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Dear Readers,

It may be a remarkable twist of fate, but it was certainly no accident that science was quicker to discover and decipher the macrocosm of the external world than to explore the microcosm of its internal counterpart. In the earliest days, man’s attention was focused on the sun, moon and stars. Then came the plant and animal kingdoms that populate the surface of our planet. Only then did science turn its attention to humankind and develop disciplines that investigate man’s thoughts and actions using methods similar to those that proved effective in the study of nature, both animate and inanimate.

The history of the Max Planck Society has seen a similar change in the focus of attention. The early emphasis on chemistry, physics and astronomy when the foundations of the Society were first laid was followed by a strong expansion of the life sciences in the postwar era. Research in the cognitive sciences was a still later addition, with such disciplines as psychology, anthropology, ethology, linguistics and brain sciences. The emphasis here is on human cognition – both in comparison with and as distinct from the cognitive abilities of other mammals.

Cognitive science is a network of disciplines that lives from the variety of each individual one and from the interaction between them. What these individual disciplines have in common is their interest in the central focus of cognitive science research: the desire to understand what people do and think, what their actions and thoughts depend on, and what processes and mechanisms they are based on. What distinguishes these disciplines are the theoretical and methodological approaches they adopt and the explanations they regard as valid.

As a rule, the same phenomena are the subject of parallel study in multiple disciplines. Thus, for example, the elementary processes of social interaction are the simultaneous focus of anthropological, psychological, ethological and neuroscience research. In conventional wisdom, such a convergence of interests is generally interpreted as competition – with the consequence that the adherents of different disciplines engage in debates as endless as they are fruitless as to the worth or worthlessness of their approaches. In the wisdom of shared networking, on the other hand, convergence is utilized as an aid to cooperation – with the result that the counterproductive question of who has the better explanation is replaced by the more productive question of how the explanations arrived at by individual disciplines can be related to one another.

The notable successes that cognitive science research has achieved in recent times undoubtedly owe, in part, to the exploitation of these multidisciplinary synergies. In addition, there is also an astonishing theoretical dynamic that distinguishes this research. However young the network that links these disciplines may be, it can already look back on a radical historic change in the bias of theory: the transition from individual to social cognition. In all of the cognitive science disciplines, the realization has gained acceptance in recent years that, while cognitive achievements may be performed by and through individuals, their bases arise and are formed in the social exchange between individuals.

The Focus topic selected for this issue reflects the social turn that this insight has brought to the cognitive sciences. Max Planck Society research groups have played a key role in shaping this development.

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ON THE COVER: Everyone masters the art of mind reading – that is how we are able to understand others as individuals with their own perceptions, feelings and thoughts. And only in this way can we imagine what another is thinking, and precisely coordinate our actions with theirs.
Researchers use this trap to capture H$_3^+$ particles in order to simulate the chemistry of space in the lab.

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Meadows reflect more sunlight than forests do. That is why deforestation has long been changing the climate locally.

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First World Health Summit in Berlin

The first World Health Summit, entitled “The Evolution of Medicine,” took place in Berlin on October 14-18, 2009. The conference was the brainchild of Berlin’s Charité school of medicine, which hosted the event in cooperation with the Université Paris Descartes. German Federal Chancellor Angela Merkel and French President Nicolas Sarkozy agreed to act as the patrons of the event. A total of around 700 experts from the worlds of science, politics and business assembled to discuss solutions to global health issues. “Good health is a fundamental human right, as well as an important economic factor,” stressed Professor Axel Kahn of the Université Paris Descartes, one of the two Presidents of the World Health Summit. “With an aging society, continuing inequalities, negligent actions and the resulting illnesses, this poses a real challenge. That is why every available resource must be mobilized,” demanded Mary Robinson, former President of Ireland. She is also the chair of the GAVI Alliance, a non-governmental organization that champions healthcare for mothers and children in developing and newly industrialized countries, an improved health system in these nations and new technical solutions to provide access to medical care for all.

As part of the session on personalized medicine headed by Max Planck President Peter Gruss, and in light of constantly rising healthcare costs, the former Director of the National Institutes of Health (NIH), Elias Zerhouni, called for a paradigm shift in medicine, away from disease management and toward precision medicine that is capable of detecting and preventing diseases at the preclinical stage. Faced with an aging population and an increase in chronic diseases, the only way to reduce costs is through precise and personalized medicine, Mr. Zerhouni argued. The technological foundations are even now being laid by rapid developments in genome research, as well as in other fields of biology and in associated technologies. Experts regard climate change as the greatest global threat in the 21st century, holding it responsible for an estimated 300,000 deaths each year. And yet the subject of health was little more than a side issue at the recent Climate Conference in Copenhagen in December.

At the instigation of the Charité, a coalition of top-level international medical institutes and academies of science – the so-called M8 Alliance – was established during the World Health Summit. Its members “offer a guarantee of progress and accept responsibility for ensuring that every means available to academic medicine is exploited to achieve good health for all.” The Alliance aims to raise awareness of the urgency of global health challenges, and to intensify coordinated action on the part of politicians, civil society, industry and the medical community.

The Max Planck Society and Siemens Host a Future Dialogue

Some 40 years ago, in his book *The Limits to Growth*, Dennis Meadows sounded a warning that mankind was consuming resources at a faster rate than planet Earth could stand. At the Future Dialogue, hosted by the Max Planck Society and Siemens and attended by over 400 scientists, politicians and business managers, Meadows once again urged that “we must change our behavior.” As Max Planck Society President Peter Gruss emphasized, the challenge can be met only if science, industry and politics act together. Former German Foreign Minister Joschka Fischer argued that politicians must create a framework for more sustainable enterprise. Siemens, as CEO Peter Löscher explained, is already focused entirely on green technologies.

“An entirely inadequate, halfhearted step”

Michael Hüttner is working on his doctorate at the Max Planck Institute for Biogeochemistry in Jena and is a member of the Young Expert Team representing the Global Observatory, a combined venture by young scientists set up to monitor the climate talks in Copenhagen.

Mr. Hüttner, are you frustrated?

**Michael Hüttner:** Yes, there is no other way to put it. From a scientific perspective, the minimal compromise that has been reached here is an entirely inadequate, halfhearted step in implementing the action plan agreed on in Bali.

What does the action plan call for?

**Michael Hüttner:** The nations attending the Bali climate conference in 2007 agreed to negotiate, over the next two years, a long-term global emissions reduction target with some ambitious medium-term targets for both industrialized and developing countries, as well as an effective system of monitoring these reduction commitments. At the same time, the industrialized countries promised financial support to assist the developing countries in adapting to climate change, introducing new technologies and reducing the emissions resulting from stripping and degrading their forests. Only in terms of financial commitments does the outcome of the Copenhagen conference go some way toward meeting expectations. Other than that, the notable feature of the Copenhagen Accords is the stated intention to limit the rise in average global temperatures to less than two degrees Celsius.

Just how binding is the two-degree guardrail?

**Michael Hüttner:** The final document is not an official United Nations resolution that requires a consensus between all nations. Instead of signing the document in recognition of its validity, the lead negotiators simply added an appendix confirming that they have noted it. This was the only way to arrive at any outcome at all. And in the end, the developing countries most affected were blackmailed into it. Had they objected, the aid commitments would have been null and void.

With almost 120 heads of state and government striving to reach agreement in Copenhagen, couldn’t we have expected more to be achieved?

**Michael Hüttner:** The presence of so many senior statesmen and the huge commitment by society in general created a tremendous momentum that was not taken advantage of. It will be hard to recreate such a situation a second time.

Did you have the impression that the concerns of the scientists in Copenhagen found too little interest?

**Michael Hüttner:** The representatives of the German delegation consulted with us. For example, I had the chance to talk to the delegates about climate-related forestry policy – my field of research. Besides the official negotiations at these climate conferences, there are always fringe events where scientists present their latest findings. Normally the politicians are also there to listen, but this time, for example, German Development Minister Dirk Niebel stayed only long enough to deliver his own presentation and then left again. That shows the pressure under which the negotiations took place.

In what respects did the negotiators pay too little attention to the findings of science?

**Michael Hüttner:** Primarily in terms of the reduction targets needed to achieve the two-degree goal, and also the monitoring regulations that require states to document their efforts.

What reduction targets should the nations have set in order to achieve the two-degree limit?

**Michael Hüttner:** There is no direct causal relationship. We as scientists can only quote probabilities. There is a 50 to 70 percent chance that we will achieve the two-degree objective if, between now and 2020, the industrialized countries reduce their greenhouse gas emissions by 25 to 40 percent – relative to 1990 levels. The developing countries would have to reduce their emissions by 2020 by 15 to 30 percent relative to the present day.

So there is a substantial degree of uncertainty as to whether the two-degree goal will be met – even with much more ambitious reductions than those now agreed on?

**Michael Hüttner:** Correct. Which is why I believe that the scientific debate should be followed up by a sociological debate on climate change. Society must ask itself: How great a risk are we willing to accept? Take medications, for example: Who would be willing to accept even a 30 to 50 percent risk of serious side effects?

Bearing this in mind, is it sufficient for global emissions of greenhouse gases to peak between 2015 and 2020, and then slowly decline?

**Michael Hüttner:** From a scientific perspective, we really ought to be reaching the crest by 2015. If it takes until 2020 to reach that point, we would have to save 8 percent per year – the same amount as the EU tried to save over five years in the Kyoto protocol. That would be possible only with a huge economic effort.

So what will happen now?

**Michael Hüttner:** The first commitment period under the Kyoto protocol ends in 2012. In the future, there will presumably be, in addition to the Kyoto protocol with its strict rules on reductions and reporting, a second protocol with less stringent rules. Hopefully that is something the developing countries and the USA will then agree to. It will probably include another minimal compromise. However, I have hopes that the USA may change its stance once the elections to the House of Representatives next year are over and the Senate has reached a decision on the 17 percent reduction relative to 2005.
LOEWE Center Launched in Marburg

Under the LOEWE program, the government of the German federal state of Hesse will make a total of 410 million euros in science sponsorship available through 2013. The LOEWE Center, inaugurated in Marburg in November, is dedicated to the fledgling research field of synthetic microbiology and bundles the broad-based microbiological expertise developed at the Max Planck Institute for Terrestrial Microbiology and the Philipps-Universität Marburg. Over the next three years, the LOEWE Center will receive 21 million euros in funding. This is the second LOEWE Center in which the Max Planck Society is playing a part—the state of Hesse has also already earmarked 15 million euros for a LOEWE Center devoted to lung and respiratory diseases with the involvement of the Max Planck Institute for Heart and Lung Research in Bad Nauheim.

The Lessons of Nature

Natural materials are comprised of very few components, yet they still possess a wide variety of microstructures. Nature needs just a tiny number of ingredients to create such composites as mother-of-pearl and teeth, which exhibit outstanding material properties such as high breaking resistance. In the case of artificial materials, the opposite applies: generally, there are only a limited number of hierarchical levels, but a plethora of potential substances that can be combined.

A new program run by the German Research Foundation (DFG) is investigating the construction principles and manufacture of hierarchically structured materials based on the models of nature. In 13 different projects involving more than 10 universities and Max Planck Institutes, scientists are attempting to develop high-performance materials inspired by insect hairs, nutshells and plants.

Successful Result in the Contest for EU Research Funding

Max Planck Institutes were the recipients of a total of eight Advanced Grants awarded by the European Research Council (ERC) in 2009. This put the Max Planck Society in fourth place among the top research institutions in Europe (the CNRS, ETH Zurich and Cambridge University each received ten grants).

In Germany, the MPS tops the list, followed by the Ludwig Maximilian University Munich with three grants and the Technical University Munich and the Helmholtz Association with two successful applications each. The Advanced Grants can be applied for by established scientists. Six Starting Grants were awarded to Max Planck Society junior scientists in September last year.
New Supercomputer at the German Computing Center for Climate Research

A large part of the science underpinning the World Climate Conference in Copenhagen originated from the German High Performance Computing Center for Climate and Earth System Research (DKRZ) in Hamburg. The DKRZ has now taken delivery of a new 35-million-euro supercomputer funded by the German Federal Ministry for Education and Research. Codenamed “Blizzard,” the new climate computer will allow the Center to forecast future climate changes with even greater accuracy. With a peak computing speed of 158 teraflop/s (floating point operations per second), Blizzard is around 60 times more powerful than its predecessor, and one of the world’s biggest supercomputers. Blizzard will even be able to model rotating storm systems and very small marine vortexes. In addition to studying the atmosphere and the oceans, with the new supercomputer scientists will be able to integrate processes that take place in ice, soil and vegetation, and their impact on carbon distribution, and thus also on the greenhouse effect.

On the Net

Diversity Is the Spice of Life
The website of the United Nations Association of Germany is a goldmine of information – and not just for school kids doing biology homework. Anyone with an interest in biodiversity can take a look at the image galleries of threatened animal and plant species and watch videos on the subject. Facts, figures and illustrative maps guide visitors through the history of the Convention on Biodiversity and the protection of species. This site successfully raises the curtain on the International Year of Biodiversity in 2010:
http://www.dgvn.de/una-germany.html

Dancing Inside Cells
An adult human being is made up of 100 trillion individual cells. Inside each of these cells, life follows a carefully choreographed routine: DNA is transcribed and translated into proteins that, in turn, are transported to the correct locations in the cell. A process that sounds as dry as dust when explained in a textbook becomes a work of art when biological animations are set to music and displayed using the latest computer technology. The “BioVisions” multimedia project undertaken by Harvard University is an open invitation to learn and be amazed:
http://multimedia.mcb.harvard.edu/

Age Research Online
The newly established Max Planck Institute for the Biology of Aging is now online with an attractively designed and informative website that is regularly updated. The site contains current news items, details of career opportunities and a clear description of the institute’s research focus and departments. A clear-cut color coding system also makes the site easy to navigate. Older visitors will also appreciate the facility to increase the text size, making the articles easier to read.
http://www.age.mpg.de

Lest We Forget
“The modern history of memory begins at the moment when one realizes that it is not just individuals who have the capacity to remember, but also collectives, nations, even cities,” says 2009 Max Planck Research Award winner Aleida Assman. The literary scholar, who is portrayed in this film, conducts research in Konstanz. Since the 1990s she has focused on the subject of cultural memory, remembering and forgetting. As a pioneer in the history of memory, she has frequently added a social dimension to debates on issues ranging from the Holocaust to the creation of a European culture of remembrance.
http://www.filme.mpg.de
Top: Zebrafish grow in the space of three months from a fertilized egg cell to the stage of sexual maturity. The mouth aperture is already clearly identifiable in these two-day-old larvae. What look like eyes are indentations surrounded by lashes: the future olfactory organs. Scientists use these embryos as examples to study the development of tissue and organs. A genetic defect in the larva, shown here on the left, is causing problems in the development of the skin. Photo: Jürgen Berger, Mahendra Sonawane

Bottom: The dance of the praying mantis: As soon as this predator is in danger, she adopts a threatening posture. She displays her splendid coloring, spreads her limbs and throws her enemies into confusion. She is prepared at any moment to deal a lightning-fast counterblow with her hooked talons. Photo: Igor Siwanowicz

Award-Winning Science Images

Whether by making art of science or seeing science through the eyes of art: Max Planck researchers regularly emerge as the winners of photographic competitions. Three of their pictures were singled out in 2009 as “Images of Research.”
This colored scanning electron microscope image shows a white blood cell (dyed red) in the act of destroying tuberculosis bacteria (yellow). The bacteria are surrounded by the cell membrane of the scavenger cell, then drawn inside and rendered harmless.

Photo: Volker Brinkmann
Following arduous expeditions and decades of work, Charles Darwin and some of his contemporaries succeeded in developing a theory on the evolution of life by observing variation, selection and spatial distribution. Today, 150 years later, many biodiversity researchers are still explorers and describers. They are hoping to derive, from the spatial and temporal patterns of the immense diversity of life on Earth, rules that explain the processes of adaptation and evolution of species and communities.

To date, this has been a complex and often inefficient process. But progress in genome sequencing and bioinformatics is now creating major opportunities for a much better understanding of biodiversity. The study of the immeasurable diversity of life is making great strides – and just in time: like many other nations, Germany had ratified the Convention on Biological Diversity (CBD) and is obliged to develop a strategy for counteracting species and habitat losses by 2010, including sociopolitical, economic and cultural measures such as promoting biodiversity research.

A simple but nonetheless still unanswered question in biodiversity research is that of “how many”: estimates on the number of species that currently populate our planet vary between ten million and ten billion. How many different species of animals, plants, fungi, single-celled protozoa and bacteria are there on Earth? These questions come up in the public discussion especially in connection with the finding that we are currently in an age of mass extinction of species.

But such fundamental questions about the diversity of life also derive from the natural curiosity of humans about the makeup of their environment – just like the children’s song “Do you know how many stars there are?” In astronomy, systematic cataloging of stars is indeed a key component of the research approach. Tracking diversity has been a core issue in biology for centuries, too, but now that we are seeking to understand biodiversity, it is rather taking a back seat.

Biology currently takes a very functional approach. Collecting and describing is shrugged off as free of hypotheses. With this stance, however, biology runs the risk of robbing itself of one of its basic principles.

We live in an age of mass extinction
The diversity of species on our planet is vital, and research into it needs new impetus.
Systematic tracking of biodiversity must become a goal of basic research. Even for the most conservative estimate of ten million species, at the current rate, it would take another 400 years to complete a full inventory of just the animals and plants on Earth. We need to accelerate the process of scientifically identifying species, describing them and even naming them by at least one order of magnitude. Only in this way can we obtain an encyclopedia of life within a reasonable time.

A “census” is a systematic method of biodiversity research. Its main goal is to quantitatively track biodiversity at all taxonomic and organizational levels, thus creating solid foundations both for research into habitats and for developing strategies to preserve them. In basic research, the transition to a quantitative description always represents a great gain in knowledge. This will be no different in the case of biodiversity. By systematically researching biodiversity, we will recognize the patterns that point to the adaptation of organisms and their communities to the changing environment, as well as to the consequences for material flows and food networks.

Besides the question of “how many,” there are the questions of “where” and “when” – of the spatial and temporal dynamics in the number and relative frequency of organisms in their habitat, and their relationship to one another and to the inanimate environment. In this context, the focus is increasingly shifting from individual organisms to symbioses, from understanding biological niches to the dimensions of habitats and movement corridors. Modern biodiversity researchers are thus expected not only to compare molecular data sets with each other, but also to link them with data from Earth observations to derive trends and rules.

In cooperation with other branches of the Earth and life sciences, it should also be possible to answer the most difficult question, that of “why.” What does it mean, ecologically speaking, when a taxonomic group exhibits immense diversity? How important is biodiversity for the function and productivity of ecosystems? Are rare species also important to communities? How valuable is species diversity to us? And what happens to an ecosystem if just a single member disappears? Can this cause the system to become unstable, like in the butterfly effect in chaos theory? There is already agreement in society and politics that biodiversity and the underlying genetic resources are essential to human life. Biodiversity is relevant to nutrition, natural products, medicine and ecological stability, but also to cultural and aesthetic experience. For centuries, however, human activity has been reducing biological diversity at an ever-increasing pace. This causes the inherent value of biological organisms to be irretrievably lost.

New land areas are constantly being put to agricultural use for the world’s rapidly growing population, and energy crops are accounting for more and more of this land use. Solutions are being sought for the negative effects of climate change. However, converting natural vegetation to plantations for carbon fixation in an effort to protect the climate will not only sanction the next wave of species extinction, but virtually subsidize it.

The current discussion about climate change shows that the environment can change regionally much faster than previously thought. Some events, such as the melting of glaciers and sea ice, the in-
creasing flooding of river delta regions or the spread of new diseases, take place on time scales like those used in lab experiments to study natural adaptations. Nevertheless, there is surprisingly little research on the biological consequences of global change to address these phenomena. Against this background, the – thus far sparse – long-term ecological observations on land and at sea are becoming increasingly valuable to science.

The theoretical, conceptual and infrastructural basis of this discipline is not in good shape, either. The reasons for this are rooted in history and scientific culture and owe, for example, to the separation of taxonomic research from other life and environmental sciences, or to the lack of integration of molecular and classical methods of biology in university departments and museums.

We believe that the multidisciplinary branch of science known as biodiversity research, as a part of environmental research and Earth observation, is undergoing a shift – just as medical research has taken completely new approaches to studying humans and their various symbionts, parasites and pathogens since the age of high-throughput genome sequencing.

One of the most urgent problems, and one that has ever affected all areas of biodiversity research, is the characterization and counting of species. There are currently many species concepts, specialized for each group of organisms. The biological species concept of Ernst Mayr, which defines species as “groups of actually or potentially interbreeding natural populations, which are reproductively isolated from oth-

Comparative sequence analysis will permit more accurate analyses of species formation

It’s about reinventing an old discipline without losing sight of its roots

er such groups,” can reasonably be applied only to the higher animals and flowering plants, not to fungi, protozoa and the two kingdoms of prokaryotes, the bacteria and archaea.

Single-celled organisms and most of the highly diverse small invertebrates that exist in soils, sediments and aquatic habitats, or as parasites or symbionts on plants and animals, harbor many cryptic species that cannot be phenotypically distinguished, but often have completely different functions in the environment. For this reason, the “general lineage” concept that defines species as independent evolutionary lineages has been gaining ground in recent years. Identifying such lineages requires integrating different sets of characters rather than applying solely classical morphological methods.

DNA-based techniques promise a way out of this dilemma, having developed rapidly in recent years. High-throughput technologies (such as next-generation sequencing, NGS) now make it possible to track biodiversity quantitatively beyond the narrow limits of specialized biological groups with their specific species concepts.

Furthermore, comparative sequence analysis will permit more accurate analyses of species formation and, in conjunction with population genetics models, can contribute to a desperately needed comparability of species concepts.
For microorganisms such as bacteria and archaea, which occur in several thousand taxonomic units per liter of water or sediment – of which we still know only a few percent – only the high-throughput methods of molecular biology permit study on various spatial and temporal scales. In connection with high-resolution measurements of contextual environmental parameters, it also allows comparative sequence analysis to study rules of organisms’ association with each other and with special niches or habitats, and to quantify changes in diversity that are influenced by environmental factors. Given the high number and variety of microorganisms even in the most extreme habitats, knowledge of biodiversity is an important foundation and possibly even an important functional parameter of ecosystems.

Biodiversity is an important functional parameter of ecosystems

Metagenomics provides many new findings on microorganisms

Rethinking the traditional categorization that Carl von Linné once used to bring order to animate nature may be an important result of such studies.

Initial attempts to sequence all genomes occurring in a habitat – the so-called metagenome – have already brought many new findings on the dominant microorganisms. In many habitats, a few species of bacteria or archaea appear to dominate a significant portion of the biomass of the community. What makes these species so successful? Or might it, in fact, be a heterogeneous collection of many differently adapted ecological types?

Genetic and epigenetic adaptation to a changing environment may be of particular importance as a response of species to rapid climate change. However, we currently understand far too little of the mechanisms that permit a species to adapt to new conditions and habitats. A combination of methods from quantitative genetics and genome analysis of microorganisms are currently producing new approaches for decoding the functional principles.

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Likewise, we are hoping for answers to questions regarding the origins of life and its ability to adapt to the environment.

The role and repercussions of biodiversity on general geochemical and climatological conditions are high on the list of global change issues, as are food webs and the flow of energy and matter through ecosystems. We still know very little about how the network of interacting organisms reacts to and buffers changes in environmental parameters, such as temperature and CO$_2$ concentration. Using solid knowledge of these most important components of biodiversity in certain habitats as a basis, it will be possible to approach these questions with models and experiments.

The comparative study of ecosystem functions and connections with biodiversity and the environment can extend from the early history of the Earth to biological models, and focuses on linking and synthesizing field data and experimental findings with ecosystem models.

In this regard, biodiversity research can help provide more precise answers to the elemental questions of “where from” (evolution) and “where to” (the future of life on Earth) and thus put the spotlight on the ecological relationship of humans to their environment. Here, biology needs structures like those we currently know from major international experiments in physics and astronomy. Research into the evolution, function and ecology of biodiversity on Earth is so fundamental for humankind that we should not shy away from this new dimension.

**THE AUTHORS**

**Rudolf Amann**, born in 1961, headed the “Molecular Ecology” Independent Junior Research Group at the Max Planck Institute for Marine Microbiology in Bremen. He has been a Director and Scientific Member at the Institute and a professor at the University of Bremen since 2001.

**Antje Boetius**, born in 1967, became head of the “Microbial Habitats” research group at the Bremen-based Max Planck Institute for Marine Microbiology in 2003. She has been a professor of geomicrobiology at the University of Bremen since March 2009, and won the Leibniz Prize the same year.

**Diethard Tautz**, born in 1957, was a group leader at the University of Munich’s Institute of Genetics, then a professor at the Zoological Institute of the same university, and finally a professor at the Institute for Genetics at the University of Cologne. He became a Director at the Max Planck Institute for Evolutionary Biology in 2007.
As far as cognitive scientists are concerned, the children’s game “I spy with my little eye” is anything but child’s play. It is based on the assumption that the person whose turn it is can imagine what the other players are able to see – or not. But do dogs and apes, for instance, also share this ability? At the Max Planck Institute for Evolutionary Anthropology in Leipzig, scientists study social cognition factors in different species.

TEXT BIRGIT FENZEL

Theory of mind is the scientific term for the art of mind reading. This ability enables people to apprehend others as individuals with their own perceptions, feelings and thoughts and, based on this, to imagine what is going on with them. For researchers, the theory of mind is one of the cornerstones of learning and teaching, and therefore also of the emergence of culture – one need only think here of the role imitation and demonstration play in the passing on of knowledge in the context of language acquisition.

It was long assumed that the theory of mind was a uniquely human ability that developed over the course of evolution. However, scientists working with Michael Tomasello in the Department of Developmental and Comparative Psychology at the Max Planck Institute for Evolutionary Anthropology in Leipzig observed that chimpanzees also display some of the key features of this ability to perceive the perspectives and intentions of others. In order to find out what apes know about the perceptions of their group members, psychologist Josep Call exploited the extreme food possessiveness displayed by ape house inhabitants in the Wolfgang Köhler Primate Research Center by concealing pieces of fruit in the enclosure. The lower orders actually dared to take the extra portion only when they had observed that the alpha male had either not noticed the food being hidden or did not have the food in his field of vision.

This relativizes the hitherto accepted belief that the theory of mind is an exclusively human ability. But how much do apes actually understand about the state of knowledge of others? Is it possible that they are able to use pointing gestures or other referential indications in communicative contexts? “These questions are extremely fascinating for us,” says biologist Juliane Bräuer, who researches the social cognition in various animal species in Tomasello’s department. “The comparison between the different species provides us with insight into ourselves and what has changed in the course of our development. After all, how human cognition developed during the course of evolution is one of our big questions.”

Humans are thus endowed with the ability to put themselves in the perception and action perspectives of others, and this ability plays a major role in early childhood language acquisition. The child learns the names of objects from the mother or father by pointing to them. It is now also assumed that gestures actually lie at the root of language: the sounds and words only followed after the pointing.

However, as Call and his colleagues discovered to their amazement while researching at the Wolfgang Köhler Primate Research Center, the great apes did not follow even the broadest of hints: a series of studies with hidden pieces of fruit showed that pointing does not work in human-ape communication – the apes clearly do not understand what their human test partners want to tell them when they point to a certain container. Based on these findings, it appeared that the ability to interpret communicative gestures is a talent exclusive to Homo sapiens. If man’s closest relation in ontogenetic terms cannot understand pointing gestures, who can? The answer came from an unexpected source: “My dog can do it!” claimed then...
Practice makes perfect – also in the way dogs observe people. According to research, this is not the only communicative skill aimed at humans with which dogs have become experts over a period of 15,000 years.
With this off-hand comment, Hare landed himself a commission to carry out his own research project. It quickly emerged that his dog was not the only extraordinarily gifted canine communicator that was able to interpret human pointing gestures. As had been done in the ape house, the “object-choice test” was used here, too. The dogs were presented with two identical upturned containers, only one of which contained a dog biscuit. The dogs could not have known which container concealed the biscuit as they had not seen it being hidden. Their human test partner then pointed to the container with the interesting content. After this, the dogs were allowed to choose, and did so, by touching the container of their choice with their noses or paws. If they chose the correct one, they were rewarded with the contents; if they chose the wrong one, they were left empty-handed. To ensure that the dogs were not being led by their sensitive noses, a control condition was carried out in which there were no referential clues to the correct container. “If the animal made alternately correct and incorrect selections in this case, it was clear that it was not able to smell the food,” says Juliane Bräuer, explaining how Hare’s claim was put to the test.

This study alone revealed that Brian Hare’s claim was no empty promise. The dogs showed a clear preference for the container to which the human had pointed: the unspoken message had clearly been heard. “Hare’s article about dog cognition was published in 1998,” explains the 33-year-old biologist. She herself has been working at the Max Planck Institute since 1999 and wrote her graduate diploma thesis there in 2002. Around the same time, a group of researchers in Budapest were exploring the question as to how human gestures can be of use to dogs.

FROM LAST CHOICE TO TOP OF THE CLASS

The scientific community was initially somewhat lukewarm in its reception of the studies carried out in Leipzig and Budapest. “Hardly anyone had any interest in dogs. They were seen as unsuitable test subjects because they live in an unnatural environment. And it was believed that the results of such studies did not reflect their true nature,” says Bräuer, explaining why dogs had moved into research’s blind spot. Moreover, dogs had long been dismissed as “incomplete” wolves, as they no longer possess many of the skills of their ancestors who did not live in captivity. For example, their sense of smell and hearing are significantly less acute than those of their self-sufficient wild forebears. Nonetheless, even in the earliest of the behavioral studies carried out in Leipzig, the very species that had supposedly become degenerate through domestication astonished researchers with its cognitive and social skills, and emerged from many comparative studies as the new top student who easily outperformed the primates in Pongoland.

But how can a dog do this? Do they learn gestures like a “foreign language” as puppies through their close association with humans? Or could this ability even be innate? To find out, doctoral student Julia Riedel and her colleagues carried out the object-choice test with young dogs ranging between 6 and 16 weeks of age. In order to exclude the possibility that the puppies were simply trying their luck with the container nearest to the hand of the person making the gesture – it is a well known fact that hands are of great interest to dogs – an additional condition was added to the study that forced the dogs to move away from the hand to reach the containers.

“Puppies of all age groups interpreted the pointing gesture as an indication of hidden food equally well, and selected the correct container,” reports Riedel. This result was an indication that the ability to follow human communicative gestures does not have to be learned by dogs but is innate. “This
Two containers, one biscuit, no trace of a smell. Even without using their noses, dogs of all breeds were immediately able to establish where the reward was hidden. Unlike the apes, they instantly understood the pointing gesture.
The command “stop” is valid only as long as a person is watching them. In the studies, the dogs were always obedient when the human gaze was directed at them – and almost always stole the treat when they felt unobserved.

in turn, suggests that millennia of domestication played a crucial role in its emergence.” The observation is further corroborated by studies with hand-reared wolves that, despite also being used to humans and their forms of expression, do not understand pointing.

How well dogs actually know what others can and cannot see was demonstrated by a different study that Bräuer developed with her colleague Juliane Kaminski. The idea for the study was inspired by Bräuer’s dog Mora. When out on a walk one day, Mora discovered a thoughtlessly discarded sandwich and viewed it as a welcome addition to her menu. On hearing the command “stop” she obediently dropped her loot and was accordingly praised for this action by her owner. However, as soon as Bräuer turned around, Mora immediately grabbed the sandwich again and quickly devoured it behind her owner’s back.

“The most interesting studies are always those that relate directly to the way in which the tested animal lives,” says the Max Planck researcher. As most dog owners can confirm, what she had experienced in the park with her dog was very typical of everyday life with the domestic canine: the dog is not allowed on the sofa or bed, but immediately sits on it as soon as he feels unserved; the dog should stay in its basket, but jumps out as soon as its master leaves the room; the dog is not allowed to take food from the table, but as soon as it is alone in the room, the chocolate is devoured.

GOOD BEHAVIOR IS ALWAYS A QUESTION OF VANTAGE POINT

The design of the study in the dog bungalow, with which Bräuer and Kaminski aimed to establish whether dogs know what others can see, was comparatively simple. To begin with, a treat was placed at the dog’s feet. The humans forbade the dogs to eat it using the usual command. The humans then varied their behavior. On one occasion, they merely turned away and then left the room entirely; another time, they sat on a stool and played with a Gameboy. “In each case, their attention was not directed at the dog,” Kaminski says, describing the most important condition of the study. Only in the control condition did the humans actually look at the dogs. Each round took exactly three minutes.

“Admittedly, it was not a particularly pleasant test for a well trained dog,” concedes Bräuer. “But under the right conditions, it was ultimately able to ignore the ban, just as my dog had done in the park.” And Mora’s conspecifics did, indeed, behave in exactly the same way as she had. Instead of sitting there obediently, merely enjoying the view of the treat, they quickly stole the food when they felt unobserved. However, they almost never took it when they were watched by their human test partner.

“We can conclude from these results that dogs can distinguish whether a person is watching them or not, and
that they behave differently on this basis,” says Juliane Bräuer. A particularly interesting observation that also emerged from these studies is that dogs can also distinguish between open and closed eyes – a remarkable skill.

However, the two researchers did not want to accept these results alone as proof that dogs actually understand what a human can or cannot see in such situations. After all, the dogs may simply have reacted to the eyes of their partners because they have learned that humans are always attentive when their eyes can be seen. To find out whether or not dogs actually understand this cognitive change in perspective, the two researchers embarked on a further series of studies. This time the test took the form of a play situation with two toys that they placed on the floor between the human and the dog. Then they placed a barrier in front of each toy: one barrier was opaque and blocked the human’s view of the toy, while the second was transparent and gave a clear view of the toy. Both objects were equally visible to the dog, which sat on the other side of the barrier.

RECORD VOCABULARY WITH OVER 200 WORDS

The human participant then asked the dog to bring one of the toys to her using the command “bring” – without, however referring specifically to the toy. If the dogs could understand anything about the person’s perspective and what she could see, they would display a preference for the toy behind the transparent barrier, as this was the only one in her field of vision. Therefore, the command could refer only to the toy behind the transparent barrier. If, however, the dog reacted only to the eye as stimulus, it should not show a preference for either of the two toys, and carry each of them to the person with equal frequency, because it would perceive the latter’s eyes in conjunction with both toys.

The dogs in fact opted more frequently for the object in front of the transparent barrier. However, it was entirely possible that the dog simply showed a preference for the transparent barrier, for example because the toy looked brighter there or because it had in this way a better view of the human while he carried it. For this reason, the study was supplemented with two further control conditions in which the dog should not have shown any preference for either of the two toys.

In one condition, the person was able to see both objects because she was sitting at the dog’s side; in the other one, she could see neither of them because she was sitting with her back to the set-up. The dogs displayed a certain preference for the transparent barrier when the human was turned away from them; however, their greatest preference was reserved for the case in which the human sat opposite and really saw only the toy behind the transparent barrier. “This result could mean...
that dogs actually do understand, to a certain extent, what humans can see,” says Juliane Kaminski.

Whether or not dogs make ideal partners for the game “I spy with my little eye” remains unclear. However, there can be no doubt that they possess the basic skills necessary to play it. Bräuer, who came to work with dogs through her research on apes, has been the scientific coordinator of the dog research for two years, and coordinates ongoing projects with Susanne Mauritz. She enables interested dog owners to register their interest in participating in the observational studies through media appeals. “People are happy to come to us because they are curious to know what their dogs can actually do, and because they know that we will take good care of the dogs, and challenge them mentally,” says Mauritz.

Over the years, the two researchers have gotten to know some particularly gifted dogs that not only are very good at interpreting human gestures and looks, but that also have an astonishing passive vocabulary. “Some can identify several hundred objects by name,” says Kaminski. The unbeaten champion in this particular discipline was Rico, a nine-year-old Border Collie who could recognize and classify over 200 toys by name.

Kaminski and her colleagues carried out a study to investigate whether Rico could learn the names of new toys through a process of exclusion. To this end, they distributed new and known toys in a room while the collie waited in an adjacent room with his owner. He was then asked to bring a toy to the owner, the name of which he had never heard and which he had never seen before. Rico did, in fact, solve this task.

Dogs not only bring objects that are indicated to them by name, they can also distinguish known from unknown objects by a process of exclusion, and in this way learn new words. On request, they also retrieve objects that are shown to them in photos or as miniatures.
right off the bat, dismissing another theoretical human USP in one fell swoop: this manner of learning labels for objects, which is known as fast-mapping, was also previously considered to be an exclusively human skill.

**WHAT DOGS REVEAL ABOUT HUMANS**

As further studies revealed, Rico is a particularly gifted linguist, but his talent is by no means unique in the canine world. Other representatives of his species almost equaled him in terms of vocabulary. The fact that the best results were achieved by other Border Collies gave the researchers some food for thought. Whether this talent is a particular feature of the Border Collie breed is a fascinating question that remains open, reports Susanne Mauritz. “However, we avoid the term intelligence when we speak about our research.”

Instead, the focus is on identifying the special cognitive capacities that an animal species possesses and that are necessary for its survival. This is, above all, a question of specialization and evolutionary adaptation. For example, although dogs mostly achieved better results than other animal species in the studies on human-dog communication, they encountered greater difficulties in studies that required social learning through imitation or the resolution of problems by understanding causal links.

The apes, however, performed particularly well in these tests. When the researcher shook the container containing the reward, it was immediately clear to the ape that there had to be something inside it. The dogs, on the other hand, were unable to draw conclusions about the contents from the noise. “It is easy to explain these results. They are indicative of the environment in which both species must survive,” explains Juliane Bräuer. Due to the enormous competition for food that prevails in groups of apes, an ape would never dream of showing a fellow group member a source of food. Causal understanding, however, is helpful in the search for food in the tropical forest. By shaking a nut, the ape can establish whether it is worth cracking.

Dogs, on the other hand, do not have to worry about looking for food or other problems of this nature. They live with humans who provide for their needs. It is, however, an advantage for them to understand humans as well as possible. As a result, dogs have developed into real communication professionals over the past 15,000 years.

The Leipzig-based researchers are particularly interested in cognitive talents of dogs that are otherwise found only in humans, such as understanding pointing gestures. “This particular canine skill could, perhaps, provide us with information about our own development,” hopes Bräuer. “For example, information about what natural selection may have influenced in us humans. It is very likely that we encouraged the friendly, attentive dogs who established contact with us. It is possible, therefore, that in the course of human evolution, friendly individuals succeeded in asserting themselves, thus fostering in humans an extremely pronounced willingness to cooperate.”

The question as to whether such conclusions may be drawn from the skills of the dogs remains purely speculative. However, the work being carried out by the Max Planck scientists may well help in clarifying some of the mysteries that surround human evolution.

**GLOSSARY**

**Cognition**

Cognition means the faculty of knowledge. It refers both to the mental processes in which individuals engage, such as thoughts, opinions, desires and intentions, and to information-processing operations, such as problem-solving and language. These operations enable individuals to flexibly adapt their behavior and to learn from their interaction with their environment.

**Ontogenesis**

This term describes the development of the individual and his characteristics in the biological and psychological sense. Unlike phylogenesis, which refers to the emergence and development of a species, ontogenesis it is limited to the development of the individual.

**Pongoland**

The Wolfgang Köhler Primate Research Center (“Pongoland”) is a project of the Max Planck Institute for Evolutionary Anthropology and is operated in collaboration with the Leipzig Zoo. The research carried out at the Center focuses on the behavior and cognition of the four species of great apes: chimpanzees, gorillas, orangutans and bonobos. Not only can visitors to the zoo observe the animals in interior and exterior enclosures, they can also observe the work being carried out by the scientists.
How long a student must wait for the master’s response depends on more than just the complexity of the question. As linguists from Nijmegen discovered, it also depends on the language being spoken.
A Telling Silence

A phone call between two friends or small talk on the street – this is the glue that holds human society together. Nick Enfield and Stephen Levinson, researchers at the Max Planck Institute for Psycholinguistics in the Dutch city of Nijmegen, are interested in such everyday conversational situations. They want to know how language, culture and cognition interrelate.

Nick Enfield moved into his office at the Max Planck Institute on the outskirts of the Radboud University campus in Nijmegen nine years ago. The institute building is situated in the middle of a forest and looks so inconspicuous from the outside that no one would ever guess that this is a place where scientists study the essence of what makes us human. That is, after all, exactly what Enfield and his fellow scientists aim to achieve when they spend days and weeks patiently transcribing every “um” and “ah” of a recorded conversation.

Without communication, no sociality

Humans are unique among species in terms of the complexity of their interaction with conspecifics. “These endless possibilities and the will to cooperate with others, to form friendships, to manipulate others for one’s own benefit or to quarrel with strangers – you don’t find that anywhere else to the same extent as in human society,” says Nick Enfield.

In his quest for the roots of this drive to be social, Enfield soon found his way to our everyday use of language – including sign language, gestures and facial expressions, such as eyebrows raised in skepticism or a hand raised in defense. It is only thanks to their sophisticated capacity for communication that people are able to interact and cooperate. If it weren’t for this, it would be pure coincidence if any of a human being’s actions were at all coordinated with those of another human being.

However, if the desire to cooperate is a characteristic of the human species and any form of language is the expression of this desire, does this not suggest the existence of universal principles of human communication across all cultures? A kind of “universal infrastructure,” as the Max Planck scientist calls it, that regulates coexistence in every human society.

The psycholinguists have already come up with some initial ideas on what this fundamental infrastructure might look like. For a conversation to go without a hitch, both the speaker and the listener have to see themselves in a similar situation. The listener must work out whether the sentence “I’m thirsty” is a purely informational utterance or whether it is also a request for something to drink. Even more indispensable is the ability to correctly read the speaker’s intention when irony, sarcasm or simply an imprecise mode of expression are involved – as they are in almost any informal conversation.
Levinson and his team conducted an fMRI study to examine how this unspoken mutual understanding is achieved. If the sender signifies a communicative intention of an unconventional nature, the same regions of the brain are activated in both the speaker and the recipient – the recipient apparently simulates the intentions of the sender.

GOSSIP AS THE BEDROCK OF COMMUNICATION

Scientists use theory of mind to describe our ability to get into someone else’s thoughts, and for Enfield and his fellow scientists, this theory is one of the core elements of human communication and cooperation. But how, for example, does a listener recognize that the speaker is about to stop speaking and give the other a turn to speak? Nick Enfield examined this issue with the help of an experiment in which his subjects were played excerpts of a phone conversation between two Dutch-speaking friends. The test persons were asked to press a button the moment they thought the speaker was about to finish speaking. The experiment simulated a situation that occurs in every conversation: the fact that it takes about half a second to produce a response to what is heard in a simple, casual chat means that it is necessary to predict when the conversation partner is going to stop talking in order to avoid long pauses.

“An ideal conversation has no gaps and no overlaps in the sense of people speaking at the same time,” says Enfield. There are still lulls in a conversation, of course, but they usually convey some sort of meaning. In fact, one of the findings of Enfield’s studies is that positive responses to yes/no questions are expressed faster than negative responses in all cultures. If the speaker notices the brief pause of a few milliseconds, their partner’s potentially negative response can be anticipated.

In his tests, Enfield manipulated the sound recordings, in one case making the words incomprehensible without changing attributes such as the pitch, volume and duration of what was said. The experimental subjects found it much more difficult to anticipate the end of a turn at conversation than they did when the recording was unedited. If, on the other hand, Enfield modified the pitch, the subjects had no trouble whatsoever.

Thus, it is rather the individual words and grammar than the pitch that indicate that a speaker is about to end their contribution to the conversation. “At least this is true of Dutch, and probably other European languages, too,” says Enfield. “But what it’s like in a language like Japanese, in which a great deal of words can simply be omitted, we just don’t know yet.”

Nevertheless, the psycholinguists noticed that there is one thing that all languages have in common. “All languages ensure that people can cooperate,” says the Max Planck scientist, referencing anthropologist Robin Dunbar. The latter postulates that language evolved 200,000 to 400,000 years ago as a tool for regulating social matters in what is, for primates, a fairly large-scale society. According to his theory, gossiping was the engine of the development that eventually reached its peak in half a million different languages. Linguists estimate that there are around 7,000 languages spoken in the world today. And in only about 10 percent of them did someone go to the trouble of writing down grammar rules and extensive lists of vocabulary. According to the Ethnologue database, 82 percent of languages are spoken by communities with fewer than 100,000 members, while 40 percent even have fewer than 10,000 speakers.

A PSYCHOLOGISTS’ NIGHTMARE

Nick Enfield knows only too well what it means to study languages like Kri, which is spoken by only 300 people
living in a remote part of Southeast Asia. Enfield’s office contains photos of colorfully dressed speakers of the language to remind him of the annual “field season,” the time when he leaves the Netherlands to spend a few weeks in the foreign culture. Early on, he was surprised by the distinct hierarchies that manifested themselves in each apparently insignificant exchange of banter: the senior person sat virtually enthroned above whoever the dialog partner was – even if it meant that the latter had to literally kneel out in the street.

The scientists follow the everyday lives of the people in Asia or Africa with a video camera. Who initiates a conversation, where are they looking when they do so, how and when does the other person respond? “You can’t avoid becoming a part of the foreign society when you do this,” explains Enfield. “After all, we live among the people we study, we eat with them, we join in their celebrations.” Test conditions of this kind are a nightmare for psychologists, he says, because they are difficult to control. Since everything is happening in real time, a situation can never be repeated exactly.

The researchers eventually get back to their desks with hundreds of hours of video recordings. That’s when the most time-consuming part of the work begins. Like zoologists who return home from an excursion and need to examine under the microscope the legs of the beetles they collected and measure them down to the last millimeter, the psycholinguists transform their video recordings into annotated records, transcribing everything precisely, right down to the last millisecond. Those who refer back to their notes are amazed at how incomplete the sentences in a conversation usually are. The researchers do not skip a single pause or a single stammer, but this degree of meticulousness takes time: the accurate transcription of one minute of video recordings takes about two hours.

Sometimes Enfield feels like a deep-sea researcher discovering a strange world of exotic species: creatures that look totally different than anything they have seen before but that, like all organisms, nevertheless pursue the objective of surviving and reproducing. It’s similar with the languages of the world, says Enfield. Structural similarities between a Western European language and Kri will be hard to find, but in the highly industrialized West as in the Asian jungle, the respective language serves to organize interhuman activities.

If, however, the quest is to exchange factual information and nothing else, the spoken language, at least, is not always necessary, comments Enfield. The scientist knows this from his own experience of visiting a foreign country for the first time and having to come to grips with the new language before anything else. “It’s always challenging, but it’s fun,” he says. “You know you’ll make progress just as soon as you invest some time in it.”

CHOMSKY’S UNIVERSAL GRAMMAR IS DEAD

Thanks to their experience in field research, the Max Planck scientists are challenging an established theory of linguistics with their own theory of a universal infrastructure of linguistic usage. To this day, Noam Chomsky’s concept of a single, deep grammar that is valid for all languages is still the dominant one in the discipline. Followers of Chomsky’s teachings claim to be able to work out universal commonalities in language structure. According to them, all languages have structures like nouns, verbs, adjectives and auxiliaries, as well as rules on word order in a sentence.

Not true, says linguist and anthropologist Stephen Levinson, Director at the Max Planck Institute in Nijmegen, citing examples from languages that an untrained language user could not even pronounce: “Riau Indonesian has no rules governing word order; the Austral-
ian languages Kayardild and Bininj Gun-wok have no auxiliary verbs; and in Lao, a special verb form is used instead of adjectives.

Furthermore, there are certain specific characteristics that no inventor of an artificial language would ever think up, as they appear, at first glance, to be too obscure. For instance, the Native American language Kiowa has no standard form for the plural. Instead, speakers indicate whether they’re talking about an unusual number for a specific object, such as more than two legs or only two individual pebbles.

All languages appear to have a common purpose: communication that makes possible the organization of society. But the existence of universality on a structural level – that is, Chomsky’s universal grammar described above – is something that he and Nick Enfield consider to be a myth. “Languages differ so significantly at every level of their structure that we find it difficult to identify even a single feature that is common to all of them,” says the Max Planck Director. “We are the only species whose communication systems fundamentally differ from each other in form and content. If you think about the evolution of language but ignore this fact, you miss the one characteristic that makes our species remarkable.”

Michael Tomasello backs Stephen Levinson up on this point. A Director at the Leipzig-based Max Planck Institute for Evolutionary Anthropology, Tomasello states emphatically: “Universal grammar is dead,” pointing out that scientists are not able to say exactly what it is that is supposed to be universal – nor do they have any clear way of finding out.

A STOPWATCH ON THE PULSE OF LANGUAGE

The universal infrastructure postulated by Levinson and Enfield, however, is deeper – and therefore less obvious. It manifests itself in such aspects as the time lag before a response is articulated. And the researchers hold that they can prove this universal infrastructure by demonstrating that there are rules for informal linguistic usage that people of all cultures follow. Each of the psycholinguists speaks a handful of exotic languages to ensure that they are equipped for these kinds of intercultural studies. Enfield is an expert in Lao and Kri, and can also make himself understood in Khmer and Chinese. His boss, Levinson, has thus far specialized in languages of India, Mesoamerica, Australia and New Guinea.

But even if the scientists have no trouble communicating, cross-cultural studies are very time consuming and costly. Organizing a study in just a single Western European language, on the other hand, is much easier, says Enfield, explaining that they barely even need to advertise for test subjects in such cases. The fact that most study findings stem from this relatively restricted cultural milieu is something he calls “ethnocentrism”.

To get around this problem, Nick Enfield expanded the topic of one of his most recently published studies to encompass a total of ten languages from five continents: Italian, English, Danish and Japanese were examined alongside languages from Mexico, Laos,
Namibia and Papua New Guinea. The psycholinguists wanted to find out how much time elapses in the various language areas before a person reacts to a simple yes or no question in conversation. In a bid to make their study as true to life as possible, the scientists analyzed real-life situations that they had previously filmed in the individual cultures concerned.

In Lao, for example, two men discussed what route they should take with their truck to reach the next village. The findings support Enfield's theory of a fundamental infrastructure in everyday linguistic usage: when it came to questions that could be answered with a yes or a no, people in all language areas responded, on average, after 208 milliseconds. “This time lapse is evidently a universal target,” says the scientist.

The study did, however, uncover minor culture-specific variations. The Japanese answered the fastest, the Danes the slowest. “The infrastructure of language use as we see it is not fixed – it's a bunch of principles that can grow into specific local traits, thereby shaping a culture,” says Stephen Levinson, explaining this finding.

How closely language use and culture are interwoven in people’s everyday lives is something on which Nick Enfield and five other scientists plan to gather evidence in another research project. Since January, Enfield is heading the Human Sociality and Systems of Language Use project, financed with two million euros from the European Research Council.

Whose job is it to clear up misunderstandings in a casual conversation? How strongly can a person express a particular wish? Here too, the psycholinguists want to answer questions like these for a total of seven different languages. Enfield’s box of technology, including his video camera, is all packed and ready to go. Soon he will be back in Laos to meet up again with the colorfully dressed speakers whose photos adorn the filing cabinet in his office.

GLOSSARY

Theory of mind (ToM)
The ability to get into someone else’s thoughts, to identify that person’s intentions and align one’s own behavior accordingly. By the classical tests, children do not seem have a fully developed ToM until the age of about four; when they become able to explicitly identify the beliefs and assumptions of another person as incorrect. However, work at the MPI in Nijmegen has shown implicit ToM as early as one year.

Universal grammar
The innate human ability to form new sentences with the help of a few grammatical rules and a limited vocabulary. As evidence of universal grammar, linguist Noam Chomsky alleged that any healthy child could learn any language as its mother tongue. However, universal grammar is often also understood to be a bunch of principles that are common to all of the languages of the world (such as certain rules of sentence structure, lexical units like nouns, verbs, etc.). Many scientists have criticized this notion due to counterexamples for most of the proposals.

Transcription
Transferring audio recordings of spoken language to a written record, often in a specially devised writing system. In the case of scientists Levinson and Enfield, it even includes all lulls in conversation, fillers and incomplete sentence fragments. For linguists and psycholinguists, it is one of the most time-consuming aspects of their studies.
The more the musicians synchronize and coordinate their movements while playing, the better the duet sounds.
Because I Know What You’re Doing

When people work together, they have to coordinate their actions very closely. Wolfgang Prinz, Director at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig, and his colleagues are investigating precisely what goes on in their heads in the process.

TEXT PETER ZEKERT

Playing in a duet or a musical ensemble means harmonizing with others in more than one sense. The sounds produced by the musicians will combine to form a unified voice only if each note played by the individual members complements those produced by the rest of the group. And musicians are not the only ones who need an acute awareness of the other people around them. We all need this in the course of our everyday lives, which consist of a series of major and minor social interactions in which we repeatedly and intuitively adapt to other people.

Whether giving way as pedestrians to other oncoming pedestrians, shaking hands with another person, helping someone carry a sofa up a staircase, dancing or playing basketball, all of our actions must be coordinated with those of other people. But how is it that we always realize so quickly what they are going to do? Wolfgang Prinz is interested in the basic processes involved in this kind of joint action. The Director of the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig conducts research into social behavior on the micro level. The fact is that a great deal more cognitive activity lies behind our everyday interaction with other people than we realize.

The way in which the actions we perform in conjunction with others form a unified whole is something that usually functions automatically and something we notice mainly when things go wrong – when the musical ensemble produces the wrong note, when a pass to a team member goes awry, or when a foot lands on a tango partner’s toes.

THOUGHT PROCESSES EXTEND THE CONNECTION

On closer examination, the effortless and silent nature of this coordination, which is accomplished in mere fractions of a second, is truly astonishing. The possession of sensitive “antennae” and the ability to respond quickly is not sufficient to explain it. “People can cooperate with others so smoothly because they usually know in advance what the other person is going to do,” says Wolfgang Prinz.

Behind this capacity lie mechanisms that remain largely unconscious and that have become an object of research only in recent years. For a long time, psychologists assumed that such processes followed a linear scheme. “The sequence perception – cognition – action was accepted as the classic model,” explains the Max Planck researcher. Based on this model, actions we perceive in others would first have to undergo a complex thought process to be understood.

We would then have to weigh up the different action options and initiate the corresponding movements in order to eventually react. “This process would simply be too slow for many of the lightning-fast interactions we engage in every day,” says Prinz.

He quickly came to the conclusion that there had to be a shortcut that leads directly from the perception of an action carried out by another to our own action. Back in the early 1990s, the scientist formulated the theory of common coding, according to which perception and action are linked, at least in part, by shared cognitive and neuronal resources.

Initially, he was rather isolated in this view. However, this situation came to an abrupt end when brain cells were found in Macaque monkeys that did
exactly what Prinz had predicted theoretically: the so-called mirror neurons became active in the primates both when they themselves reached for a piece of fruit and when they merely observed another individual carrying out the same action. Neurons with this dual function are still being sought in humans. The fact that they exist is viewed as a certainty as, in humans too, the mere perception of an action can activate the same motoric areas that are also responsible for its implementation.

The consequences of this phenomenon can be observed in everyday life: everyone has experienced how contagious the effect of yawning or laughing can be. Also, when we observe the sitting posture and movement of a partner in a conversation, we often imitate both actions involuntarily. It is suspected that the hub of the human mirror system is located in the premotor cortex. Numerous studies have demonstrated that this area is the pivotal point between sensory perception and action control.

RUNNING THROUGH IT ALL IN YOUR HEAD FIRST

As the immediate neighbor of the motor cortex, the movement center of the brain, the premotor cortex connects audio-visual input with the planning and implementation of our movements. As a result, it is assigned a key role in our interaction with other people.

It is now assumed that simulation processes that take place in the premotor cortex help us understand other people’s actions. “The behavior of others is translated into action goals there,” explains Wolfgang Prinz. “By acting out what other people do internally, we can understand it better than through logical comprehension. It is then possible to deduce from the internal simulation what a person is likely to do next.”

Natalie Sebanz, a former doctoral student of Wolfgang Prinz, was the first to study this imperceptible influence of such processes on our actions. Today, she conducts research into joint action with her own research group at Radboud University Nijmegen in the Netherlands. Sebanz designed a stimulus-response experiment for this purpose, which was carried out both by one person alone and by two people together.

The test subjects were presented with images of a hand that had either a red or a green ring on its index finger. Depending on the color of the ring, they were instructed to press a button on either their left or their right side as quickly as possible. An additional challenge was incorporated into the experiment in that the finger was shown not only wearing the ring in question but also pointing to the left or right. “The direction in which the finger is pointing is actually irrelevant to the test subjects, as they are supposed to react only
to the color stimulus,” says the researcher. However, it is impossible to ignore spatial information. This phenomenon is known as the Simon effect.

Thus, if the finger on the screen pointed left although the button to be pressed was on the right, this delayed the test subject’s reaction. “This effect was of interest in the context of social processes,” says Natalie Sebanz, “because it arises only when one person is responsible for both buttons.” If the test subject operates only one of the two buttons, the Simon effect disappears.

It emerged from Sebanz’s experiment that the effect returns immediately when a partner is positioned at the side of the test subject. “When the color stimulus tells me that it’s my turn, but the finger displayed on the screen is pointing to the person beside me, again, it takes me a moment longer to react,” explains Sebanz. The two people together acted like one person who had two hands to coordinate.

This is due to the fact that both participants not only had their own tasks on their minds, but also the element for which the other person was responsible. This phenomenon is known as co-representation: even if a task is involved in which it is more of a hindrance than not, you keep the other person on your radar – and constantly, at that. Even when it was not an individual test subject’s turn, their brain simulated the other person’s action.

Because the process of observing or imagining the other person’s action already activates the subject’s own motor areas for this action, an impulse arises to complete the action oneself. In order to prevent us from immediately imitating what we observe with others, this action impulse must be suppressed. It was possible to measure the increased brain activity necessary for this via EEG.

Natalie Sebanz suspects that co-representation may be of such fundamental importance for life in social groups that, over the course of evolution, it became automatic and etched in the human brain. “It is in our nature to cooperate with others.”

ALWAYS KEEPING THE ACTIONS OF OTHERS IN MIND

The Sebanz experiment created the basis for wide-ranging research on joint action. The effect of co-representation on shared tasks is now being examined from a number of different perspectives.

One of these concerns making music in a group. Studies carried out with the help of functional magnetic resonance imaging have now shown that simulation activity in the human brain is strongest if the actions we perceive in others also belong to our own action repertoire. For instance, if a sonata is played to both non-musicians and experienced pianists, the motor areas of the latter’s brains are significantly more active – they play along internally.

“Musicians that play in a duet or ensemble are a good example of complex and real-time coordination during joint action,” says Peter Keller, head of the Independent Junior Research Group “Music Cognition and Action” at the Max Planck Institute in Leipzig. Keller, who was born in Australia, comes from a musical family. His sister is a renowned jazz pianist back home and he himself studied both trombone and musicology. “During the many hours we practiced back then, it became increasingly clear to me that playing together is not merely a matter of mastering one’s own instrument, it is an elaborate form of social behavior.”

Bringing oneself in accord with other musicians is an extremely challenging process, explains Keller, because on the one hand, everything must be very accurately coordinated in terms of tempo, while on the other hand, musicians repeatedly deviate from regularity. “Otherwise, their playing would seem mechanical and devoid of individual expression.”

If they hold onto a note for a bit longer, spontaneously change tempo, or play louder or softer, everyone else in the group must adapt to these new departures. This necessitates permanent concentration on the part of the musicians – and in numerous respects: not only must each of the players pay attention to the sounds they produce, but they must simultaneously listen to those produced by the other players and monitor the overall sound. “This requires highly developed cognitive resources,” says Peter Keller.

In order to find out how musicians synchronize with one another and what kind of similarities and differenc-
es exist between various forms of joint music-making, such as piano duos, mixed-instrument ensembles and choirs, musicians are regularly invited to perform miniature concerts in the Leipzig laboratory. The focus in this research is on nuances that are barely perceptible for the most part. The researchers use electronic keyboards for their tests, as this allows them to obtain extremely accurate data on the duration and intensity of key strokes, and on the minutest asynchronies in the performances. These are always present and, on average, typically range between 30 and 50 milliseconds in good musical ensembles.

**EACH ONE IS THEIR OWN BEST PARTNER IN A DUET**

The scientists recently demonstrated for the first time that action simulation is also important for the temporal coordination of action. In the study, pianists each practiced one part of several duets that were previously unknown to them. A few months later, they were invited back to play the complementary second part. It was revealed that they could synchronize best with a recorded version of the first part if they had played it themselves.

“The simulated timing coincides best with the actual behavior if both are the product of the same cognitive-motor system,” says Keller. Each pianist was thus his or her own ideal duet partner. Moreover, as Keller and his colleagues observed, pianists playing duets manage to synchronize better with their partners the more similar their

The scientists record the minutest motoric nuances in the joint playing by attaching motion capture markers, usually used for lifelike 3-D animation, to the bodies of the musicians.
movements are while playing. The researchers measured the small differences in the forward and backward swaying of the upper body, which helps keep the player in time, by attaching motion capture markers – which are usually used for lifelike 3-D animation – to the musicians’ backs.

The researchers are currently investigating whether this link also exists for other instruments and larger groups. As a result, loud metallic rhythms can now regularly be heard emanating from their laboratory. Inside, music students from Leipzig can be found sitting in a semicircle on the floor playing Gamelan – a form of music particularly common in Java, Bali and Indonesia – which involves beating small pot-like bronze gongs.

As was the case with the pianists, the researchers also use motion capture techniques here to evaluate the subtlest nuances of movement later at the computer. “This way, you can see details that you might otherwise miss – for example, who orients themselves to whom within the group, who tends to lead the others when playing, and who adopts a subordinate role,” says Keller. It is interesting to note that such relationships often seem to emerge spontaneously. Precisely what lies behind this in cognitive terms is something he can only speculate about at this stage.

This is one of many questions about the social side of our brain that will be investigated in the near future. The researchers at the Max Planck Institute for Human Cognitive and Brain Sciences are studying, among other things, the conditions under which co-representation takes place and whether it is more pronounced if one person knows the other person involved. The scientists would also like to identify the point at which the idea of other people’s action arise in early childhood development.

INDUSTRIAL ROBOTS WITH KNOWLEDGE OF HUMAN NATURE

Although this work is currently classified as basic research, when the mechanisms of joint action are better understood, the outcomes will be of interest for many applied fields, including, for example, cognitive robotics. Researchers in this field have been working for some time on programming artificial social intelligence with a view to endowing industrial robots with soft skills and knowledge of human nature at some point in the future. Music and dance education could also benefit from such a development. And finally, the new insights could also provide a better understanding of disorders that affect people’s capacity for empathy, for example in the case of autism and certain brain injuries, and lead to the development of better approaches in future treatment.

GLOSSARY

Common coding
The theory of common coding states that perception and action are based on the same cognitive processes. This prompts the assumption that they are connected and can interact directly with each other.

Mirror neurons
Nerve cells that become active both when carrying out an action and when only observing an action. They were first described by Italian neurologists Giacomo Rizzolatti and Vittorio Gallese.

Premotor cortex
An area of the cerebral cortex that is responsible for the planning of actions.

Electroencephalography (EEG)
During an EEG, changes in brain activity are measured using electrodes, which are attached to the scalp.

Co-representation
The phenomenon whereby the actions of one person activate the same neurons in an observer.

Functional magnetic resonance imaging (fMRI)
An imaging process that renders visible the areas of the brain that become active for certain tasks and stimulus conditions.
Crying in a Foreign Accent

Babies, even newborns, make different sounds depending on their native language.

The wailing of French and German babies is not the same – right from the first days of life. This is the finding of a study by researchers from the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig, the Centre for Pre-language Development and Developmental Disorders at the University Clinic in Würzburg, and the Laboratory of Cognitive Sciences and Linguistics at the Ecole Normale Supérieure in Paris. The scientists compared recordings of 30 French and 30 German babies aged between two and five days. While the French newborns more frequently produced rising melodies, the German infants cried with a falling pitch. The reason for this is presumably the differing intonation patterns of the two languages, which the infants perceive while they are still in the womb and which they later imitate. The researchers believe that the evolutionary roots of this behavior extend back to long before the emergence of spoken language. The imitation of melodies developed over millions of years and, in all likelihood, plays a role in mother-child bonding in the first few days of life. (Current Biology, November 5, 2009)

A Switch for Atomic Bits

Fine work, indeed: Researchers at the Max Planck Institute for Microstructure Physics in Halle have found a way to manipulate the magnetization of single atoms. Using simulations, they established that single atoms can be switched from “spin up” to “spin down” with the tip of a scanning tunneling microscope simply by varying the distance between the tip and the atom. The magnetic moment of the spin acts like a tiny bar magnet. Depending on the direction in which its north pole points, a bar magnet, and therefore an atom, can store “0” or “1” for a bit. The work conducted by the Halle-based physicists thus represents an advancement in the area of spintronics. This technology works with the spins of electrons and not, as in traditional electronics, with their charges. It is hoped that the technology will enable the production of computers that are smaller, faster and more energy efficient. After all, electronic processes are slower than spin processes, and the bits are stored in tens of thousands of atoms. (Physical Review Letters, July 30, 2009)

A question of distance: With longer distances, the magnetic moment in the atom aligns itself parallel to the one in the tip of the scanning tunneling microscope (left). If the distance is shorter, it aligns itself in the opposite direction (right).
In the future, it might be possible for a diseased pancreas to very easily heal itself. Scientists at the Max Planck Institute for Biophysical Chemistry have stimulated insulin production in the pancreas of diabetic mice by switching on a single gene called Pax4. The gene launches a chain of signals that reprogram progenitor cells or cells with other functions so that they manufacture insulin. Just a few days after the researchers activated Pax4, new insulin-producing cells formed in the pancreas. Before this procedure can also help diabetes sufferers, the scientists must first find another switch that will halt the reprogramming. Without a stop button, too many insulin-producing cells would develop in the pancreas, which would then neglect its other duties.

Compared with a normal mouse (left), the researchers increase the number of insulin-producing cells in the pancreas significantly when they activate the Pax4 gene in mice.

**Closer to the Bubbling Ball of Gas**

The Sun is bubbling. Accumulations of gas rise and fall, giving the Sun its grainy surface structure, its granulation. Dark spots appear and disappear, clouds of matter billow upwards – and all of these phenomena are driven by magnetic fields. The SUNRISE balloon telescope, a joint project headed by the Max Planck Institute for Solar System Research in Katlenburg-Lindau with partners in Germany, Spain and the USA, has now provided images that show the complex interplay on the visible surface of the Sun in an unprecedented level of detail. The researchers used a helium balloon to lift the six-ton SUNRISE telescope to an altitude of 37 kilometers, where it collected data on the Sun’s magnetic field and the ultraviolet light that is absorbed by the atmosphere down below. The researchers want to use the images to explain the Sun’s activity in detail, in particular the connection between brightness and the strength of the magnetic field.

The grainy Sun: The images show the Sun’s granulation in four different colors in ultraviolet light. The section represents 1/20,000 of the total surface. The light structures are the basic elements of the magnetic fields.
Europe’s Rural Regions Are Damaging the Climate

Nitrous oxides and methane from farming are causing the climate balance in Europe to deteriorate drastically.

More greenhouse gases are rising over Europe than was previously believed to be the case. These include not only the carbon dioxide emitted by industry and traffic, but also methane and nitrous oxides. A group of European researchers working with scientists at the Max Planck Institute for Biogeochemistry in Jena has now drawn up a balance sheet that also takes these significant greenhouse gases into account for the first time. The gases are generated mainly by livestock breeding and intensive farming, and have an extremely negative impact on the European climate balance. Until now, Europe’s terrestrial ecosystems, including forests, grasslands and moors, were thought to act by and large as sinks for greenhouse gases.

However, the researchers have found that this is not the case. Although forests do indeed absorb 19 percent of the carbon dioxide that is released into the air, the cultivation of other types of land generates such large quantities of climate-damaging gases that this effect is nearly negated. And taken alone, the rural EU regions, not including the forests in eastern countries like Russia, actually have a negative impact on the atmosphere. (Nature Geoscience, November 22, 2009)

A Head Start for Energy Saving

Mammals’ brains work extremely efficiently. Neurobiologists at the Max Planck Institute for Brain Research in Frankfurt and the University of London have found that mammalian nerve cells need three times less energy to conduct signals than do the nerve cells of an octopus. The axon, the long fibrous extension of a nerve cell, transmits signals using an action potential that travels along it, briefly changing the voltage between the inside and the outside of the cell. Sodium ions flow through specialized channels into the cell and increase the membrane potential from minus 70 to plus 30 millivolts. The potassium ions flow out of the cell to compensate for the flow of sodium. The scientists have now established that the interaction of the ion flows in mammals saves considerable amounts of energy. The duration of the sodium flow and that of the potassium flow counteracting it hardly overlap: the sodium channels open. Thus, in mammals, far fewer sodium ions enter into the cell to create the action potential than is the case in invertebrates, such as octopi. As a result, the cell need not expend a lot of energy pumping them back again in readiness for the next action potential. (Science, September 11, 2009)
Blossoming in Old Age

Plants also flower on short dark days

It’s just a month away – higher temperatures and more hours of daylight will awaken life in the first spring flowers. But plants also know when it is time to flower without these signals. Max Planck scientists at the Institute for Developmental Biology in Tübingen have discovered a new signal path in the shoot cells of thale cress that allow the plants to bloom even if the prevailing conditions are unfavorable. The micro-RNA156 molecule prevents genes that are important for flower formation from being translated into proteins, thus stopping flower formation.

However, according to the developmental biologists in Tübingen, the concentration of micro-RNA156 decreases with age, meaning that the flowering genes can stimulate flower growth independently of external factors. This ensures that the plants do not wait forever for the ideal time to flower and miss their time to reproduce. (Cell, August 21, 2009)

Measuring with Small Atomic Clouds

Scientists at the Max Planck Institute for Quantum Optics in Garching and at the Ludwig Maximilian University in Munich have succeeded in making something good even better. They manipulated atoms on a special microchip, an “atom chip,” with microwave fields to construct an atom interferometer. An atom interferometer is a very sensitive piece of measuring equipment that uses the quantum mechanical wave properties of atoms. Two small clouds of atoms are laid one on top of the other, just like light waves in a traditional interferometer. These create an interference pattern that depends on the external forces acting on the atomic clouds. In this way, the atom interferometer can record rotational movement very precisely, in an airplane, for example, or measure the gravitational field of the Earth and thus possibly help in the search for raw materials. It can be used in many different ways on atom chips, as they are robust and compact. (Nature Physics, August 2009)

Ill-Informed about Cancer Screening

The benefits of cancer screening are overestimated in Germany. A Europe-wide study by the Harding Center for Risk Literacy and the market research company Gesellschaft für Konsumforschung revealed that most German citizens are not aware of the real benefits and risks of early cancer detection. Doctors and health associations recommend regular screening so that cancers can be detected and treated at an early stage. However, around 90 percent of those surveyed in Germany overestimate the benefits of mammograms for breast cancer screening and PSA tests for prostate cancer screening, making for a very poor showing in a European comparison. One reason for this could be misleading information brochures. The study showed that 40 percent of Germans regularly use these as sources of advice – twice as many as the European average. It is these individuals in particular who tend to overestimate the benefits of early detection. Furthermore, doctors in Germany are evidently not providing their patients with adequate statistical information regarding benefits and risks. (Journal of the National Cancer Institute, September 2, 2009)
It’s a favorite theme in many Hollywood movies: after meeting with an accident in the desert or the jungle, the hero walks in a circle as he searches for a way out, and ends up right back where he started. Researchers from the Max Planck Institute for Biological Cybernetics have shown for the first time in an experiment that this idea is not just the product of filmmakers’ imaginations.

The Sahara in Tunisia and an extensive woodlands region in the Rhineland served as test areas. In these environments, which lacked any prominent orientation points, most of the test subjects stopped walking in a straight line soon after setting off. “It really is like in the movies – some of the subjects crossed their own paths several times without noticing,” relates Jan Souman from the MPI in Tübingen. The subjects managed to walk in a straight line only when the sky was cloudless, orienting themselves based on the position of the Sun. The scientists were surprised at how helpless people obviously are without any external orientation aids. On average, a blindfolded person moves no further than 100 meters from their starting point. It appears that inaccurate directional information from the eyes, ears and balance organs are the reason why hardly anyone can walk in a straight line for more than 20 meters – and not because their legs are of different lengths or varying strength, as is widely assumed. (Current Biology, August 20, 2009)

Direct hit in the hunt for a planet: Researchers from the Max Planck Institute for Astronomy in Heidelberg have discovered and imaged a faint object in the sky orbiting the star GJ 758. Its mass is estimated to be between 10 and 40 Jupiter masses. This indicates that the find is either a huge planet or a brown dwarf, that is, a failed sun.

One thing is certain: At a temperature of around 330 degrees Celsius, GJ 758 B is the coldest companion of a sun-like star ever imaged. And it will probably get even colder. This is because GJ 758 B orbits its central star at a similar distance as Neptune, the outermost planet in our planetary system, orbits our Sun. Its surface must be similarly cold, namely around minus 200 degrees Celsius. This explains why the astronomers in Heidelberg assume that the newly discovered planet is still young and that its temperature will drop even further. (arXiv.org/abs/0911.1127)
Caught at the Border

Live observations reveal how immune cells infiltrate the brain in multiple sclerosis

Researchers at the Max Planck Institute for Neurobiology in Martinsried have caught immune cells in the act of penetrating brain tissue. Usually, the blood-brain barrier defends the central nervous system from the body’s own defense cells. In some diseases, such as multiple sclerosis, however, aggressive immune cells disregard it and pass through the special blood vessel walls that are supposed to protect the brain. The scientists have now observed this in detail, which will help in the search for therapies used to treat such diseases as multiple sclerosis.

The researchers marked T-cells, a special component of the immune system, with green fluorescent protein and observed them under a light microscope. First, large numbers of the immune cells attach themselves to the blood vessel walls; then they even begin to crawl along them against the blood flow, as if they were looking for a gap. T-cells have not been known to behave in this way before. After a period of time ranging from a few minutes to a few hours, some of the immune cells squeeze through the blood vessel wall. Behind the blood-brain barrier, the invaders continue their search until they encounter phagocytes, the garbage collectors of the immune system. Once in contact with these, the T-cells excrete inflammatory messenger substances that attract other T-cells and start the attack on the nervous system.

Two Genes, Few Scales

The mirror carp saves cooks a lot of work – at least since medieval monks succeeded in breeding a variant with almost no scales. Scientists at the Max Planck Institute for Developmental Biology in Tübingen have now revealed that, ever since, it has actually had two copies of the gene that provided its covering of scales before the monks’ intervention.

However, one of the copies mutated and can thus no longer contribute to scale formation. If the fish did not have a reserve gene to fall back on, it would not be able to survive, since the gene is responsible for more than just the formation of its scales. It also holds the blueprint for a receptor without which the fish embryo cannot develop. For reasons not yet explained, this copy is switched off as soon as the gene has carried out its vital tasks and before the scales grow. It appears that duplicating a gene also affects its regulation. Reserve genes also play a role when organisms develop new characteristics. They take over the old functions of the genes, while a mutated copy produces new characteristics. (Current Biology, October 13, 2009)

Tasty and almost scale-free: Thanks to a gene duplication, the mirror carp has only a sparse covering of scales.
Bringing the heavens to the lab is difficult. Setting up the heavens in the lab, on the other hand, is a bit easier. That’s exactly what researchers working with Andreas Wolf are doing. At the Max Planck Institute for Nuclear Physics in Heidelberg, they reproduce chemical reactions that take place in distant interstellar clouds.

TEXT THOMAS BÜHRKE

The Test Storage Ring (TSR) has been in operation at the Max Planck Institute for Nuclear Physics for some 20 years now. It is a racetrack of sorts, with a 55-meter circumference, on which charged particles race around, guided by magnets. Compared with its big brothers, such as the new super-accelerator LHC at the European particle physics lab in Geneva, the TSR is quite modest. But by no means is it ready for the scrap pile yet – quite the contrary. Equipped with sophisticated technology, the apparatus continues to deliver excellent measurement data.

A few years ago, for instance, physicists in Heidelberg used the storage ring to test Einstein’s theory of relativity with unparalleled precision (Max-PlanckResearch 2/2004, page 20 ff.). And for Andreas Wolf’s research group, the TSR has also been serving a very different purpose for several years: the study of chemical and physical reactions that lead to the formation of molecules in space.

The most productive chemistry labs in space are giant clouds composed of gas and dust. In photos, they make a very dense impression: they appear to be impenetrable, and attenuate the light of stars located behind them. Nevertheless, with an average of 10,000 particles per cubic centimeter, the densities are much lower than in a cleanroom lab on Earth. It is the clouds’ enormous expanse of several light-years that makes them opaque to light.

MOLECULES CONTRIBUTE TO STAR FORMATION

These clouds of gas and dust are the birthplaces of stars and the production plants of molecules. In recent decades, astronomers have discovered a great variety of molecules there. Today, they know of some 150 species, from simple compounds, such as the hydroxyl radical (OH), water (H₂O) and carbon monoxide (CO), to such complex organic substances as glycolaldehyde (CH₂OHCHO), a sugar, and ethylene glycol (HOCH₂CH₂OH). The search for glycine, the simplest amino acid and one of the basic building blocks of DNA, is running at full speed worldwide.

The interstellar molecules intervene in cosmic activities in various ways. For instance, in the formation of many molecules, energy is released in the form of radiation and discharged into space. This causes the cloud to cool down and contract further – a process that is necessary in order for the matter to ultimately be able to coalesce to form stars. This also raises the question of whether the organic molecules involved here played a causal role in the formation of life on Earth.

Molecules can form in space in two ways: for one, atoms and molecules accumulate on dust particles and react there with other atoms. For another, these particles collide with each other and aggregate in free space. “We are using the storage ring to study such gaseous-phase reactions,” says Andreas Wolf.
A glimpse of a delivery room for stars: Cold interstellar clouds – in this image the Eagle Nebula – are home to a complex network of chemical reactions. Researchers are trying to decode this network in their terrestrial labs.
At first glance, the idea seems paradoxical. Prevailing temperatures in the molecular clouds are around 10 Kelvin (minus 263 degrees Celsius), so that the atoms and molecules there move very slowly. In the TSR, however, the particles circulate at around 20,000 kilometers per second, which is about 7 percent of the speed of light. That is why a trick is needed in order to imitate certain interstellar reactions in the TSR.

What reaches the storage ring are positively charged ions – atoms or molecules that have lost an electron from their shell. One section of the storage ring contains an electron cooler. This is where electrons are fed in at a very specific speed. They accompany the ion beam for nearly two meters before being guided back out of the ring. In this electron bath, the particles collide and influence each other with their electrical forces.

As a result, ions that are faster than the electrons are slowed down, and slower ones are sped up. In this way, the particle speeds gradually align with one another. This happens for each revolution, or several hundred thousand times per second, until finally all electrons and ions are traveling at nearly the same speed.

**A COLD BEAM MADE UP OF A HUNDRED MILLION IONS**

If we imagine riding on one of the ions, the surrounding electrons would appear to be hardly moving at all. This is the same phenomenon we experience on the highway when two vehicles are traveling alongside each other at nearly the same speed. This almost negligible relative speed means, from a physics perspective, that ions and electrons together form a surprisingly cool gas – just like in an interstellar cloud at a temperature near absolute zero, or minus 273.15 degrees Celsius (0 Kelvin). For this reason, physicists also refer to it as a cold beam, which, in the TSR, can contain as many as a hundred million ions.

As if that weren’t enough, in the TSR, not only can ions and electrons be brought to the same speed, but they can also fly past each other at almost any speed. “We use this to simulate different temperatures at which the reactions take place,” explains Wolf. This is based on the physical notion that atoms and molecules move increasingly quickly as temperatures rise. However, the electrons are not only responsible for cooling the ion beam – they are simultaneously their reaction partners. In other words, in the TSR, Wolf and his colleagues do not reproduce just any reactions, but exclusively electron attachments. These, however, play an important role in the web of interstellar chemistry. A key position here is that held by the H$_3^+$ ion.

Theorists had long wondered what happens when an H$_3^+$ ion takes on a negatively charged electron. In a naive view, one would suspect that the two particles join to form a neutral H$_3$ molecule, because opposite charges attract. But it isn’t quite that simple. Whether an electron can attach or not...
depends on whether the electrons can take on an appropriate state in the attachment process.

Theorists concluded, following calculations of electron energies, that such a “gateway” does not open up for cold electrons at H$_3^+$, and the attachment process should thus occur extremely rarely in space. “Based on their observations, astrophysicists have long been skeptical about this statement,” says Wolf. That is why the Max Planck researchers in Heidelberg decided to study this reaction in the TSR.

**ENERGY CAUSES MOLECULES TO SPIN LIKE TOPS**

The experiment required the production of an extremely cold H$_3^+$ gas. Wolf’s colleague Holger Kreckel took on this task. He built a device that allowed ions to be trapped in an electromagnetic field. Then they were cooled with helium to temperatures found in space, and only then guided into the TSR. The result left no doubt: the experiments produced much higher attachment rates than predicted. What had the theorists forgotten?

When considering chemical reactions, one normally focuses on what happens in the electron shells of the participating atoms or molecules. In reality, however, there is more going on: when an electron approaching from outside begins to penetrate the electron shell of a positive ion, it has already gained kinetic energy. It must release this energy if it wants to remain in the molecule. The experiments permit only one explanation: a portion of this energy sets the molecule’s nuclei in motion, causing it to spin like a top. While the theorists were hesitant to consider this process, the results confirm its existence and, in fact, its crucial importance for the attachment of cold electrons.

The second thrust of the Heidelberg experiments is clearly evident here: not only astrophysics will benefit from the results, but also the quantum physics description of atoms and molecules. And it goes even further: As already mentioned, in the TSR, it is possible to set the speed difference with which electrons and ions fly past each other. In this way, it is also possible to define how much energy the electrons transfer to the ions upon attachment.

When Wolf and his colleagues then varied this energy within a certain range, they noticed that the attachment rate did not change continuously, but rather exhibited maxima and minima. Again, quantum physics provides the explanation: while a humming top can spin at any speed, a molecule can change its speed only stepwise – in quanta. Any time an elec-
tron carries precisely the right excitation energy for the rotation, the attachment rate increases.

Wolf’s experiments thus contribute to a complete quantum physics description of molecules. And a difficult one it is – already failing for even the simplest molecules, such as H$_2$+. However, the researchers attach such great importance to this that they have, in recent years, organized several conferences specifically on this topic.

WATER SUPPLIER FOR THE COSMIC NETWORK

But electron attachment has yet another consequence: it destroys the molecule. Since the approaching electron transfers to the nuclei most of the energy released when it becomes bound, the molecule splits. As a result, an H$_2$+ ion yields, for instance, an H$_2$ molecule and an H atom. The chemical composition of the products can easily be measured in the TSR.

Magnetic fields force the positively charged H$_2$+ ions into their orbit in the TSR beam tube. Fragments such as H$_2$ and H, however, are electrically neutral, so they don’t react to the field, and fly out of the storage ring. Last year, Wolf’s group installed a detector here known as the EMU (energy-sensitive multistrip detector), which measures the mass and momentum of the penetrating particles. EMU was created in collaboration with colleagues from the Weizmann Institute in Rehovot, Israel.

With up to a thousand “images” per second, EMU can now register the momentum and molecular mass of all products for individual dissociation reactions – a major technological feat. This data can be used to reconstruct the processes that occur when electrons are attached, and when the molecule subsequently breaks apart like balls on a billiard table.

Andreas Wolf and his colleagues used this method to study a number of attachment reactions. One of the most recent examples is the hydronium ion H$_3$O+. It is particularly interesting because, in electron attachment, it can decay into H$_2$O and OH, and is thus – at temperatures near absolute zero – one of the cosmic suppliers of water. The matter is complicated by the fact that it can also break into other fragments, such as OH plus two H atoms or O plus H plus H$_2$. This array of decay possibilities makes analyzing the EMU data a difficult puzzle. However, it can be solved. The result: in 20 percent of all decays, H$_3$O+ yields water.

What was surprising here was that the molecules are highly energetically excited. “In a sense, cold collisions create hot water,” explains Wolf.

MANY FINGERPRINTS, BUT NO MATCHING CULPRIT

These findings contribute to sky research in two ways. On one hand, the measurement data become parameters in computer models with which the complex network of reactions in interstellar clouds are calculated; and on the other, they serve to identify molecules. Astronomers detect them with the help of their spectra. Particularly in the infrared and radio range, the various species make themselves known through an abundance of emission or absorption lines at very specific wavelengths – they leave behind characteristic fingerprints, as it were.

Identification is possible only by comparing these lines with lab spectra. However, many lines still cannot be matched to any known types of molecules. Some of them could stem from highly excited molecules that are released upon cold electron attachment to a parent molecule. That, at least, is what the Heidelberg experiments show.
Furthermore, there are even implications for biology. A few years ago, a team of scientists from Canada and the US found indications that the carrier of genetic information, the DNA molecule, can break apart when it takes on electrons. Here, too, it seems that, for reasons related to quantum physics, certain energies are preferred. The TSR experiments confirm this hypothesis.

But the experiments at the Max Planck Institute for Nuclear Physics are not possible with such large biomolecules, because the TSR can store only ions with a maximum mass of about 40 atomic mass units (abbreviated u). For comparison, the \( \text{H}_2\text{O}^+ \) ion has 19 u, and ethylene glycol \((\text{HOCH}_2\text{CH}_2\text{OH})\) already comes in at 62 u. Andreas Wolf wants to overcome this mass limitation with a new storage ring. The cryogenic electrostatic storage ring (CSR) will be more compact than its predecessor, with a circumference of 35 meters. But what really makes it stand out is its ability to cool to 2 Kelvin using liquid helium. This will make it possible to store molecular ions with larger masses, up to biological macromolecules. Cold electron attachment experiments will be possible for molecules measuring up to 160 u – not for DNA, but amino acids are well within reach.

A test facility has already made sufficient progress that it can be used for simple quantum physics experiments. Wolf anticipates the “first beam” in the cryogenic storage ring in 2012. Then, with special detectors, it will also be available to other groups from the Heidelberg-based institute for their experiments. With its helium cooling, the CSR has one thing in common with the LHC in Geneva. “We approach the technological challenges on the scale of this facility with targeted developments and step-by-step component testing,” says Andreas Wolf.

The physicists in the Stored and Cooled Ions Division can thus continue contributing to a better understanding of the complex field of astrochemistry, uncover fundamental quantum physical aspects of molecules, and aid in the search for reliable theoretical models.

GLOSSARY

Electron
An elementary particle with a negative charge. In atoms and molecules, electrons form the outer electron shell and govern chemical reactions.

Ion
An atom or molecule that has lost or gained one or more electrons and is thus electrically charged, either positively or negatively.

Opacity
Opacity (adjective: opaque) is a measure of a material’s transparency. The greater the opacity of a substance, the less light is able to penetrate it and the cloudier it appears. In space, this cloudiness is apparent primarily as interstellar gas and dust clouds.

Proton
One of the building blocks of atomic nuclei, with a positive elementary charge. It consists of three quarks and is around 1.800 times heavier than the electron.

The research program came about through the close collaboration between Dirk Schwalm, as the Director of the heavy-ion physics division at the Max Planck Institute for Nuclear Physics until 2005, and Daniel Zajfman, as head of his research group at the Weizmann Institute of Science in Rehovot, Israel. It is based on the collaboration of many former and current members of the working group. Klaus Blaum’s Stored and Cooled Ions Division, which was established in 2007, creates the ideal conditions for this research field and is expanding its options by building the cryogenic storage ring (CSR).
Dragnet Investigation in the Virus Kingdom

Computing power is emerging as an indispensable weapon for scientists engaged in the fight against influenza. Experts working with Alice Carolyn McHardy from the Max Planck Institute for Informatics in Saarbrücken are developing software that detects, in viral genomes, suspicious patterns that betray the presence of the next trigger of a global flu epidemic – even before the next flu season has begun.

TEXT TIM SCHRÖDER
During the cold winter months, a sneeze on an airplane or a cough on a train is enough to make us all think of the flu. And since spring 2009, a new pathogen has been traveling the world, accompanying people by air and sea from America to all other continents. It even made newspaper headlines in fall 2009: the new H1N1 virus.

By mid-January 2010, 22,000 people around the world had died of the infection commonly referred to as the “swine flu”. Just how many people have been infected is anyone’s guess. What is certain, however, is that H1N1 has presented humanity with the first case of global influenza, the first pandemic of the 21st century. And yet, up to now, the virus has proven relatively harmless: in 1918, a predecessor of the new H1N1 virus was responsible for the deaths of almost 50 million people. That pandemic went down in history as the Spanish flu. Strangely, this strain of the virus mainly claims the lives of strong young people, while the old and weak tend to remain unharmed.

**FLU VACCINE DEVELOPMENT – A RACE AGAINST THE CLOCK**

For a long time, doctors had no explanation to offer for this. It was not until a few years ago that researchers were able to observe a similar phenomenon in monkeys. The pathogen clearly allows the immune system to “boil over.” If a person is infected, his or her immune response releases an excess of infection messengers – inflammation-promoting substances that are supposed to help
fight the pathogen, but that attack the body’s own tissues in the process. The immune systems of strong young people, in particular, simply produce too much of a good thing here.

Scientists are now very familiar with the flu virus. It has long been classified into different groups that can be clearly differentiated on the basis of genetic characteristics and typical protein structures. Large volumes of vaccine are produced against human flu viruses every year, with the intention of protecting against infection. However, sometimes the viruses mutate so rapidly and unexpectedly in some corner of the world that humans are unable to act against them in time. A new pathogen that is not targeted by existing vaccines spreads quickly. The fight against flu viruses is thus, above all, a race against the clock.

Will the scientists succeed in tracking down a new virus variant in time before it establishes itself globally in the next impending flu epidemic? Only then can manufacturers adapt the vaccines to the new pathogens before they trigger a major flu epidemic. The researchers usually win this race. Around every four years, however, the viruses outpace them.

The scientists from the Max Planck Institute for Informatics are thus arming themselves with computing power in the war against the flu virus. The experts working with Alice Carolyn McHardy are developing software that specializes in extracting secrets from the genetic material of viruses and bacteria. One aim of the bioinformaticians is that computers will one day be able to detect, in viral genomes, suspicious patterns that betray the presence of the next trigger of a global flu epidemic – even before the next flu season has begun.

WHICH GENETIC CHANGE MAKES THE VIRUS DANGEROUS?

There are three types of influenza viruses: types A, B and C. The most significant are the influenza A pathogens, as these cause the major pandemics. For influenza A, there are many dozens of different flu virus strains that circulate among birds, but also among pigs. Occasionally, a virus emerges from these animal viruses that makes the transition to humans, like the current swine flu virus. The normal human flu viruses, in contrast, continue to develop from year to year, particularly in Southeast Asia. From there they spread throughout the world just in time for the annual flu season.

A flu virus is like a prickly ball whose spines are formed by the protein hemagglutinin. At the tips of the spines is a kind of lock structure at which the virus can deliberately dock onto the surface of animal and human cells. Whether or not the structures on the cell surface fit into the virus hemagglutinin and thereby gain entry into a cell depends primarily on the fine structure of this binding site. Should the two parts find each other, the disaster takes its course. The membrane of the host cell opens and the virus slips into the cell and releases its genetic strands in the interior of the cell.

The virus reprograms the cell into a compliant zombie and the cell becomes a virus production site. It obediently synthesizes virus components that are then combined to form hundreds of new viruses. At this point, a second important virus protein, neuraminidase, becomes active. The neuraminidase opens the cell membrane in such a way that the freshly produced viruses can pour out like soldiers from a troop carrier.

Viruses can carry different variants of the hemagglutinin (H) and neuraminidase (N) proteins on their membranes and are classified accordingly: H1N1 or H3N2, for example. But how do viruses from pigs transform themselves into potent human pathogens? First, through changes in their genetic material. Viruses replicate at breakneck speed. After just a few hours, infected cells release millions of new viruses. The genome must be duplicated for each new virus generation. Errors frequently arise in this process. Some genetic components (the bases) are copied incorrectly during the reading of the genomic template. Such mutations are occasionally fatal to the virus itself. Sometimes they are irrelevant. From time to time, however, the virus becomes really dangerous as a result of this process.
Moreover, another characteristic of the flu viruses gives them an extraordinary capacity for adaptation: their genome is not composed of a single strand, but is cleanly packed in eight individual packages called segments. Like suitcases at an airport, it is entirely possible for such packages to become mixed up. This can happen if a cell is simultaneously infected by two viruses – a human virus and a pig virus, for example. Both viruses pour their genomic segments into the cell – a total of 16 segments that are replicated at breakneck speed.

A DENSE SEARCH GRID

From time to time, the following sequence of events unfolds: During the assembly of the new viruses, the reproductive apparatus steers a segment from the wrong virus into the offspring. This mixing of the genetic material is known as reassortment. This may well have occurred with the swine flu: different viruses contributed segments to the new virus and this changed its characteristics in such a way that it became an agent of disease that is also transmitted between humans.

When the vaccine developed against the H1N1 virus is administered, the body produces antibodies that recognize and block the hemagglutinin on the virus. The virus can no longer dock onto the cells, and the infection is halted.

Researchers are constantly on the lookout for genetic changes in influenza A viruses that could pose a threat – not only in the new H1N1 swine flu virus, but also in the other known suspects, such as the classic human H1N1 and H3N2 viruses. The global search grid is dense. Blood samples are regularly taken from patients at 112 institutions and clinics in 83 countries on behalf of the World Health Organization (WHO). They are then genetically analyzed and sent to four large flu centers.

Every six months, a committee of experts convenes to examine the latest genetic analysis data to detect suspicious mutations or even reassortments. The experts try to identify from the gene sequences how the virus’ form, its proteins, the hemagglutinin and the antigen will change to enable the virus to circumvent the current vaccine. They try to predict what form a new vaccine that will help fight such a virus should take if the virus in question were to pose a threat. Accordingly, the vaccines are developed on an ongoing basis and adapted to the modern influenza A types. But this does not always work.

“Up to now, the exact links between the genetic changes and the emergence of a new flu strain have not been fully understood,” says Alice Carolyn McHardy, head of the Independent Research Group Computational Genomics & Epidemiology. “For example, why do some reassortments cause viruses to trigger the illness, while others do not? Does this require other genetic characteristics?” In an attempt to find answers to these questions, McHardy has transformed the computers in her office in Saarbrücken into prognosis tools whose task it is to unravel the complex interactions at work here.

She uses statistical learning techniques for this purpose. “These methods are able to relate the most wide-ranging data sets with each other and to track down hidden connections between them.” To begin with, the learning method is fed with known data, such as the genetic information from viruses that triggered flu epidemics in the past. To this is added the information about when and where the virus showed up or the form taken by the protein structure of the hemagglutinin. Based on a process akin to a dragnet op-

[Diagram of the influenza A virus showing the various proteins and their functions.]
The computer then produces numerical values that answer the following questions: To what extent do the new gene sequences resemble the structures of a successful virus? How likely is it that there will be an outbreak of the disease?

McHardy uses support vector machines (SVM) and other statistical learning techniques for this work. These transform information into data points: numerical values that hang like stars in the firmament of a vast number space. When new data is entered into the system, the SVM assigns the new values to the floating numbers – the closer they are to a trained value, the more similar the data.

The Saarbrücken-based researchers are as yet unable to provide current forecasts for the new flu season, as the programs are still being optimized. Nevertheless, when McHardy recently entered the data for a well-known flu virus into the SVM for test purposes, it duly responded “very likely to be infectious.”

“But we don’t just want to find out whether a new virus variant will become established in the future and become the flu pathogen of the season,” says McHardy. “We also want to be able to forecast when this will happen.” The WHO experts are currently trying to predict for one year the new virus strain that will dominate and thus spread throughout the world as the agent of...
Fighting the flu with computer power: The scientists from the Computational Genomics and Epidemiology research group on their quest for the trigger of future flu epidemics. Back row, from left: Christina Tusche, Kaustubh Patil, Johannes Droege; front row, from left: Lars Steinbrück, Alice McHardy and Sebastian Konietzny.

the disease in the ensuing flu season. They currently miss this target in one out of four cases. When this happens, a different variant of the virus becomes established than the one they expected, and then there is no well-matched vaccine available for it.

McHardy’s goal is to increase the reliability of this annual forecast. Flu arises in the northern hemisphere primarily from November to February, when weather conditions are cold and damp. In the southern hemisphere, people are affected by the illness in the southern winter months, between May and October. Such data are also fed into the SVM and other learning methods to be able to understand the viruses. McHardy has no doubt that it will one day be possible to produce a more reliable forecast. The software program Geno2Pheno, with which doctors can determine how quickly resistance to AIDS drugs develops, was already developed at her institute (MaxPlanckResearch 4/2005, p. 21 ff.).

Moreover, McHardy has an abundance of computing resources to draw on in her work, as GISAID, the world’s largest virus gene database, is located in the cellar of the institute. For a few years now, researchers from all over the world have been feeding the results of the genetic analysis of influenza viruses into this database, which other researchers can access free of charge. “It makes complete sense to pool the data about the viruses, as this helps us to understand their nature as a whole,” says McHardy. “Viruses are small with a very manageable genome. Researching causal relationships with them is thus a straightforward matter.”

Viruses are one of McHardy’s interests. The other is the genome of bacteria, which she also aims to decode with the help of support vector machines and related learning processes. The researcher specializes in imposing order on metagenomes – a wild mixture of genetic sequences identified from a variety of different microorganisms. A metagenome does not represent the genetic material of a single individual, but of many organisms – sometimes even thousands of them. But what is the point of studying this chaos?

THE SEARCH FOR SUPERPROTEINS

It is a known fact that extreme habitats, such as hot springs, for example, spawn special life forms – for instance, bacteria that can thrive in water as hot as 120 degrees Celsius. Scientists and industry expect that studying these bacteria will give rise to new substances, such as heat-resistant proteins. These could be used, for example, in the production of cosmetics or foodstuffs, namely for production processes that require high temperatures. For this reason, scientists are now searching on land and at sea for such extraordinary new microbes.

The simplest solution would be to be able to breed the unicellular organisms in the laboratory and investigate them thoroughly there for new substances. However, many bacteria do not thrive in test tubes. Researchers have thus been rolling up their sleeves for some time now, collecting soil samples by the shovelful and immediately analyzing the entire genetic material of the microbial inhabitants. The hope is that promising genes will be found that contain information about new superproteins.

The problem, however, is that metagenomic analysis usually provides thousands of minute genetic fragments, of which only a few can be assigned to an organism. This is where McHardy’s method, which the researcher has already fed with the genetic fragments of known bacterial groups, comes into play. In this instance, the support vector machine was trained especially in a characteristic of the bacterial genome: short, recurring sequences of bases, known as oligomers, such as the base sequence ACTGAT. Interestingly, certain oligomers are characteristic of the genome of different bacterial groups, just like a fingerprint.

These oligomers arise not only in one, but in several locations of the DNA
DIGESTION WITHOUT ANY METHANE EMISSIONS

This process is called “binning” and involves the assignment to the correct bacterial group – the respective “bin” – fragment by fragment. In some cases, the statistical learning method can allocate up to 90 percent of the genetic fragments correctly based on the oligomers. How well the method works depends, ultimately, on the volume and quality of the training data. The computer scientists in Saarbrücken only occasionally achieved values of between 30 and 40 percent.

Among the most intriguing metagenome studies in which Alice Carolyn McHardy has participated is the analysis of bacterial communities from the intestines of termites and digestive systems of the Australian wallaby, a bush kangaroo. Both species digest wood and release hydrogen, the molecule that humans aim to one day exploit on a mass scale in the production of fuel cells.

The distinctive feature of the digestive process of these insects and mammals is that, unlike bovine digestion, almost no climate-damaging methane gas is released during hydrogen production. If scientists could succeed in imitating this process in the laboratory, it may be possible to develop a completely new environmentally friendly method of hydrogen production.

The results of the analysis are promising. McHardy’s SVM was able to assign the crucial metagenome fragments to different microorganisms. As a result, it is now known which bacteria in the animal intestine participate in the miracle of climate-neutral hydrogen production – and, moreover, which proteins and metabolic processes lead to hydrogen.

“Work is now being carried out to identify from the samples the microorganisms that are involved, and to analyze them further,” says McHardy.

The metagenome analysis is still in its early days. Many habitats have thus far been studied only at a very basic level. “And we always need some preliminary knowledge to train our methods,” says the Max Planck researcher. “But the advantage of the SVM method is that its training requires only small volumes of data,” she adds. And McHardy has already shown what can be achieved. The search for the secrets contained in genome sequences continues. Thanks to the hunt in extreme habitats, such as the Arctic, where bacteria thrive in minus temperatures, metagenomics is gaining in significance. And thanks to bioinformatics, some other new, out-of-the-ordinary discoveries are bound to soon join the wallaby intestinal flora.

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Magic Spheres from Oil and Water

As vehicles for drugs, in dyes, or for the manufacture of data storage devices – the nanospheres and nanocapsules that Katharina Landfester and her fellow scientists at the Max Planck Institute for Polymer Research produce promise a variety of applications. This was made possible only by fundamental insights into the way they are made.

TEXT PETER HERGERSBERG
When Katharina Landfester held a small glass of the milky fluid in her hand for the first time, she had no idea what was in it. A mixture as unremarkable as its name and sharing more than just its appearance with milk sloshed around in the vessel. It was a miniemulsion, of which milk is a very good example: tiny droplets of fat are dispersed in a large amount of water and kept afloat by proteins and fats, among other things.

But a miniemulsion from Katharina Landfester’s laboratory does more than milk can. The chemist’s team produces ingenious nanospheres and nanocapsules from their droplets, constructing vehicles for many things: the particles could transport drugs specifically to tumors, or mark diseased tissue in order to make it visible in computer tomography. They could also help pack data onto memory chips at higher density.

The history of the multifunctional particles began in 1997. Katharina Landfester was then a junior researcher working with colloids: nanoscale or microscale particles or droplets that float in a different medium. “At that time, I wanted to study abroad to gather ideas for my research,” says Katharina Landfester, now Director at the Max Planck Institute for Polymer Research in Mainz: “But there are not many places in the world for colloid chemists to go.” So she went to work with Mohammed El-Aasser at Lehigh University in Bethlehem, USA.

In the 1970s, the Egyptian chemical process engineer was the first to produce miniemulsions in order to open up a simple route to obtaining fine dispersions: mixtures that contain very small particles in a liquid medium, just like wall paint or printer ink. El-Aasser mixed the starting materials for polymers into the oily phase and allowed them to react in the miniemulsions to form polymers, which immediately assumed the form of nanospheres. But he had actually wanted to produce just simple spheres, and spheres that consisted of a single type of polymer.

In conventional emulsions, in which the chemical industry has already been producing little polymer spheres for decades, the possibilities are also limited. Only simple particles, barely smaller than one thousandth of a millimeter, are created in those emulsions, and their size also frequently varies greatly. It is not possible to encapsulate any kind of freight in such oil-water mixtures because the starting materials of the polymers quickly escape from the droplets, which serve as chemical reactors.

NANOPARTICLES WITH OPENERS, ANCHORS AND STEALTH EFFECT

In the miniemulsions mixed by Mohammed El-Aasser’s group, however, the droplet-shaped nanoreactors stayed tightly sealed. Katharina Landfester thus sensed quite early on that it also had to be possible for them to create more complex chemical constructions. But she never dreamed back then that they would be able to make many of nanotechnology’s promises a reality. It is not possible to encapsulate any kind of freight in such oil-water mixtures because the starting materials of the polymers quickly escape from the droplets, which serve as chemical reactors.

The researchers headed by Katharina Landfester equip the particles with an opening mechanism, provide them with an anchor for certain cells, or a stealth layer, so that the particles can move though the body unhindered. The particles owe these special accesso-ries to a variety of chemical tricks that the polymer researchers use. But this was made possible only by the fundamental insights Katharina Landfester gained as head of a research group on miniemulsions under Markus Antonietti, Director at the Max Planck Institute of Colloids and Interfaces.
The miniemulsions of the first generation were not suitable for producing a large number of different polymer particles. When the chemists changed their composition, the oil droplets on the water merged to form a layer of oil before the polymer had formed. And when they did stay stable, this was just a matter of chance. At least that is how it appeared. “This made it clear that we had to take a close look at the physical-chemical processes in the miniemulsions,” says Landfester. If these were understood, she thought, it might be possible to specifically select the composition of the miniemulsions so that multifunctional nanoparticles could be produced.

When she explains these connections today, she starts with the factors that keep milk homogeneous: it begins with the proteins that enclose the fat droplets. They act as a surfactant, just like a detergent, which prevents the droplets from merging. Nevertheless, the cream quickly separates out in milk that comes fresh from the cow. Some of its fat droplets are large, and due to their low density, they rise and form a layer of cream. The milk is therefore homogenized: it is sprayed onto a metal plate so that the fat droplets split to form smaller spheres. These are so small that their buoyancy is no longer sufficient to move them to the surface.

The chemists from Mainz homogenize their miniemulsions with an ultrasonication tip. This is routine work for Anna Musyanovych. She heads the group working on chemistry in miniemulsions. The lab specifically equipped for this purpose houses several metal cabinets, each one about the size of a wall cupboard in a kitchen. Anna Musyanovych fixes little glass vessels containing a mixture of oil, water and a surfactant under the ultrasonication tip in such a way that it hangs just above the bottom of the vessels. With a hissing sound and vibrations that are not very strong but very fast, the ultrasonication tip breaks up the oil droplets into nanodroplets.

STABILITY FOR TINY DROPLETS

But surfactant and droplet size are not enough to keep an emulsion stable over several hours, or long enough to produce polymers in them. The miniemulsion becomes stable only with the addition of a co-stabilizer: a substance that dissolves almost exclusively in the oil droplets. “I had already assumed that this reagent would have some kind of effect,” says Katharina Landfester.

And indeed she discovered that these ominous substances acted as osmotic reagents – if they were chosen correctly. In milk, certain fats also act like osmotic reagents. The ones that do this are insoluble in water. Landfester discovered this after studying the processes that slowly separate oil and water in an emulsion. In addition to the contacts between the droplets that the surfactant prevents, Ostwald ripening also contributes to this: larger oil droplets grow at the expense of smaller ones. “In small droplets, there is a higher internal pressure,” explains Katharina Landfester: “We see a similar thing when blowing up a balloon: it’s more difficult to inflate while it’s still small.” The oil escapes the pressure in the smaller droplets by diffusing into the larger droplets through the water.

The diffusion of the oil molecules can be prevented with a counter-pressure – and this is precisely what the osmotic reagent that is dissolved in the oil droplets builds up. Since nature always tries to achieve equilibrium, the reagent feels best when it is present in all droplets at the same concentration. Otherwise, osmosis occurs.

Katharina Landfester again uses an example from everyday life to explain osmosis: “As long as lettuce is in water, it stays crisp. It collapses in the vinaigrette because the ion concentration in the vinegar is higher than in the lettuce leaf.” In order to achieve equilibrium of the concentration, water seeps out of the lettuce. Something
similar would happen in a miniemulsion if the osmotic reagent were to concentrate in a shrinking droplet while diluting in a growing one. The Ostwald ripening is thus finished before it has really begun.

“When this became clear, we were able to produce miniemulsions using the starting materials for many different reactions,” says Landfester. The possibilities for chemical nanotinkering now knew almost no bounds because the miniemulsions provide almost everything the plastics industry has to offer: polyacrylate, used in acrylic glass, for example, polyurethane, used as foams for insulating houses, polyester, nylon and biodegradable polymers such as starch, and even semiconducting polymers.

If the researchers create nanoparticles out of two polymer materials that do not mix, even so-called Janus particles are formed, which have two polymer faces. “Nanoparticles like these can result in coatings that possess the properties of both materials,” explains Anna Musyanovych. Or they combine two semi-conducting polymers for a solar cell.

Katharina Landfester’s team of chemists started to use the great variety of polymers that could now be produced in the miniemulsions to encapsulate dye pigments, such as carbon black particles. “We mix them into the oily liquid with the ingredients of the polymer material,” explains Anna Musyanovych. The researchers then trigger the formation of the polymer, which encapsulates the pigments. Some manufacturers of printer ink are already using this method to prevent the pigments from agglomerating. Their inks then produce images that have a better resolution, and that do not smudge.

“So we thought: if it works with pigments, it should also work with magnetite,” says Landfester. A patient must be injected with a contrast agent in the form of nanoparticles containing ferromagnetic materials. It is difficult to study polymer spheres in the electron beam, however, because it destroys the polymers more or less quickly. Ingo Lieberwirth’s microscopy team is one of the few in the world that specializes in the microscopy of soft matter. This requires throttling the beam of electrons down to an extremely low intensity. They also fix the polymers so that they can withstand the electron beam for a longer time.

However, two disadvantages remain: Electron microscopes provide images of only a few particles. Moreover, the particles must be dried or frozen in their dispersion. In order to observe the particles in their natural medium, the researchers in Mainz must use complementary methods (see box on p. 64). The microscopy group is thus working on using high-resolution laser scanning microscopy (STED) for polymers.
specific body cells. They therefore encapsulate the contrast agent in a polymer capsule with chemical hooks protruding from its surface. The antibodies can then adhere to these.

A LAYER THAT MAKES THE PARTICLES HYDROPHOBIC

The packaged particles of magnetite also need a stealth layer so that the immune system guards do not fish the foreign particles out of the blood vessels on the way to their target cells. The cornucopia of polymers also provides the researchers with a suitable material: polyethylene glycol, PEG for short, which does not set alarm bells ringing in the immune defense system. The researchers then also stir constituents with PEG appendages into the magnetite packaging mix. The finished particles now not only carry hooks for the biochemical address labels, but also camouflaging PEG chains.

There is only one problem with the idea of ingenious multifunctional packaging for the magnetite particles: the particles initially oppose any type of polymeric capsules. If Anna Mus-
Yanosynych were to mix them with oil, water and the other constituents, they would then float only in the aqueous part and not in the oil droplets: magnetite clearly prefers to spend its time in water. “We must therefore hydrophobize the magnetite particles,” says Anna Musyanovych. The chemist reverses the preference for an aqueous environment into a preference for an oily environment by first surrounding the magnetite particles with a film of oleic acid before packing them into the multifunctional capsule.

If the nanoparticles allow themselves to be specifically sent to particular cells, it stands to reason that they could also be used as drug carriers. But active substances that are encapsulated in solid polymeric spheres are of no help here. They really need to arrive at the place they are to do their work in liquid form. And there is the additional point that some contrast agents for magnetic resonance imagers are available only in liquid form. “Our next thought was thus to encapsulate a liquid,” says Katharina Landfester. And an aqueous one, if possible, because the capsule contents with a dissolved active agent should ultimately mix with the aqueous medium of the cell interior.

At that time, the researchers already had a solution ready by which to create polymers in droplets of water: the inverse miniemulsion. It consists primarily of oil containing floating droplets of water. The starting materials of the polymer that form in the droplets must now dissolve in water instead of oil. And there are plenty of these substances around, as well.

AN ORDERLY WAY TO BUILD DATA STORAGE SYSTEMS

When the chemists want to equip the water droplets with a solid capsule, they are also helped by the fact that many polymers precipitate out of the liquid as solid particles as soon as they are formed. This does not usually occur at the edge of the droplet, but as minute polymer grains in the interior of the liquid droplets. But the rich diversity of chemistry provides a helping hand here: some polymers are formed from one constituent that dissolves in the aqueous liquid, and another that prefers an oily environment. The two come together to form a polymer chain only at the boundary of the liquids – in other words, at the edge of the droplet, so the growing polymer forms a capsule all by itself.

This capsule can thus be used to smuggle an active substance into, for example, a tumor cell – all that is missing is an opener to release the agent. But of course chemistry has a solution for this problem, too. In fact, it has several, depending on whether the capsule can be opened through an increased temperature, through a change in the acid-base properties of the surroundings, by enzymes or by UV light. The chemists working with Katharina Landfester provide the polymeric capsules with simple, predetermined chemical breaking points that release the contents when the appropriate mechanism perforates the capsule.

The development of the magic spheres has so far gone more or less according to plan. “One way or another, all the stages have usually worked just as we thought they would,” says Katharina Landfester. There was only one point when it almost looked as if a project would fail. “We wanted to use nanoparticles for nanolithography,” explains the researcher. The chemists tried to use nanocapsules to produce nanodots of a metal salt on a substrate, namely in a regular pattern that forms by itself. Such metal salts can be transformed into metal spots that could be used for data storage.

But the particles did not initially display any noticeable sense of order: “We first formed nanocapsules with a metal salt solution,” explains Landfester. The capsules formed a regular pattern on a substrate, but as soon as the researchers dried them out, the salt did not deposit in an orderly pattern. The result was the same for the attempt to encapsulate metal salt in polymeric material, distribute the filled grains over the surface and then etch away the polymer with a plasma beam. “In the beginning, nothing we tried
Many keys, easy access: The more functional groups the fluorescent nanoparticles carry, the easier it is for them to gain access to the cells. From left to right, their proportion in the shell increases from 0 to 10 percent.

worked out,” recalls the chemist. But the researchers then dissolved the salt in the polymer material. Now, when they removed the polymer using the plasma beam, the spheres shriveled up like shrinking balloons until finally – precisely in their center – the spots of metal were left behind. The chemists now control their size via the amount of salt in the polymer, and the distance between them via the size of the polymer spheres.

They can now conjure up all sorts of capsules and particles for different purposes. Simple capsules could slowly release perfume in washing powder, or biominerals in toothpaste to regenerate damaged tooth enamel.

POISONOUS PARCELS FOR TUMOR CELLS

For doctors at the university hospital in Ulm, the chemists in Mainz have prepared more complex nanocapsules that could help heal damaged tissue. The nanocapsules contain substances that stimulate the stem cells to differentiate. The doctors smuggle stem cells and nanocapsules into the diseased tissue, where the nanovehicle’s load stimulates the stem cells to form healthy heart tissue. As part of the same project, the Mainz-based chemists have also packed fluorescent substances and magnetic contrast media into nanoparticles that penetrate into the stem cells. The doctors in Ulm use suitable microscopes and MR imaging methods to enable the particles to show them the route the stem cells follow in the tissue.

Katharina Landfester’s team has designed a container for active substances for biotechnologists at the University of Stuttgart. The container is designed like a hazelnut and could fight breast tumors. Its core is formed by a nanoparticle whose surface is coated with a strong toxin. The chemists encapsulate the core and address the toxic parcel to the cancer cells using appropriate antibodies so that it attacks only the tumor – but this it does with that much more vigor. Healthy cells are largely spared by the poison. The pharmaceutical industry would have to develop the active substance container further for it to become a marketable drug. “In my view, people here have become less willing in recent years to take risks involving approaches that are still at the basic research stage,” says Katharina Landfester.

Maybe particles from several capsules will also be used in genetic engineering, or even in gene therapy. Such particles could serve as a vehicle for DNA or RNA. The outer shell could carry the door opener for the cell, while the inner shell could give the particles access to the nucleus. The colloid researchers are working with researchers from the University of Mainz to investigate the best way to smuggle genes into the genome. They are currently studying what form the surfaces of the particles must take in order to penetrate into the nucleus.

A similar problem confronts them in their attempts to smuggle nanoparticles through the blood-brain barrier. These physiological barriers protect the central nervous system from invaders and also prevent most drugs from gaining access. This is why many potential drugs for the treatment of nervous diseases are thwarted here. The polymer researchers in Mainz are now doing all the fine-tuning they can to provide their particles with the means to access the brain. Katharina Landfester suspects that, here too, the surfaces of the particles are key.

“I do think we should take another close look at the chemical details of the blood-brain barrier,” she says. Medical researchers have concentrated too much on the system as a whole, she thinks. She therefore wants to approach this problem from the same point of view that once revealed the potential of the miniemulsions – namely the point of view of the colloid chemist.

GLOSSARY

Miniemulsion
A mixture of oil and water in which droplets of one liquid float in the other in a fine dispersion. Unlike conventional emulsions, ultrasound tears the droplets apart and makes them a fairly uniform size on the nanoscale. Moreover, the miniemulsion is stabilized by the osmotic reagent: a substance that dissolves almost exclusively in the droplets and prevents larger droplets from forming at the expense of the smaller ones.

Polymers
Includes all synthetic materials. They consist of chain-like or reticular molecules comprised of building blocks of a mono- mer, or sometimes different monomers. They are distinguished by their starting materials and their chain type.

Surfactant
A substance whose molecules have a water-soluble and an oil-soluble end.
Würzburg´s new top location...
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Sylvie Röke cycles in the foyer of the Max Planck Institute for Metals Research for demonstration purposes only, but she loves cycling in the Swabian hills and dales around Stuttgart.
Diving into Surfaces

The experiments for her doctoral studies did not work out quite as planned the first time around. After switching gears and continued work, however, Sylvie Roke opened up a completely new perspective on soft matter. At the Max Planck Institute for Metals Research, she also uses this method to investigate potential new drugs and biological materials.

A PORTRAIT BY UTA DEFFKE

Sometimes it is the small, everyday things that still hide big secrets. Take some oil, for example, and pour it into a bowl of water. The two liquids won’t mix, as everyone knows from an oil and vinegar vinaigrette. Only a vigorous shake makes the oil floating on top disperse into the water in the form of fine droplets. Chemists call this an emulsion. We encounter these everywhere in daily life, for example in the form of milk, butter, shampoo and vaccines. But what determines the size of the droplets, their stability, or their interaction with the surrounding liquid? Why does everything change if certain substances are added? And how can this be influenced for a specific purpose?

The answers to these questions are hidden at the interface of the droplets. Sylvie Roke draws a black circle on the whiteboard and another one around it. “This interface is only about one nanometer thick, but it is fundamentally different from the rest of the liquid,” explains the physicist. The liquid there is rather viscous and contains many more charges, which have an attractive or repulsive effect on each other and on their surroundings. But what exactly do these molecules look like? How are they arranged and why? Is there a difference between a curved surface and a planar interface?

CHALLENGING TEXTBOOK WISDOM IS FUN

Initial speculations about this were already circulating in specialist literature a century ago. “There are lots of theories on droplet interfaces,” says Roke, “but so far there have not been any direct measurements.” There were simply no suitable methods that would have enabled the researchers to access the interfaces of tiny droplets. Sylvie Roke has developed an optical method that makes this possible for the first time. “We can now jettison a large number of old ideas,” she says. “This is fun, of course; but it is also quite difficult to carry out research that goes against textbook wisdom, because we are viewed with a particularly critical eye, of course.”

In spite of her delicate appearance and her mere 32 years, it does not sound as if Sylvie Roke is intimidated by this. On the contrary. The young researcher loves such challenges and knows what she can do and what she wants. When she talks about her work and her plans, she makes vivid gestures, demonstrates the motion of molecules with the aid of a slinky and sketches formulas and pictures on the board. She also demonstrates comic talent when talking, as she imitates other people’s intonation and facial expressions.

Sylvie Roke sits in her office on the sixth floor of a new building on the outskirts of Stuttgart. Glass facade, concrete core – the Max Planck Institute for Metals Research. Since 2005, she has been heading her own, open-topic Max Planck Research Group, which now comprises seven scientists from Brazil, Spain, the US, France, the Netherlands and Germany. She is often asked just how she came to be at an institute for metals research, of all places. Historically, the institute was indeed dedicated strictly to research on metals, but nowadays one finds behind the doors of the
institute offices and laboratories where researchers work on a broad spectrum of materials and topics. And soft matter, which cannot unequivocally be assigned to solid or liquid matter, is also the latest trend here – including biological materials.

Interfaces play a key role in many processes. They determine the electronic properties of computer chips and the mechanical stability of solid bodies. They affect transport processes through cells, when medication is administered, for example, and the interaction of particles with their environment. The physical and chemical properties of nanomaterials are based almost exclusively on the properties of their surfaces, because the smaller the dimensions of a body are, the more dominant is the contribution of its surface, and the more important it is to understand it.

CELL WALLS AND DROPLETS IN A NEW LIGHT

There are several established methods for investigating planar surfaces, ranging from scanning probe techniques to imaging with electrons to optical spectroscopic methods. These methods have contributed decisively to the continuous miniaturization of microelectronics. However, these techniques are of very limited use in investigating the surfaces of soft matter, such as cells and emulsions. There are several problems at once: quite a few of the methods require vacuum conditions, where liquids immediately evaporate; and the interesting surfaces are often hidden in liquids or in solid materials so that electrons cannot reach them. Moreover, the particles are very small and their surfaces are thus curved, with the result that reflection experiments are impossible.

The most promising tool for investigating soft matter is light, because it can penetrate liquids and solid bodies. Furthermore, light is already being used to investigate surface structures, specifically in the form of second-order nonlinear optical spectroscopy. In a nutshell, this method shows how the molecules vibrate at surfaces, which in turn can be used to derive their structure.

But the sophisticated method works in this form only with planar surfaces, because a reflected light beam is necessary for detection and analysis. However, the curved surfaces of small particles scatter light in different directions, so that no reflected beam can be measured. Sylvie Roke uses the idea that one can nevertheless use the scattered light to gain information about the surface molecules. She uses the scattering effect for the specific purpose of gaining insight into, for example, the molecular surface composition, chirality or charge that is present in the interfacial region.

In order to realize nonlinear light-scattering spectroscopy, Sylvie requires a sound knowledge of the particle scattering processes. Only then can she correctly interpret the data. In the laboratory, lasers are set up on a large table with many mirrors and lenses that shape the variously colored light beams. Ultrashort intense flashes of light are required for the oscillations of the surface molecules to generate sufficiently strong signals. And because they are so short, they are also suitable for observing the temporal behavior of the excited molecular oscillations in a quick sequence of snapshots, as in a stroboscope.

MAJOR AWARDS FOLLOW THE FIRST PUBLICATIONS

The researchers headed by Sylvie Roke have used this method to prove, for example, that a suspension of colloidal glass particles – small spheres in a liquid – takes on a gel-like consistency if the molecular chains, which sit like hairs on the colloidal surface, arrange themselves alternately with molecules of the liquid. The molecular hairs thus influence the properties of the material, in this case the material to gel. The researchers also showed that the surface of soap sitting on small oil droplets in water is fundamentally different from soap sitting on the planar interface between bulk oil and bulk water. Moreover, the Max Planck scientists are continuously working on improving the sensitivity of their apparatus and integrating new optical effects.

In 2008, Sylvie Roke was awarded the Hertha Sponer Prize of the German Physical Society (DPG) for her development. And back in 2006, she received the Dutch Minerva Prijs, which is a biannual prize for a scientific paper. “This is something quite special for me,” says Roke with some pride. “Some researchers have been honored for their lifetime achievements with this award, and I received it after only a few publications.”
Sylvie Roke was already in a bit of a hurry at the very beginning of her life. Maybe in slightly too much of a hurry, because she was born three months premature, and initially had to fight for survival. Even later in life, she was more occupied than other children with growing up and getting stronger. Luckily she had her sister, who was one year older and served as a great example. “Being one year older, she was always taller and better than I was, but she took me along nevertheless. She learned how to play soccer, so I had to learn, too. When she wanted us to run through the forest, I ran with her. And when she wanted to climb trees, we climbed trees. Following her around was very important for my development. And it was fun.”

At some point, when she was 15 or 16, Sylvie Roke found her own way in life. And it was at this time that she also became interested in science. Mathematics appeared to her to be a very natural way of thinking, and she also found physics and chemistry easy. She began to read trade journals and enjoyed the idea of ending up doing something like that. So it was that she found her niche – in her family, as well, because both of her parents are in the legal profession. And her sister? “She became a psychiatrist and is responsible for the social side,” says Roke with a wink of an eye.

At the university in Utrecht, close to her little home town, she started to study chemistry. But when her questions as to why things happened got on the nerves of the university lecturers time and again during the lectures for her bachelor’s degree, one of them simply recommended that she switch to physics. So that is what she did. After another two and a half years, Roke not only completed her physics degree, but also her chemistry degree, both with highest honors. While working on her master’s thesis at the Institute for Atomic and Molecular Physics in Amsterdam, she became engrossed for the first time in the investigation of surfaces – a classic interface between physics and chemistry. When the research group moved to Leiden University and the chance was offered to enter the discipline of laser physics, Roke moved with them to write her doctoral thesis.

At first, this didn’t work out quite as planned – the experiments weren’t successful. Sylvie Roke started brooding and thought of three possible causes: “One: I am a lousy scientist; two: the whole idea is wrong; or three: the cause...
is the bad signal-to-noise ratio.” In order to find out whether the only really alarming hypothesis – the first one – was correct or not, she decided to simply start a new project. And she already had one in mind.

“IF YOU WANT SOMETHING, THERE IS ALWAYS A WAY”

During the third year of her doctoral studies, she spent a few weeks at Columbia University in New York. There she met people who combined nonlinear optics in the visible spectrum with light scattering. So why not combine light scattering with spectroscopy in the infrared range, which is particularly suited to the analysis of molecular structures?

Within a few months, she had constructed a laser system on the basis of this idea, and showed that it was possible, in principle, to use it to determine the surface properties of particles. “In retrospect, I was very lucky there,” she says, “because my test particles were of just the right size to enable me to measure them with relative ease.”

She had thus restored her “scientific honor,” and after completing her doctoral studies, again with highest honors, she left Holland to take up a postdoc position. “As these things happen, I met Michael Grunze at a conference. We had a nice conversation, he had an interesting position in physical chemistry available, and I ended up in Heidelberg with an Alexander von Humboldt fellowship.” The hosting professor also drew her attention to the open-topic Max Planck Research Group program and encouraged the young researcher to apply.

Sylvie Roke confesses that, at that time, she didn’t really know very much about the Max Planck Society and its possibilities. While in Heidelberg, however, she got to know Joachim Spatz, who was in the process of joining the Max Planck Institute for Metals Research. He was working with nanostructured surfaces and with biological materials, and he advised her to apply there as well. She was successful: her idea and the initial results of her new method convinced not only the jurors of the Max Planck Society, but also the Board of Directors in Stuttgart.

This promised her a great opportunity, not only in scientific terms. Her boyfriend had declared that he was prepared to move from the Netherlands to Stuttgart if she got the job with the research group. “It is very important to me that we don’t have to have a long-distance relationship,” says Roke. “I know that many people do this, but I could not and did not want to. And if you want something, there is always a way ….”

And how does it feel being Dutch in Germany? And even more so in the heart of Swabia, the almost mountainous, model region of German orderliness? “Well,” she groans slightly, “it’s different. And this takes some getting used to at first.” She has since grown somewhat apart from her home country, however: “When I go back to the Netherlands now, I often get irritated and think: Can’t this work ‘normally’ for once? I don’t really belong here.
anymore.” The biggest difference, she says, is probably that the Germans live a much more orderly life and also keep to the rules: “If it says: ‘No bicycle parking,’ you won’t see any bikes parked there.”

**COMPETITIVE ON THE BIKE, AS WELL**

The fact that Sylvie Roke is from the Netherlands becomes obvious, if it wasn’t already, when she talks about her favorite sports: cycling and speed skating. “I love the speed on ice, it’s almost like flying,” she gushes. Unfortunately, the ice rink in the neighboring town of Kornwestheim burned down last year, and alternative speed skating rinks are few and far between. Frozen canals are rather rare, even in Holland. But when people can skate from town to town and be enchanted by the icy landscape and the fantastic views of the old towns, there is, of course, a very special atmosphere and a big national party.

Sylvie Roke enjoys cycling in the hills and dales around Stuttgart. “I like cycling uphill,” she confesses. A fighter by nature, she also enjoys a classic ride: she has already conquered Mont Ventoux, the notorious, bleak mountain of the Tour de France, eleven times. And when the weather outside is nasty, or a proper mountain is not within reach, there is always the home-trainer with DVD and computer. “I can simply put on Alpes d’Huez and the trainer translates this for my eyes and legs.”

The physicist is also not averse to using the latest technology for reading. While drinking her cup of tea at break-
fast, she likes to use her e-book reader. It has the feel of a real book and is very practical, she says – it saves a lot of baggage, especially when traveling. In terms of content, however, she prefers history: Persian Fire by Tom Holland, for example, on the war between the Persians and the Greeks. She also thinks Bill Bryson’s “A Short History of Nearly Everything” is particularly good. What she values about this sweeping broadside of popular science is that it makes the bigger picture clear.

Bryson does not simply list discoveries chronologically. He thus does much more justice to the course of science, Roke thinks. The overall view of something was important to her even as a student. That is why she participated in the “Universiteit Vrij van Nut,” the “University of Uselessness,” which was founded by biology professor Frits Bienfait. In two-week summer camps without television or computer, she met students from all faculties who came together to discuss diverse and controversial subjects. A boxers’ responsibility for his (or her) own brain, for example. “These were very important experiences for me, opportunities to consider things so intensely and from very different perspectives,” sums up Roke.

She also tries to implement this integrated approach in her Max Planck Group. Here, chemists and physicists work together on both the experiment and the corresponding theories. Just recently they published a complete theory for their scattering method, the so-called nonlinear Mie theory. This enables them to describe the scattering process on spherical particles for any type of medium. In the future, they want to extend the theory to differently shaped particles as well, to enable the study of deformations (of cells) or of viruses. The theory makes a significant contribution to interpreting the measurement results correctly, and to further optimizing the experimental setup.

**IMPORTANT CLUES FOR THE DRUGS OF THE FUTURE**

A medical project with the University of Utrecht has just been completed. “I literally met the researcher in the elevator and he told me about the problem he had,” remembers Sylvie Roke. The medical researchers had developed tiny spheres of biodegradable plastic to possibly fight secondary liver cancer. These microspheres contain small quantities of holmium that is radioactivated to emit beta radiation to destroy tumors.

In order to optimize the therapy, they wanted to find out more about the biodegradable plastic microspheres: where exactly the holmium was located in them and how they were interacting with the body fluids.

The Max Planck researchers were initially confused by the results of their measurements on the particles. The scattering phenomena they observed could not be explained by the surfaces of the plastic spheres. Instead, all indications suggested that the plastic molecules within the sphere formed crystalline regions. Roke found that the holmium located inside these regions is in a configuration that is so stable that it doesn’t get released even after an activation process of several hours. Sylvie Roke believes that this is an important finding for the design of future drugs. “It is very satisfying to discover something fundamental that, at the same time, is also very useful, isn’t it?”

The holmium-loaded microspheres are now being tested in clinical studies.

Sylvie Roke does not spend much time in the lab these days. She is writing publications and planning for the future – planning to publish her ideas and results further, also in talks, because her group is the only one in the world taking this approach to particle and droplet surfaces. And you cannot bump into everyone who could be interested in that in an elevator.
And her personal future? There are no plans for any children, Sylvie Roke and her partner agree on that. “I like being an aunt and I Skype a lot with my nephew and niece. But children demand a lot of energy, I can see this with my sister. I enjoy what I do very much. Not many people have such an opportunity, and I think I should take advantage of it.”

The next big project has already begun anyway: In 2009 she was awarded one of the coveted ERC grants from EU research support in the amount of 1.1 million euros to study emulsions. This will keep her busy until the end of 2014. Sylvie Roke is not worried about her long-term future: “There was a certain risk involved in starting work on my idea here.” But now, since all ideas she started with work, she and her fellow scientists can investigate the smallest structures of soft matter and resolve the processes very well as a function of time and thus contribute to developing materials with new properties. “There are so many questions to be answered that we will certainly be occupied with this for the next 20 years. The Max Planck Society offers ideal conditions for that.”

GLOSSARY

**Soft matter**
Matter that is neither unequivocally solid nor liquid. Soft matter undergoes changes easily. It is characterized by the fact that small temperature changes in the vicinity of a system produce major changes in the system itself. Biological materials are soft. Milk, for example: without a refrigerator, it quickly turns sour. In solid materials, the associated temperature increase has no such effect.

**Colloids**
Small particles with a diameter in the size range of nanometers to microns.

**Nonlinear vibrational spectroscopy**
In contrast to linear spectroscopy, this is operated with not one, but two lasers for irradiation. The first one excites a molecule to vibrate. The molecules react to different frequencies depending on their structure. The second laser excites the molecule to emit a photon itself. This method works only with molecules in an asymmetrical environment, so for example on surfaces.

**Light scattering**
Light that strikes a particle from one direction is scattered in different directions. The incident light then temporarily converts the particle into an electric dipole, which oscillates and thus emits light. The direction of the scattered light depends on the size and shape of the particles. In the case of nonlinear light scattering, the molecular surface structure also determines the direction of light.
Agriculture instead of forests. The natural vegetation in many parts of the world has been replaced by cropland and pastures. This has consequences for the climate.
Agriculture
Is Plowing Up the Climate

Since the earliest beginnings of agriculture and livestock farming, mankind has been transforming areas of natural vegetation into cropland and pastures. However, the vegetation covering the continents influences our climate in a variety of ways. Humans thus may well have been responsible for changes in the climate long before they started to burn oil and coal on a massive scale. Scientists at the Max Planck Institute for Meteorology in Hamburg have studied the spread of agriculture over the past millennium. Their research shows that mankind had a significant impact on climate, especially on the local level, even before the advent of industrialization.

TEXT JULIA PONGRATZ, CHRISTIAN REICK (MAX PLANCK INSTITUTE FOR METEOROLOGY)

The study of church registers is an activity that is generally associated with theologians and genealogists rather than with natural scientists. Indeed, most people would find it very hard to imagine that such registers also contain important information for climate researchers. But these records, which go back many centuries, contain important information about population development and thus also about how much land area was used for agriculture. However, transforming natural vegetation into agricultural lands has consequences for the climate. We climate researchers are thus very fortunate that demographers have already done the work in recent decades and derived data on global population development from historical documents. Based on this data, we can deduce information about the human influence on climate many centuries into the past.

The pre-industrial era is particularly suitable for analyzing the consequences of land use on climate. Prior to 1850, the global expansion of agriculture was the only “manmade” disturbance to the global climate system. Since the expansion of agriculture often required the clearing of forests, the carbon stored in the wood eventually ended up in the atmosphere as part of carbon dioxide, a greenhouse gas. It was not until the mid-20th century that the amount of carbon dioxide that humans released into the atmosphere by burning fossil fuels significantly exceeded that caused by agricultural expansion. Since then, the global climate change that is now being observed has been caused largely by emissions arising from the combustion of coal, oil, and gas.

CONTINENTS ACT AS CARBON RESERVOIRS

So the destruction of vegetation leads to the emission of carbon dioxide. At the same time, the Earth’s flora renders part of the carbon dioxide released into the atmosphere harmless again. Plants absorb carbon dioxide from the atmosphere through photosynthesis and bind the carbon it contains in organic compounds, releasing oxygen in the process. In the 1990s, for example, each year, the continents reabsorbed around one gigaton (one billion tons) of the approximately 6.4 gigatons of carbon that were released annually through
The combustion of coal, oil, and gas. The continents thus actually store 15 percent of fossil emissions each year. This phenomenon is referred to as the land carbon sink. In this way, the vegetation on the continents can counteract the increase in the global temperature, as global warming is directly linked to the increase in the concentration of carbon dioxide in the atmosphere: carbon dioxide reduces the permeability of the atmosphere to the thermal back-radiation of the Earth, and the lower atmospheric layers warm up as a result. Therefore, by absorbing carbon, the land carbon sink mitigates the increase in temperature that might otherwise be expected as a result of the combustion of fossil fuels and the expansion of agricultural areas.

However, vegetation is also relevant for climate in another respect. The different types of vegetation influence the exchange of energy, water and momentum between the atmosphere and the Earth’s surface. This affects particularly the regional climate. For example, grassland typically looks brighter than forest from a bird’s-eye view – scientists refer to this as a higher albedo. Grassland thus reflects sunlight better and warms up less. At the same time, forests evaporate more water through their leaves and needles, as they often have deep roots and can therefore cool themselves better than shallow-rooting grasslands. Which of these effects pre-

dominates – warming through solar radiation or self-cooling through evaporation – depends, among other things, on the position of the Sun, the availability of water in the soil, the level of atmospheric humidity and the type of vegetation involved. The vegetation cover thus shapes local climate in combination with the prevailing mean solar radiation, wind direction and precipitation. This is why we at the Max Planck Institute for Meteorology examine how strongly changes in vegetation influence the absorption of solar radiation and their consequences for the carbon-dioxide exchange between the land masses and the atmosphere.

Climate has changed naturally since the end of the last ice age 10,000 years ago. As a result, new plant communities have formed and spread. But on top of these natural changes, human activities, such as agriculture, forestry and urbanization, have had a substantial influence on the interaction of the atmosphere and the vegetation on the continents. Calculations have shown that, today, around 24 percent...
More and more people need more and more food: Cropland in the year 800 (left) and in the year 2000 (right). The color bar shows the fraction of total area used for agricultural purposes (gray: 0%, violet: 100%).

of global plant growth is controlled by humans. In the millennia between 9,000 and 5,000 years before the present day, agriculture and livestock farming developed independently of each other in at least four regions: the so-called Fertile Crescent of Asia Minor, parts of China, and Central and South America. From there, the cultures that practiced agriculture spread and gradually replaced the historically older hunting and gathering societies. Unfortunately, there are very few detailed records available on how much land in a region was used for agriculture at a particular point in time. This lack of data has hindered the study of changes in global vegetation distribution and their role in climate events to date.

A GLOBAL AGRICULTURE MAP

For this reason, we had to use other information sources for our study, namely the data on population development mentioned at the outset. Population size and agricultural area are closely linked. Before the industrial revolution, long-distance trade was limited to valuable goods such as spices; basic foodstuffs could hardly be transported in sufficient quantities across long distances. The area of agricultural land required in the period between the Middle Ages and the Industrial Revolution can thus be inferred from the regional population figures. We used this correlation and generated a data set that traces the distribution of cropland and pastures throughout the world starting in the year 800. Uncertainties relating to the population data and the influence of changing agricultural methods are taken into account in the calculations. In addition, we reconstructed the changes in the distribution of forests and natural grass- and shrubland caused by the agricultural expansion. It emerges from this that natural vegetation had already decreased significantly in the pre-industrial era, making way for arable and livestock farming.

The last millennium is particularly interesting in this regard: between the year 800 and the early 18th century, the global population tripled, reaching one billion people. This increase must have
been accompanied by agricultural expansion on an unprecedented scale. If we do not find that anthropogenic climate change took place during this period, we must not expect it during the preceding millennia, either. In this case, and as is usually assumed, the anthropogenic influence on the climate would have begun only with the large-scale burning of oil and coal during the industrial revolution.

Our study, however, reaches a different conclusion. Today, climate models enable us to simulate the interaction between vegetation, the atmosphere and the oceans over extended periods on mainframe computers. Based on the reconstruction of land use in the last millennium and an Earth system model developed at our institute, we can estimate the impact of agriculture on the carbon cycle and the climate. Our results show that, in the centers of historical agriculture in Europe, India, and China, agriculture spread extensively between 800 and 1850 at the cost of forest area, and led to the loss of 53 gigatons of carbon worldwide. At the same time, 25 gigatons of carbon were sequestered in the land carbon sink.

Thus, almost half of the emissions were taken back up by the vegetation, especially in regions that were left to nature’s devices, like tropical rain forests. This happens because plants grow faster under higher atmospheric carbon dioxide concentration. As a result, they can bind more of the greenhouse gas and compensate, at least in part, for the increase of the gas in the atmosphere. Scientists refer to this process as the “carbon dioxide fertilization” of plants.

LOCAL CLIMATE CHANGE EVEN WITHOUT INDUSTRIAL ACTIVITY

These figures prove that a net volume of around 28 gigatons of carbon was released into the atmosphere as a result of agricultural development in the pre-industrial period of the last millennium. These emissions remained very small for hundreds of years, and it was only during the period between the 16th and 18th centuries that they affected the concentration of atmospheric carbon dioxide beyond a level that could be explained by natural climate variations alone. As a result, it would appear that humans did not increase the carbon dioxide concentration in the atmosphere until a relatively late point in time – albeit still prior to the advent of industrialization. However, this increase in carbon dioxide was too small to perceptibly alter the temperature at the global level.

At the regional level, in contrast, humans already influenced the climate prior to industrialization. Simulations show that, due to the changes in the albedo of the land surface through land use, mankind altered the energy balance in some regions as early as a thousand years ago. In Europe, India and China, in particular, the amount of absorbed solar radiation decreased by around two watts per square meter. A change of this magnitude at the regional level is just as large as the current global greenhouse effect; however, it has the opposite impact, as it causes cooling rather than warming.

Even historical events can leave their traces on the climate through such biogeophysical effects. For example, there was a clear reversal of the increasing human influence on Europe’s energy balance in the 14th century. This change was brought about by the bu-
Bright grasslands reflect more solar energy than comparatively darker cultivated fields and forests. In this way, the type of vegetation influences the local climate.
Bonic plague, which claimed the lives of around one third of the population and in the wake of which large expanses of agricultural land were temporarily abandoned. The Mongol invasion of China in the 13th century and the diseases spread among the high cultures of the Americas by the invasion of the Europeans had similar consequences.

CLIMATE PROTECTION THROUGH FORESTATION?

We conclude that humans caused changes in the regional energy balance already in pre-industrial times and increased the carbon dioxide content of the atmosphere. They disrupted the carbon cycle and reduced the forest carbon sink through deforestation. All this created a legacy of the past by the time humans entered the industrial era, so the land use of the past continues to affect current and future climate conditions.

While the influence of land use on the climate was only an unintentional side-effect up to now, it is planned to make targeted use of this effect in the future to counteract climate change. As a result, various demands are made for the reforestation of agricultural areas to withdraw carbon dioxide from the atmosphere and mitigate current climate change. However, reforestation does not always have the effect of mitigating climate change – it can also accelerate global warming. Studies show that, in mid- and high latitudes, the reduction in albedo due to reforestation causes so much extra solar radiation to be absorbed that the cooling effect from the uptake of carbon dioxide has no impact. In the tropics, in contrast, the high level of evaporation in the forests plays a greater role and, combined with the uptake of carbon dioxide, has a net cooling effect. Preventing deforestation of the tropical rain forest, which is being deforested to gain agricultural land, could thus be more effective than the reforestation in moderate zones. Therefore, also in the future, the development of the climate will depend on agricultural decisions.

GLOSSARY

Albedo
Albedo is a measure of how strongly continents, oceans and clouds reflect sunlight. Lighter areas have a higher albedo than darker ones.

Carbon sink
The land masses and oceans can remove carbon from the atmosphere and bind it for long periods. On land, this process involves primarily vegetation, which absorbs carbon dioxide and forms organic compounds from it. However, carbon dioxide is also bound during geological processes, such as the formation of limestone.
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How the Laser Came to Light

In the early days, lasers faced an uphill struggle. Now they enjoy a vast range of applications. This laser at France’s Centre d’Essais des Landes measures the composition and turbulence of the atmosphere.
Fifty years have passed since a laser first shone. Now these intense light sources can be found everywhere, from the auto industry to CD players. In a joint project, researchers at the Max Planck Institute for Economics are helping to trace the laser’s economic development – and in the process, they are challenging some common assumptions about how new technologies come to be established.

The Martians are coming! And they are armed with invincible ray guns! As far back as 1898, American author Herbert G. Wells wove such a tale of horror in his book *The War of the Worlds* – more than half a century before the marvel of Light Amplification by Stimulated Emission of Radiation – that is, the laser – had even been invented. “Certainly by the time Einstein formulated the theory of stimulated emission in 1916, it was scientifically proven that such a light source would come into existence,” confirms Helmuth Albrecht, an expert in the history of technology at the TU Bergakademie Freiberg. “Its principal properties were also known: extremely tight bundling and high energy density. Long before the laser was actually invented, it was even a known fact that it could be used to measure distances and transmit data.”

Albrecht is one of the partners in the LASSSIE project: “Lasers: A Spatial-Sectoral System of Innovation and its Evolution.” It explores the evolution of the laser innovation system, also including researchers from the Max Planck Institute for Economics and Friedrich Schiller University, both in Jena.

**MEANINGFUL TECHNOLOGY POLICY**

Using the development of the laser as their example, they are jointly seeking to identify general patterns of technology transfer and economic development. The laser is the ideal candidate. Advances in laser technology would be inconceivable without a steady stream of new research findings. In addition, there is a well developed commercial sector that exploits a wide variety of laser products and applications. And last but not least, its development can be studied within the framework of international comparisons.

At the forefront of the project is the issue of the systemic nature of laser development. “In the 1950s, the naive belief still persisted that technology and enterprise developed along the lines laid down by the relevant institutions: first comes basic research, then applied research, and finally, the technology is taken over by industry,” explains Jena-based regional economist Michael Fritsch, who is also doing entrepreneurship research. “Today, however, we recognize the existence of what are called innovation systems – actors who are dependent on one another and interact with one another, but are spatially separated and spread across the fields of enterprise, politics and research.”

This concept also plays a role in economic policy. “It reflects the widespread assumption that coordinated interaction between politics, public research sponsorship and the corporate sector is more beneficial to the national economy than completely unfettered competition,” says Fritsch. One instance frequently cited as proof of this concept is the success of Japanese industry in the 1980s, which was closely managed by the then Ministry of Commerce and Industry (now the Ministry of International Trade and Industry, MITI).

However, the fact is that little is known about what happens on a micro-level. This is unfortunate, to put it mildly, as an understanding of the context would be a valuable aid in formulating a meaningful technology policy. The partners in the LASSSIE project thus hope to find out to what extent laser technology development in Germany took the form of “coordinated interaction” – or some other form.
Guido Bünstorf, head of a research group in the Evolutionary Economics Group at the Max Planck Institute in Jena and co-initiator of LASSIE, has, in recent years, studied the development of a whole series of industries, mostly in close collaboration with Steven Klepper, an economist at Carnegie Mellon University. In the course of their work, the two researchers discovered that development in the industrial sector generally does not follow the pattern set in Japan in the 1980s, but is more akin to Darwin’s theory of evolution. It is not so much a question of a “system” as one of momentous exceptions.

Klepper showed that the entire Detroit-based US auto industry emerged from the nucleus of a single company: Olds Motor Works. General Motors, Cadillac, Ford, Dodge and Chevrolet are all descended from Olds. Semiconductor manufacturing in Silicon Valley and the “rubber capital of the world,” Akron, have similar origins. Located on the Ohio and Erie Canal, Akron, at the end of the 19th century, was growing fast and prospering from the transshipment of coal and cereal products. A postcard in Bünstorf’s office depicts a cartoon image of 1930s euphoria with imposing skyscrapers, broad streets and a blimp in the sky: “Greetings from Akron Ohio.”

The New York-based rubber manufacturer Goodrich found willing investors and settled in Akron. In 1888, his sons took over the business and were soon producing the first pneumatic automobile tires. Initially in cooperation with Goodrich, a maker of carriage tires named Harvey S. Firestone also set up shop. And finally, the sons of the investor who had backed Goodrich senior went on to found a tire firm of their own, called Goodyear. These three firms were the progenitors of almost the entire American tire industry.

Bünstorf and Klepper gathered and statistically evaluated vast quantities of detailed information and data on the cases they studied. They analyzed behavior patterns and used their findings to test mathematical models of industrial development. Lasers, too, are among their research interests.

NO SYSTEM CHARACTER

LASSIE began with something akin to a bet. “It all started when we were sitting around the Klepper family’s kitchen table in Pittsburgh,” Guido Bünstorf recalls. “I told Steve about my plans for the laser project. He said, ‘I don’t believe in innovation systems.’” Who actually won the bet depends on the timescale applied; however, it was Steve Klepper who ultimately emerged the loser. For more than ten years, the laser industry in Germany had no system character. According to LASSIE, this feature eventually emerged in the 1980s.

The research project traces the development process in detail. The initial investigations are already complete. When the project partners met in November in the wood-paneled conference room at the Max Planck Institute in Jena, a stack of freshly completed master’s theses lay on the table. Helmut Albrecht was there from Freiberg, Guido Bünstorf traveled from Kassel, where he holds a professorship, and Michael Frisch came from the university in Jena where he holds the chair of business dynamics, innovation and economic change. Also in attendance was Wolfgang Ziegler, head of the patent information office at the University of Jena, who became aware of the project when he, too, applied to the...
Volkswagen Foundation. “It was a stroke of luck for us: Ziegler himself has a background in laser research and knows all about what happened in East Germany,” says Bünstorf.

The meeting began with a student presentation of a study on team building. In his thesis, the student had analyzed “patents classified under IPC H01s that deal with laser sources. German applicants only.” Between 1961 and 2005, there were 3,369 laser-related patent applications that fit the bill. The student had studied the size and stability of each team of inventors: were patents registered more frequently by inventors working together in the same team combination? In comparison, how often were patents registered by inventors working alone? The answers to these questions provide insight into the system character of the industry.

The extensively analyzed data show some clear trends. There is a distinct and continuous increase in team size – which presumably reflects the increasing complexity of the subject matter. At the same time, there are indications that scientists are switching from one team to another with increasing frequency – a sign of increasing networking. The meeting prompts questions, ideas and suggestions. Would it be possible to analyze the data by field of application? Could the same principle be applied to publications rather than patents? What would be the result for other industries?

“An important part of the LASSIE project lies in gathering data,” says Guido Bünstorf. Company registers, patent applications, publication statistics, dissertations, trade fair catalogs and trade journals are all grist to the mill. And then there are also interviews with the principal participants in industry and research. “We are compiling a database of events sorted by year – at a level of detail that, over the almost fifty-year period we are looking at, does not, to my knowledge, exist anywhere in the world for any other technology.” The researchers aim to be able to track individual persons over time as they progress through the innovation system – from their dissertation to publications and patent applications to the possible founding of a business.

Michael Fritsch sums up the picture painted by the data as follows: “In the 1960s and 1970s, there was hardly any cooperation. There were few spinoffs from universities or existing companies, and spatial mobility between companies was minimal. Exchanges between academic and industrial re-
searchers were limited to conferences.” There was no systemic aspect to the development process at the time. It was not until the 1980s that networking began in various forms on the laser scene. Research sponsorship (a dissertation topic in its own right) took on greater importance and the establishment of application-oriented research facilities, such as the Fraunhofer Institute for Laser Technology (ILT) in Aachen and the Institut für Strahlwerkzeuge (IFSW) in Stuttgart, received political support.

These observations prompt a fascinating question: How do we explain the fact that Germany was able to acquire a leading international position in some important areas of laser technology even though a system as such—and thus also broad public support—did not exist until the 1980s? Is the link between economic success and targeted support for key technologies perhaps less cohesive than is commonly assumed in economic and research policy? A look back at history offers some useful clues.

**AN OUTSIDER SCORES A BIG HIT**

The laser was invented by Theodore H. Maiman—a scientific outsider working in a research laboratory at Hughes Aircraft Corporation in California. “Maiman must have made his breakthrough some time early in the summer of 1960,” explains Albrecht. “He succeeded in generating a laser effect with a ruby crystal.” At the same time, but without being aware of Maiman, a working group headed by the future winner of the Nobel Prize for Physics, Arthur Schawlow, was also working on a laser. Schawlow’s group also managed to generate a laser beam just a few months later, in October 1960, and, unlike their rival Maiman, they published the results in the journal *Physical Review Letters*. “And that was where it started,” says Albrecht. “Everyone immediately began trying to reproduce the experiments, and by the turn of the year 1961, most had managed it.”

Before the Second World War, Siemens in Munich had been conducting research with a view to using microwaves for communications purposes. After the restrictions on research were lifted by the Allies in 1955, they picked up where they left off. In 1961, the company had two teams working in competition with one another on this new technology. They actually succeeded in replicating the laser even before the Schawlow team had published its results. This was to have a lasting effect on...
the German research landscape. Thanks to Siemens, Munich became the stronghold of laser research in Germany, competing with Jena and Berlin – a development to which the Institute for Plasma Physics in Garching, founded in 1960 and incorporated into the Max Planck Society in 1971, also contributed.

Having succeeded in replicating the laser, an initial series of experiments was launched predominantly in the fields of communications technology and materials processing. The properties of the new technology were systematically explored. New forms of lasers were discovered in rapid succession: within a few years, first the ruby and then helium-neon gas lasers were followed by glass lasers, cesium gas lasers and low-temperature semiconductor lasers, ion lasers, carbon dioxide lasers, chemical lasers and dye lasers.

Science itself initially provided a market for the new technology. “Laboratories scrambled to get their hands on a laser, not just in industry, but at universities and schools, as well,” explains Helmut Albrecht. In 1971, two students from the Max Planck Institute for Biophysical Chemistry in Göttingen set up a company called Lambda Physik. Producing traveling-wave nitrogen lasers for the research market, it went on to become one of the most successful Max Planck Society spinoffs ever.

However, it took another ten years for the laser to establish itself as an industrial production tool. The key problem lay in designing a technology that would function reliably under industrial conditions as a component part of a material processing plant. The beam guidance, in particular, proved to be critical. “To start with, a mirror system was tried out. But it was very difficult because, with even the slightest maladjustment, the beam was out of line,” Albrecht continues. It was not until the arrival of fiber-optic cables, which could be used as optical waveguides, that it became possible to build the modern, highly flexible production systems that now handle cutting, drilling and welding tasks in many branches of industry.

Although the laser was invented in the US, it was German engineers and equipment manufacturers who made it a commercial success in industrial production. One of the first applications of the laser was in drilling watch springs and jewels for the precision engineering company Haas in the tiny Black Forest town of Schramberg. In 1970, Haas purchased the first Nd:glass laser for spot-welding coil springs before setting up the subsidiary HAAS-Laser in 1972 to build its own equipment. Another prominent example was Berthold Leibinger, general manager of the Trumpf machine tool company, who in 1979 introduced the first Trumatic punching and laser cutting machine, which became a great commercial success.

GERMANY BECOMES THE MARKET LEADER

German industry became the world market leader in the use of lasers for materials processing. And it did so, at least in the early years, entirely without political support. What’s more, for economic researchers, the success of German laser technology may possibly indicate that the European paradox is misjudged. In economic research, the term European paradox is used to describe the theory that the industrial nations of Europe are not lacking in the ability to innovate, but rather in the will and the talent to exploit their innovations commercially – which is why they supposedly lag behind the US in terms of enterprise. However, when proven German expertise in precision manufacturing came head to head with a new technology, the Germans clearly appreciated the commercial potential of the laser and set about exploiting it.

The presence or absence of a system and the European paradox were not the only aspects in which the laser man-

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1 Lasers were initially used mainly for research purposes, for example to generate interference patterns. These occur when a beam divided into two paths is recombined and one path is slightly altered.

2 Arthur Schawlow (a) developed the laser at the same time as Theodore Maiman (e). Neither of them knew that they were competing with one another.
reports Steven Klepper. “That was a complete mystery to us.” Their surprise was even greater when Klepper established that the absence of any shakeout was limited to the period from 1961 to 1994 – after which the number of firms was reduced by almost half. Why should this happen at such a late stage?

**LITTLE EVIDENCE OF THE EFFECTS OF MASS PRODUCTION**

Klepper and his colleagues looked at the various segments of the market and were able to establish that, just because a company produced a laser with one particular wavelength, it did not necessarily enjoy a competitive advantage in manufacturing and marketing other types of lasers. For this reason, there was little evidence of the effects of mass production and thus no shakeout in the early years. But why did the situation change? “A new invention! The diode-pumped solid state laser. This changed the economics of the industry,” Klepper argues. “Suddenly it was possible to generate many different wavelengths using the same fundamental technique.”

If this reasoning is correct, then something similar should be evident in Germany. In fact, as Bünstorf explains, “Compared with the US, the development in Germany was a little delayed. But the pattern is the same: rather late in the day, the usual processes of industrial development were set in motion.”

Laser diodes have since done their part to ensure that lasers are ubiquitous – in CD players, traffic control systems, medical equipment, supermarket checkouts, and they are even responsible for printing the sell-by date on plastic water bottles. Yet, despite the success with which the technology is being applied in more and more fields, the heady days of the laser may already be over. “We haven’t been able to discern any further increase in the number of publications in recent years,” reports Bünstorf. The initial phase of technical development and the associated increase in research activity seems to have already reached an end. “With the whole world describing the 21st century as the age of optical technology, that’s not what we would have expected.”
We foster technical journalism. The „Vogel Foundation Dr. Eckernkamp” has been funding an endowed professorship at the Würzburg-Schweinfurt University of Applied Sciences since 2008. The Masters Degree course in Technical Journalism, which is the only one of its kind in Southern Germany, provides a well-rounded, multi-media centric education, strengthening the knowledge base in Germany.
The noise was deafening: At dusk on November 7, 1969, at precisely 5:52 p.m. local time, a four-stage Scout-B launcher lifted off from the Western Test Range in Vandenberg, California. Shortly afterward, a voice from a loudspeaker announced the news everyone had been waiting for: "We have lift-off!" For the assembled scientists and engineers watching the launch, this was the signal to break out the champagne: AZUR, the first German satellite, was heading for space after almost five years of development.

Some 45 minutes after launch, the German control center in the Bavarian town of Oberpfaffenhofen announced that it had received the first data, and that the arm on which the magnetometer was installed, and the yoyo system that decelerated the spin of the satellite, were working correctly. AZUR had reached its planned orbit without a hitch. Permanent magnets used the Earth's magnetic field to align the space probe and thus stabilize it. Some 5,300 solar cells on its outer skin guaranteed its energy supply.

The plan was for AZUR to orbit Earth in a strongly elliptical polar orbit at a height of between 383 and 3,145 kilometers, and transmit data to Earth from eight measuring instruments. Its mission: to investigate charge exchange processes in the inner Van Allen Belt – a ring of high-energy particles that are trapped by the Earth's magnetic field. In addition, the scientists wanted to measure energetic particles from solar flares with the aid of the satellite, and investigate the phenomenon of the northern lights.

With AZUR, Germany leapt into space in the same year in which mankind first set foot on the Moon – 12 years after the Russian satellite Sputnik 1 had heralded the age of space travel. In 1969, only five nations, apart from the Soviet Union and the USA, had their own satellites: Great Britain, Italy, France, Canada and Australia. After World War II, the decisions of the Allied Control Council had thwarted Germany's plans for its own space flights.

It was only after the Federal Republic obtained its sovereignty in 1955 that Germany was again allowed to carry out research on space flight, but the necessary expertise was lacking. German companies had practically no experience in the construction of spacecraft. In 1962, the aviation pioneer and entrepreneur Ludwig Bölkow initiated the first German space project. He was the driving force in national aviation and space travel, and championed the development of new technologies in his country.

The most important cooperation partner was the US space agency NASA, which provided support for project management and technical matters. After three years of preparation and planning, and numerous discussions, NASA and the Federal Ministry for Scientific Research signed a Memorandum of Understanding on July 17, 1965 with the aim of starting a joint satellite project – 625A-1 – later called AZUR. The plan was for Germany to develop a satellite and its scientific payload, with the US providing a launcher to bring the satellite into its orbit and monitoring the space vehicle's trajectory with its ground stations.

AZUR was a challenge for Germany, and not only due to its lack of technical experience. There was neither an organization to coordinate the project, nor did the necessary infrastructure exist – there were no test ranges or ground stations. The Society for Space Research (GFw) was established for the sole purpose of managing the complete project.

Erhard Keppler of the Max Planck Institute for Aeronomy in Lindau/Harz took on the role of scientific head of AZUR. In 1966, the then 35-year-old physicist also initiated the construction of a ground operating station on the site of the German Aerospace Center (DLR), which was intended to make it possible to control the satellite, monitor its orbit and receive the data from space. This initiated the establishment of what would later become the renowned German Space Operations Center (GSOC) in Oberpfaffenhofen, southwest of Munich.

Keppler also arranged for the construction of three ground stations in Sodankylä (Finland), Reykjavik (Iceland) and Fort Churchill (Canada), in order to be able to investigate solar X-ray flares.
in the upper polar atmosphere in real time. The operation of these stations turned out to be a logistical masterpiece because, at regular intervals, the control center in Oberpfaffenhofen had to produce new punched tapes containing the control commands to adjust the antennas. Lufthansa pilots flew them to the relevant country and intermediaries took them to their destination.

In order to test satellites before their launch, the company IABG in Ottobrunn, near Munich, built suitable testing facilities, including vibrating tables, thermal vacuum chambers and a high-tech magnet testing unit. It comes as no surprise that the total cost of the project went way over budget: AZUR carried a final price tag of well in excess of 70 million German marks instead of the planned 30 million marks.

The scientific experiments had been selected in consultation with NASA from 100 submitted project proposals. Five scientific institutes were involved in the development and assembly of the measuring instruments aboard the satellite, which was 115 centimeters long and weighed around 72 kilograms: The Max Planck Institute for Aeronomy, the Max Planck Institute for Extraterrestrial Physics in Garching, the Institute for Nuclear Physics in Kiel, the Institute for Geophysics and Meteorology in Braunschweig and the Institute for Atmospheric Physics at the German Test and Research Institute for Aviation and Space Flight (DFVLR) in Oberpfaffenhofen.

When one considers how much time (...) has been spent on the organizational preparation (...) alone, one can understand the scientists’ wish that, after Azur (...), the wheels of German “space bureaucracy” will turn not only as precisely but also as quickly as the speed of space research in other countries has been dictating for the past decade.

All instruments had to be manufactured in duplicate, as NASA had stipulated that the performance of the equipment had to be validated by flying it on sounding rockets before the real mission. To this end, it provided four sounding rockets, two of the javelin type and two of the Nike Apache type, which were launched in 1966 and 1967 from Fort Churchill in Canada, from Kiruna in Sweden and from Natal in Brazil. The tests were successful – a further hurdle had been cleared.

In September 1967, work was finally able to begin on the production of the qualification, prototype and flight models of AZUR. Between the beginning of the qualification tests and the launch, a large number of faults were remedied. In early October 1969, the ground operating system commenced its permanent simulation operation right on time in order to be prepared for the flight phase. Things went off without a hitch during launch preparations on the range in California.

AZUR transmitted the measurement data it collected during its roughly two-hour orbit around the Earth in real time to the ground stations. Simultaneously, a magnetic tape on board recorded the data. As soon as the satellite flew over the ground station in Oberpfaffenhofen, the control center called up the tape. Unfortunately, the tape recorder stopped working just four weeks after the launch; nevertheless, the researchers were still able to receive around 70 percent of the data in real time by involving additional real time ground stations. Overall, the satellite transmitted 30 billion bits of information in real time and around 250 million bits of data on tape.

On June 29, 1970, 233 days after the launch, contact was suddenly lost. The cause was never ascertained, but the high radiation level to which AZUR was exposed on its orbit probably damaged the data transmitter. Although the satellite did not attain its planned lifetime of one year, research, politics and industry considered the project to have been a complete success. It provided valuable scientific insights that contributed above all to a better understanding of the physics of the Earth’s radiation belt, and brought together state institutions, scientific institutes and companies. Six German companies provided the complete functional systems of the satellite. The system leader, Messerschmitt-Bölkow-Blohm GmbH (MBB), brought all the various strands together.

The knowledge and experience gained by the German researchers and companies paved the way for participation in future space projects. And it must not be forgotten that AZUR was the start of a close German-American collaboration in the field of space research. This cooperation made it possible to undertake such successful projects as the two HELIOS Sun probes, for example, which set off on their journey into space in 1974 and 1976 from Cape Kennedy in Florida to carry out research in the vicinity of the Sun. AZUR continued to orbit through space even after it had lost contact with Earth. And it may still be orbiting today. Although some sources reported that the space vehicle burned up upon entering the Earth’s atmosphere some ten years after its launch, other information indicated that the satellite is still in space – together with thousands more that have followed it since.

Dr. Erhard Keppler was the scientific project manager of AZUR and later the Technical Managing Director at the Max Planck Institute for Aeronomy in Katlenburg-Lindau. He passed away in February 2010.
"I Don’t Want to Be for Ever in the Laboratory"

How symposia encourage transdisciplinarity – an interview with Carlos Acevedo-Rocha

Scientists and artists came together at the end of 2009 at Administrative Headquarters and at the MPI for Biochemistry for a symposium on the theme of tackling “New boundaries in science.” Mexican-born IMPRS grantee Carlos G. Acevedo-Rocha, a doctoral student at the MPI for Biochemistry and principal organizer of the symposium, explained the background to the event.

MaxPlanckResearch: How did you come up with the idea of organizing the symposium?
Carlos G. Acevedo-Rocha: It stemmed from three previous meetings that I attended: the 2005 DAAD summer academy “New Frontiers in Science” in Munich, the 2006 meeting of Nobel Prize winners in Lindau and the Max Planck PhDnet event entitled “The Art of Science- The Science of Art” in 2008, which I helped to organize. These events inspired me to combine art and science and encourage a dialog between scientists researching in different fields. At the Nobel Prize winners’ meeting, a selected group of guests were invited to listen to presentations by the principal scientists. And so all three events merged into the concept for the symposium.

Why did you invest so much time and effort in an event like this?
Carlos G. Acevedo-Rocha: I wanted to learn how to organize such a thing. Besides, a lot of colleagues have supported me. My Ph.D. supervisor Nediljko Budisa allows me the freedom to devote time to projects like this alongside my doctoral studies. I am very grateful for that.

How did the scientists react to your inquiry?
Carlos G. Acevedo-Rocha: Many of them thought it was a very good idea, although some were skeptical that the symposium might be lacking in scientific depth. But Nobel Prize winner Richard Ernst was fully behind the concept. I think that his agreement convinced a lot of those who were doubtful at first.

The first part of the “Art and Science” symposium was attended by just a small group at Administrative Headquarters, while the second part that was open to all was held at the MPI for Biochemistry. Why did you choose two different venues?
Carlos G. Acevedo-Rocha: For the first day I looked around for a central, easily accessible location in Munich. The idea occurred to me at the Max Planck Forum that Headquarters would be ideal. And Dr. Bludau immediately offered to invite the guests who were attending. On the second day, however, with visitors from all over Germany, the auditorium at the MPI for Biochemistry offered more room.

One of the topics discussed at the symposium was the responsibility that scientists bear towards the environment and society. Is that something you learn about as a student or doctoral candidate?
Carlos G. Acevedo-Rocha: As a student I attended a lecture on ethics, but that was not connected with my scientific studies. Otherwise, I am aware of very few events on the subject, and even those are often not intended for junior scientists. Although Max Planck PhDnet does have something to offer.

Would you like to organize more interdisciplinary events in the future?
Carlos G. Acevedo-Rocha: Oh yes! I would like to encourage the exchange of ideas, because science and art are just different ways of looking at reality, not a contradiction. Transdisciplinarity is becoming more and more important because science is increasingly specialized and split up into individual disciplines. If we are to meet the challenges of the future, we need experts in different disciplines to be working together. Might it not be a good idea to set up an MPI for Transdisciplinarity?

How do you see your professional future?
Carlos G. Acevedo-Rocha: I enjoy research, but I don’t want to be for ever in the laboratory. I would like to make children and young people more familiar with subjects such as science and environmentalism. And I am interested in what science could do to help communities that live in poverty.
An Example of Tolerance and Openness

Max Planck Institutes take part in commemorating the destruction of Magdeburg and Dresden

Staff at the MPI for the Dynamics of Complex Technical Systems in Magdeburg and the MPI for Molecular Cell Biology and Genetics in Dresden have joined in setting an example of tolerance and openness. In both locations they took part in events to commemorate the cities’ destruction in World War II.

Under the banner of “science is international,” a number of scientific organizations joined together in Magdeburg on January 16 to demonstrate that international exchanges are essential to excellent science. It was on this day 65 years ago that the capital of Saxony-Anhalt suffered heavy bombing in which 90 percent of the old heart of the city was destroyed. There were occasions in the past when the day of remembrance was subverted by neo-Nazis for their own purposes, but since 2009, a broad “Alliance Against the Far Right” has campaigned against this. Besides the Max Planck Institute for the Dynamics of Complex Technical Systems, the Otto von Guericke University, the Magdeburg-Stendal University and the Leibniz Institute for Neurobiology also took part in the “2nd Democracy Mile” of colorful stands and stages that stretched through Magdeburg’s inner city. The event proved once again that xenophobia and right-wing extremism have no place in Magdeburg.

Less than a month later it was time for many members of staff at the Max Planck Institute for Molecular Cell Biology and Genetics in Dresden to show their commitment – around half the institute’s workforce are drawn from 45 foreign countries. Following the murder of Marwa el-Sherbini, whose husband is a doctoral student at the institute, the issue of xenophobia took on new weight and new urgency. Last year, the Mayor of Dresden Helma Orosz visited the institute personally to hear what the staff from overseas had to say, how they are faring, what concerns them and what needs to change. One of the requests to emerge from this discussion was that on the anniversary of the bombing of Dresden on February 13, a clear distinction should be drawn in favor of peaceful, considerate and humble remembrance and against abuse of such acts of commemoration by neo-Nazis.

A clear signal has now indeed been given. The human chain initiated by Mayor von Orosz was an overwhelming success as around 15,000 people clasped hands, among them many of the institute’s employees. Marino Zerital, Managing Director at the MPI in Dresden, sees this as an encouraging message: “We believe the city and its inhabitants deserve great credit for their commitment and for the clear and decisive way they have addressed this problem. It is essential for a strong and watchful democracy to stand up against violence, xenophobia and far-right radicalism.”
More Experiments, More Diversity, More Women!

Impressions of the forward-looking conference "Between Science and Fiction – Society and Gender 2030"

By 2030, almost a third of Germany’s declining population will be over the age of 65. How are businesses and organizations going to operate in the future with fewer and fewer qualified young people entering the scientific labor market? One option is to provide targeted support for women. The conference hosted by the Max Planck Society (MPS) and the European Academy for Women in Politics and Business (EAF) in December at the Harnack-Haus focused on just how to develop long-term prospects for female members of staff.

“What will our daily lives be like in 2030? What is the outlook for the future, and what role will women have to play?” These were the questions posed by Max Planck Society Secretary General Barbara Bludau as she opened the conference entitled “Between Science and Fiction – Society and Gender 2030” and called upon the 80 or so guests to “think the unheard-of and the unthinkable.” On the other hand, as Founding President of the EAF Barbara Schaeffer-Hegel emphasized, it is imperative not to overlook social conditions. True to its watchwords, “Committed to change,” the EAF has been advising the business, political and scientific communities on equal opportunities since 1996, as well as running its own career development programs for women.

The fact that women are still a rarity in senior positions was confirmed by Linda Basch, President of the National Council for Research on Women in New York. Another US speaker to turn her attention to gender issues in science was Londa Schiebinger (Stan-
Bettina Flitner from her project “Frauen, die forschen” (Women in science) presented an unconventional view of a series of leading female scientists. The conference showed that, despite the ground that still remains to be made up, science seems to offer more ideas and ways of working to encourage a more women-friendly environment than are available in the business world. Thinking outside the box is second-nature in science. The challenge for the future will be to recognize diversity and differences as a source of enrichment and exploit these to maximum advantage – whether in exploring new areas of research or in recruiting female talent.

Bludau summed up the central point at issue here: “Why are so many women lost to us simply because they cease their scientific careers after taking a doctorate?”

Not only are the still predominantly male-oriented organizational structures of the working world to blame, in which women – who tend to think along more social lines – are easily lost. There is also the fact that women often have a different definition of scientific problems. A demand for “more experiments” was voiced by Lorraine Daston, Director at the MPI for the History of Science. “Max Planck Institutes with their less rigid structures are an ideal environment in which to experiment with new ways of scientific working.”

However, examples of how to overcome barriers and break the mold can also be drawn from very different fields. Elisabeth Schweeger, exhibition curator and director of the Herrenhausen Festival, urged her audience to take an unconventional approach and look for scientific working models in the world of art. Conversely, by the end of the conference it was clear that women in the world of art are discovering models in science. A display of photographs by

Groups for Young Researchers Get New Names

The panels of the Max Planck Society were discussing the matter for some time, but eventually clarity was achieved. At the end of 2009, the “Independent Junior Research Groups” acquired a new name and are now known as “Max Planck Research Groups.”

The scientific researchers heading such groups are called “Max Planck Research Group Leaders.” Research groups at the universities have to include the university at which they are located in their name. The name change was prompted by the English term “Independent Junior Research Group.” “We felt that the ‘Junior’, in particular, was not appropriate on an international level,” says Valentin Stein, spokesman for the Research Groups in the Biology and Medicine Section. Further terms that should be used officially are “Minerva Research Groups” of the W2 Minerva Programme and “Otto Hahn Research Groups,” which are headed by the designated winners of the centrally awarded Otto Hahn Medals.
A Poster to Remember

Taking a hammer to a computer hard disk is not the most sophisticated way to access the data it holds. The reality is that data theft is a far more subtle affair. The data protection officers at Germany’s research institutes are committed to stopping the thieves in their tracks. To mark this year’s European Data Protection Day, they began a joint awareness campaign with slogans such as “Research not espionage” and “Science needs privacy.”

Data Protection Day was first initiated in 2006 by the Council of Europe, and takes place each year on January 28 to mark the signing on this day in 1981 of the European Data Protection Convention. The focus of this year’s national campaign in Germany was on medical data. The provocative title “Risks and side-effects for the patient’s right to privacy” was designed to draw attention to the imperative need to treat personal data with all due care if science is to improve its perception in the public eye. This is the only way to persuade people to voluntarily participate in scientific studies.

The Max Planck Society, too, in its capacity as an employer, is under obligation not to process data on its employees on any other than employment-related grounds, explained Rainer Gerling, who is the central Data Protection Officer at Max Planck headquarters. Part of his job is to make MPS employees aware of the issue of data protection. He works to ensure compliance with the law and is always available as a point of contact. Together with colleagues at the Helmholtz Association, the Leibniz Association, the Fraunhofer Gesellschaft and the German Research Foundation, Rainer Gerling is also a member of a working party that has initiated a poster campaign specifically for the research community.

To give the staff at Max Planck Institutes an added interest in the importance of data security, the team headed by Rainer Gerling came up with a competition: Employees who hang up a poster at an eye-catching location in their institute buildings and send in a photo to prove it are rewarded with a prize. The MPI for Ethnological Research in Halle took up the challenge, and won a copy of the book “Die Google-Falle” (The Google trap) by Gerald Reischl. Another winner was the MPI for the Study of Religious and Ethnic Diversity in Göttingen, where, despite the inclement winter weather, the poster took pride of place outside the institute entrance where no one could miss it.

Admission to Doctoral Program with a Bachelor’s Degree

The Max Planck Society is not permitted to use its public funds for the support of international students who apply for admission to an International Max Planck Research School (IMPRS) on the basis of a bachelor’s and not a master’s degree. Since the end of 2009, this gap in funding has been bridged by the Max Planck Foundation (MPF) providing private grants in the annual amount of 700,000 euros for 70 doctoral students. Such funds can be used either for participation in a combined master’s/PhD course or in an orientation phase at an IMPRS.
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