige, trust and creditworthiness were closely intertwined, so much so that they even used the same word for both “honor” and “creditworthiness”.

Now everyone is pulling together in the same direction. This project, which looks at India and Europe at once, is, after all, a work of translation, both literally and substantively. “Trying to transfer European models to an Indian context one-to-one simply doesn’t work,” explains Sajjad. Just as it can often be impossible to translate expressions directly, one word in Urdu or Persian into one word in German or English. Words and phrases have to be paraphrased instead, the context explained, the implicit connotations pointed out.

Whenever Mohammad Sajjad wants to explain the work he does, he really has to go into detail. Take the concept of love: Sufism has many different types and levels of love on the path to Allah. Many different expressions, finely nuanced, are used to indicate the various states of love for God that the mystics have attained. It is simply not enough for Sajjad to translate these theological notions into English words. He has to explain to his fellow scholars the very different world that lies behind the terms.

Project leader Margrit Pernau is well aware of the difficulties of looking at different cultural worlds: people can be prone to measuring the other culture against their own standards. It is important that this does not happen to India in the context of researching the historiography of emotions. Instead, the scholars want to develop joint models that draw on approaches and research in both Europe and India. Their aim is to see more by adopting different perspectives.

TRUST DEFINES ECONOMIC HISTORY

“The concept of emotions is an easy one to work with as a historian. This is true not only for the history of civilization, which more or less goes without saying, but also for areas like economic history, too,” says Pernau. Trust, for example, is a central notion that can be used to describe economic history: “In the current economic crisis, we can see for ourselves how important an emotion like trust is for the economy’s ability to function.” This is no different today than it ever was.

The other Indian doctoral student in Pernau’s group is working in a similar vein: he is studying the concept of honor in the modern Hindu national movement, with specific reference to a certain commercial elite in Gujarat between 1858 and 1922. In the mercantile world of these entrepreneurs, honor, prestige, trust and creditworthiness were closely intertwined, so much so that they even used the same word for both “honor” and “creditworthiness”. The doctoral student is exploring how the traditional concepts of honor and creditworthiness and the feelings associated with them were transferred to the emerging Hindu nationalism, and how they were transformed in the process.

Margrit Pernau herself studied the significance of religion for the social status of a certain group of Muslim merchants in Delhi known as the Panjabi traders. At the turn of the 20th century, these traders were masters of

Homage: Excerpt from a commemorative publication to mark the silver jubilee of the Nizam of Hyderabad in 1937. The Muslim ruler (Nizam) presided over the Indian princely state of Hyderabad between 1724 and 1948.

Photos: Norbert Michalke (2)





left: Doctoral students Mohammad Sajjad and Monika Freier in a discussion with Salil Misra, Professor of History at Delhi University (from left).
right: Studying sources: Monika Freier discusses the content of an advice book for Muslims with project head Margrit Pernau (right).



an extensive trade empire and they were some of the wealthiest Muslims in Delhi before the partition of India in 1947.

Being relatively new to wealth, these converts sought to elevate their social status, given that immigrants from Islamic countries were traditionally at the top of the social hierarchy. The latter were known as *ashraf* (from the adjective *sharif*, meaning noble) and held a higher social status than their converted fellow believers from among the local population, the *ajlaf*.

The Panjabi traders were *ajlaf*, as they had converted to Islam from various Hindu castes in the course of the 19th century. "Religion was what guaranteed internal cohesion within this group," says Pernau. But the significance of religion went even deeper: it paved the way for social advancement for the Panjabi. This was because the Panjabi had joined the Islamic reform movement, which had been centered in Delhi since the middle of the 18th century.

The reformers fiercely criticized the ruling Islamic elite and called for a re-

turn to religious sources: their ideal was based on personal devoutness and advocacy of Islam, for instance in the form of charity, rather than on genealogy. "As such, the values of reformist Islam were completely distinct from the behavioral norms of the traditional upper class," says Pernau.

The Panjabi subsequently built numerous mosques and schools and became very active in charitable causes. Thanks to their personal devoutness and tremendous dedication, the *ajlaf* had now attained social respect in addition to wealth. "Religion was the most important means of transcending social borders," explains the scholar, adding, "religion also guaranteed the Panjabi a right to a high social rank."

HISTORICAL DEVELOPMENT IS NOT FORGOTTEN

This has long been a central theme in Margrit Pernau's research: in her post-doctoral thesis, she investigated the emergence of a Muslim middle class in 19th century Delhi. Being a historian, developments in Germany were naturally in the back of her mind – along with how German and European historians had spent many years struggling to define the "bourgeoisie" for the Western European cultural zone.

Yet she did not force the traditional historical model of civil society to fit into the Indian context, but rather examined the historical development in Delhi in all of its individuality and diversity.

According to her analysis, "the role played by secularization – the withdrawal of religion from the public realm and the creation of political and civil-society structures – in the formation of a bourgeoisie in continental Europe was something that the religious reform movement took over to a certain extent in the Indian context." Pernau's method of research has been described as outstanding by the Association of German Historians, which awarded her its Habilitation Prize.

Margrit Pernau's own childhood experience is what motivated her to choose India as a research topic. Between the ages of five and eight, she lived in Delhi, one of many places her father worked in during his career. She later returned to Delhi as a scholar to spend a research residency of almost seven years there, subsequently going back every now and again to look for sources. Now based in Berlin, she studies the Indian cultural sphere from here in Europe. Her work on the historiography of emotions is, in fact, touching on a relatively new field



Evidently, emotions are richer in historiographical information than was previously thought. Should historians devote more attention to how emotions are perceived?

within the science of history. “Emotions – this could become a basic category of historical research,” she feels. Perhaps the concept will enjoy a similar scientific career as the category “gender.” Pernau believes this is possible: “I am reminded of the discussions we had in the 1970s on the significance of gender for history as a branch of science. Historians began explicitly writing the historical narrative of women – in addition to the traditional historiography in which women had been marginalized.”

BEING CIVILIZED MEANS BEING IN CONTROL OF YOUR EMOTIONS

In subsequent years, however, the historiography of women – a subject given a lot of specific, extra attention – increasingly grew into a more comprehensive gender history. The traditional historiography was frequently reexamined to ascertain whether and how the category of gender had been taken into account. A number of innovative methodological approaches emerged.

The gender viewpoint not only furnished the science of history with the new and specific sub-discipline of gender history, it also had a fundamental influence on the way historiography was studied thereafter. Margrit Pernau likens the idea to a house: “Emotions do not make up just one part of the vast house of history. Emotions are something that pervades every room,” she says.

And so scholars need to look for them in all rooms. Historians in search of the emotions of the past could use the feelings to describe the history of politics and power. This was demon-

strated by Pernau in a groundbreaking essay in which she investigated the “civilizing mission” of the British colonial powers in India from the middle of the 18th century to the middle of the 19th century. In doing so, she revealed how the concept of civilization can be linked to emotions: a person is civilized if they can control their (negative) emotions.

“With the Enlightenment, however, the attempt to civilize people’s emotions evolved from an individual task into a social task,” writes the Max Planck researcher. Specific individuals are no longer the only ones to be labeled as civilized or non-civilized and

barbaric – entire societies are now characterized as such. They are then assumed to be at a higher or lower stage of historical development accordingly. At the same time, the concept is increasingly proving to have universal validity – since the 19th century, people’s own civility is expressed more and more in the “attempt to civilize others.”

Evidently, emotions are richer in historiographical information than was previously thought. Should historians devote more attention to how emotions are perceived? The team at the Max Planck Institute for Human Development in Berlin is working on it. ◀

GLOSSARY

Indian Islam

In the 8th and 11th centuries, parts of India were conquered by Muslim forces from Afghanistan. Prior to this, Arabic merchants had already propagated Islam on the west coast of India. Muslim dynasties ruled on the Indian subcontinent for around 600 years, for instance in the Delhi Sultanate between 1211 and 1315 and the Mogul Empire from 1526. Missionaries representing the Sufi tradition also played an important role in the propagation of Islam.

Mogul

Dynasty of Mongolian descent (1526 to 1858). The Mogul Empire reached the height of its power in the 16th and 17th centuries. The start of British colonial rule in 1756 spelled the beginning of the end of this era. The British formally deposed the last of the great Mogul emperors in 1858. The language of the state and courts in the Mogul Empire was Persian.

Sufism

One of the main currents in Islam, often described as mystical. Sufism is a generic term under which many variants are subsumed. The followers of Sufism, Sufis, seek direct and personal religious experience: they aspire to have a spiritual union with God. To this end, they developed methods to place themselves in ecstatic trance states. They formed formal orders from the 12th century onward.

Gender history

Gender history originally emerged from the increased attention devoted to the subject of women in historical research from the 1960s onward. At the time, feminists in particular were critical of the fact that supposedly neutral historiography was often written from a purely male perspective. “Gender” has since become established as a separate category that not only incorporates biological gender, but is also regarded as a social and historical construct. Historians are exploring topics such as the relationship between genders and gender-based power relationships.

Ears Tuned to Water

To a bat, flat, horizontal surfaces sound like water

Sounds like water:
A greater mouse-eared
bat tries to drink from
a metal sheet.



Bats can detect streams, ponds and lakes with their ultrasonic sounds because the water surface acts like a mirror: it reflects their calls in such a way that they receive hardly any echo at all. According to Stefan Greif and Björn Siemers from the Max Planck Institute for Ornithology in Seez, bats interpret flat horizontal surfaces as water. When the researchers simulated water surfaces with sheets made of metal, wood and plastic, the 15 bats in the experiment still tried to drink from them.

Although they also use their sight and their senses of smell and touch for identification, echolocation appears to dominate all of these other senses. The researchers now want to find out how the countless numbers of man-made flat surfaces, such as skylights, car roofs and greenhouses, affect bat behavior.

(NATURE COMMUNICATIONS, November 2, 2010)

The Technical Tricks of a Quantum Key

Commercial suppliers of quantum cryptography close a security loophole

It is possible to encrypt data so that it is absolutely safe – in principle. Quantum cryptography foils anyone who tries to hack into a data line: the hacker can intercept the signals, but can't pass them on without errors. This is because, when the quantum signals are both received and sent, they retain a random characteristic signature. Researchers at the Max Planck Institute for the Physics of Light and the Universities of Trondheim and Erlangen-Nuremberg, however, have shown that existing systems still have a technological weakness: the current signal detectors do not distinguish between weak quantum signals and the bright light pulses on which classical physics is based. This means that a hacker can

dazzle the recipient's signal detector with commercially available devices – a process that goes unnoticed. But the researchers have already developed countermeasures, in a joint venture with the manufacturer ID Quantique.

(NATURE PHOTONICS ONLINE, August 29, 2010)



Hackers on a security mission: Nitin Jain (left) and Christoffer Wittmann test devices that use quantum cryptography to transmit data.

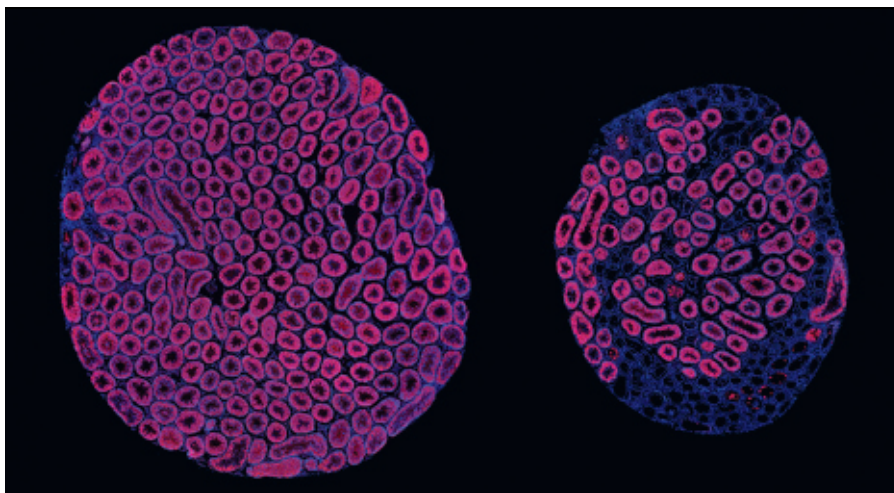
A Spray to Replace Injections

In the future, it might be possible to administer insulin as a spray via the lungs, rendering inconvenient injections superfluous. A team of researchers, including those working with Helmuth Möhwald at the Max Planck Institute of Colloids and Interfaces, has produced loosely packed microspheres of uniform size and shape from insulin and other proteins used in medicine. The micro-particles are thoroughly absorbed by the body, where they release an accurate dose of proteins. To produce these transport vehicles, the researchers first created porous grains of calcium carbonate, the main constituent of chalk. These were mixed with a protein solution and the protein molecules allowed to penetrate the cavities in the chalk. When the researchers varied the pH value, the proteins in the pores flocculated out, the chalk matrix dissolved and the protein shrank into microspheres. (ANGEWANDTE CHEMIE, October 22, 2010)

Be Smart and Multiply

One gene influences both brain size and fertility

Compared to other animal groups, mammals have large brains – something that might be an accompanying effect of their fertility. Max Planck researchers from Dresden and Leipzig have now found a link between brain size and the size of the reproductive organs. It appears that one gene controls both brain development and the function of the testicles and ovaries. Mice with a defective variant of the *Aspm* gene develop a smaller brain, and in some cases, their ovaries and testicles are drastically undersized. This gene, which is responsible for the correct arrangement of the cell division spindle apparatus, also affects brain growth in humans. Humans with a defective *Aspm* have a significantly smaller head and a smaller brain. The researchers do not yet know whether those affected also form fewer reproductive system cells. It is pos-



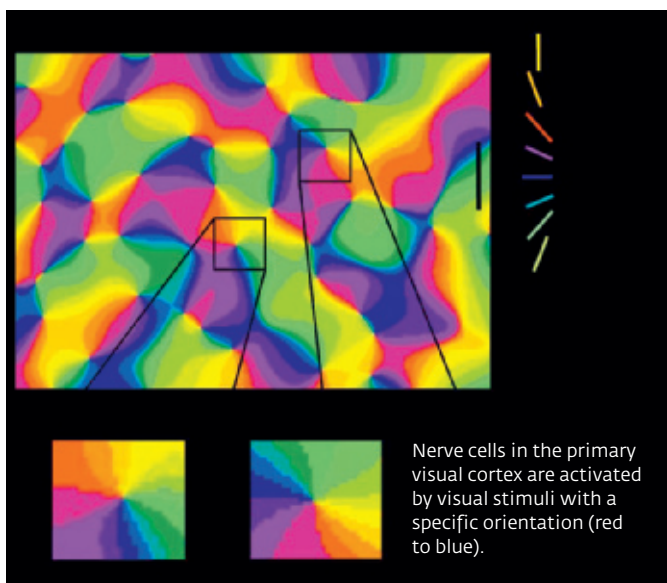
sible that not only brain growth, but also higher rates of reproduction have caused evolutionary changes to *Aspm*.

(PNAS, September 6, 2010)

A cross-section through testicles: In a mouse with a functioning *Aspm* gene (left), they contain sufficient sperm-producing cells (red). A genetically altered mouse with a defective *Aspm* gene, in contrast, has significantly smaller testicles and produces less sperm (right).

A Head Full of π

Nerve cells in the brain are arranged in accordance with mathematical rules



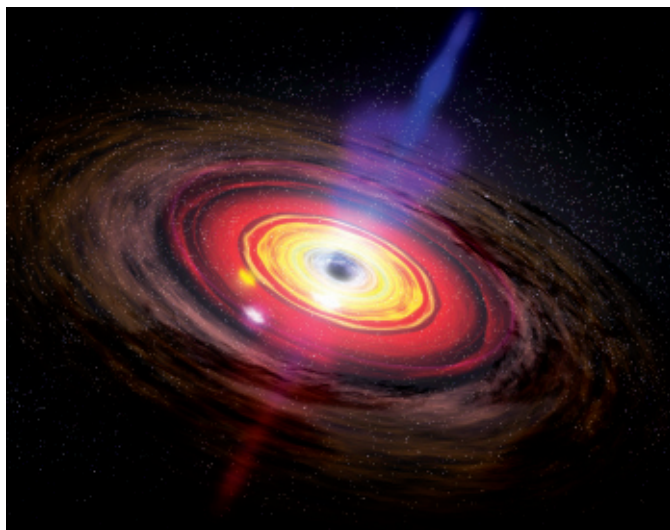
π has fascinated humans for millennia. This mathematical constant occurs not only in mathematical and physical formulas, but also in our brains, in an arrangement of “pinwheels” in the primary visual cortex. Each blade of the pinwheel contains nerve cells that are activated by stimuli with the same orientation, such as the sight of vertical beams. The average pinwheel density per unit area is exactly π , presumably because every orientation from 0-360 degrees is represented equally in the pattern. Furthermore, scientists at the Max Planck Institute for Dynamics and Self-Organization in Göttingen have proven that a pinwheel pattern of this kind always occurs when the nerve cells are wired together according to certain rules. Genes and environmental influences thus don’t play much of a role in the creation of the orientation map. Rather, the nerve cells organize themselves largely on their own, which explains why the neurons are organized as pinwheels in most mammals with well-developed visual systems. In many mammals with poor eyesight, cells with different orientation preferences are scattered randomly throughout the visual cortex.

(SCIENCE, November 19, 2010)

“Last Scream” from a Black Hole

Researchers create plasmas similar to those surrounding exotic objects

Black holes are voracious feeders: they devour neighboring gas clouds and stars in huge quantities. As the “food” is caught and spirals ever faster into the gullet, it becomes in-



creasingly dense and heats up to millions of degrees Celsius. Before the material finally disappears, it emits an enormously intense X-ray into space. This “last scream” in the form of characteristic spectral lines comes from iron as it sheds electrons. Researchers at the Max Planck Institute for Nuclear Physics, working with colleagues at the Synchrotron X-ray source BESSY II in Berlin, have reproduced this process in the laboratory. They heated iron atoms to temperatures similar to those in the interior of the Sun – or those surrounding a black hole. The spectral lines they measured perfectly matched those detected at X-ray observatories. It emerged in the process that most theoretical computations do not reflect the line positions accurately enough. For example, scientists have long puzzled over the interpretations of the data from the active galactic nucleus NGC 3783. The researchers in Heidelberg, however, identified, among several model calculations, a theoretical procedure that makes the most accurate predictions – and thus created a new way to understand the physics of plasmas surrounding exotic objects. (PHYSICAL REVIEW LETTERS, October 27, 2010)

Exotic structure: Matter swirls turbulently around a black hole. What exactly is going on here?

Turning Over a New Leaf

A new technique allows filigree structures to be created in metal carbides

Chemists from the Max Planck Institute for Colloids and Interfaces have, quite literally, been copying nature. Using a new process, they transformed the skeleton of a leaf almost completely into magnetic iron carbide. To do this, the researchers treat the leaf with iron acetate, nitrogen and heat. The technique allows them to create metal carbides from every carbonaceous structure. But there are more benefits to this than just making attractively shaped objects. For example, the filigree biological structures could provide catalysts and electrodes with a large surface, thus making them particularly efficient.

(ANGEWANDTE CHEMIE, AUGUST 16, 2010)



A magnetic leaf: A simple chemical process transforms the leaf into iron carbide, which is magnetic and conducts electricity.

The Genes of Others

Every human being is unique and yet similar in many respects to other humans. This is also reflected in our genes. On the one hand, there are over 16 million variations in the human genome. At the same time, the genomes of all humans are 99.5 percent identical. In comparison, humans and chimpanzees share 96 percent of their DNA. Scientists working on the 1,000 Genome Project, a team that includes Hans Lehrach and Ralf Sudbrak from the Max Planck Institute for Molecular Genetics in Berlin, have analyzed the full genomes of 179 people, and the protein coding genes of 697 people “letter by letter.” According to this study, each person has from 250 to 300 mutations that prevent the genes in question from functioning normally. Furthermore, each of them has from 50 to 100 gene variants that are associated with an inherited disease, and 60 new mutations that were not present in their parents. (NATURE, October 28, 2010)

Successful – Thanks to Mother

To mate successfully, bonobo males need high social ranking and help from their mothers



Success is sexy – this apparently applies not only to humans, but also to pygmy chimpanzees. Scientists working with Gottfried Hohmann from the Max Planck Institute for Evolutionary Anthropology in Leipzig have found that the more often a bonobo male can mate with females, the higher his social status. But even less successful chimps can rack up some points with the ladies. The presence of their mothers helps bonobo males achieve better results in the mating stakes. As mature male bonobos remain with their group, mothers and sons are inseparable, even when the sons have reached adulthood. The high dominance status of the females helps their male offspring in conflicts with other males. However, they do not provide such help to unrelated males. In this way, the mothers increase the number of future grandchildren.

(PROCEEDINGS OF THE ROYAL SOCIETY B: BIOLOGICAL SCIENCES, September 1, 2010)

Behind every strong man there is a strong woman: Camillo is the highest-ranking bonobo male in the study group. He is often to be found near his mother.

Not Skill, but Luck

Sports betting is addictive

The announcement of the winning lottery numbers is preceded by a warning: "Gambling can be addictive." Does that also apply to games of skill, such as sports betting? Indeed it does, say Emanuel Towfigh and Andreas Glöckner from the Max Planck Institute for Research on Collective Goods in Bonn. In fact, they say, they present an even greater risk than games of pure chance. In order to find out whether a gambler's skill is a factor in betting successfully on sporting events, they asked over 200 people to bet on the outcome of soccer matches. Soccer aficionados calculated that they had a better chance of winning than was actually the case. The researchers in Bonn showed that people who were knowledgeable about soccer did only slightly better than those with no knowledge of the sport if they predicted the result no more than three days before the game. With a longer prediction horizon, the bet on the outcome of the match became a complete gamble. Precisely because skill plays some role, people overestimate their influence on the result. The more control players believe they have over the outcome of a game, the higher the potential for addiction. The scientists are therefore of the view that bookmakers should be subject to governmental regulation. (JURISTENZEITUNG, November 8, 2010)



Because soccer fans in Germany frequently overestimate their ability to make accurate assessments, sports gambling can easily become addictive.

Jupiter from Another Galaxy

An exoplanet orbits an immigrant red giant

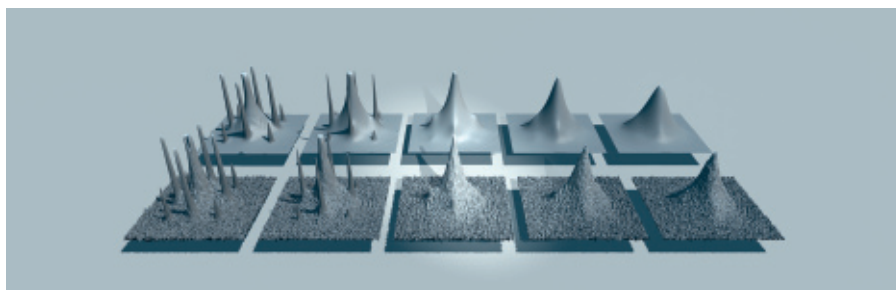
Astronomers have discovered the first exoplanet from another galaxy. The planet's host star was part of a dwarf galaxy that was swallowed up by our galaxy billions of years ago and that expanded into a red giant at the end of its life. The exoplanet, named HIP 13044 b, has a minimum mass of 1.25 times the mass of Jupiter. The researchers from the Max Planck Institute for Astronomy suspect that the currently very small orbit of HIP 13044 b – it circles its sun in just 16.2 days at an average distance of 18 mil-

lion kilometers – was originally considerably larger; apparently it shifted toward its star during the red giant phase. Any planets that once orbited between HIP 13044 b and their star presumably also moved closer to their sun – and were consumed by it. The days of HIP 13044 b also appear to be numbered: in the next phase of its evolution, the star will expand so much that it will engulf this planet, too. A similar fate awaits the Earth and its sibling planets in a few billion years.

(SCIENCE EXPRESS, November 18, 2010)

Test Run for a Quantum Simulator

Modifying atoms in an optical lattice controls their state



When the sharp tips in these diffraction pictures disappear (third section from the left), the trapped atoms change their state.

Answers to some of the big questions in physics will soon be within closer reach. A team of researchers including physicists working with Immanuel Bloch at the Max Planck Institute for Quantum Optics has made a big step toward the quantum simulator. An in-

strument of this type simulates an unfamiliar quantum system with a familiar one. It could be made up of atoms that lie in an optical lattice of overlaid laser beams, as if in an egg carton. The atom ensemble is intended to imitate materials such as those that become superconductive – that is, lose their electrical resistance – at relatively high temperatures, but still well below zero de-

grees Celsius. An understanding of the details of this change of state would help in the search for materials that conduct electricity without resistance at more normal temperatures. A precondition for this is that the physicists have detailed knowledge of the properties of atoms in the lattice and can control them. Bloch and his colleagues have thus observed how rubidium atoms change their state in response to the temperature and the strength of the optical lattice that results from the intensity of the lasers. The observations correspond to extremely complex calculations with traditional computers, leading the researchers to expect that the quantum simulator also correctly imitates the physical processes where conventional computers fail. (NATURE PHYSICS, October 3, 2010)

Artificial Light Confuses Birds

Light pollution is a factor in blue-tit reproduction

Humans frequently turn night into day. This is confusing for birds: for example, the males of some songbird species start singing earlier in the morning if they live at the edge of a wood that is exposed to street lighting. A study by scientists working with Bart Kempenaers at the Max Planck Institute of Ornithology in Seewiesen has shown that robins start to sing 80 minutes before other members of the species that sleep in the dark. Female blue tits lay their eggs one and a half days earlier where artificial light shines at night. In turn, street lights encourage male blue tits to be unfaithful; they have twice as many young with other females compared to males whose territory is dark at night. Under artificial light, the females choose the wrong – meaning unfaithful – partner more often. The researchers now want to find out whether these behavioral changes influence the chances of survival in the offspring. (CURRENT BIOLOGY, September 16, 2010)

Less Steam in Earth's Greenhouse

Despite climate change, less water is evaporating from the ground and from plants

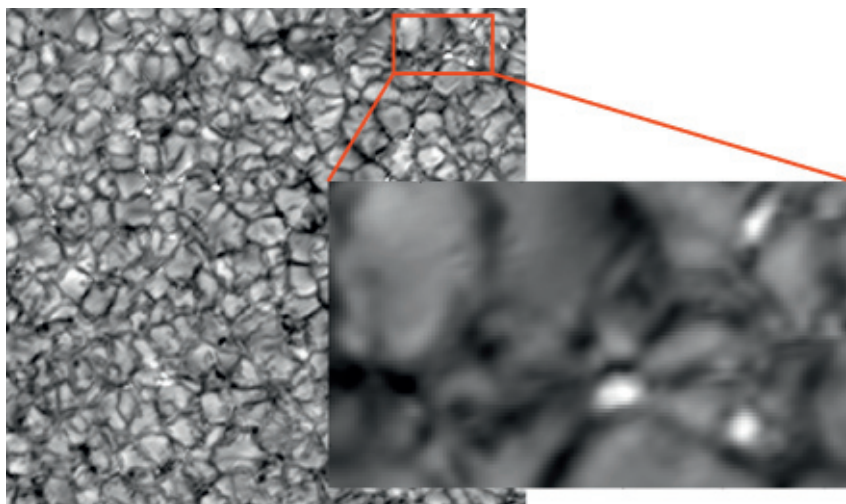
The climate system is a pump that no one has yet fully understood. Researchers working on the Fluxnet initiative with Markus Reichstein at the Max Planck Institute for Biogeochemistry in Jena have now discovered another anomaly: using satellite data and 250 measuring stations spread around the globe, they found that less water evaporated worldwide between 1998 and 2008 than global warming would have led them to expect. Climate researchers previously assumed that climate change is accelerating the global water cycle. However, particularly in southern Africa, Australia and South America, the ground has become increasingly dry, so that less moisture has been able to evaporate. Why the land surface in the southern hemisphere has become drier and whether this trend will continue remains unclear. According to the researchers, it is not necessarily a consequence of climate change. (NATURE, October 10, 2010)

The Magnetic Building Blocks of the Sun

The *Sunrise* balloon telescope reveals tiny structures on the visible surface

The Sun is a turbulent place: hot plasma wells up out of the interior, cools and sinks back again. On the visible surface, called the photosphere, the bubbling streams form a pattern similar to grains of rice, called granulation. The Sun's plasma streams are closely linked with its magnetic properties, because the kinetic energy of the flows is converted to magnetic energy. Some magnetic fields can be seen in the dark sunspots that can be as large as the Earth, but there are also much smaller structures. Tiny areas of brightness between the granules are an indicator of their presence. This is where the strong magnetic fields of the plasma force themselves outward, allowing a view deep inside the interior of the Sun. These structures, called bright points, have been made visible for the first time by the *Sunrise* balloon telescope. Scientists from the Max Planck Institute for Solar System Research report that the magnetic fields within these areas, which are just a few hundred kilometers in size, are 3,000 times stronger than the Earth's magnetic field.

(THE ASTROPHYSICAL JOURNAL LETTERS, October 15, 2010)



Bubbling grains of rice: This image from the *Sunrise* balloon telescope shows the granules in the photosphere, measuring several thousand kilometers in size. Between them shine bright points of just a few hundred kilometers in size. These are clearly visible in the magnified image.

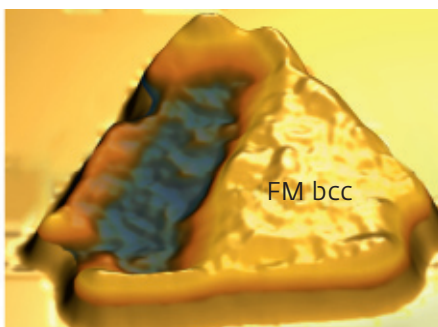
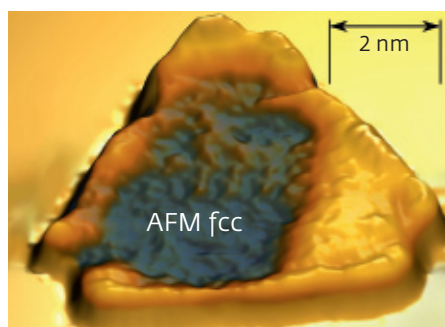
More Room on Microchips

Magneto-electric coupling makes it possible to drastically increase the density of data on storage media

A new storage technology may soon make it possible to pack data up to 400 times more densely than before. For the first time, a team of researchers has written information into data points with an electrical field. The data points are a mere two nanometers long and one nanometer wide, and store the zero or one of a bit in two dif-

ferent magnetic orientations of the material. Traditional hard drives also record data magnetically, but they are also written onto and read from magnetically. Ingrid Mertig, Fellow at the Max Planck Institute for Microstructure Physics, and her colleagues at the University of Halle have calculated that it is possible to use magneto-

electric coupling to invert the magnetic polarization of a very thin layer of iron in a much finer resolution than with a magnetic head. Physicists at the Karlsruhe Institute of Technology have confirmed this in an experiment with a scanning tunneling microscope that works at very low temperatures. (NATURE NANOTECHNOLOGY, October 31, 2010)



An electrically written magnetic data point: Before an electrical field is applied, the antiferromagnetic region (left) dominates, blue in the scanning tunneling microscope image. Afterward, the yellow, ferromagnetic region dominates.



"Around that area there are indeed numerous small nebulous patches so close together that, upon seeing the region, one is positively startled by the strange appearance of this 'nebula cluster'." This was the sentiment expressed by Heidelberg-based astronomer Max Wolf in 1901 about the galaxy cluster in the constellation Coma Berenices. The cluster Abell 2218 presents a similar appearance to the viewer today on this image from the *Hubble Space Telescope*. The "strange appearance" – the many blue and orange arcs – owes, in this case, to the effect of a gravitational lens.

The Warped Ways of Cosmic Light

Albert Einstein predicted them, modern giant telescopes detected them – and **Klaus Dolag** simulates them on a computer: gravitational lenses. The academic staff member at the **Max Planck Institute for Astrophysics** in Garching and at the **University Observatory Munich** uses this physical phenomenon to such ends as weighing galaxy clusters and probing that ominous substance known as dark matter.

TEXT **HELMUT HORNUNG**

The sky over Principe was cloudy and the mood in the camp on the coconut plantation had hit rock bottom. Having set out from England, the men had been traveling for weeks to reach the volcanic island in the Gulf of Guinea. Their goal: to write scientific history. They wanted nothing less than to prove a bold theory that a German physicist by the name of Albert Einstein had recently published. According to this theory, the gravity of a massive object should bend space, similar to the indentation made by a lead ball on a rubber blanket. If a marble is then rolled toward the ball, the marble will deviate from its originally straight course and, depending on its initial velocity, follow a more or less curved path. On this day, May 29, 1919, it would be possible to test this prediction of Einstein's general theory of relativity on the island of Principe. And then the weather turned out to be miserable!

But the expedition led by astronomer Arthur Stanley Eddington had neither a blanket nor a ball with them, but rather a telescope and camera. The researchers wanted to use these to record

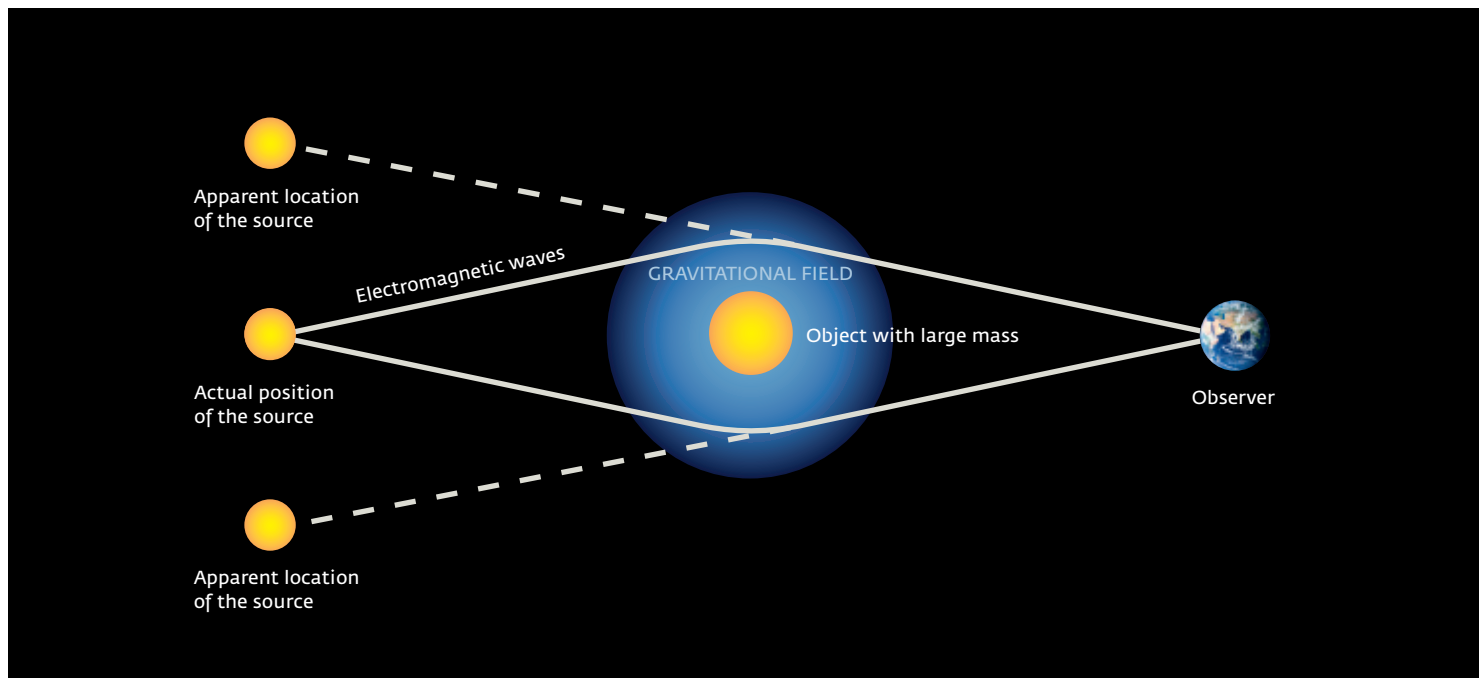
a total eclipse of the Sun. The test was simple: if a massive object bends space, then the Sun must also cause the passing light from stars to deviate from its straight course. In other words, the points of light in the immediate vicinity of the black Sun should be shifted ever so slightly with respect to their true position in the sky. To check this, Eddington had recorded the star field six months earlier without any interference from the Sun, using the same instruments that he now aimed impatiently at the cloud-covered, slowly darkening Sun.

VIRTUAL TELESCOPES PEER INTO SPACE

And the astronomer was rewarded for his perseverance. During totality, the clouds parted for a few moments and Eddington managed to capture two images. "Lights All Askew in the Heavens" appeared on the front page of the New York Times on November 10, 1919. The "shifted lights in the sky" proved that the general relativity theory was correct – and established Albert Einstein as a legend.

More recent analyses of Eddington's findings show that the values measured at that time did, indeed, correspond to the prediction, but that they are apparently the result of an instrument error of, as it so happens, the very same magnitude. But the gravitational effect has since been measured many times and perfectly confirmed – not a doubt remains. So Klaus Dolag doesn't have to concern himself with evidence of any sort. He simply works with the effect – and applies the physical principle to weigh galaxy clusters or to track down the hidden matter in the universe. Moreover, the staff member at the Max Planck Institute for Astrophysics and at the University Observatory Munich doesn't even need a cloudless sky: Klaus Dolag does his research with computer simulations, creating virtual telescopes.

To understand this, let us take another detour through history. Because the Sun bends the path of starlight, Albert Einstein had speculated in the journal *SCIENCE* in 1936 that a star could diffract the light from an object behind it – which propagates in a straight line in empty space – similar to a glass lens. In this way, the light



from this object should be amplified, much like the Sun's rays passing through a magnifying glass; and furthermore, multiple images of one and the same object might be created.

EINSTEIN HIMSELF DIDN'T BELIEVE IT COULD BE PROVEN

In 1937, Swiss astronomer Fritz Zwicky introduced the possibility of a galaxy acting as a lens that creates distorted images of more distant galaxy systems lying beyond it. Different images are created depending on the spatial orientation of observer, lens and object. If all three lie exactly in a line (the optical axis), a ring is formed. If they lie to one side of the optical axis, the images of the background sources appear as more or less strongly curved arcs. It is not just individual objects such as galaxies that act as lenses, but frequently galaxy clusters – accumulations of enormous concentrations of matter that we observe as many, relatively tightly clustered galaxy systems.

Regarding the practical proof of the gravitational lensing effect, Albert Einstein remained skeptical. He said that

the effect – and especially the ring that was named after him – was too small: “Of course we have no hope of observing the phenomenon directly.” In 1979, researchers discovered the first quasar whose light was split off into multiple images by the gravitational field of a galaxy lying on the line of sight with the Earth. Quasars are the active cores of young galaxies. Driven by massive black holes, they have a very high energy output.

The type and shape of the lensed images follow the laws of optics and gravitation. Thus, similar to classical optics, it is possible to draw important conclusions from the cosmic images, about, for instance, the lens material or the composition of the medium – that is, about how mass is distributed within the galaxies, or the structure of the space. Galaxy clusters are particularly interesting for researchers like Klaus Dolag: “They are the largest systems in the universe that are bound together by gravity. That is why they have especially marked gravitational lensing effects.” This also explains why they benefit science in so many ways. And just what is the benefit?

Take, for example, the galaxy cluster Abell 2218, which is some two billion light-years away in the constellation Draco. On images from large telescopes, dozens of small arcs in different colors and shapes tell of galaxies that lie more than six billion light-years beyond Abell 2218 and that, without its effect, wouldn't be visible at all. In short, gravitational lenses act as natural telescopes. The powerful magnifying effect of the Abell 1689 cluster led, for instance, to the discovery of one of the most distant galaxies known to date. We see it today in the light it emitted 700 million years after the Big Bang.

TIME MACHINES SHOW THE DEVELOPMENT OF THE GALAXIES

Because the speed of light is finite, the observation of distant objects is simultaneously a journey back in time. The universe has changed significantly since its birth 13.7 billion years ago. The galaxies, for example, have since developed in a certain way. Because telescopes (and gravitational lenses) act like time machines, they offer as-



left side: A gravitational lens functions essentially according to laws similar to those that apply in optics. In this case, however, the "glass" is a large mass – such as a galaxy or a galaxy cluster.

left: Experimenting with space on the computer: Astrophysicist Klaus Dolag.

tronomers outstanding insights into the evolution of space.

In the case of Abell 2218, massive elliptical galaxies crowd together in the center; photos show, a bit outside of the middle, a further small cluster core. Apparently two galaxy clusters are merging together. This fact alone is an important indication for astronomers that such mergers shape the appearance of space. It seems that a particularly large amount of luminous arcs appear when the gravitational lens is composed of two merging clusters. This gives the researchers insight into the structural formation of the universe.

This aspect is of great importance: "One of the things cosmology has to explain is why, after the Big Bang, such things as galaxies and extended galaxy clusters in which stars and planets agglomerated emerged from what was originally quite an even distribution of matter," says Klaus Dolag. Dark matter, which makes up some 23 percent of the universe, plays an important role here. The nature of this mysterious substance is literally in the dark.

As mentioned, the images also contain information about the cluster act-

ing as a lens. For example, it quickly becomes apparent that the visible mass contained in galaxies is not even close to being sufficient to hold together such a gigantic cluster as Abell 2218, with its several hundred members. Furthermore, the visible matter is not nearly adequate to produce the multiple arc-shaped images of the objects lying beyond it. After all, the optical properties of a gravitational lens are determined by its surface density.

INFLATION IS DRIVING THE UNIVERSE APART

Conversely, the astronomers can draw conclusions about the distribution of the masses within a gravitational lens, and distinguish the invisible and visible components from one another. "Gravitational lenses are the only direct method for determining the proportion of dark matter," says Dolag.

And finally, gravitational lenses are precise tools for decoding the geometry of the cosmos. In the standard model, space was born with a "bang" 13.7 billion years ago. Scientists prefer to call this a singularity that can't even

be described with physical laws. According to the model, at the age of 10^{-35} seconds, the cosmos expanded by 50 orders of magnitude, from the diameter of a proton to that of an orange. That moment, known as inflation, increased the bubbling in the quantum soup to macroscopic dimensions. These structures are visible in the baby photos of space, in the light of microwaves, as color-coded spots having minimally different temperatures; they were emitted 380,000 years after the Big Bang and are being picked up today by satellites such as *WMAP* and *Planck*.

The universe has been expanding since inflation, but for the past approximately five billion years, the rate has been much faster than expected. The mysterious driving force acts furiously and makes up around 73 percent of the energy density of space. A disturbing concept: 73 percent dark energy, 23 percent dark matter – the cosmos is made up primarily of an unknown substance. Baryonic matter – making up our old familiar protons, neutrons and electrons – accounts for just 4 percent; we see only this tiny

MAPPING THE SKY

The universe is full of matter, both visible and, above all, invisible. On its way to us, the light from distant galaxies must traverse space and is diffracted by the gravity of the matter contained therein. This kind of gravitational lensing effect distorts the images – the cosmic landscape looks as if it were being viewed through a carelessly polished piece of glass. When as many distortions as possible have been observed, conclusions can be drawn about, for instance, the mass of the matter in space between us and the distant galaxies.

The more of these light sources are observed, the more accurate this technique becomes. The best telescopes reveal some 100,000 background galaxies in a section of sky the apparent size of the full moon. To reliably determine the image distortion caused by gravity,

the astronomers need the light from 200 different galaxies. This means that the smallest area on which the “lensing” mass can be determined corresponds to a size of 0.2 percent of the surface area of the full moon.

That may seem like little, but translated to the dimensions of space, such a section shows only very coarse structures, such as the largest galaxy clusters. Furthermore, it becomes that much more interesting for the cosmologists the further back in time they can look. To do this, however, the background objects must be as far away as possible, which means that they have only a very weak glow and are thus difficult to observe.

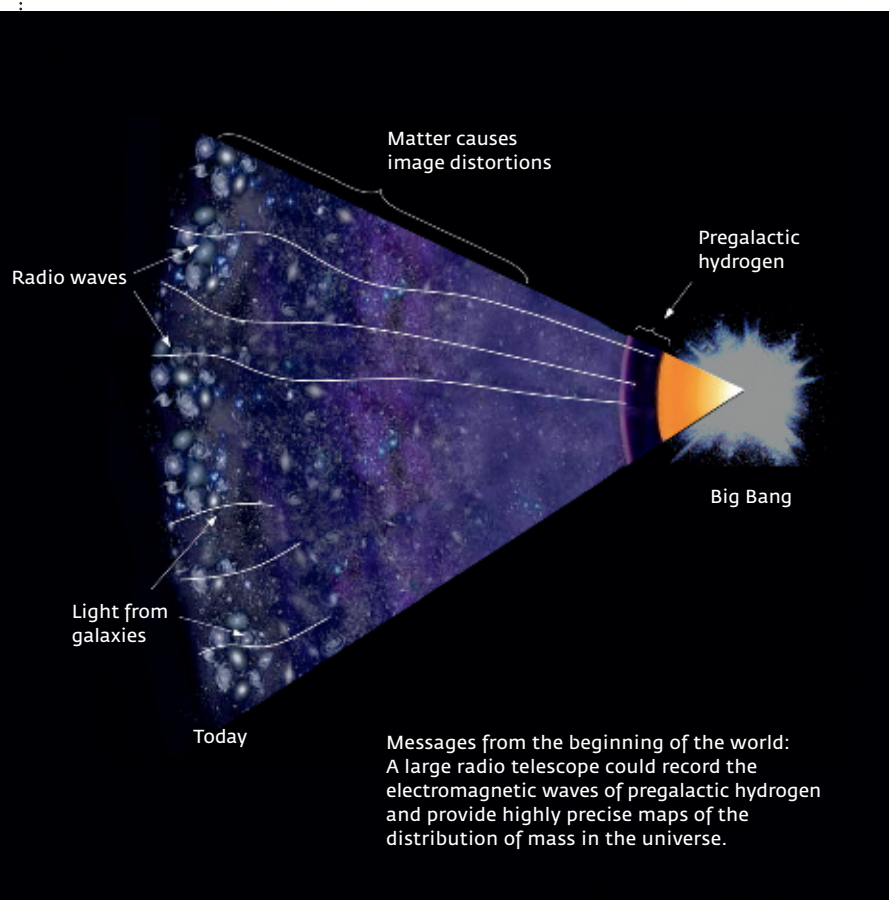
An alternative to background galaxies should therefore meet three conditions: they should be distant, easy to

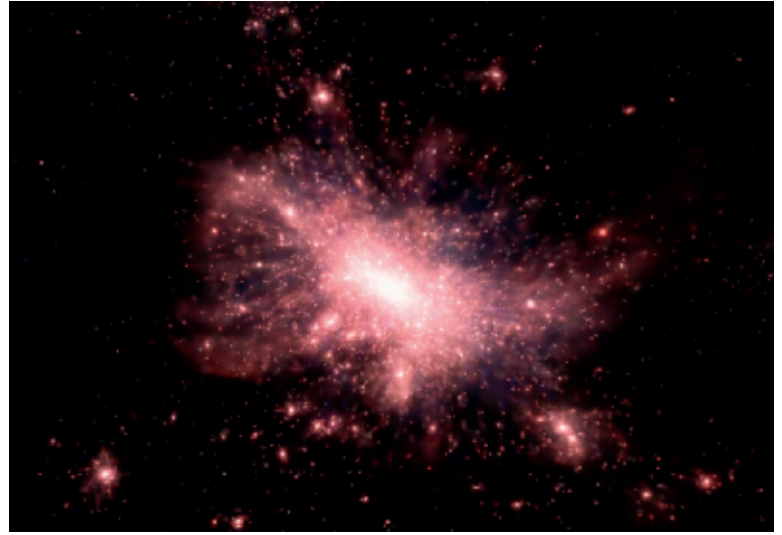
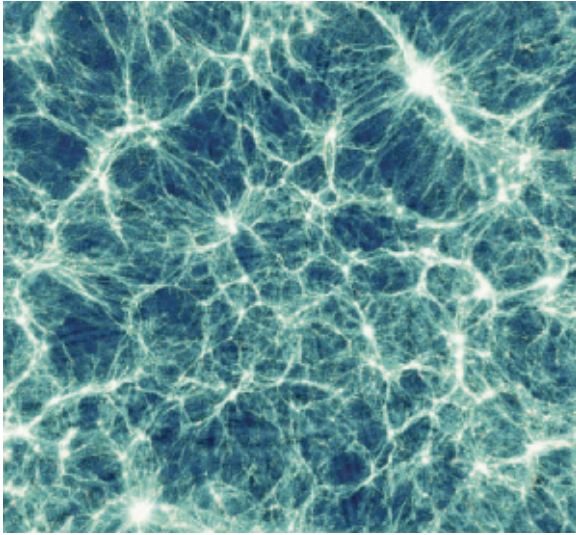
observe and numerous. For this reason, Ben Metcalf and Simon White from the Max Planck Institute for Astrophysics in Garching proposed radio waves from a time when the galaxies weren't yet even born. It seems this radiation really does exist: some 100 million years after the Big Bang, the first stars and galaxies formed from inhomogeneities in the neutral hydrogen gas. Their UV light heated up the gas, which then emitted radio waves with a wavelength of 21 centimeters. Since then, space has expanded – and with it, the signals should have grown to wavelengths of 2 to 20 meters.

According to the standard model of the Big Bang, the pregalactic hydrogen exhibited various structures, such as node-like swellings from which galaxies later formed. The pattern of the structures imprinted itself on the signals: according to Metcalf and White, there should be as many as 1,000 such structures at various distances. A radio telescope ought to be able to distinguish them and to create, from the distortions of the signals, a map of the large-scale distribution of cosmic matter. Its resolution would be 20 times better than the maps obtained using background galaxies.

There's just one catch: the radio telescope would have to be very large and occupy an area of 1,000 square kilometers – about 100 times as much as the central receiver of the new electronic telescope LOFAR (MAXPLANCKRESEARCH 4/2010, page 6). But in a few years, “fiction” could become “science”: as Ben Metcalf and Simon White have shown, the planned SKA radio system, with a collection surface of one square kilometer, should already be able to investigate, for example, the mysterious dark energy with greater precision than any instrument before it. Maybe the researchers would then be close to solving one of the greatest cosmological mysteries and would know what is driving the world apart at its core.

Helmut Hornung





- left | If researchers feed their computers with such data as energy and matter content, density and expansion rate, then over time, their programs produce a filament-like network that resembles the structure of real space.
- right | Such condensations of matter in the computer-generated cosmic network are considered to be seeds of galaxies and galaxy clusters.

portion with the naked eye or with telescopes, as planets and stars, gaseous nebula and galaxies.

A NETWORK OF INTRICATE FIBERS EMERGES ON THE COMPUTER

The researchers describe the universe as a whole using a set of parameters that characterize the amount of energy and matter, the density and the expansion rate. A further key value is the cosmological constant, a form of time-invariant dark energy. In the department of Director Simon White, a group at the Max Planck Institute for Astrophysics is using the ingredients mentioned above to create the universe on a computer (MAXPLANCKRESEARCH 4/2006, page 46 ff.). To do this, the cosmologists start a few hundred thousand years after the Big Bang and watch how, over time, the computer spins a network of intricate fibers and pearl-like bulges, the seeds of galaxies.

Klaus Dolag uses simulations, too. That is, he uses computer programs to build gravitational lenses. To do this,

he takes not only masses and density fields into account, but also dark matter and baryonic gas. From these ingredients, his software reconstructs the development of large-scale structures and the evolution of galaxies. Dolag's colleagues use a similar approach, for example in their famous millennium simulation. There, to a virtual cube of space having a side length of 2.1 billion light-years, they added no fewer than ten trillion solar masses of dark matter, spread among ten billion units of virtual matter.

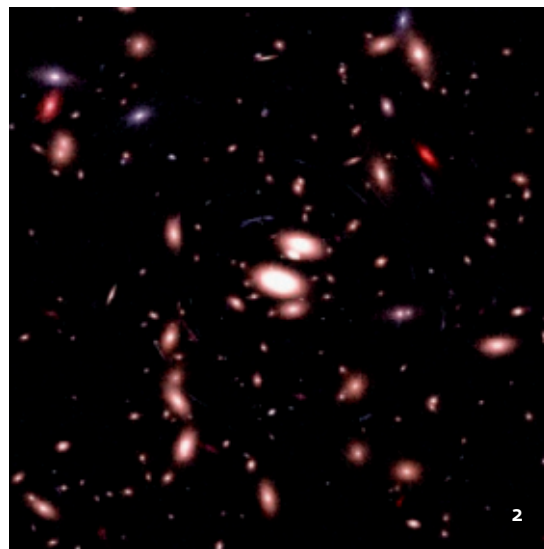
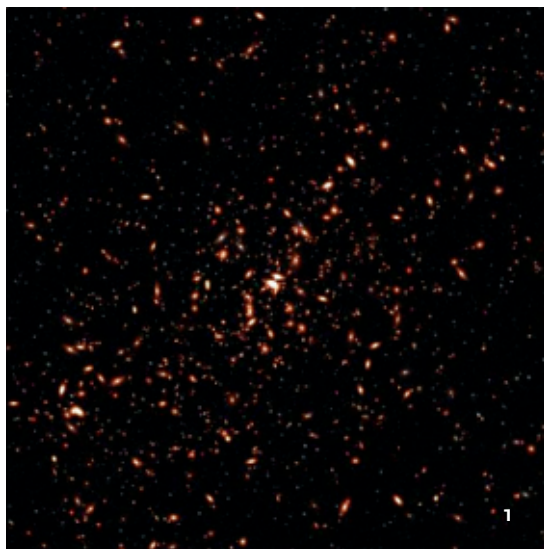
"Our simulations use even more physics," says Klaus Dolag. "Because we also take baryonic matter into account, we can simulate the appearance of galaxies and galaxy clusters in various wavelength ranges, such as in X-ray light." The artificial cosmos is formed from essentially two layers: a few hundred to a thousand foreground galaxies and countless background galaxies distributed according to a model that corresponds to nature. Superimposing the two layers on the computer yields an image of a virtual section of sky.

Because the foreground galaxies act as a gravitational lens, they influence the images of the background galaxies; their shape depends on the structure of the lens. In this way, Dolag obtains a virtual gravitational lens that can be played with. He can then study how the images change, for example when more or less mass is assumed, or the distances between the galaxies are changed.

THE LENS STRUCTURE INFLUENCES THE IMAGES

Klaus Dolag shows images of his simulations, which seem so deceptively real that a layperson can't even distinguish them from images taken with large telescopes. In fact, the programs also include instrument data: the diameter of the telescope mirror, spectral ranges and filter properties, and exposure times for the images.

All this effort is not an end in itself. One group, of which Klaus Dolag was also a member, simulated observations of a galaxy field such as might one day



be possible with the space telescope *Euclid* planned by the European Space Agency (ESA). One of the scientists' aims was to measure arcs – their length, thickness and curvature. It was hoped that these virtual gravitational lensing effects would offer valuable information about the effects actually observed in space.

"We found interesting connections," says Dolag. "For example, the length-to-width ratio of the arcs is a good indicator and permits conclusions about the distribution of mass in a gravitational lens." The simulations also showed that observation effects can influence the measurement of the arcs. Dolag says: "We will have to take that into account when interpreting future observations."

So it's about testing models on reality. Or comparing different measurement methods with each other. In an essay that recently appeared in the journal *ASTRONOMY & ASTROPHYSICS*, Klaus Dolag and his colleagues address the issue of determining the mass of galaxy clusters. There are two main options available: gravitational lenses and X-ray observations. The latter are based on the fact that, between the

galaxies in a cluster, there is hot gas that emits X-rays. The observations can be used to create a mass profile of the galaxy cluster – assuming that the distribution of the intergalactic gas can be described with simple models and that it is in hydrostatic balance, or in other words, that gravity keeps it in form.

ERRORS INCREASE NEAR THE EDGE OF THE CLUSTER

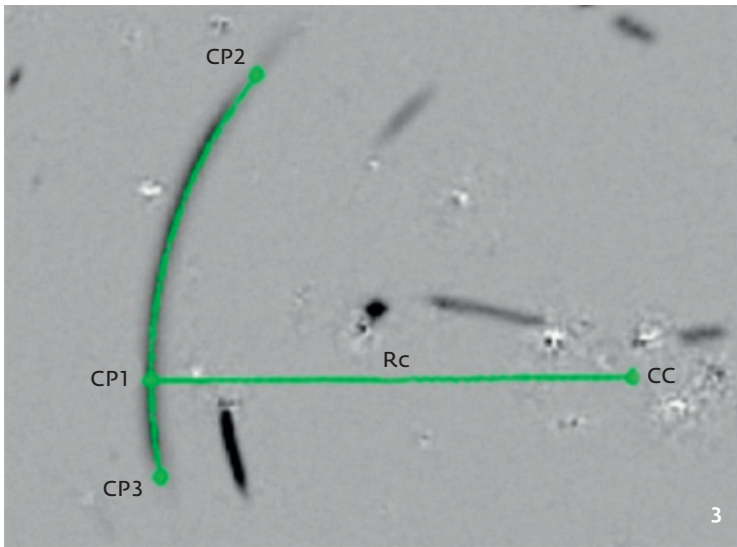
"In practice, there are problems, since there are often discrepancies between the results of the two methods," says Dolag. His team thus created three galaxy clusters and first simulated observations with an artificial X-ray telescope and then images with a gravitational lens. In the center of the cluster, strong lensing effects appeared that made it possible to determine the mass fairly precisely. However, extrapolating from the measurements near the edges of the cluster, where weak lens effects appeared, led to relatively large errors.

Furthermore, with weak lensing effects, the measurements worked best when the masses in the lensing galaxy

clusters were distributed evenly; the more "streaks" there were in the lenses, the larger the errors became. Also, the true structure of the galaxy clusters in space – in other words, their shape in all three dimensions – likewise influenced the results; for instance, the mass of a lens is generally overestimated when its optical axis points directly toward the observer. "Using such simulations, we test how the models for describing the distribution of matter in gravitational lenses need to be improved in order to approximate reality as closely as possible," says Klaus Dolag.

But, thanks to their simulations, the researchers also found a few error sources in the X-ray observations. If, for example, the gas between the galaxies was not exactly in the aforementioned hydrostatic balance, then the results deviated from reality by as much as 20 percent.

"Comparing the two methods on a case-by-case basis is indeed rather complicated. Nevertheless, observing many clusters will give us valuable clues about the physics of the gas between the galaxies. Not least, we should be able to calibrate the X-ray measurements based on the results



- 1 Color composite of a simulated galaxy cluster. For this photo, scientists reconstructed the instrument properties of the *Subaru* telescope at the Mauna Kea Observatories in Hawaii.
- 2 The same virtual galaxy cluster as in photo (1), this time viewed through the – likewise simulated – *Hubble Space Telescope*.
- 3 The strong gravitational lensing effect distorts the images from background galaxies into arcs. Their shape permits conclusions about the lenses (usually galaxy clusters). Such images produced on the computer help researchers better assess and analyze the data obtained in nature.

from gravitational lensing effects,” says Klaus Dolag, summarizing the outcome of their work.

COSMIC ZOOM ON DISTANT OBJECTS

The more closely the astronomers scan the universe with their telescopes, the more gravitational lenses they find. Special search programs like the *Cosmic Evolution Survey (COSMOS)* and the *Sloan Lens ACS Survey (SLACS)* are uncovering dozens of new objects for the scientists. These also find such exotic specimens as the three different colored arcs that are grouped around a galaxy; in this system, it is possible that two lenses are acting together and zooming in to the image of an immensely distant galaxy. This would allow the astronomers to glimpse that much further back into the past (see box on page 68).

In parallel with improving the detection methods, scientists such as Klaus Dolag are fine-tuning their simulations. The more exact their computer reproductions of the cosmos are, the more accurate their statements about the evolution of the galaxies and

the development of the universe as a whole will become. Even now, the physics of gravitational lenses is showing initial approaches to examining different models and testing cosmological parameters. Although the re-

searchers don’t have to travel to exotic locations as they did in 1929 to make big discoveries, exploring space is still an adventure – even if doing so requires only the right algorithms and fast computers. ◀

GLOSSARY

Cosmological constant Λ

A positive constant introduced by Albert Einstein (1879 to 1955) in his gravitational field equations to prevent the contraction of the universe due to gravitational attraction. In 1998, Λ (lambda) experienced a renaissance when the rapid expansion of space was discovered. It is still not clear what causes Λ .

Millennium simulation

Researchers use supercomputers to investigate the question of how today’s galaxies and stars were able to form from what was, directly after the Big Bang, a formless universe. With the appropriate ingredients, such as dark matter, the simulation does indeed show the emergence of major irregularities when small manipulations are introduced. Cosmologists from Germany, the UK, Canada, Japan and the US are participating in the project, which is being led by the Max Planck Institute for Astrophysics.

Planck

The European probe that was launched in May 2009 together with the infrared *Herschel* observatory is expected to closely examine the cosmic microwave background, but with much greater precision than *WMAP*. The first complete image of the sky was published in summer 2010.

WMAP

The US satellite *Wilkinson Microwave Anisotropy Probe* was launched in 2001 and transmitted data to the Earth up until a few months ago. The aim of the mission was to investigate cosmic background radiation, and especially irregularities stemming from large-scale cosmic structures. The famous *WMAP* map shows the universe as it appeared 380,000 years after its birth.

The Tangled NETs of the Immune System

When scientists can't believe their eyes, it is very likely that they are on to something quite extraordinary. This was precisely the case for **Arturo Zychlinsky** and his colleagues at the **Max Planck Institute for Infection Biology** in Berlin. White blood cells that cast net-like structures to ensnare pathogens? No one had ever seen the likes of it before. Now the first patients are reaping the benefits of this discovery.

TEXT **KLAUS WILHELM**

The boy could hardly breathe and required oxygen support. He found it very difficult to walk. The fungal infection in his lungs was threatening to spread. The eight-year-old had suffered from an immune system disorder known as chronic granulomatous disease (CGD) since birth. He had been laid low by recurring fungal infections and nobody knew why his immune system found it difficult to fight these particular invaders. A gene therapy developed by a team headed by Janine Reichenbach and Reinhard Seger at Zurich University Hospital saved the boy's life. "It's wonderful," enthuses Volker Brinkmann, leader of the Microscopy Research Group at the Max Planck Institute for Infection Biology in Berlin. The biologist was involved only indirectly in the treatment of the young patient – or, to be more precise, his contribution was purely scientific. It was based on his research on neutrophil granulocytes, cells that play a very important role in the innate immune system, and on the net-like structures these cells create to ensnare pathogens – Neutrophil Extracellular Traps, NETs for short.

One of the most exciting immunological discoveries of recent decades comes from the institute located on the site of the famous Charité Hospital in Berlin, once the workplace of legendary infectious disease researchers Robert Koch and Paul Ehrlich. Based on the studies carried out by the Berlin-based scientists, it became evident that the young patient's neutrophils were incapable of forming NETs. According to Brinkmann, this "has dire consequences, particularly in the fight against fungal infections."

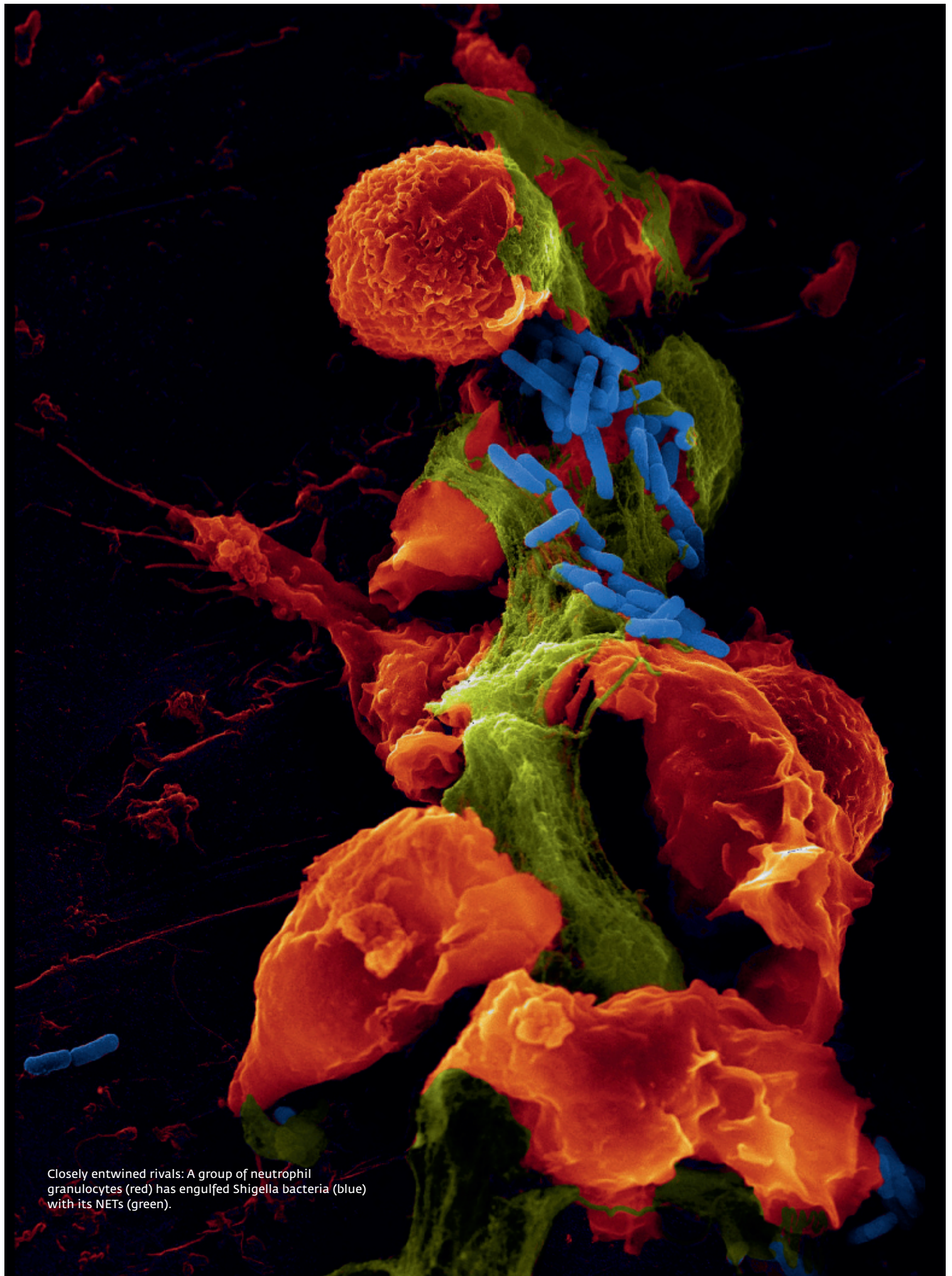
AN ARTIFICIAL OR NATURAL PHENOMENON?

The scientist is in his office examining an image of the NETs, taken using one of his high-tech microscopes in the adjacent laboratories. From a purely aesthetic perspective, the image is nothing short of delightful and resembles, at first glance, a cluster of vividly colored threads and dots. Brinkmann was the first person to see something similar to this image in 2003, when nobody knew of the existence of these defensive cellular and molecular webs that suddenly appeared under his microscope.

Arturo Zychlinsky, Director at the Max Planck Institute for Infection Biology and head of the Cellular Microbiology research group, was also initially at a loss when presented with these strange structures. "I thought it was an artifact," he admits – in other words, an artificial phenomenon that is generated by laboratory conditions and does not arise naturally in the organism.

What's more, Arturo Zychlinsky, who was born and bred in Mexico City, had a very long track record in infection biology and was a renowned expert in the field. As a young man he was fascinated by microbes and the immune system that defends the body against them. It was thus clear to him from an early age that the study of microbiology and immunology was the only career option worth pursuing. When it eventually came to choosing a topic for his doctorate, he opted for a subject relating to innate immune defense.

Compared to the sophistication of the acquired or adaptive immune system, the innate immune system was considered a rather simple and blunt instrument. It is based on the principle of using tailor-made weapons to destroy all germs, be they viral, bacterial,



Closely entwined rivals: A group of neutrophil granulocytes (red) has engulfed *Shigella* bacteria (blue) with its NETs (green).

parasitical or fungal in nature, and thereafter creating a long-term memory of the pathogen's molecular calling card to enable faster and more effective action in the case of a repeat infection.

The adaptive immune system consists of a myriad of specialized cells with various sub-classes, even more messenger substances and signaling molecules, and tailor-made antibodies – in other words, a veritable and inconceivably complex jungle of cellular communication and signal processing. In the young Zychlinsky's view, it was "too complicated for me to research," as he candidly admits.

FAST-REACTING INNATE IMMUNE SYSTEM

The supposedly less complex innate immune system presented a far more attractive proposition. Even the ancient Greeks knew of its existence and described inflammatory processes. "Inflammation is the response of the innate immune system to infection," says Zychlinsky, and involves, among other things, pain and the reddening of tissue. The innate immune response is a kind of vanguard, an initial firewall that attacks invading pathogens in a matter

of minutes and, superficially at least, involves a less intricate line of defense than the adaptive immune system.

"It's as old as the hills," speculates Zychlinsky with good reason; probably as old as multicellular animal life itself, so a good 500 to 600 million years old. Its cells and molecules have existed in sponges and insects, fish and frogs since organisms started to live off and exploit other organisms.

The macrophages are among the most important cells of the innate immune system. They literally devour germs – albeit with far less gusto than the neutrophil granulocytes that fulfill this task a hundred times more effectively and that the bone marrow produces daily by the millions. Of all white blood cells, 70 percent are neutrophils. And adult humans are fortunate enough to carry a good half pound of them around in their systems. They roam through the blood and simply await activation by the immune system's custodian cells (the dendritic cells), which patrol the body's tissues and are activated in turn by messenger substances like interleukins.

When they receive the signal "pathogens found in neighboring tissue!", the rounded neutrophils, with their ex-

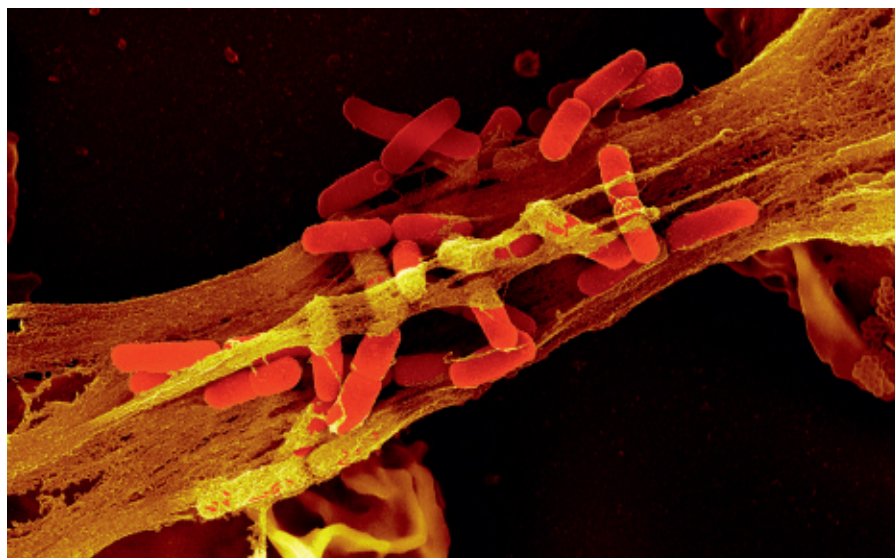
tensively lobed cell nucleus, rush from the blood stream to the wall of the vessel in which they are currently located, seek out the tiniest opening, make themselves as elongated and slim as possible, slip through the opening, and hasten to the site of the infection.

"These foot soldiers of the immune system," as Arturo Zychlinsky calls them, are very well armed and always primed for action. They do not divide and, irrespective of whether they have been deployed or not, die after a maximum lifespan of six hours. Once they reach the site of the bacterial invasion, they decide which approach to adopt against the invader. They either devour it in a split-second process or they flood the infected area with granule proteins, bacteria killers they have stored in their dozens of small depots. "These contain a top-class arsenal for fighting pathogens," explains Volker Brinkmann.

One of these enzymes is neutrophil elastase, which Arturo Zychlinsky's team has been investigating since his time at New York University School of Medicine. Elastase also annihilates the bacterial proteins that render the microbes pathogenic to humans. Zychlinsky and his colleagues have shown

left | A *Klebsiella* bacterium in the lung of a mouse has been caught in the NETs.

right | NETs fight *Shigella* bacteria. The bacterial dysentery pathogens are killed by the antibacterial effect of the chromatin.





Volker Brinkmann (left) and Arturo Zychlinsky discovered the NETs together with colleagues. Since this discovery, the immune mechanism continues to present the two researchers with new puzzles to solve.

that elastase can break down the virulence factors of *Shigella* bacteria, which cause dysentery, a dangerous diarrheal illness.

In 2003, the Berlin researchers wanted to identify the place where the *Shigella* bacteria and elastase meet in the neutrophils. This was a task for Volker Brinkmann and his microscopy team, who used a stain to locate the elastase in a neutrophil culture that had been infected with *Shigella*, enabling them to make it visible under their light and electron microscopes. "Elastase suddenly appeared in these colorful balls located outside the cells," remembers Brinkmann. "That was strange."

The scientists then conducted further experiments in which they also deliberately stained the neutrophils' genetic material. This sophisticated approach provided definitive proof of the existence of the NETs: "They were always there," says Brinkmann. The possibility that they were an artifact could thus be excluded.

Since publication of this astonishing discovery in the journal *SCIENCE*, numerous research teams have tilled this new field, including, of course, the Berlin-based scientists. Today, seven

years later, they have an impressive film to show their guests, presenting the process in fast motion. It is a highly dynamic process accompanied by dramatic changes in the neutrophil granulocytes. "Like suicide bombers who blow themselves up," is how doctoral student Kathleen Metzler describes the scene, since the formation of the NETs also signals the simultaneous demise of the granulocytes.

CHROMATIN IN THE NETS ACTS AS A POTENT ANTIBIOTIC

Under the scanning electron microscope, the NETs appear as fine fibers and particles that link the threads to form more complex structures. This causes the formation of a ball in which the bacteria become engulfed. The main ingredient of this ball is chromatin. This mixture of DNA and proteins is normally found in the cell nucleus and contains genetic information.

Most of the proteins contained in the chromatin are histones, which lend the DNA an ordered structure. During the formation of the NETs, some of the histones are cut so that the DNA threads can unfold. In addition to chromatin

and histones, the NETs also contain between 20 and 25 proteins from the cell plasma of the neutrophils that can kill the bacteria or render their virulence factors harmless.

In Arturo Zychlinsky's view, however, the histones are "the most important antimicrobial substances in the NETs." The fact that histones can fight bacteria was discovered by US scientist James Hirsch as far back as 1958. His finding, however, did not attract much support among immunology experts. Histones that have been purified in the laboratory are far more effective at killing bacteria than all other known autologous antibiotics. "But we have absolutely no idea how they do it," says the Max Planck researcher.

It is also unclear whether histones in the organism play a role in the immune response. Zychlinsky suspects that the histones developed in the course of evolution to protect genetic material from bacterial attacks. However, he is unable to prove this. What is known is that the fatal NETs ensnare fungi and, of course, bacteria, such as *Shigella*, *Salmonella*, pneumococci and staphylococci, which can cause food poisoning and toxic shock syndrome. >

» The cells run a program that inevitably signals their own demise – a case of suicide for the common good.

The Max Planck scientists demonstrated the presence of NETs not only in experimental cell cultures but also in tissue samples from patients with appendicitis and bacillary dysentery (shigellosis). Interestingly, this process functions just as well as the devouring of the pathogens: “As many bacteria perish in the NETs as are digested by living neutrophils,” says Arturo Zychlinsky.

The aforementioned film also shows how the neutrophils can mobilize vital components of the cell nucleus and eject them from the cell. Once activated by the presence of a bacterium in the vicinity or by immune system messenger substances, the cells run a program that inevitably signals their own demise – a case of suicide for the common good. Initially, the structure of the nucleus and the granules changes. “The membrane around the nucleus disintegrates, the granules dissolve, and the components of the NETs can mix in the cell interior as a result,” says Volker Brinkmann.

All of this unfolds within a period of two hours. A stage between life and death follows. In the final act, after three hours, the cell contracts again until the cell membrane tears and the highly active mixture is expelled. Outside the cell, it unfolds and forms the NETs, which engulf the bacteria.

“We do not yet know what happens at the molecular level,” says Zychlinsky. Due to their short lifespan, neutrophils are very difficult to study in the laboratory. What is definite is that when certain receptors on the neutrophil surface receive the death signal, within 20 minutes, the cell activates an enzyme known as NADPH oxidase that produces aggressive oxygen radicals from normal oxygen molecules – so-called superoxide. When the Berlin researchers inhibit this enzyme, NET formation does not occur.

LUPUS PATIENTS FORM ANTIBODIES AGAINST NETS

Kathleen Metzler worked with chronic granulomatosis disease patients, fellow sufferers of the eight-year-old gene therapy patient. The genes for the production of NADPH oxidase are defective in these patients, so they are unable to form NETs. As the American scientist discovered, people with a mutation in the gene for the enzyme myeloperoxidase – which is also involved in oxygen radical formation – are also unable to form NETs. However, the resulting immune weakness is often less serious in this case. Using cell samples from these patients, the doctoral student and her colleagues

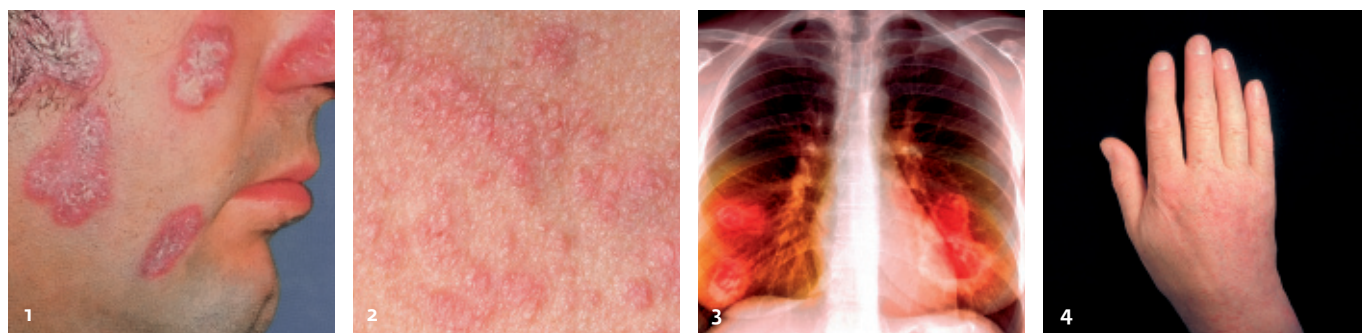
aimed to establish why oxygen radicals are so crucial to NETs formation.

Like every useful biological phenomenon, the formation of the NETs comes at a price. The Max Planck researchers suspected this from the outset and referred to a serious autoimmune disease, systemic lupus erythematosus (SLE), in their original publication in the journal *SCIENCE*. With autoimmune diseases, the adaptive immune system incorrectly directs its weapons, for example antibodies, at structures belonging to its own organism.

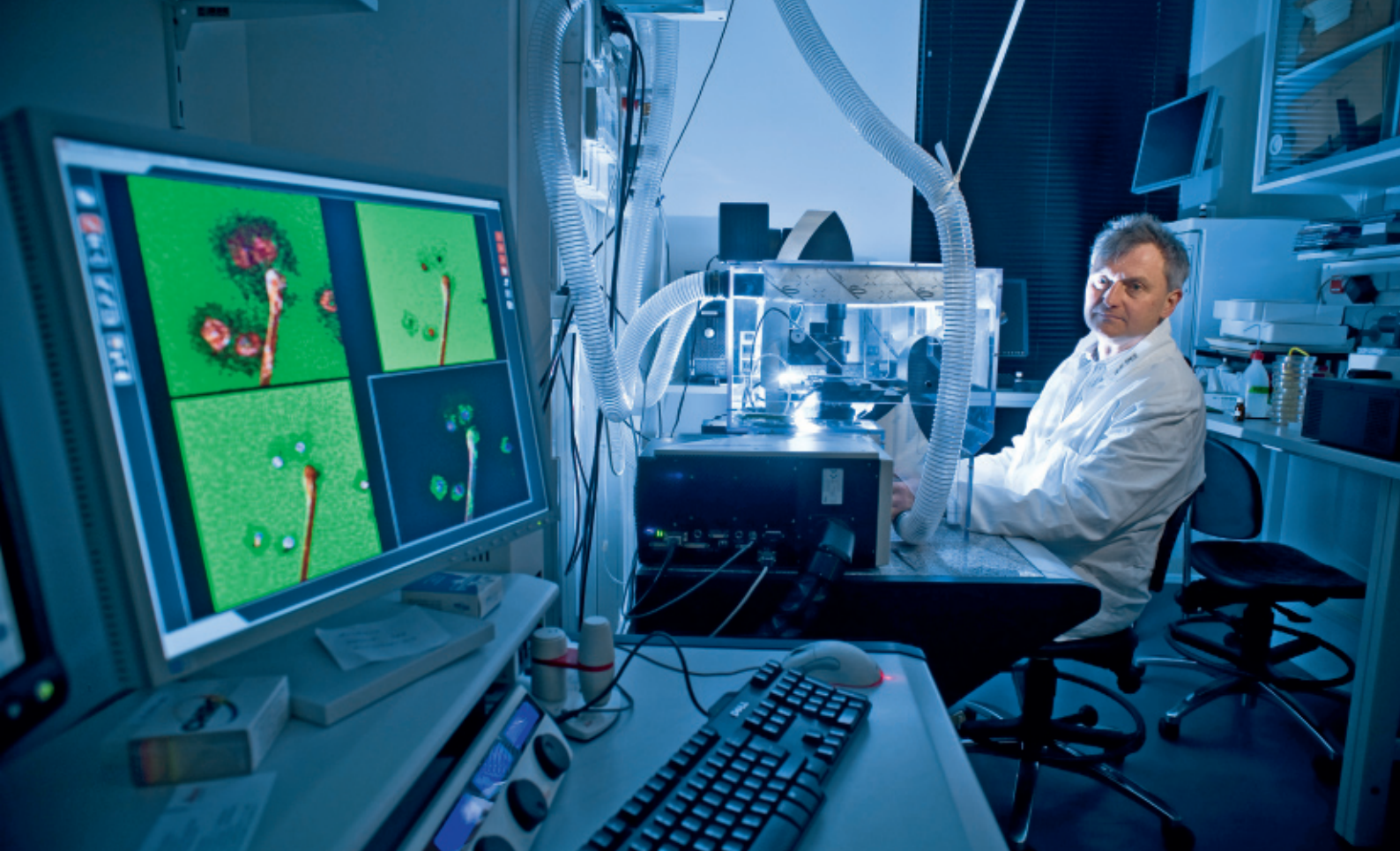
Lupus is ten times more common in women than in men. Its characteristic symptoms, which include skin rashes – such as the typical butterfly-shaped facial redness – joint and muscle pain, fatigue, and inflammation, are probably triggered by infections. Lupus progresses in bouts known as flares, and gets worse with each progressive flare. In some patients, the autoimmune antibodies destroy the kidneys.

A lupus diagnosis, which is difficult to make, depends on numerous factors. In all cases, the patients form three types of antibodies: against the genetic substance DNA, against histones, and against proteins from the neutrophil granules. Hence, interestingly, it produces antibodies against the specific components of the NETs.

Clearly delineated, scaly skin lesions are a typical symptom of lupus (1). Antibodies against the NETs components cause inflammation of the skin (2). Chest X-ray of a patient with Wegener's granulomatosis. This disease is a form of vasculitis that also affects the lungs and other organs. The damaged pulmonary tissue is stained orange in the photograph (3). With vasculitis, the body's own antibodies trigger an infection of the blood vessels. This can cause red patches on the skin (4).



Photos: Sciencepictures (1 and 4), SPL-Agentur Focus (2 and 3)



Moreover, an SLE attack often occurs after an infection. The scientists in Berlin thus suspect that the symptoms may be caused by the failure of the NETs to disintegrate.

Together with medical researchers from the University of Erlangen, the Max Planck researchers went to the bottom of the matter. With each new lupus flare following an infection, neutrophils apparently migrate to the center of the action and produce NETs. The timely degradation of the NETs appears to be essential to prevent the formation of new autoimmune antibodies. It would appear that the enzyme DNase-1, which circulates in the blood, usually degrades the NETs. However, this process does not work in some lupus patients. "Either they form too many NETs or the DNase is blocked," says Arturo Zychlinsky, perhaps by antibodies against the enzyme. Or the DNase-1 simply does not reach the NETs.

As the scientists have discovered, when this mechanism is defective, the antibodies accumulate particularly in the kidneys. "We can say with a considerable degree of certainty that these lupus patients have a high risk of kidney

failure," stresses Zychlinsky. Based on this discovery, it may be possible to develop a new diagnostic test to enable the prognosis of kidney failure based on the presence of an elevated concentration of antibodies against the NETs. This could also open the door to the earlier treatment of affected patients.

NEW DRUGS THAT WORK SELECTIVELY

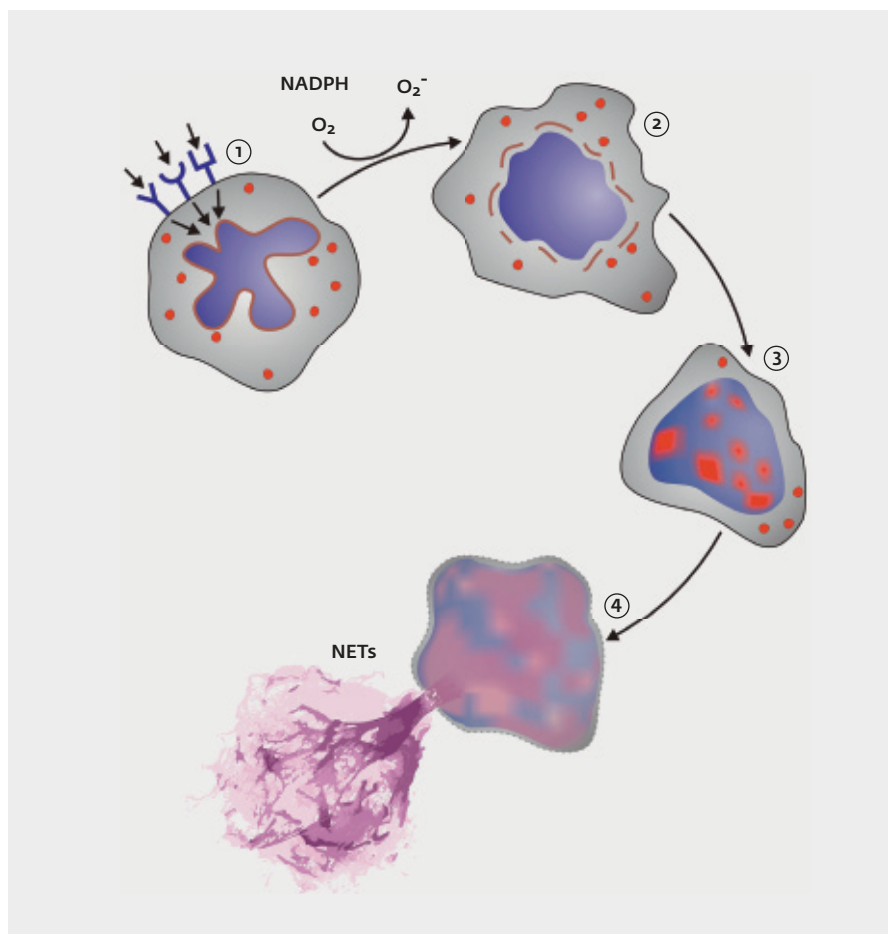
But there is still a long way to go before a treatment is developed for lupus patients. One possibility is to filter the dangerous antibodies using a kind of dialysis process. However, if the scientists succeed in decoding the molecular secrets of the disease process, a selectively effective drug may one day be found that can stop the formation of NETs in SLE patients.

The NETs also play an important role in the emergence of another rare autoimmune disease – vasculitis – in which the immune system attacks the blood vessels and kidneys. Scientists are discovering more and more that NETs are involved in disease processes – or they are suddenly able to explain previously mysterious phenomena using NETs.

Volker Brinkmann can observe the formation of the NETs in detail using a laser scanning confocal microscope.

For instance, the reason why bacteria known as staphylococci and pneumococci place a DNase on their surface had long mystified scientists. Following a research study carried out by the Max Planck researchers in Berlin and scientists at the Karolinska Institute in Stockholm, the reason for this is now clear: the purpose of the enzyme is to hack away at the NETs. If the DNases are removed from the pathogens, they pose far less of a threat to the organism. An experiment on mice has proven that, in the absence of DNases, the bacteria do not migrate to the lungs, and the risk of blood poisoning, for example, is practically eliminated.

Moreover, the NETs are clearly involved in the emergence of pre-eclampsia in pregnancy. This disease causes pregnant women to store water in their tissues and develop high blood pressure. The process can also have very serious consequences for the unborn child. The external layer of the maternal tissue forms particles in the area of contact with the embryo. If an inflam-



In order to enable neutrophil granulocytes, which are activated by signaling substances, to form NETs (1), the enzyme NADPH oxidase must first convert oxygen into superoxide. The membranes of the cell nucleus and granules then disintegrate (2) and their contents mix with the cellular fluid (3). Three hours later, the cell membrane tears in one place and the components of the NETs are "spit out" (4).

halts this dangerous process. The NETs also connect with numerous proteins that promote thrombosis. The drug heparin can also halt the formation of thromboses triggered by the NETs. The reason for this is that heparin removes the histones from the DNA. It appears that histones alone can cause the formation of the blood clots. These findings confirm an observation made in the context of population studies whereby infections are frequently linked with the formation of blood clots.

This shows how the ripples created by Arturo Zychlinsky and Volker Brinkmann's discovery, made with the help of savvy, skill and chance, continue to spread. "We are interested above all in basic scientific processes," stresses Zychlinsky. "And if a patient benefits at some point, it would make us the happiest people on earth." ◀

mation occurs and the neutrophils arrive, NETs are formed that threaten the blood supply to the embryo and that actually "congeal" the tissue, as Volker Brinkmann explains. This deprives the embryo of oxygen, with the associated potentially dramatic consequences.

According to the findings of former colleagues of Arturo Zychlinsky, NETs stimulate the formation of blood clots in veins and provide an ideal framework for them. Blood platelets adhere to the NETs, are activated and form clumps. The administration of DNase

NETS CAN TRIGGER BLOOD CLOTS

Researchers working with Dominik Hartl at Munich University Hospital also found masses of NETs in the lungs of patients with cystic fibrosis. Patients with this disease suffer from congestion of the lungs – fertile ground for recurring bacterial infections – as a result of a genetic defect. The NETs also block the lungs and exacerbate the patients' breathing problems. The worse the patients' pulmonary function is, the more NETs they have in their airways. In this instance, it would appear that NET formation is dependent on NADPH oxidase.

GLOSSARY

Innate immune system

The immune system consists of the innate (non-specific) and acquired (specific) immune systems. The innate immune defense forms the front line in the attack against pathogens. With the help of certain proteins, its cells track down substances in the germs that are foreign to the body. However, the innate immune system does not identify them specifically and does not, therefore, provide protection against renewed infection. Instead, its purpose is to prevent the emergence of a source of infection and contain its proliferation. In addition, it stimulates the acquired immune system with its B cells, T cells and antibodies.

Neutrophil granulocytes

Neutrophil granulocytes are a specific type of white blood cell (lymphocyte). They are formed in the blood marrow and form part of the innate immune system. They can recognize, engulf and kill pathogens.

Chromatin

Chromatin is a complex formed by the genetic substance DNA and proteins. It is a component of the chromosomes. The function of certain chromatin proteins, the histones, is to package the thread-like DNA molecule particularly tightly and compress it.

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Electricity from Hot Air

Even the most efficient motor generates more heat than propulsion. Thermoelectric generators, however, could convert some of this unused energy into electricity – something that **Juri Grin** and his colleagues at the **Max Planck Institute for Chemical Physics of Solids** in Dresden are hoping to achieve. They are currently searching for particularly suitable materials for this endeavor.

TEXT **CHRISTIAN MEIER**

The terms Juri Grin uses sound strange. He talks about recycling or harvesting waste heat. Waste recycling, yes – that is commonplace. But waste heat recycling? And harvesting apples, okay, but how does one harvest waste heat?

Juri Grin thinks this is absolutely imperative. “We humans allow ourselves a great luxury,” says the Director at the Max Planck Institute for Chemical Physics of Solids in Dresden. “We convert only around one third of the primary energy contained in coal, gas or oil into usable energy such as electricity or heat to heat our homes, for example.” The rest escapes unused into the atmosphere as waste heat. “We can no longer afford to do this, if for no other reason than that of climate change,” says Juri Grin.

To change this situation, the chemist and his colleagues are working on a particular way to recycle waste heat. The fundamental idea is that thermoelectric materials, or thermoelectrics for short, will convert at least some of the energy that currently goes unused into electricity. There are various

chemical compounds that can be used for this. Juri Grin’s team of researchers at the Max Planck Institute in Dresden is investigating two special classes of these substances.

A TEMPERATURE DIFFERENCE CREATES THE VOLTAGE

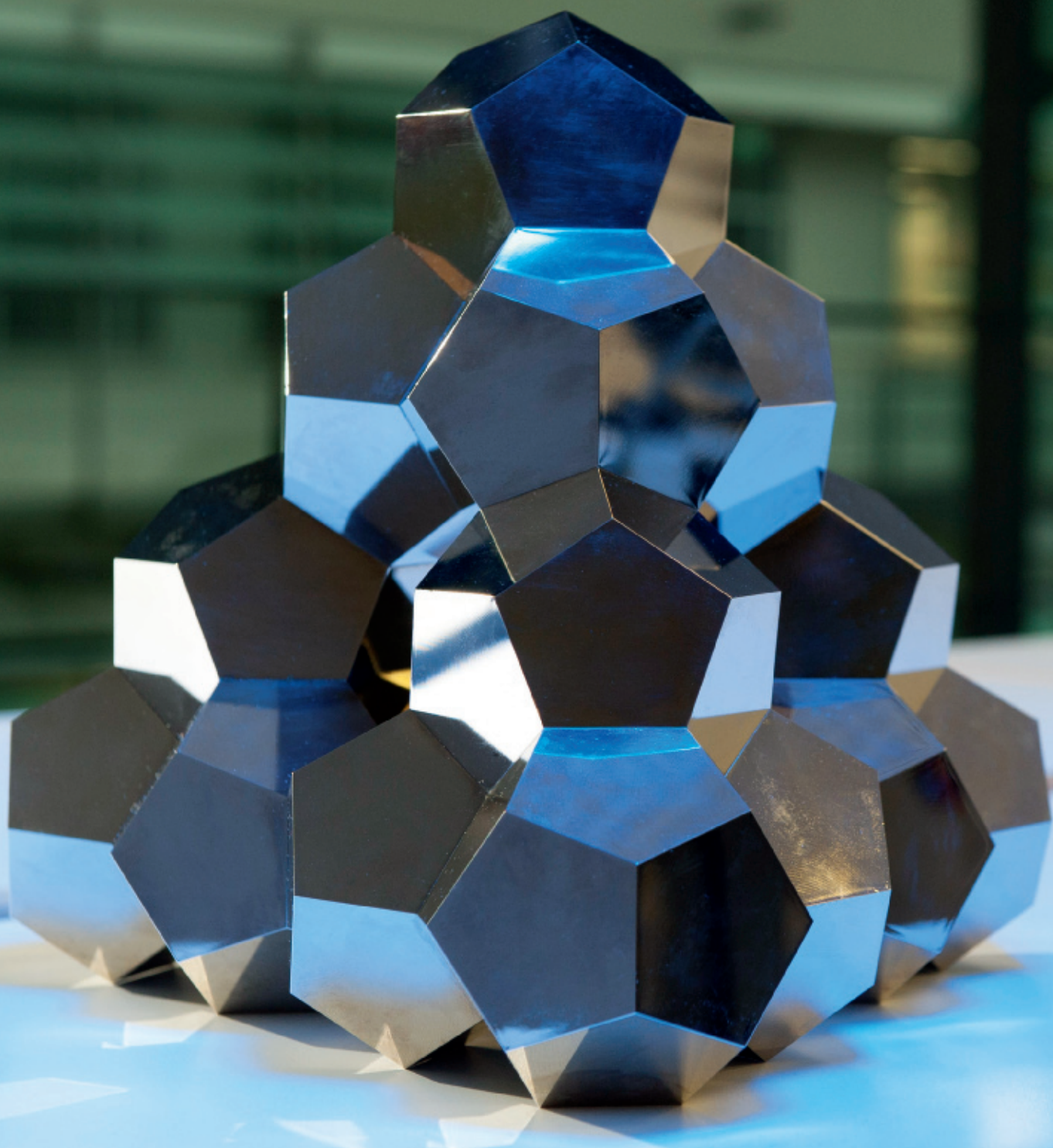
Materials that convert heat into electricity have been known since the beginning of the 19th century. Physicist Thomas Johann Seebeck discovered them quite by accident. Thermoelectrics, which consist of electrical conductors or semiconductors, have also been in use in technical applications for some time: each thermocouple makes use of the thermoelectric effect to measure temperature. These materials also produce electricity, especially where other power sources are not available, or where the power source used must suffer no wear and tear, thus not requiring maintenance – in space probes that orbit distant planets and moons, for instance.

Inside the probes, a radioactive substance decays in a reactor, generating a temperature of several hundred

degrees Celsius. The temperature in space is below minus 270 degrees. The resulting temperature difference of more than 1,000 degrees provides ideal conditions for generating electricity with a thermoelectric material incorporated into the hull of the probe, surrounding the radioactive core, because it is precisely this kind of temperature gradient that promotes thermoelectric energy conversion.

The temperature difference means that the charge carriers have a higher energy in hot parts of the material than in cold ones. This produces a voltage that increases as the difference in temperature increases.

The plan is for this principle of power generation to no longer be limited to such extreme applications as space travel, because cars and power stations also produce ample heat that currently escapes unused. For this reason, in 2008, a German automotive manufacturer installed a thermoelectric generator in a test vehicle. It converts part of the heat of the exhaust gas into electricity for the onboard electronics, thus saving fuel – a not inconsiderable 5 to 8 percent, according to the company. >



Candidate for an efficient thermoelectric material: The crystal structure of intermetallic clathrates can be recognized in the model. One atom sits at each corner of the polyhedrons, and the cavities in their interiors provide room for further atoms. A voltage can be generated in such materials if they are exposed to a temperature gradient.



The great potential of such thermoelectric generators becomes evident with a simple calculation: if only 10 percent of the cars in Germany, or around five million cars, were equipped with a thermoelectric generator that produced one kilowatt of electric power, and if each of these generators were active 200 hours per year, 100 million liters of fuel could be saved.

The only problem with this promising scenario is that there are as yet no thermoelectric generators with sufficient power, as thermoelectrics currently don't convert heat into electricity very efficiently. Researchers all over the world, including Juri Grin and his colleagues, want to change this. They are developing thermoelectric materials that have as high a quality factor as possible.

THERMAL AND ELECTRICAL CONDUCTIVITY ARE COUPLED

The quality factor, or ZT for short, is a numerical measure of how effectively a material converts thermal energy into electrical energy, and depends on three physical quantities – it increases as the Seebeck coefficient increases. Named after the discoverer of thermoelectricity, this material characteristic indicates the voltage that is produced between the ends of a thermoelectric material for one degree difference in temperature. The quality factor also increases when the electrical conductivity is as high as possible. The electrical conductivity determines how



top: This instrument can be used to measure the electrical resistance of a sample. The material is examined in a noble gas atmosphere to protect it from oxygen.

bottom: Technician Ralf Koban prepares a sample holder in order to determine the thermoelectric properties. This involves working in a glove box filled with noble gas.

well the charge carriers flow through the material. Finally, the thermal conductivity determines how fast the temperature difference, which generates the voltage, is equalized. Thus, to achieve a high quality factor, the thermal conductivity of a material should be as low as possible.

The aim is therefore to find or develop materials that have a high electrical conductivity but a low thermal conductivity. And that is precisely the problem: in conventional metals and semiconductors, thermal and electrical conductivity are coupled. Both properties are determined by the number of charge carriers, which transport current and also make a significant contribution to heat conduction.

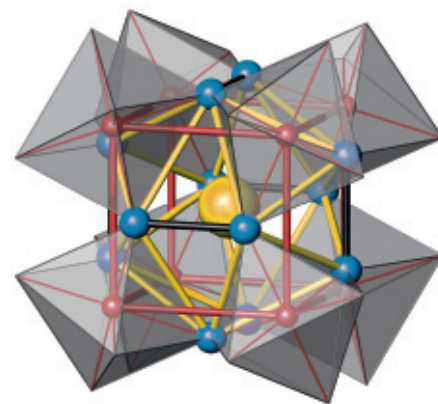
The electrical conductivity can be changed, for instance, by introducing foreign atoms into the crystal lattice of a thermoelectric material. These foreign atoms contribute higher or lower numbers of electrons to the conducting electrons than the main components do. But what the quality factor gains from the increasing electrical conductivity is canceled out by the increase in thermal conductivity. Until the 1990s, the gen-

eral opinion was that this seemingly unsolvable dilemma prevented efficient thermoelectric materials from being developed; the topic no longer generated any interest.

"But then materials were discovered whose electrical and thermal conductivity are partially decoupled," says Juri Grin. This offered a way out of the conductivity dilemma. And since it coincided with the optimization of further material characteristics, efficient thermoelectric generators suddenly seemed possible. The scientist thinks this stimulated research. The German Research Foundation is now also supporting this research in the "Nanostructured Thermoelectrics" priority program.

DIFFERENT CHEMICAL BONDING SOLVES THE DILEMMA

Juri Grin and his colleagues begin the search for efficient thermoelectric materials with a fundamental question: "We want to find out how the type of chemical bonding in a material affects its physical properties," explains Grin. So the researchers are investigating how electrical and thermal conductivity de-



View into a skutterudite with filling: The red spheres represent cobalt, rhodium or iridium atoms, and the blue ones phosphorous, arsenic or antimony. Calcium or barium atoms (yellow) are located in the voids of the lattice. Octahedral structural elements are outlined in gray.

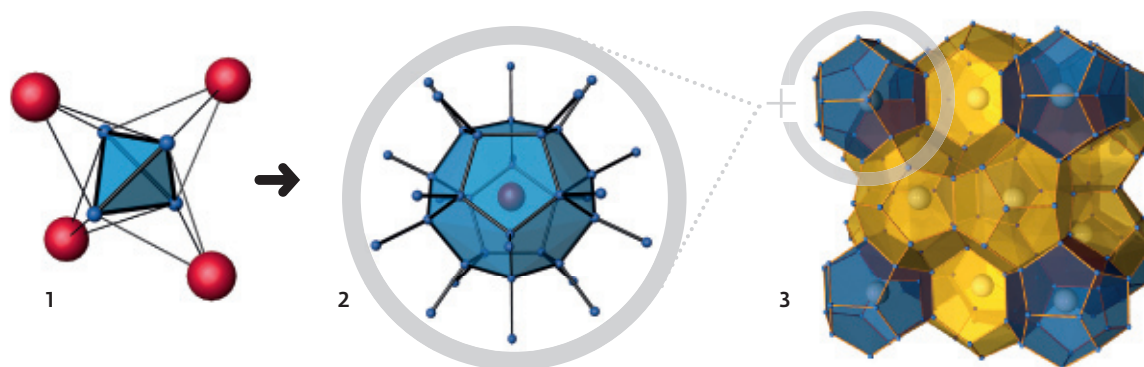
pend on whether the bonds are of an ionic nature – that is, based on electrostatic forces between ions – or whether neighboring atoms are bound together by shared electron pairs and form covalent bonds. They discovered that the two properties can be decoupled to a certain extent in clever combinations of ionic and covalent bonding. Understanding these relationships helps the scientists systematically synthesize thermoelectric materials with as high a quality factor as possible. >

HOW A THERMOELECTRIC GENERATOR WORKS

The fundamental building block of a thermoelectric generator – a thermoelectric module – resembles the Greek letter "pi," consisting of two legs that are electrically connected. One of the legs is a so-called n-conductor (the n stands for negative), the other a p-conductor (the p stands for positive). While (negatively charged) electrons provide the current flow in n-conductors, this is done in p-conductors by positively charged charge carriers, so-called holes.

The module is hot at the top, so on the side of the bar, and cold at the bottom, at the ends of the legs. Since the electrons

and holes at the hot end of each leg have a higher kinetic energy than those at the cold end, more charge carriers travel from the hot end to the cold end than move in the opposite direction in a given time. Negative charge thus collects at the cold end of the n-leg, and positive charge at the cold end of the p-leg. A thermoelectric device built in this way generates a voltage that can be used for technical applications. However, such a module produces too little current for most such applications, so many of them are connected in series, like batteries in a flashlight.



Building chemical cages: The molecular building blocks (1) of the clathrates consist of silicon (blue) and a metal (red) such as sodium, potassium or barium. They form silicon polyhedrons (2), which surround the metal atoms like cages. The polyhedrons stack up to form a voluminous structure (3).

The researchers in Dresden consider two classes of materials to be particularly promising: filled skutterudites and intermetallic clathrates. The two classes of substances are composed of different chemical elements and have different crystal structures. Skutterudites consist of phosphorous, arsenic or antimony, as well as selected elements of the iron and cobalt group or the group of platinum metals. Clathrates, in contrast, contain elements of the fourteenth group of the periodic system, namely germanium and silicon, and of the thirteenth group, such as aluminum, or of the transition metals, such as nickel. Both the skutterudites and the clathrates are particularly interesting as thermoelectrics if they contain additional metal atoms or ions. These are located in cavities that are present in the crystal structures of the materials.

“We are aiming for a comprehensive understanding of these compounds,” explains Juri Grin, because a high quality factor is not sufficient to recommend a material for generators in cars, for example. “It is also important that the material be at its most efficient between 300 and 600 degrees Celsius,” adds his colleague Michael Baitinger, because the temperature of car exhaust gases is in this range. “The material must also remain stable over a long pe-

riod of time at these temperatures,” says the researcher. And it should not expand too much when it becomes hot, or it can hardly be permanently incorporated in a generator.

A material that fulfills these requirements can be identified only with an in-depth knowledge of chemistry and physics. “In addition to the effect of the chemical bonding, we must also understand how the physical properties depend on the type of structure,” says Grin. The microstructure describes the form, size and chemical composition of the microscopically small grains that make up a solid.

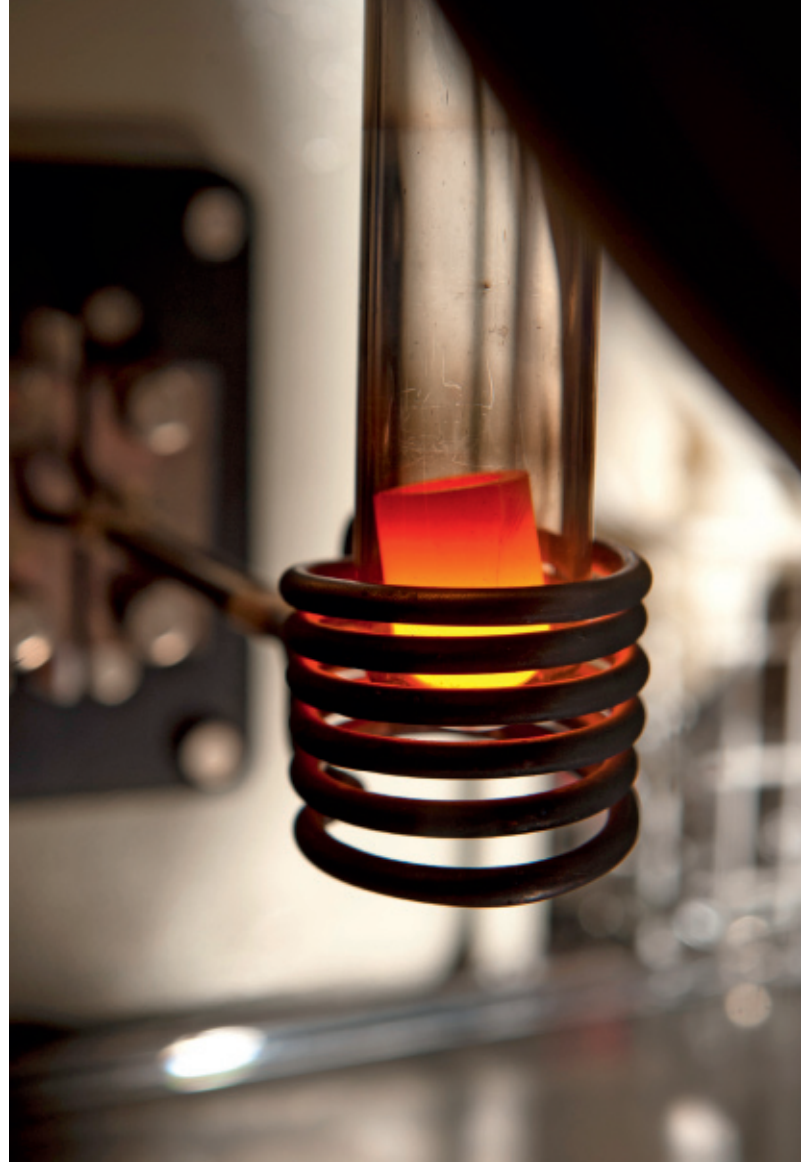
ATOMS OSCILLATING IN THEIR CAGES

To begin with, however, the most important question is: how can electrical and thermal conductivity be influenced as separately as possible? Nature provides at least a starting point for the answer. After all, in a material, heat is transported not only by the free electrons, which also flow in an electric current. This component of the thermal conductivity necessarily increases with electrical conductivity. But heat is also conducted by sound waves, or, in the language of the scientists, by phonons, which travel through the material.

Absorbing phonons makes it possible to decrease the thermal conductivity without affecting the electrical conductivity. “We found that this is possible in materials that contain both covalent and ionic bonds,” explains Grin, as is the case with intermetallic clathrates.

In the clathrates, for example, covalent bonds link most atoms of one or more types of elements to form a lattice: cavities that resemble soccer balls in shape and that are formed by pentagons or hexagons then stack up to form a delicate structure. The voids in the lattice accommodate ions of a different element. The charged particles sit there as if in a cage, trapped by the electric field of the clathrate lattice, meaning they form an ionic bonding.

The lattice of the covalently bonded atoms and the ions in the cages each play different roles. While the walls conduct the electric current, the ion in the cage scatters phonons that pass through the crystal lattice. If a phonon impacts on the cage, the ion is deflected from its most stable position in the center of the cage. This impulse causes it to oscillate in its cage like a bead in a child’s rattle. This can be visualized by imagining that the oscillating ion absorbs the energy of the phonon just like a heavy metal sphere under a skyscraper absorbs the oscillations of the building during an earthquake.



left: Chemistry uses a voltage: Ph.D. student Xianjuan Feng prepares a reaction in an arc furnace. A voltage between two electrodes produces an arc with a temperature of several thousand degrees in which the starting materials react with each other.

right: Chemistry uses a current: In the induction furnace, a conducting coil generates eddy currents in the carbon crucible and the metallic starting materials, and heats them up in such a way that the chemical conversion takes place.

In more accurate physical terms, the heat excites the lattice of the covalently bonded atoms and the trapped ions to execute oscillations at different frequencies. The two oscillations damp each other so that the heat is not conducted well on this path. This mechanism can be enhanced without affecting the electrical conductivity.

This is precisely what Juri Grin and his colleagues achieved. They synthesized both clathrates and skutterudites with different compositions and tested their suitability as thermoelectrics. But rather than choosing randomly from the seemingly endless number of possible chemical compositions, the researchers first use quantum-chemical models of the chemical bonds in a com-

pound. “In our calculations, we vary the chemical composition, the arrangement of the atoms and the crystal structure,” explains Juri Grin.

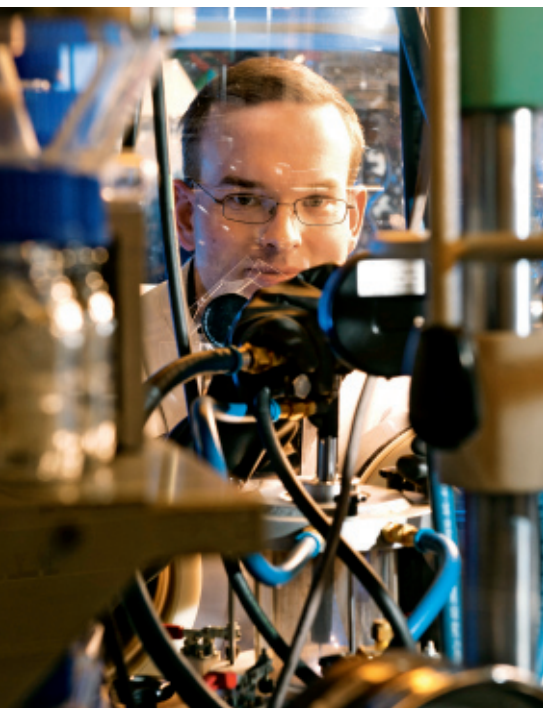
A STARTING POINT FOR EFFICIENT THERMOELECTRIC MATERIALS

The calculations show where in the crystal structure which type of bond – covalent or ionic – predominates. Compounds that are shown to crystallize in a covalently bonded lattice and whose voids surround ions are deemed to be promising candidates. The chemists are now trying to synthesize these and then analyze their precise composition and crystal structure. Together with their colleagues from Frank Steglich’s Solid State

Physics department, they are also determining the physical properties on which the quality factor depends.

Over the years, the researchers have thus identified and produced clathrates whose quality factors are comparable with the bismuth telluride that is already used in practice. “We also see a possibility to develop even more efficient thermoelectrics with this approach in the future,” says Juri Grin.

Meanwhile, the researchers in Dresden are tackling another problem that could prevent the technical application of the clathrates and skutterudites: their manufacture. For laboratory purposes, the chemists usually synthesize these substances by direct reaction of the starting materials through melting



Bodo Böhme often produces new compounds in the arc furnace (left), but he and his colleagues also test other synthesis methods (right): Here, Böhme presents a sample container containing the powders of starting materials. A gas flows over them and they react to form the target compound.

or solid-state reactions. But it takes a lot of effort before this method provides the desired material, and then it yields only relatively small quantities. The product usually does not have a uniform composition because all sorts of atomic arrangements are created in the melt. A material must thus undergo subsequent treatment with heat for days, weeks, or sometimes even months, making this method completely useless to industry.

“We wanted to further develop the preparation methods by having the starting materials react with each other in solid form,” explains Bodo Böhme, whose work focuses on the synthesis. These methods allow chemists to produce new compositions of thermoelectric materials. They need only to get the starting materials to strike up a chemical relationship when the substances are lying grain to grain and not getting involved with each other.

In different approaches, the Dresden-based researchers initially gathered indications that even solid materials can be moved to react – when

they tested the spark-plasma sintering method, abbreviated SPS, for example. This method is already used in industry for the densification of metallic or ceramic powders and the formation of parts with a defined shape. A strongly compacted powder is processed with DC pulses that are only a few milliseconds long but very powerful, so that the powder grains slightly deform and fuse together.

A CHEMICAL AGENT IMPROVES CONTROL

“We discovered that it is also possible to do chemistry with this technique,” says Grin. Under the conditions created with the SPS method, the atoms can wander to and fro between the grains and undergo reactions. But this method is not suitable for the large-scale industrial production of thermoelectrics because, like the melting, it provides only individual samples whose properties may also differ slightly from one another. Industry would like to have a method that operates continuously,

churning out the finished material like gravel on a conveyor belt.

Even during their experiments with plasma sintering, the chemists also tested means other than pressure and current pulses to force the solid starting materials to react. Eventually, the method of choice – at least for the production of the clathrates – proved to be to use an oxidizing agent – hydrogen chloride gas, to be precise. The researchers feed the gas, which produces hydrochloric acid when dissolved in water, into a reactor containing a powder of the starting substance. As the oxidizing agent now wafts over the starting compound containing all elements involved, it triggers the chemical partner selection.

“This technique opens up a new chapter in the preparation of metallic materials, such as the clathrates,” says Juri Grin. It allows chemists to influence the composition of thermoelectric materials more accurately than before.

Exactly which atoms are incorporated is decisive for the number of electrons that contribute to the con-

ductivity. The method can also be realized on an industrial scale.

Their comprehensive approach thus enabled Juri Grin's team of researchers to increase the efficiency of the thermoelectric materials, while at the same time making them easier to handle during their industrial production and actual application. To this end, they are collaborating with the Fraunhofer Institutes for Manufacturing Technology and Advanced Materials (IFAM) and for Ceramic Technologies and Systems (IKTS).

In this cooperation, which is supported by the Free State of Saxony, the Max Planck researchers are searching for the suitable thermoelectric materials and methods to produce them. The IFAM researchers form the powdery substances obtained in this process into work pieces that can be incorporated in generators. Staff at the IKTS design the

generators for this. Juri Grin and his colleagues are thus slowly approaching their goal of recycling waste heat with

thermoelectric generators – and maybe in a few years, this expression will no longer sound so strange. ◀

GLOSSARY

Thermoelectric quality factor

A measure of how well a material converts thermal energy into electrical energy.

Seebeck coefficient

Indicates the voltage created between the two ends of, for example, a rod of thermoelectric material if their temperature differs by one degree.

Group of the periodic system

Comprises the chemical elements in a given column in the periodic system of the elements (PSE), such as the halogens or the noble gases. The elements in a group have similar properties, but become more metallic the further toward the bottom of the PSE an element is.

Intermetallic clathrates

Usually consist of elements of the third and fourth main group of the PSE. They form (often together with transition metals) a voluminous framework for the crystal structure whose voids provide space for atoms or ions of further elements, such as alkali, alkaline earth or rare earth metals.

(Filled) skutterudites

Consist of elements of the fifth group of the PSE and a transition metal of the iron, cobalt or nickel group. Their crystal structure has cavities that provide space for further atoms or ions.

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Going Head to Head with Winds and Clouds

The elements, a focus of his professional life, also keep him busy in his leisure time: At the **Max Planck Institute for Meteorology** in Hamburg, **Thorsten Mauritsen** works with climate models. As an amateur pilot, he experiences wind, clouds and turbulence first hand when they combine to buffet the cockpit of his glider.

TEXT **UTA DEFFKE**

Sky and ice as far as the eye can see. Occasionally, a polar bear or two puts in an appearance. At 87.5 degrees north latitude: "It can be very gray there – and cold and damp. People say you either hate it or you love it. I think it's amazingly beautiful." When Thorsten Mauritsen flew ahead of the icebreaker on board the helicopter that was taking him and his research colleagues to the Arctic Ocean, it took only two minutes for them to be completely alone in a hostile, barren expanse. "You realize how small you are. And how astonishing it is that life can exist here at all. It's a really fantastic experience."

The Arctic is still an adventure, even in scientific terms. Climate change is driving temperatures up here twice as fast as the pace on the rest of the planet. Why this should be the case still poses many questions for researchers. In the summer of 2008, the expedition aboard the Swedish icebreaker Oden came close to answering one of them. The expedition was there to help better understand the Arctic's clouds, how they form, how they exist and disappear again. And what effect that has on the climate processes unfolding on the surface of the Earth.

Thorsten Mauritsen spent an entire year preparing for the six-week expedition. He developed experiments, ordered and set up equipment and programmed measurement routines. On August 1, 2008, together with 30 other scientists from all over the world, he set off from Spitzbergen. It took the team two weeks to find an ice floe in the Arctic Ocean that was suitable for the experiments. That summer, most of them were not thick enough.

SUCCESS DEPENDS ON PERFECT LOGISTICS

Then the ship had to turn around to be sure of making the trip back, which left just three weeks for the experiments. Unloading, setting up, starting up – everything had to work to perfection. "It was a complete success," said Mauritsen in summary. "And the only reason it all worked so well is that the preparation was so meticulous."

At the time, meteorologist Mauritsen had already spent several years researching the Arctic climate; he had also developed theories and new models, and questioned old ones. Now that he was able to gather data himself on site – temperature, ambient humidity,

pressure, aerosol particles, wind – he found it a hugely enriching experience. "This was the first time that I really understood what it means to measure all the data, ensuring high-quality data. And this gave me quite a different view of the Arctic, a feeling for things that were previously just numbers for me."

Aerosol particle number concentrations, for example. In the Arctic air, it is extremely low. On one occasion, it was so low that, when you exhaled, you couldn't see your breath. The exhaled air simply could not find any particles in the air on which to condense as droplets. This is an effect that has consequences for cloud formation.

In the meantime, Thorsten Mauritsen is back at his desk and computer – at the Max Planck Institute for Meteorology in Hamburg. Even here, the architects have made sure that the researchers are up close and intimate with the weather. The spacious stairwell surrounding the offices has a glass roof that allows an unimpeded view of the clouds, sun and rain. While a storm rages overhead, sending clouds racing across Hamburg's fall sky, Thorsten Mauritsen sits in the conference room, as calm as can be. He makes sparing use of facial expressions and hand gestures

Keeping an eye on the elements: Denmark native Thorsten Mauritsen is a passionate glider pilot and scientist at the Max Planck Institute for Meteorology.





» Thorsten Mauritsen is researching the amplification effect in the Arctic. During the 20th century, the surface of the Arctic has heated up twice as much as the average figure for the rest of the globe – by 1.5 to 2.0 versus 0.7 to 0.8 degrees.

as he talks, weighing his words with care. His large eyes look friendly and inquisitive, framed by a close-cropped horseshoe of dark blond hair, giving him a somewhat “streamlined” look – ideally suited, perhaps, to withstand the headwinds that his work occasionally provokes.

The 33-year-old Dane is researching the amplification effect in the Arctic. During the 20th century, the surface of the Arctic has heated up twice as much as the average figure for the rest of the globe – by 1.5 to 2.0 versus 0.7 to 0.8 degrees. The consequences of this effect are already dramatic – the sea ice is melting, as are the glaciers, and the tundra is thawing. This is raising the sea level and altering the habitats of plants, animals and people.

To understand the amplification phenomenon, researchers need to discover which factors affect temperature and how. The incidence and reflection of solar radiation also play a part in this, as do infrared radiation from the Earth’s surface and greenhouse gases, which absorb and emit it back toward the Earth. Even the lateral heat input from lower latitudes via the ocean and the atmosphere must also be taken into account. And finally, there are the heat exchange mechanisms between the atmosphere and the surface, through tur-

bulent motion, for example. “It is a very complex interplay between the ocean, sea ice, ground and atmosphere,” stresses Mauritsen.

In all this, clouds are still one of the greatest unknowns – in terms of both how clouds affect the climate and how climate change affects clouds. They play a key role in the heat balance of the Earth in two ways: they have a cooling effect because they reflect part of the incident sunlight, and they have a warming effect because they absorb infrared radiation from the Earth’s surface and emit part of it back down to the surface. This conflicting effect makes matters particularly difficult for the climate researchers.

A CONTRADICTION THAT INSPIRES SCIENCE

For clouds to be able to form at all, they need enough water vapor and aerosols. One day in the Arctic, Thorsten Mauritsen and his colleagues made an astonishing discovery concerning especially low particle density. “We observed that the aerosol concentration was getting lower and lower. And then at some point it seemed as if the clouds actually vanished, too. But at the same time, the temperature quickly dropped 8 degrees – that’s quite a lot.”

The trouble was that this ran counter to conventional wisdom: that a cooling effect occurs when more and more particles are injected into the air. Under these conditions, droplet count increases, but droplet size decreases. The clouds become brighter and reflect more of the incident sunlight, and the Earth becomes colder.

This contradiction fascinated Thorsten Mauritsen. “It’s true that I wasn’t an expert in this field, but I had the feeling that there could be something interesting in this.” Back in Stockholm, where he held a post-doctorate position at the university, he got to work preparing the data, delving into the fundamentals and seeking an explanation for the unusual phenomenon: the fewer particles there are, the larger the drops become. At some point, drizzle starts and the clouds become thinner and thinner until they are practically devoid of water. That is why they can absorb hardly any of the infrared radiation from the Earth, so they have no discernible warming effect, either.

Although more sunlight gets through the thin clouds to the Arctic surface, it is unable to compensate for the loss of infrared heating, as Mauritsen was able to show. The studies demonstrate once again that the Arctic has to be seen as a special case. “Our paper has already been published for discussion purposes – and many debates have ensued,” says the climate researcher.

Thorsten Mauritsen loves controversies. As he puts it, science is ultimately a contest. We take particular pleasure in refuting current theories. “We researchers actually spend much more time on controversies than on looking for new explanations,” believes Mauritsen. According to him, in principle, anyone can posit a theory – the real work lies in testing it. “After all, it’s a characteristic feature of modern science that you can never prove the general validity of a theory – all you can do is disprove it.” >

top: Working in sub-zero temperatures: In the tent, the scientists evaluate the initial data. For Thorsten Mauritsen and his colleague Sara de la Rosa, the laptop is an important tool, even in the Arctic.

bottom: Unusual camping site: The climate researchers set up their camp far from civilization.



left: Landed – but not by glider. For excursions in the Arctic, Thorsten Mauritsen uses the helicopter.

right: In the air, on land and of course on water, the researchers are on their way. In August 2008 they set out from Spitzbergen in the Swedish icebreaker *Oden*. It took the team of 30 around two weeks to find an ice floe suitable for their experiments. Above the ship is a halo of light that is scattered by ice crystals in a thin cirrus cloud.

In saying this, Mauritsen refers to the philosopher Karl Popper, who argued precisely this with his theory of falsifiability. In this line of thought, the correctness of a theory does not become more probable simply because it is supported by a particularly large number of appropriate observations. This proposition is not without its opponents among scientific theorists.

It is not just the scientific duel over clouds, wind and heat that has captured Thorsten Mauritsen's interest. His leisure time, too, is often dedicated to contests in this field, for example when he's gliding. He is the reigning Danish champion, and during the world championship last summer in Slovakia, he finished with a very respectable 15th place. "Flying well and achieving something is a great challenge for me," says Mauritsen. Of course, a thirst for adventure plays some part in it, too. "After all, up there, you are absolutely at the mercy of the weather." Thermals provide propulsion, so you look for updrafts, circle in them, gain altitude and speed, then glide to the next updraft, and so on.

"Flying takes all of your concentration. When you're flying, you forget everything else – study, family, work.

You sit, you fly, you make decisions." Peace and tranquility are the order of the day. And a fundamental understanding of meteorology. "But you often have to make decisions so quickly that there is no time to think in physical terms. Flying is more a matter of instinct," says Mauritsen – instinct that he has tested through long years of practical experience. Even while still a schoolboy, he spent hours poring over weather charts so he could climb aboard the glider the very next day and pit himself against real weather.

JUGGLING WITH PHOTONS, OPTICS AND SOFTWARE

Photography – actually his wife's profession – has become a second hobby for him. "Initially, she needed a bit of assistance with the technology. Photography is, in fact, a rather technical matter. In essence, it is all about photons, optics, computers and software. I could really help her with that. But then I started to take photos myself, and she taught me the creative aspect of it." While his wife specializes in photographing people, Thorsten Mauritsen prefers to focus on nature. He can spend hours photographing a

single flower – or capturing the beauty of the Arctic.

But he is no lone wolf. "Gliding means much more than being aloft," stresses the Max Planck researcher. "You belong to a club, and that means that you do a lot of things together." All the technical equipment needs to be maintained, and sometimes the group goes camping, swimming or has a barbecue. As far back as he can remember, Thorsten Mauritsen has been spending his weekends on the airfield.

He grew up in the Danish town of Sønderborg on the Flensburg fjord. His father would regularly take his family with him to the airfield. At 14, he was already working toward his pilot's license. Now the pilot takes his own family to the airfield – his wife and their two children, a 4-year-old son and an 18-month-old daughter. "Gliding is a social thing, so a club is a great way to get to know new people quickly when you move to a new town," says Mauritsen. That worked well in Stockholm, as it does in Hamburg now. Every other weekend, he takes time off for flying. And most of his vacations are taken up with competitions.



» Turbulence plays an important role not only in swirling layers of air and transferring heat between the Earth's surface and the atmosphere. It is also one of the major phenomena in fundamental physics that is still not well understood.

It is hardly a surprise that such a keen glider pilot should become a meteorologist. Originally, he wanted to be an engineer, perhaps building aircraft. But then his interest in natural phenomena took precedence. "After all, we will always be dependent on nature," believes Mauritsen. So he applied to study meteorology for three years in Copenhagen, continued in Stockholm, then started his doctoral thesis there – on a project about the Arctic.

However, it took a brief but memorable encounter before climate research really took hold of him – an experience he immortalized on the cover of his dissertation. "I had just started my work on the doctorate when I visited the University of Uppsala in January 2003 to attend a seminar held by Larry Mahrt. Afterwards, I wanted to meet

Professor Sergej Zilitinkevich. Of course, Sergej had forgotten the appointment, so I had to wait several hours. Finally, after not even 30 minutes, I left Sergej's office with a scrap of paper full of cryptic notes. This was the start of a wonderful collaboration."

Back in Stockholm, Mauritsen brooded over the paper, wrote down what he had understood of Zilitinkevich's varied ideas on turbulence and e-mailed it to Uppsala. The professor was enthusiastic and invited a few more colleagues to the next meeting – and from that time on, turbulence became the doctoral candidate's key research focus. Thorsten Mauritsen carefully stored the piece of paper for years and eventually gave it a place of honor as the front page of his doctoral dissertation.

Turbulence plays an important role not only in swirling layers of air and transferring heat between the Earth's surface and the atmosphere. It is also one of the major phenomena in fundamental physics that is still not well understood. In other words, just the right challenge for an ambitious young researcher. Turbulent flow is a chaotic system with a broad range of scales. The whorls may have diameters ranging from several hundred meters down to just a millimeter, and their interactions are complex.

"Big whorls have little whorls / that feed to their velocity; / and little whorls have lesser whorls / and so on to viscosity." Using this 1920 verse written by Lewis Fry Richardson, the pioneer of numerical weather forecasting, Thorsten Mauritsen finds a poetic

» Graversen and Mauritsen published their findings in the journal *NATURE*, promptly provoking objections. There were even allegations that the Stockholm researchers had not handled their reanalysis data “carefully enough.”

way to describe the fractal nature of turbulence in his doctoral dissertation.

As even the biggest swirls are too small to be accounted for in the scale of current climate models, researchers try to incorporate their effects in a different way. In his doctoral dissertation, Mauritsen developed a new type of model to account for and incorporate the special atmospheric circumstances of the Arctic. There, light, warm layers of air exist that lie very stably above the heavy, cold air near the surface. Mauritsen describes turbulence as waves. “When they are small and break, there is an exchange of air and water particles, and thus also of heat. With the very stable air layers in the Arctic, we describe turbulence as waves that contribute very little to the exchange of heat.”

CLIMATE RESEARCH – COMPLEX AND CONTROVERSIAL

Turbulence of a somewhat different kind was to trigger a further discovery that Thorsten Mauritsen made together with his colleague Rune Graversen at the end of his doctoral work. At the time, Graversen was observing the warming of the Arctic using data known as reanalysis data – data sets processed by weather forecasting models. For the period from 1979 to 2001, Graversen discovered that the temperature in the Arctic rose rapidly, especially in regions well above the surface. “Rune showed it to me and I thought about it for a day. In the end, I went back to him, quite excited, because it meant exactly the opposite of mainstream theory,” recalls Mauri-

sen. So there it was again, this love of contradicting current theories.

Conventional explanation models assume that it is the receding ice cover of the ground and sea that accelerates global warming. This is because the surface becomes darker and absorbs more solar radiation instead of reflecting it. The new observations would mean that the cause of the increased warming of the Arctic in this period may well not be an effect of the surface, or at least not solely.

Graversen and Mauritsen published their findings in the journal *NATURE*, promptly provoking objections. There were even allegations that the Stockholm-based researchers had not handled their reanalysis data “carefully enough” – and that the data might even be wrong. Two years later, another paper was published, also in *NATURE*, that presented another reanalysis dataset from the years 1989 to 2007, delivering apparent proof that the old theory was correct: greatest warming at ground level.

As a result, Mauritsen and Graversen subjected their observations to a thorough review. “We are fairly sure that these differences are not based – or not primarily based – on errors in the data we used, but on the fact that different periods were observed. It is particularly true of recent years that the ice in the Arctic has changed dramatically, so that these surface effects may well make themselves felt more strongly now.” However, Mauritsen and Graversen have no doubt whatsoever that these effects exist. “The only question is: What role do they play in each case? That is what we have yet to find out.”

This discussion reveals once again how controversial and complex climate research is, and shows that the quality and consistency of available data is always a burning issue for scientists. That is why it was such a valuable experience for Thorsten Mauritsen, after his doctoral dissertation, to go on expeditions and conduct his own experiments.

PREFERABLY A JOB IN THE COUNTRY

These days, his main interest is working with and on models. When his post-doctoral position in Stockholm came to an end, it was finally time to move on. There was an attractive job offer in Norway and another with NASA in California, but he was unable to ignite any enthusiasm in his wife for America. “In the end, I again let myself be guided entirely by my scientific interests, and I’m glad I did,” says Mauritsen. This led him in 2009 to the Max Planck Institute for Meteorology in Hamburg. “Ideally, I’d rather have a job like this somewhere in the countryside, but of course that’s a bit unrealistic.”

In the “Atmosphere in the Earth System” department headed by Bjorn Stevens, he has complete freedom to continue his research into the Arctic amplification effect – although now with a somewhat more global approach. For this, he uses the climate model that was developed at the Max Planck Institute in Hamburg. “One of the best models in the world,” Mauritsen feels. It encompasses a description both of the atmosphere and of land and ocean. He is particularly interested in melting ice surfaces, water vapor



and clouds, which he deliberately deactivates in the model to investigate their influence.

In addition, Thorsten Mauritsen works with his colleagues on further developing the Hamburg climate model for the next IPCC report. They are adapting the model so that it delivers the best possible and most up-to-date results for describing the atmosphere. Using this model, he and his colleagues then carry out simulations from the neighboring climate computing center to add to the new IPCC report.

The fact that his research takes on politically relevant dimensions spurs the young Max Planck researcher on all the more. The real motivation for his work, though, is scientific curiosity. "I'm not an idealist – after all, I also drive a car and fly to my competitions," he says. "It's great, of course, if people are interested in what you do. But that's not without its problems, since the public expects clear answers from us scientists. And very often, we just can't deliver them."

Even in his office, Thorsten Mauritsen is close to the elements. The glass roof of the Max Planck Institute for Meteorology offers an unimpeded view of the clouds, sun and rain.

Thorsten Mauritsen doesn't think it is necessarily a good thing that many climate researchers also get involved politically. Although he, too, is concerned about climate change and its consequences – very concerned, in fact – he believes that "...our strength as scientists is that we are independent. And we aren't dependent on the outcome of our research. That's the only way we can remain objective." But deep in his scientist heart there also slumbers what he calls his "crazy side": his curiosity about what would happen if the rise in CO₂ continued unabated. Would a contradiction to the theory emerge? "But as someone who likes living on planet Earth, I can easily forego this experiment." ◀

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GLOSSARY

Aerosols

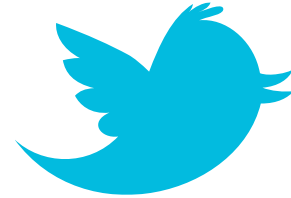
Small airborne particles on which water vapor can condense to form stable droplets. It is still not well understood how aerosols affect climate.

Karl Popper

Austrian philosopher and scientific theorist. Popper (b. 1902 in Vienna, d. 1994 in Croydon, London) founded critical rationalism and other schools of thought. The concept of falsifiability plays a key role in his scientific theory – empirical statements that are not falsifiable are classed as unscientific.

IPCC

The Intergovernmental Panel on Climate Change was founded in November 1988 by the environment program of the United Nations and the World Meteorological Organization. One of the main tasks of the IPCC, which is headquartered in Geneva, is to assess risks associated with global warming and compile prevention and adaptation strategies.



The Echo of Digital Tweets

Twitter, Facebook and their ilk – social media are increasingly dominating the Internet. But how do messages spread across these new platforms? What role does a small clique of super-influentials play? And to what extent are the traditional mass media also leading the pack online? These are the questions that interest **Krishna Gummadi** at the **Max Planck Institute for Software Systems** in Saarbrücken.

TEXT **RALF GRÖTKER**

Krishna Gummadi has no fewer than 1.75 billion tweets – text messages from the social media service Twitter. The company allows its users to “tweet” messages free of charge from any computer or Internet-capable cell phone to other users who have become “followers” of the sender. Tweets are limited to a maximum of 140 characters (which corresponds to the length of this sentence), usually including a link to a website. “A goldmine,” says the 31-year-old Indian. The treasure is securely stored on 58 computer servers in the “Wartburg,” an imposing parish hall built in Saarbrücken’s town center in the 1920s.

Here, in the immediate vicinity of the bank and a credit card company, is the home of the Max Planck Institute for Software Systems, at least until the expanding institute’s new building on the university campus is finished. Gummadi has headed the research

group “Networked Systems Research” since 2005. To understand his passion for the 1.75 billion tweets, we have to go back a bit further.

In early 2003, the SARS epidemic broke out at the Prince of Wales Hospital in Hong Kong. Investigations later showed that a single patient had directly infected 50 other patients, which led, in the end, to 156 SARS cases in that hospital alone – and then to the outbreak of the epidemic well beyond the city.

DO VIRUSES SPREAD LIKE FASHION TRENDS?

It seems that ideas and fashion behave in much the same way as diseases. The sudden success of the Hush Puppies brand is one example of this. In the mid-1990s, sales of this comfortable crepe-soled footwear had reached an all-time low. Then, suddenly, the unexpected happened: New York fashion

designer John Bartlett ordered a series of Hush Puppies for the presentation of his spring collection. The shoes had come to his attention because some people in New York’s club scene had begun to wear them. A Hush Puppies epidemic broke out. In 1995, the company sold 430,000 pairs of shoes – 400,000 more than in the previous year. The following year even saw nearly two million pairs sold.

The American science writer Malcolm Gladwell, who describes the story in his book *The Tipping Point*, has a simple but plausible explanation for such occurrences. Epidemics are triggered by influentials – people in a particular professional and social position, but also with a certain talent and attitude toward life that allows them to come into personal contact with a vast number of people.

The social epidemic theory that has been circulating as standard knowledge since as far back as the 1950s, es-



pecially in the world of marketing, has been sharply criticized again and again in the more recent past. One objection is that the spread of viruses and fashion can't be compared because, in the case of a virus, the risk of infection upon repeated contact with the pathogen is always the same, but with a fashion trend, both keeping-up and desensitization effects can occur. It was also criticized that people like Gladwell were choosing anecdotes specifically to suit their purposes.

A closer look at the events often does, in fact, show that those who are presumed to be key people are merely a product of the circumstances. Particularly the above-mentioned SARS outbreak in Hong Kong is a perfect example of this. In the Prince of Wales Hospital, everything began when the patient at issue was incorrectly diagnosed with pneumonia. Instead of isolating him, he was put in a crowded, open hall with poor air circulation. He

was hooked up to a lung ventilator – which spread the SARS viruses around the area. The case is thus a very poor example to serve as proof of the influentials theory.

EMPIRICAL STUDIES OF SOCIAL NETWORKS

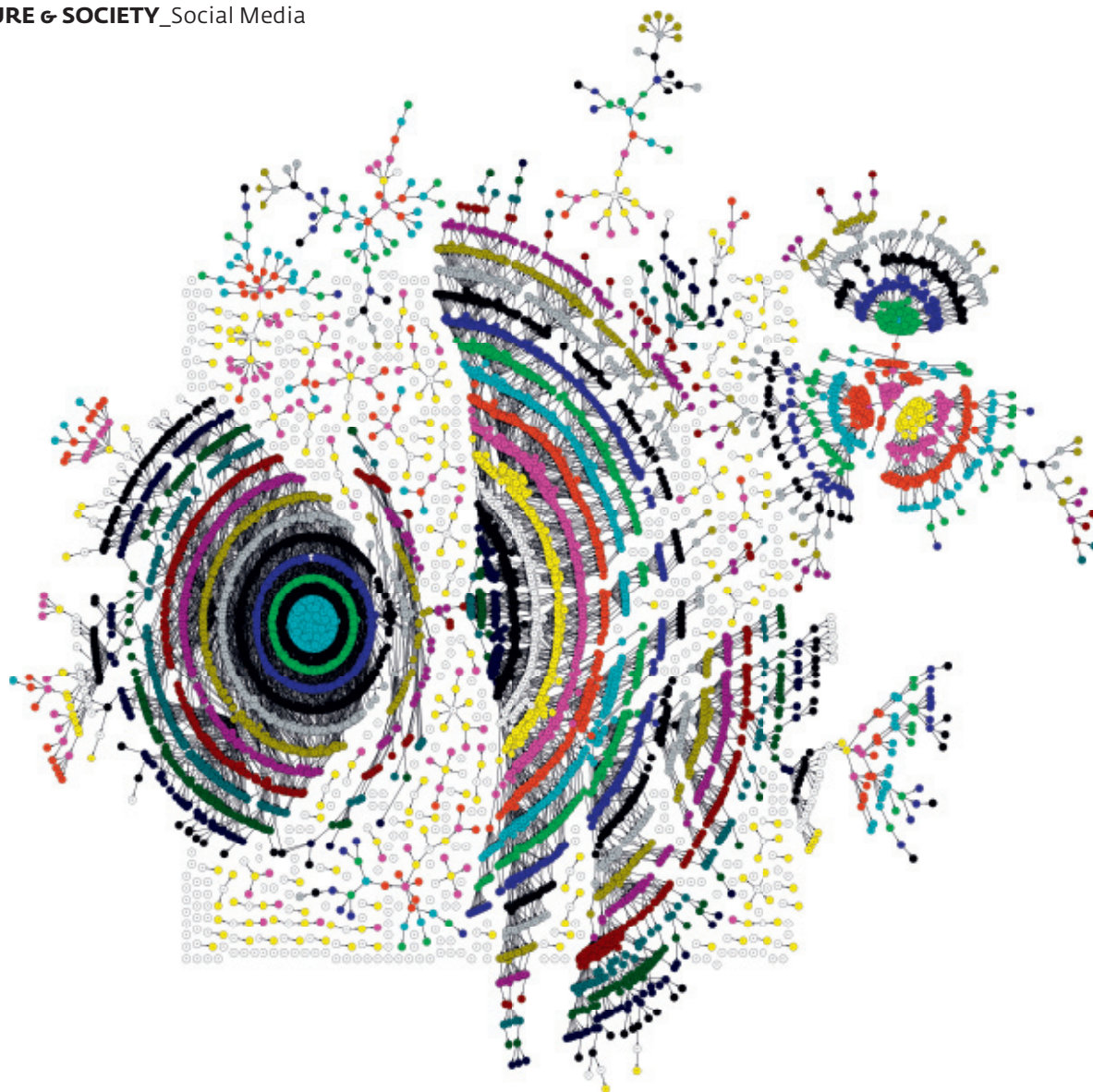
This is where Krishna Gummadi comes in. The research he conducted primarily with his colleague Meeyoung Cha, who now works as an assistant professor at the Korean Institute of Science and Technology, promises, namely, to decide the dispute over the influentials. For the past several years, Gummadi has been examining the information flows of social networks in Internet communities such as Facebook, LiveJournal, LinkedIn (the American counterpart of Xing) and Twitter.

What happens within these online networks, and how, for example, trends spread, also provides important clues

The bird tweeting the latest news from the rooftop is blue and serves Twitter as its logo (left). Users use photos or icons as identifiers (right).

about the spread of viruses and social epidemics in the physical world. After all, the fundamental structures in both cases are networks – and these definitely do have comparable properties.

Gummadi's group published some of the very first works to trace the development of online networks on a large scale in 2007. Most recently, he has been studying the usage behavior of the online service Twitter in a major series of studies. In the second half of 2009, the researchers "crawled" information – with special permission from Twitter and taking the usual data protection guidelines into account – from nearly 55 million Twitter accounts. Information that is, in principle, publicly available – just not in



A message makes waves: The graphic shows how a web address is circulated through Twitter. Each of the more than 14,000 nodes stacked in the large circulation trees, also on multiple levels, represents one user. The colors reflect the level of circulation (white, yellow, and so on – the color coding repeats after the 15th circulation level). The starting point and the first extensive node of the prominent tree in the left half of the image are hidden under the turquoise dot.

collected form – was gathered through repeated data queries to the Twitter website. From these 55 million, another 6 million active users were filtered out. These users, in turn, had sent the aforementioned 1.75 billion tweets.

Using the new data, it is now possible for the first time to examine empirically how ideas and trends spread in social networks – and in this way to sound out popular theories on word-of-mouth marketing or the diffusion of innovation. One study on which the Max Planck team is currently working is aimed at showing whether it is different users or always the same ones who successfully point their Twitter

colleagues to a certain website. Until very recently, such questions could be examined only with the aid of computer simulations or other models.

RANKING OF INFLUENTIAL TWITTER USERS

Duncan Watts, formerly a sociologist at New York's Columbia University and now in the research department at Yahoo, concluded from a test of various modeling methods that the influentials could, under certain circumstances, play a role – but that these circumstances are very narrowly defined and presumably occur relatively

infrequently. Influentials, his study concludes, are not so much people who have certain characteristics as those who have simply gotten lucky.

And this is precisely where the new Twitter study picks up. In formulating hypotheses and designing experiments, the study relies on established methods from the field of network analysis. The approach, however, is empirical. The researchers systematically combed the data to find out which websites the Twitter users had recommended to their followers. Then they compiled a ranking aimed at showing which users had contributed the most to spreading a certain web-

» Nothing happens without the mass media. Nevertheless, the great majority of less well-linked Twitter users act as an amplifier for the messages posted by the mass media.

site. To this end, the researchers trawled through millions of Twitter posts for any mention of a website address, and then examined these, in turn, for correlations and patterns. “It was a pretty hairy business,” says Gummadi. Tasks like this bring even large computer systems to the limits of their capacities.

An obvious objection here is that the behavior of online networks like Twitter implies just as little about other social phenomena as the spread of viruses does about social epidemics. In a strict sense, this is true. On the other hand, it is precisely by analyzing social media that one can develop a sense of which subtleties can make a key difference – both online and on the street.

For example, the study of a team led by Jure Leskovec from Carnegie Mellon University showed that most recommendation chains on the popular US product recommendation site Epinion end in a gaping void after a few links – which doesn’t exactly bode well for the spread of social epidemics. The photo site Flickr, which was the subject of a study that preceded Gummadi’s Twitter analysis, is a different story. “Most images do not spread far here,” is the gist of Krishna Gummadi’s findings. “A few superstars among the photos account for the majority of recommendations.” So the conditions here are more favorable for epidemics.

A recently published study based on the Twitter data examines in detail how the various communication paths within Twitter differ. On Twitter, it is possible to simply “follow” someone – that is, to subscribe to his or her tweets – without this following needing to be confirmed by the other person, unlike “friending” on Facebook. Further, one can retweet messages – that is, forward messages one receives – to one’s “fol-

lowers.” And finally, one can reply to messages from any Twitter user, which results in a “mention” for that user.

CELEBRITIES RECEIVE THE MOST MENTIONS

If we examine these three forms of action independently, we no longer have one, but essentially three separate Twitter networks. As a result, we find that, in the category “users with the most followers,” news sites, celebrities and politicians were the most influential players. The news sources likewise led in the category “retweeted,” along with prominent business advisers. Finally, the celebrities received the most “mentions.” This means that having thousands of followers does not necessarily make a Twitter user an influential – or, in any case, it is no indication that the message one wants to get out is actually picked up and circulated.

The study also showed that influential Twitter users are usually successful in a variety of fields, not just on a single topic (unlike, for instance, the communities on the Epinion platform, which are usually about a specific product). Also, the influentials are not just one-hit wonders. They remain successful over an extended period. “Influence here is not a product of chance, but the result of concerted efforts,” finds Gummadi’s study, countering Watts, the influentials skeptic.

And something else is striking: the prominent role that mass media and their representatives play in online social networks. This role does not necessarily fit with how we conceive of word-of-mouth marketing. Krishna Gummadi’s team took this observation as an occasion to launch a new study. “We wanted to know what happens when we simply remove highly linked players from the game, like the

Tracking a message: Massimiliano Marcon, Krishna Gummadi, Bimal Viswanath and Nuno Santos (from left) discuss how information spreads in social groups.



sites of news broadcasters and newspapers,” says the network researcher.

They selected the emergence of British amateur pop singer Susan Boyd in Twitter posts in 2009 as a test event. The outcome: 60 percent of all Twitter users first learned of Boyd from tweets posted by news sites. Meaning: Nothing happens without the mass media. Nevertheless, the great majority of less well-linked Twitter users acts as an amplifier for the messages posted by the mass media. After all, this majority contributed 5 percent to the spread of the news about Susan Boyd.

USEFUL ANALYSES FOR MARKETING EXPERTS

There are many other things that could be investigated using Twitter data. “I would be interested in knowing whether services that are used for recommendations lead to an increase in the spectrum of individually consumed media – that is, whether I read things that I would never have known from traditional mass media channels,” says Gummadi. Another project: “We could find out how fashion trends and customs spread.” For instance, it has recently become common on Twitter to use so-called tiny URLs instead of mile-long website addresses. The

data set would permit highly precise tracking of who brought what type of tiny URL into play and when. “Something like this would be useful as a starting point for finding out how innovations spread.”

The results of such analyses could definitely be useful for marketing experts. Here, too, it is now thought that the power of influentials plays a lesser role than was previously believed. “The Web has changed. Today, nearly everyone is registered on Xing or Facebook – it is hardly possible anymore to say who is the most relevant,” says Christian Wilfer, managing director of Dialog Solutions, an agency that specializes in viral marketing. Further, “It always depends on the product,” adds word-of-mouth expert Martin Oetting of trnd. “If I’m advertising a fabric softener, there is hardly likely to be a group of particularly influential communicators. Normal consumers who are highly involved are far more important.”

The trnd marketing community devised its strategy accordingly: instead of just a few consumers, it “immunizes” many thousand who have registered as product testers on trnd’s online platform with the latest products. But unlike Dialog Solutions, which pursues a similar plan with its Share-

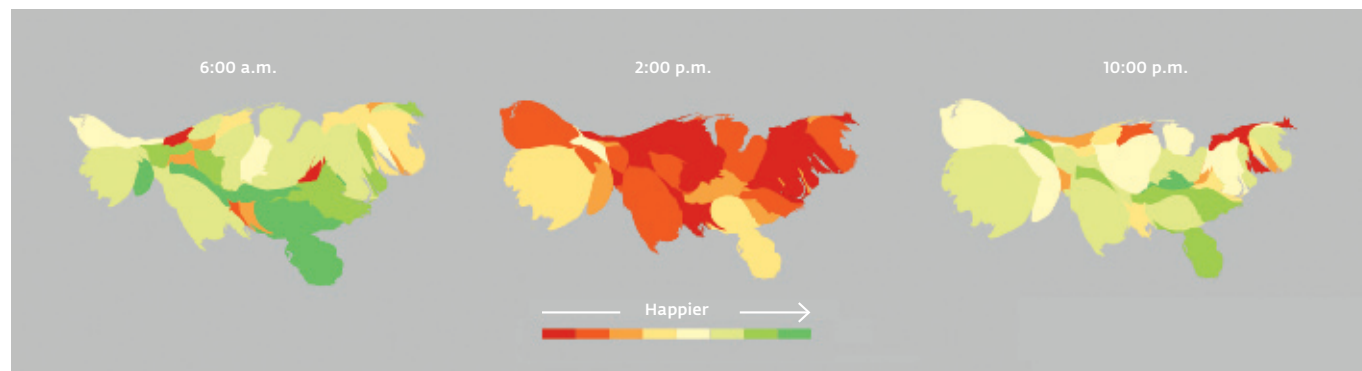
ifyoulike platform, trnd concentrates on offline communication – because after all, people listen to their friends differently than they do to “friends” on Facebook.

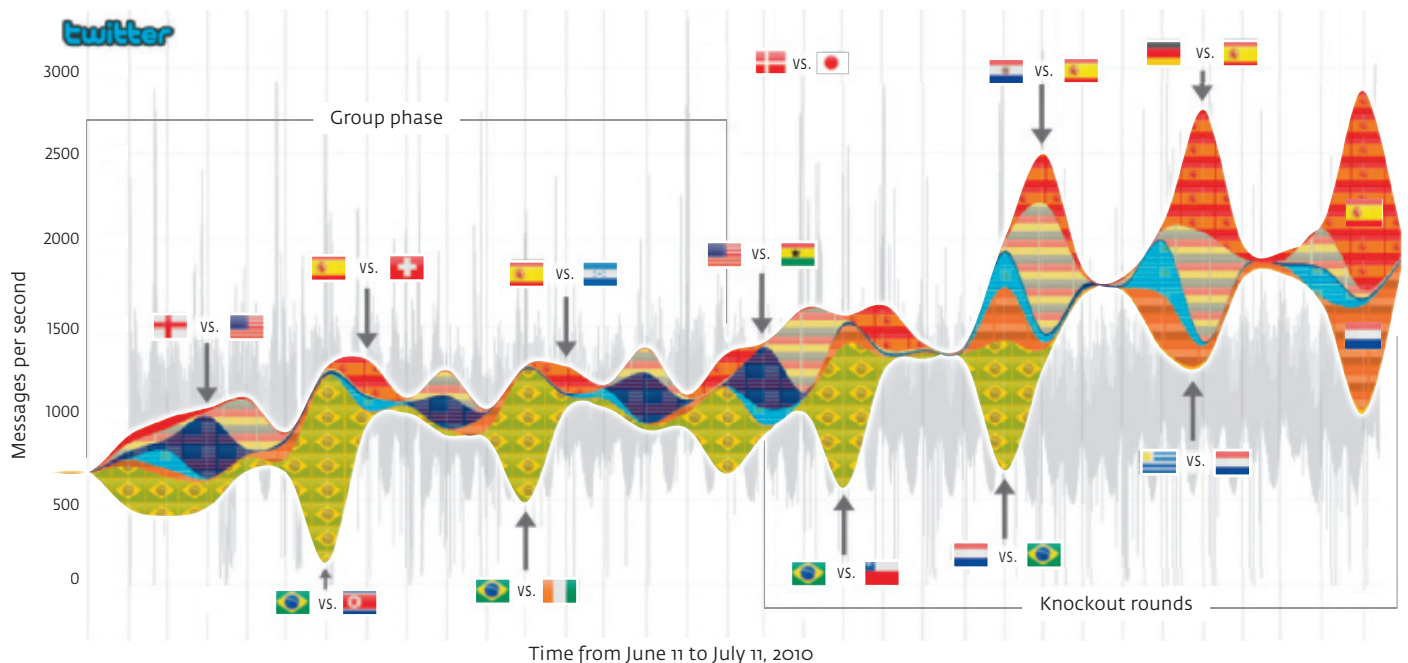
Analyzing networks in social media in the manner in which Krishna Gummadi and his colleagues in Saarbrücken do is relevant for practical applications, but not just for marketing and innovation research. Knowing exactly how networks are structured is also a requirement for algorithms for fighting spam. Spammers boost their online reputation by linking their sites and user accounts as much as possible. But this approach often results merely in closed link universes – with no connection to the clusters of honorable netizens. Algorithms can aid in identifying and crippling such spam clusters.

SOCIAL SEARCH POSES COMPETITION FOR GOOGLE

Another area of application is social search: searching, not in the World Wide Web, but within the community of like-minded individuals. A prototype of such a search method was developed a few years ago under the direction of Alan Mislove, a former student of Gummadi’s who is now an assistant professor at Northeastern

The daily emotional roller coaster in the US: Based on the words used in Twitter messages, with points accorded to certain mood-related words, it is possible to assess the mood of Twitter users in the individual US states at various times of day. Red indicates a rather bad mood, green a better one. According to this information, people in the western and southeastern states are generally happier, but the mood hits a low everywhere in the early afternoon. The states are distorted because their surface areas indicate the share of messages sent from there in all tweets in the US.





Twittering during the 2010 soccer World Cup: The graphic indicates, for the period from June 11 to July 11, how many Twitter messages per second contained, as a marked keyword, the name of the country whose flag appears in the background of the peaks. To better distinguish the message density of the selected countries, some of the peaks point upward and some downward. Overall, the number of tweets with country names rose toward the end of the WM. The total number of tweets per second is shown in gray in the background.

University in Boston. “We wanted to know how much one can benefit from searching in their social environment,” says Mislove.

Whenever one of the ten researchers involved in the project called up a website, its description and contents were stored in the institute’s internal network. If one of the researchers then

searched the Internet, he or she would see, in addition to the Google list, a list of the websites the team had visited. The advantage here is that “PeerSpective,” as the project was called, also showed entries in online library catalogs that aren’t listed in Google.

The pilot study showed that nearly 8 percent of all of the search results that

were actually shown could be found with PeerSpective alone. It is seldom that anyone stacks up so well against Google. Mislove succeeded in doing this with software that he cobbled together by himself in just one week.

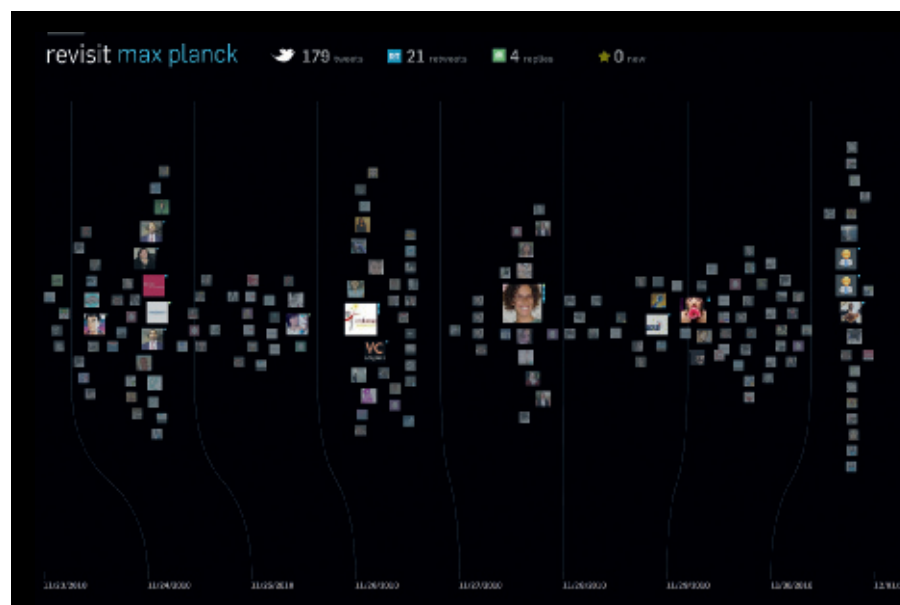
The first search engines using the principle of PeerSpective are already on the market. One example is Swicki, from the California-based company Eurekster. The research departments of Yahoo, Google and Microsoft also have plans for social search. However, novel search engines have not yet taken hold as strongly as integrated solutions along the lines of “See what your friends are sharing on Facebook” and “E-mailed – Blogged – Viewed most” on the pages of the *NEW YORK TIMES*, or the integration of “Buzz” in Google’s “gmail.”

Regardless of what approach is taken to social search, in order for it to work, one first has to find the right community for a given search query. Gummadi and his team recently addressed this issue. They tried to use one of the usual algorithms to detect groups within a network in order to filter people with similar interests. Sur-

FISHING FOR INFORMATION

Much of the content of social media platforms is publicly accessible because the users have agreed to its publication. Normally, however, only the company operating a social media platform can access all of this data to, for example, analyze it for statistical purposes. But it is also possible for outsiders to use automated search queries to gather and pool information that is otherwise scattered throughout a given social network. These search queries are done with digital search robots, also known as “web crawlers.” Internet search en-

gines also use crawlers to create an index of the sites available on the World Wide Web. This index is then accessed when an actual search query is run. Most social media sites limit the number of search queries that a given Internet user may execute, so that third parties can’t benefit economically from the data through database analyses. Researchers who want to “crawl” these sites to obtain information about the nature of network structures in social media therefore usually have to request permission from the social media service in question.



Who tweets about the Max Planck Society and when? For the week from November 23 to December 1, 2010, the graph shows when messages were sent containing the words "Max Planck". Symbols stacked vertically indicate tweets that were sent at the same time. Tweets appear closer to the center the more replies they received or the more frequently they were retweeted. Messages that appear large are either new or – as here, in the case of a retrospective analysis – randomly selected messages. The Max Planck Society has been active on Twitter since October 2010.

prisingly, however, the algorithm did not allow them to detect a few groups that they knew existed.

TWITTER MESSAGES AS A PUBLIC OPINION BAROMETER

First, a bit of sociology was needed here. It turns out that not all groups are created equal. Some groups (called "communities" in sociology) are held together by personal connections: "Just like a few of us here at the institute meet each week to play poker – because we simply like to hang out together," as Krishna Gummadi says with a smile. Other groups (the "societies") are subject-based – "like Greenpeace." In subject-based groups, most of the participants don't know each other at all. Gummadi remarks, "We first had to become aware of this difference. That is why the algorithm we used first, which merely filtered participants that were connected through particularly few links, couldn't find these clusters."

Listening to Krishna Gummadi, one gets the impression that the range of practical issues to which the results of network analysis could have a di-

rect bearing on social media is nearly endless. One of the latest projects is a national public opinion barometer. Alan Mislove analyzed Twitter messages in the US with a view to what emotional state they reflect. His findings are displayed in an animated map in which the individual states are ranked on a color scale from green (happy) to yellow (neutral) to red (not happy) – and change color over the course of the day.

By itself, the public opinion barometer is just fun and games. But it demonstrates what information lies dormant in social media. The operators of Twitter know literally how the world ticks. They can watch what people are talking about and what they are doing with their money. From this, one can derive forecasts – whether share prices of automotive companies will drop, or how much money a newly released film will take in at the box office by the end of the first week. That itself is fascinating. On the other hand: "It's really crazy how much power these companies have," says Gummadi. So it is understandable why someone would consider 1.75 billion tweets to be a goldmine. ◀

GLOSSARY

Social media

Online platforms for sharing opinions, messages and media content, such as photos, within social networks. Popular social media sites in Germany include the business community Xing, the StudiVZ platform, aimed at students, Facebook, the photo site Flickr, and Twitter.

Word-of-mouth marketing

Spreading recommendations or information through personal communication. Network structures, where, similar to the route network of international air traffic, a few hubs act as distributors, promote the quick spread of advertising messages. A special form of "word of mouth" is collective filtering, which is used, for example, for the personal book and media recommendations at Amazon.

Social epidemic theory

According to the explanatory model that has recently been supported particularly by American science writer Malcolm Gladwell, opinions and advertising messages spread in a similar way as pathogens. The influentials theory plays a key role in this model. According to this theory, the development and magnitude of an epidemic are driven primarily by the existence of a small group of people who have a particularly large number of social contacts.

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Moon Dust Is Not to Be Sneezed At

When the astronauts of the *Apollo 11* mission returned to Earth, they had almost 22 kilograms of rock from the surface of the moon in their baggage. **Josef Zähringer** from the Max Planck Institute for Nuclear Physics in Heidelberg was one of the first researchers allowed to analyze the material in the US. Two months later, Heinrich Wänke's team at the **Max Planck Institute for Chemistry** in Mainz also received a grain.

TEXT **HELMUT HORNUNG**

Thursday, September 18, 1969, late afternoon. At Frankfurt airport, a pale, tired-looking man gets off the plane. His name: Dr. Hans Voshage. His destination: the Max Planck Institute for Chemistry. In his carry-on luggage: 105.9 grams of moon. Value: priceless. Voshage now embarks on the final stage of his trip, the drive to Mainz. It is less than 48 hours since he left Mainz to jet off to Houston, Texas, to pick up the valuable cargo and bring it to Germany. On the evening of September 18, 1969, Voshage enters the institute where the impatient Director Heinrich Wänke and his staff are waiting for him. It takes only a few minutes for the scientists to begin with their first measurements. The second exploration of the moon commences.

Flashback: Sunday, July 20, 1969, 9:18 p.m. Central European Time. With its last drop of fuel, the Eagle lunar module touches down in the Sea of Tranquility. A few hours later, Neil Armstrong is the first human being to set foot on the moon, followed 20 minutes later by Buzz Aldrin. Six hundred million people watch the fuzzy television pictures that show two grainy figures skipping across the screen like kangaroos in slow motion. In the studios of the *Westdeutscher Rundfunk* broadcasting station in Cologne,

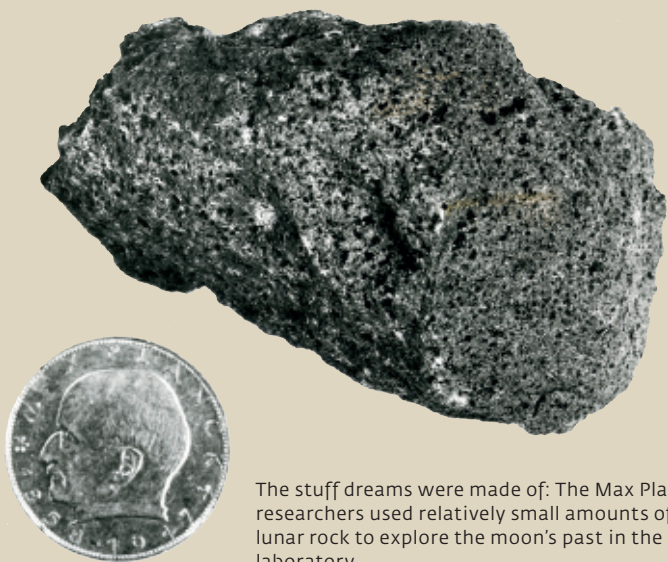
Heinrich Wänke watches the screen. The scientist is one of the experts presenting the "giant leap for mankind" live on German television. Wänke is particularly excited as he watches events unfold, because his institute will be one of those permitted to conduct laboratory investigations on the lunar rock that the astronauts are collecting.

"NASA had invited tenders for the analysis of the samples. We took part – and were successful," recalls Heinrich Wänke. The researchers in his cosmochemistry department had gained an international reputation over many years through their investigation of meteorites. The American space agency likewise accepted the applications from scientists in Cologne and Tübingen. The Max Planck Institute for Nuclear Physics in Heidelberg was also among those chosen. Director Josef Zähringer was granted a particular honor: he was invited to Houston to collaborate on the preliminary evaluation of the material.

On their return, the containers sealed on the moon were first irradiated with ultraviolet light and disinfected with peracetic acid before being rinsed in sterile water and dried in nitrogen gas. Only then were the researchers allowed to see them. "The arrival of the *Apollo 11* samples was very exciting. The scientists had the problem of deciding who would be allowed to take the first historical look," wrote Zähringer in an article for the 1970 Yearbook of the Max Planck Society. "But when the sample container was finally opened and the rocks were visible for the first time, one could see only looks of disappointment. The rocks resembled a heap of coke. They were covered with a layer of very fine dust and it was not possible to recognize any mineralogical details."

Nevertheless, the measurements were of historical significance and were conducted under unusual conditions: the researchers had to handle the samples in hermetically sealed glove boxes for fear of deadly moon bacteria or poisonous dust. There were some hitches: a torn glove and a burst supply pipe in the sample chamber. Those responsible at NASA were afraid that such occurrences would endanger the scientists and possibly contaminate them with germs. So they had to join the astronauts, who had been sitting in a transportable quarantine module since their return, and look at the world through a small window.

Josef Zähringer also had a little accident – so he, too, had to "go into quarantine." The Max Planck researcher took it in stride and even got something positive out of it: "The direct contact with



The stuff dreams were made of: The Max Planck researchers used relatively small amounts of lunar rock to explore the moon's past in the laboratory.



The researchers employed very elaborate analyses to tackle the extraterrestrial material – as demonstrated here by Bernhard Spettel from the Max Planck Institute for Chemistry in Mainz.

Earth's companion is scarred by craters that were created as cosmic lumps of rock impacted on its surface. Lava flows that

the astronauts was a great advantage for identifying the rock samples, because they could answer many questions with information that was still fresh in their minds," he writes. Zähringer found the lunar explorers to be "normal, very nice and very humorous men." Despite the three weeks of isolation, the crew had their fun and spent their time playing poker.

Josef Zähringer, who died in a traffic accident in July 1970, had already taken a first scientific look at the lunar rock when Heinrich Wänke began his analyses on the evening of September 18, 1969. He wanted to investigate the composition of the material in order to settle questions about how the moon was formed, its age and the influence of the solar wind. "We were at the beginning of a new phase of moon research," says Wänke. And speed was of the essence: "The unstable radio isotopes increasingly decayed every day and thus became more and more difficult to measure." On October 10, the Max Planck Institute for Chemistry in Mainz received another 140 grams of the moon. Wänke's colleague Heinrich Hintenberger, head of the mass spectrometry department, took a very close look.

SÜDDEUTSCHE ZEITUNG, SEPTEMBER 19, 1969



A total of 116.74 grams of sand and dust from the moon landed at Frankfurt airport in the baggage of two scientists who had travelled from the US in two different planes. Dr. Hans Voshage from the Max Planck Institute for Chemistry in Mainz and Professor Josef Zähringer from the Max Planck Institute for Nuclear Physics in Heidelberg personally brought the samples they had received from NASA from Houston (Texas) to Germany for further investigation.»

The stuff planetologists' dreams were made of was not allowed to simply lie around in the laboratory. NASA had stipulated that the material was to be stored in a safe. The researchers in Mainz organized one and had it installed in Director Wänke's office. "The Americans didn't think much of locking it up with a key," says Wänke smiling, "It had to be a safe with a combination lock." Quite understandably, the scientists had more important things on their minds than this combination of numbers, and one day the slip of paper with the code was nowhere to be found – the safe had to be opened by a special company, with considerable effort ...

So what did the researchers find out? "Give me a piece of the moon and I will tell you how our solar system was formed," said American Nobel laureate Harold C. Urey before the *Apollo* flights. This hope was in vain – not least because the rocks and dust from the surface are by no means pure primeval substance. On the contrary, the moon has been changed over the eons by smelting processes, so it is not the geologically primitive celestial body that most experts had believed it to be.

had spread across the surface after particularly large fragments had collided with the infant moon formed the so-called seas. In addition, the permanent bombardment of smaller meteorites pulverizes the rock and covers the surface of the moon with a meter-thick layer of dust. This regolith contains not only sand grains, but also glassy inclusions. The researchers discovered that the samples contained a dozen minerals, above all pyroxene, plagioclase and ilmenite.

The most important question, however, was: How was the moon formed? An age determination of the lunar rock showed that it can't be much younger than the Earth, or around four and a half billion years old. Overall, the moon appeared to be very similar to our own planet: "It seemed to us to be a piece of the Earth," says Heinrich Wänke. The scientist used his investigations to derive the theory that the moon really does originate from our planet. The theory proposes that a celestial body the size of Mars struck primeval Earth with a sort of glancing blow. The collision ejected large amounts of material from the crust and mantle into orbit – where it formed the moon. "In the 1980s, computer simulations confirmed this scenario," says Wänke.

And the researchers' analyses confirmed something else: the Americans really had been to the moon! Because in addition to the Apollo samples, the researchers in Mainz later also received material collected by unmanned Russian spacecraft. "The samples from both missions matched so well that this killed off the theory that the Americans had staged the landing in Hollywood studios – unless the Russians were in cahoots with them," says Friedrich Begemann, former Director of the isotope cosmology department.

Back to 1969: One clear evening in the fall, Heinrich Wänke returned from Begemann's office, where the two researchers had been grinding up lunar rock in a mortar. The full moon lit up the night sky. Wänke was looking at the Sea of Tranquility with the naked eye. Then he blew his nose – and stopped short: there in his handkerchief were two tiny dark grains – material from the moon, breathed in as he worked with the pestle. "That was frightening, because NASA insisted that every individual dust particle was to be accurately accounted for," explains Wänke with a grin. "After giving it a lot of thought, I decided not to record my findings after all. To this day the Americans don't know anything about this."

NASA, by the way, is the legal owner of the samples. The Max Planck Institute for Chemistry returned the last grains from the moon in fall 2008. In spring 2009, the space agency sent confirmation of their receipt.

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“The Max Planck Center Will Make Computer Science More Attractive”

For Naveen Garg, it is a calling: seeking solutions to what the computer science community describes as difficult problems. Spanning diverse areas of application, the solutions may one day help boost the computational prowess of computers, allow sales teams to plan more efficient routes, and improve the performance of complex systems – from computer networks to spacecraft. Garg, a professor of computer science at the Indian Institute of Technology, New Delhi, spent three years at the Max Planck Institute for Informatics, Saarbrücken, during the 1990s. He is now Co-Director of the Indo-German Max Planck Center for Computer Science (IMPECS), the Max Planck Society's first center in India, an initiative to promote education and research through a network of academic researchers in India and Germany.

You studied computer science at IIT New Delhi as an undergraduate. Many IIT students have a tradition of pursuing studies in the United States after their first degree. What prompted you to stay on for postgraduate education?

Naveen Garg: During my final undergraduate year here at IIT, I was involved in a project on designing algorithms for random number generation. I was guided at the time by Vijay Vazirani, a computer science professor who had moved from Cornell to IIT Delhi. I was fascinated by the topic and the collaboration with Dr. Vazirani. At the end of the year, it seemed to make sense for me to continue my postgraduate studies right here.

Could you tell us something about your area of research?

It's an area called algorithm design in which we try to devise smart techniques to solve complex problems. There are some computational problems that do not have easy or quick solutions. We've been trying to design efficient algorithms to get as close as possible to exact solutions. A classic example is the traveling salesman problem. A salesman has to cover a large number of locations – let's say 50 to 100 cities. What is the most efficient route? This is not a trivial problem – the

fastest algorithms and computers of today could take millions of years to figure out a solution. Such challenges provide the motivation for designing more efficient algorithms.

Are there other examples?

Take for instance the field of scheduling: Suppose you're a manager and have to assign a set of tasks to ten people. How should the manager distribute tasks? If you have one person to assign the job to, it's easy – the single person does the entire set of tasks in a sequential manner. But when you have multiple people, the problem is really hard. Solutions to this type of problem may find application in improving the performance of computers or in efficient distribution of tasks in complex systems such as aircraft or spacecraft.

What made you pick the Max Planck Institute for Informatics for postdoctoral work?

For my Ph.D., I worked on approximation algorithms and wanted to continue this during postdoctoral research. There was an option from a US university, but the offer from MPI came earlier. The MPI option also appeared more attractive than the position at the US university for two reasons: the MPI position was initially for two years, while the US position was for one year, and MPI also seemed to have a set of researchers whose interests appeared to coincide with mine.

What influenced your decision to return to IIT New Delhi?

I was familiar with IIT New Delhi, and I knew I would get good undergraduate students here. Also, the teaching and research environment in India provides a bit more academic freedom than in a typical US university, where you have significant academic pressures – pressures that are likely to drive academics to pursue fashion-driven research topics rather than what one really wants to do. And theoretical computer science involves a lot of mathematics – we don't have to worry about expensive laboratory infrastructure.



Naveen Garg

Could you tell us something about IMPECS?

I was on a sabbatical at the Max Planck Institute for Informatics in 2006 and 2007. Kurt Mehlhorn, who was my mentor and collaborator during my stay there from 1994 to 1997, was now the vice president, and we began discussing the idea of a center. It was inaugurated last year, and is intended to serve as a bridge for research and exchange of ideas between computer science communities in India and Germany. IMPECS is supported equally by the Max Planck Society and India's Ministry of Science and Technology. We expect ten academic groups to be part of this network in India. The initiative will facilitate exchange of students and faculty, as well as computer science workshops that broaden the participants' toolboxes. Lectures and travel to meetings may be other mechanisms for collaboration.

What sort of outcome from the IMPECS would make you most satisfied?

One thing I'd really like to see is an increase in the quantity and quality of research in India in the field of computer science – more computer science Ph.D.'s. The number of Ph.D.'s in computer science at present is small – there are perhaps 40 to 50 per year – while the number is many-fold higher in China. Some of us are hoping that, through its workshops and interactions, the Max Planck Center will make research in computer science more attractive.

Interview: Ganapati Mudur



At Home Everywhere in the World

The Max Planck Society has a global network of research partners – especially in India

Max Planck institutes operate within a worldwide network based on international cooperation and projects. International cooperation promotes scientific performance and productivity, creating scientific added value and, in many research fields, making it possible to actually achieve a critical mass.

India is an important and attractive partner for the Max Planck Society. The nation is developing into a global player of the 21st century, and one with major economic and scientific potential. Conversely, the interest of young, Indian junior scientists in Germany and in the Max Planck Society is also growing. Between 1998 and 2002, the share of these individuals among foreign doctoral students rose from 2.2 to 11 percent – one more reason for putting the collaboration with India on a new footing.

On October 6, 2004, Max Planck President Peter Gruss and State Secretary V.S. Ramamurthy, in the presence of then Federal Chancellor Gerhard Schröder and the Indian Minister for Science and Technology M. Kapil Sibal, signed a Memorandum of Understanding in New Delhi on the future scientific cooperation between the two countries. The contract provides various tools for strengthening the scientific cooperation between the Max Planck Society and research institutes in India.

The newly established cooperation with India is turning into a success story: in 2009 alone, more than 600 junior and guest scientists from India visited Max Planck institutes – a rise of more than 80 percent in the past five years. In terms of the international exchange of young scientists, this has made India one of the two largest partner countries of the Max Planck Society. Every tenth foreign doctoral student at Max Planck institutes now comes from India. Many of them are involved in research as part of an International Max Planck Research School. In addition, there are almost 50 cooperative projects between Max Planck institutes and research facilities

in India, and offers such as Partner Groups and Max Planck India Fellowships are also developing successfully.

Since 2008, the Max Planck Society has had a representation at the German Embassy in New Delhi. On February 3, 2010, then Federal Chancellor Horst Köhler, together with the Indian research minister Prithviraj Chavan, opened an Indo-German Max Planck Center for Computer Science at the Indian Institute of Technology in Delhi. Participating in this venture on the German side are the Max Planck Institutes for Computer Science and for Software Systems in Saarbrücken and Kaiserslautern.

In general, the Max Planck Society has developed various instruments that are specifically tailored to advance international collaboration. Such instruments include the establishment of Max Planck Centers, Partner Groups and Fellowships.

MAX PLANCK CENTERS

Max Planck Centers are platforms for institutional cooperation between Max Planck institutes and outstanding international research facilities, giving both partners the opportunity to pool their knowledge, experience and expertise, creating scientific added value by combining complementary methods and knowledge. This is a way for Max Planck Centers to promote, in particular, the exchange of post docs, for example by holding joint workshops, providing education and advanced training facilities, working with scientists from other facilities as associated partners, promoting the common use of research infrastructure, setting up joint applications for outside funding for project cooperation, and providing reciprocal access to their research facilities and equipment. They also facilitate initial steps toward stronger institutionalized cooperation by setting up junior research and partner groups.

The Centers are financed by the institutional funding of each partner, or by funds provided by the relevant national project grants, which in some cases can also be transferred abroad. Max Planck Centers do not have any independent legal capacity. The basis for setting up a Center is simply an agreement on the research program, the measures to be undertaken and the financial, personnel and infrastructure resources available for the particular Center. Max Planck Centers are normally set up on a fixed-term basis of five years with a one-time option to extend this for a further five years.

Algorithms are the focus at the above-mentioned Indo-German Max Planck Center for Computer Science in Delhi. With their help, scientists can, for example, quickly and reliably identify large prime numbers. These play an important role in cryptography, which is also used to encode, for instance, online credit card transactions. There are currently two German-Indian research groups under the umbrella of this Center, which was officially opened in January 2010. Further research groups are planned for 2011.

To date, the establishment of five Max Planck Centers has been approved. These have already taken up their activities, or will do so in the next few months. Further Max Planck Centers are planned with partners in Japan, the US, France and Israel.

PARTNER GROUPS

There are currently 44 Partner Groups worldwide. These are useful instruments in the joint promotion of junior scientists with countries that are interested in strengthening their

research through international cooperation. Examples include India, China, Middle and Eastern European countries, Russia and Argentina.

Partner Groups can be set up with an institute abroad with the proviso that, following a research residency at a Max Planck institute, top junior scientists (post docs) return to a leading and appropriately equipped laboratory in their home country and carry out further research on a subject that is also of interest to their previous host Max Planck institute.

The work of the Partner Groups is evaluated after three years and, provided the evaluation is positive, can be extended to five years.

MAX PLANCK FELLOWSHIPS

Qualified and promising Indian post docs up to a maximum of 35 years of age who already have a recognizable scientific profile can apply for Max Planck India Fellowships (MPIFs). Time previously spent at a Max Planck institute is not a requirement.

Successful applicants for MPIFs receive an annual travel allowance of 3,000 euros for a period totaling four years. The Indian Department of Science & Technology also provides additional travel funds for MPIFs from the Biology & Medicine Section and the Chemistry, Physics & Technology Section. Indian scientists who receive this grant must spend at least one month a year at a Max Planck institute. The host Max Planck institute pays for the subsistence costs incurred. The selection procedures are the same as for the program for Partner Groups.

Talent from the Knowledge Superpower

The booming country on its way to becoming the superpower of the knowledge economy: India is a land of superlatives. The world's seventh-largest country, its population of 1.17 billion comprises an enormous pool of talent, including research scientists. These scientists form the basis of a strategic partnership with the Max Planck Society (MPS) in which internationalization is seen as a prerequisite for successful science, and one that opens up different cultural perspectives on research. Felix Kahle has been the Max Planck Society's on-site representative since 2008, and occupies an office in the German Embassy in New Delhi.

"India is developing into a global player of the 21st century, with great economic and scientific potential," says Felix Kahle. Even though India remains a land of stark contrasts, it is also

a place where nothing is impossible. According to Kahle, the optimism in the Indian science community is tangible. The government is investing massively, and recently announced the Decade of Innovation. Now they plan to extend the higher education system and its research capacity. The first results can be seen in the successful establishment of five new non-university Indian Institutes of Science Education and Research (IISER), where the Max Planck Society is already expanding its scientific collaboration. In order to train and educate the 14 million students already in the system, young scientists must be attracted back from their training placements abroad. "Many of them have or have had contacts with Germany and, of course, with our Max Planck institutes," affirms Kahle, adding that this makes

them attractive for further collaboration with the Max Planck Society.

Outside Europe, India is second only to China as the most important international partner of the MPS. The new generation of young Indian scientists has shown a growing interest in Germany and the MPS since the late 1990s – one more reason to set the collaboration on a new footing in 2004: After a Max Planck delegation with members from all three sections had examined the opportunities for research collaboration, Max Planck President Peter Gruss signed a contract on scientific cooperation in the presence of then Federal Chancellor Gerhard Schröder and Indian Minister of Science Kapil Sibal. "It turned into a great success story," stresses Felix Kahle. Last year alone, 616 junior scientists and guest scientists from India came to Max Planck institutes, representing an

increase of more than 80 percent during the last six years. Approximately one in ten of the non-German doctoral students at Max Planck institutes now comes from India. Many of them are conducting research within the framework of an International Max Planck Research School (IMPRS), and Kahle ensures that training placements at these schools are announced on the website of the German Embassy in New Delhi.

In addition, there are almost 50 collaborative projects between Max Planck institutes and Indian research institutions, and the number of Partner Groups has increased impressively. These groups provide career prospects for Indian postdoctoral researchers who have already spent extended research periods at Max Planck institutes and then return to recognized institutions in their own country to continue their research into topics that are also of interest to the MPS. In the last ten years alone, 24 such groups have been established, 19 of which still exist today. A prestigious meeting was held in February to forge bonds between Partner Group Leaders, forming a network characterized by the Max Planck spirit, and to share information about their research activities. Former Partner Group Leaders and Directors of the respective Max Planck host institutes traveled to New Delhi for the occasion. "It is wonderful to see how these scientists perceive the corporate identity of the Max Planck Society and how enthusiastic they are about Germany," says Felix Kahle, full of praise for the good atmosphere among the participants. He also visited the first Indian exhibition by



Networking in the spirit of the Max Planck Society: In February, all Indian Partner Group Leaders met to share information about their research activities, among other things.

Anish Kapoor, the world-renowned India-born sculptor who has been living in London for a number of decades now. Kapoor is considered an outstanding example of "brain circulation," as it is described in academic circles.

Cross-cultural collaboration between different ways of thinking is also the order of the day at the Indo-German Max Planck Center for Computer Science, opened by German Federal President Horst Köhler at New Delhi's Indian Institute of Technology in early 2010. The Center represents a newly established style of close cooperation, initiated here with the Max Planck Institutes for Informatics and for Software Systems and now extended to another four MPS centers in other countries.

The fact that the first Max Planck Center was established in India tells its own story, says Kahle, who is also Science Consultant at the German Embassy, and is a good example of the synergies that arise from the physical proximity of the Max Planck Society representation with the German Embassy. "It was new territory for both

parties, but the collegial exchange and cooperation is excellent." The Embassy sees the activities of the Max Planck Society as an important building block in the context of scientific cooperation between the two countries. "And the fact that we provide sustainable support for the Indian Ministry of Science's objective to encourage successful Indian researchers abroad to come home is completely in line with the Embassy's mission to highlight science as a fundamental pillar of Indo-German relations," says Kahle.

Kahle's activities have been well received by Max Planck Directors in Germany, too, as exemplified by an international conference in New Delhi organized recently by the German Embassy, the Max Planck Society, the Konrad Adenauer Foundation (KAS) and the German Society for International Cooperation (GIZ), and attended by lawyers working in the area of intellectual property. Once again, Kahle was able to breathe life into the maxim "Minerva meets Saraswati" – the latter being the Indian goddess of learning.



Our man in India: Felix Kahle has been the Max Planck Society's on-site representative since 2008, and occupies an office in the German Embassy in New Delhi.

Research Establishments

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

Holland

- Nijmegen

Italy

- Rome
- Florence

USA

- Florida

BRAZIL

- Manaus



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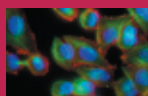
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