Next Generation Sequencing for Everyday and Everyone

Introducing the GS Junior Benchtop System

Simplified Workflow and Bioinformatics

Perfectly sized for labs that require:
- Direct, clonal sequencing of amplicons (PCR products)
- Targeted human resequencing
- De novo sequencing of microbial genomes
- Metagenomic characterization of complex environmental samples
- Pathogen detection
- …and many more applications, all for a price with extraordinary value!

Learn more at www.gsjunior.com

GS Junior System

For life science research only. Not for use in diagnostic procedures.

454 LIFE SCIENCES and 454 SEQUENCING are trademarks of 454 Life Sciences Corporation, Branford, CT, USA, a Roche company. GS FLX TITANUM and GS JUNIOR are trademarks of Roche.

© 2010 Roche Diagnostics. All rights reserved.
In the preface to his book *Analysis of Sensations*, which was published in 1886, physicist Ernst Mach made the following “antimetaphysical remarks”:

“The great results achieved by physical science in modern times – results not restricted to its own sphere but embracing that of other sciences which employ its help – have brought it about that physical ways of thinking and physical modes of procedure enjoy on all hands unwonted prominence, and that the greatest expectations are associated with their application. In keeping with this drift of modern inquiry, the physiology of the senses, gradually abandoning the method of investigating sensations in themselves followed by men like Goethe, Schopenhauer, and others, but with greatest success by Johannes Muller, has also assumed an almost exclusively physical character.”

When Ernst Mach penned these lines, he had no idea of the extent to which his thoughts would be confirmed in the 20th century. Bats rely on echolocation (“sonar”) to hunt their prey, birds use the Earth’s magnetic field to navigate (“compass”) and fish are able to orient themselves even in murky waters thanks to a self-generated electric field (“radar”). These are examples of physical phenomena that animals make use of. Three topics in this issue describe the interplay of such disparate sensory faculties for navigation.

Ernst Mach continued:

“This tendency must appear to us as not altogether appropriate, when we reflect that physics, despite its considerable development, nevertheless constitutes but a portion of a larger collective body of knowledge, and that it is unable, with its limited intellectual implements, created for limited and special purposes, to exhaust all the subject matter in question.”

Modern brain research shows how right Ernst Mach was in this observation, too. Indeed, we have now gathered an enormous amount of knowledge about where the different sensory perception areas are located in the brain and how sensory stimuli are processed. However, the manner in which this puzzle forms a complete sensation is still unknown to us. Korbinian Brodmann, one of the first colleagues of Oskar Vogt, the founder of the then future Max Planck Institute for Brain Research, described, on the one hand, this unsolved problem of localization, and, on the other, integral perception, with a nice comparison:

“In this sense, the mosaic of the cerebrum could perhaps be compared with the keys of a piano. One key does not produce a chord; it is the interplay of several keys that produce a melody and music. In the same way, no top performance or consciousness phenomenon can be expected from one single area of the brain. Mental events are created only through the interaction of multiplicity – maybe even through the entirety of the cerebral areas.”

Heinz Wässle
Director Emeritus at the Max Planck Institute for Brain Research
Orientation

**16 Odor Trail through Ant Country**
In addition to a sun compass and visual landmarks, the desert ant also uses its sense of smell to locate its nest. The animals even learn the distribution of various scents in the areas around their homes.

**24 On the Move with All Their Senses**
Bats see with their ears – but that’s certainly not all: They also take their orientation from the Earth’s magnetic field, calibrate their internal compass by the sunset – and may hold even more surprises in store.

**32 Memorizing a Set of Maps**
Everyone has experienced this: We arrive in a new city for the first time and want to go to our hotel. But how do we get there? What strategies do we use to get from A to B in unfamiliar territory?

---

**Contents**

**FOCUS**

16 Odor Trail through Ant Country

24 On the Move with All Their Senses

32 Memorizing a Set of Maps

**PERSPECTIVES**

06 Genetic Code 2.0
06 The Electronic LOFAR Telescope
07 “Anyone may become a killer”
08 Energetic Talks
08 Hans Schöler Lends His Name to Science
09 A Pulsar in the Screen Saver
09 High Impact Factor
09 On the Net

**VIEWPOINT**

10 Between Theory and Intuition
How important are social scientists’ forecasts for political decisions? A critical analysis.

**FOCUS**

16 Odor Trail through Ant Country
24 On the Move with All Their Senses
32 Memorizing a Set of Maps

---

ON THE COVER: Which way? To reach a destination, we need to obtain detailed information about our surroundings. People and animals use a variety of strategies to do this. Max Planck researchers have devised sophisticated experiments to decode the secrets of orientation.

Cover photomontage: Ants Kalytta, iStockphoto
<table>
<thead>
<tr>
<th>Page</th>
<th>Section</th>
<th>Title</th>
<th>Article Highlights</th>
</tr>
</thead>
<tbody>
<tr>
<td>54</td>
<td>SPECTRUM</td>
<td>Stopped: Researchers aim to disrupt the production chain of HIV viruses.</td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>BIOLOGY &amp; MEDICINE</td>
<td>Aged: Why do humans live longer than other primates? Philipp Khaitovich is researching this in Shanghai.</td>
<td></td>
</tr>
<tr>
<td>78</td>
<td>ENVIRONMENT &amp; CLIMATE</td>
<td>Eaten: Some bacteria feed on oil. Could they be useful in oil spills?</td>
<td></td>
</tr>
</tbody>
</table>

**SPECTRUM**
- What Makes Humans Human? (40)
- Carbon in a New Balance (40)
- Kicks for Black Holes (41)
- Carbon Ribbons (41)
- The Phenomenon of the Opera (42)
- Pulsars for Weighing Planets (42)
- Today Paris, Tomorrow Tokyo (42)
- Expensive Defense (43)
- Quantum Gas in Free Fall (44)
- Immunity to Malaria (44)
- Ye Shall Know Them by Their Gestures (45)
- Quantum Transistors for Photons (45)
- The Proton – Smaller Than It Was Thought to Be (45)
- Struck by a Comet (45)

**BIOLOGY & MEDICINE**
- Lost in Transcription (54)
  How does HIV get a host cell to produce viruses? Researchers are looking for the key in order to develop efficient therapies.

**CULTURE & SOCIETY**
- Building Blocks for a New Life (84)
  Individual social therapy can help reduce the risk of relapse among sex offenders.

**MATERIAL & TECHNOLOGY**
- Blood Samples Undergo Nanotesting (70)
  Researchers aim to revolutionize blood sample analysis with highly sensitive diagnostic chips.

**PHYSICS & ASTRONOMY**
- Physics in the Balance (46)
  Researchers use clever methods to weigh even tiny atomic nuclei – and in doing so, help to shed light on key questions in physics.
Genetic Code 2.0

New biological functions may be created by incorporating artificial amino acids in proteins

Proteins are the protagonists in our body. They transport substances, convey messages or carry out vital processes in their role as molecular machines. As a rule, they are made up of 20 standard amino acids whose sequence is already determined in the genetic code. In natural conditions, however, several hundred amino acids can be found and, of course, new amino acids can also be produced in the laboratory. The properties of these amino acids differ from the 20 standard amino acids, which is why certain structural and biological characteristics of proteins can be modified when amino acids are integrated.

Nediljko Budisa and his research group at the Max Planck Institute of Biochemistry have now succeeded in substituting synthetic amino acids for three different natural ones in a single experiment. Until now, only one type of synthetic amino acid could be inserted into a protein in a single experiment. Budisa’s method could be of great importance particularly for business and industry as, in his view, the production of synthetic proteins through genetic code engineering represents a solid basis for the development of new technologies. Thus, entirely new classes of products whose chemical synthesis has not been possible using only the 20 standard amino acids available in conventional protein engineering may now be open to exploration.

The Electronic LOFAR Telescope

The electronic LOFAR Telescope, a new generation of Radio technology, is officially commissioned

One of the scientific goals of LOFAR is to investigate the development of distant galaxies and the properties of cosmic particles with high energies, as well as magnetic field structures and solar activity. When fully developed, LOFAR will consist of at least 36 remote stations in the Netherlands and 8 stations in Germany, France, the UK and Sweden. Currently, 22 stations are up and running, each of which comprises hundreds of dipole antennas. Together they form a huge virtual radio telescope the size of half of Europe.
According to a verdict in the European Court of Human Rights, the preventive detention presently in place in Germany is partly in breach of the convention on human rights. The German Federal Ministries of the Interior and of Justice have long discussed a reform of this virtual imprisonment after a prison sentence. Hans-Jörg Albrecht, Director of the Max Planck Institute for Foreign and International Criminal Law in Freiburg, explains how dangerous our lives really are and the future role of preventive detention.

**Generally speaking, who is affected by preventive detention?**

**Hans-Jörg Albrecht:** Originally, preventive detention was a measure that was applied equally to property, sexual and violent crime. It was influenced by the image of the habitual offender, which stems from the 19th century. In the past 20 years, there has been a gradual shift toward violent and sexual crime. Also, the focus has moved away from past behavior, which reflects how dangerous a person is, to the question of what can be expected from a criminal offender in the future.

**Is there a reliable way to predict how dangerous a person will be?**

In a strict sense, no. Anyone may become a killer. Of course, there are individuals who fall into certain risk categories; they may be predisposed to crime, or their personality structure may show signs of abnormality. In many cases, however, we still cannot say for sure how many members of a category become violent, and we certainly can’t identify particular candidates. There are always people who will be set free only to commit serious offenses again. Other people, who would never again commit an offense were they to be set free, are placed in psychiatric care or kept in preventive detention.

**Are there scientific analyses of how many people are unjustly imprisoned beyond their original sentence?**

Such data is very scarce, for the simple reason that people who are imprisoned can’t be tested. Some natural experiments do, however, confirm that risk profiling is associated with a high error rate. In the US in the 1960s, thousands of inmates were released from forensic psychiatric care on court orders. As can be seen from the subsequent natural development, the majority of these people were never investigated for repeat offenses.

**Is there similar data from Germany?**

A similar study was recently presented in Bochum. It dealt with around 50 to 65 people for whom an application for subsequent preventive detention had been filed, but not granted. After around two or two and a half years, it turned out that most individuals from this group were not apprehended for serious offenses again. Only three or four were taken into custody for violent crime. About half of those were sentenced again, but were given fines or probation.

**How safe are we here in Germany?**

It is worth noting that the rate of extreme crime has become so low nowadays that it can hardly shrink any more. People’s lives are much safer today than 10, 20, 30 or 100 years ago. Still, the safer their lives are, the greater their need seems to be for security. This is a paradox that is reflected in legal policy.

**In what way?**

Legislation on preventive detention is a patchwork. In the past, German criminal policy – in stark contrast to the rest of Europe – concentrated on making minimal ad hoc amendments to criminal laws in order to close spontaneously detected or supposed security gaps. This created a complicated legal situation that, to some extent, is in breach of international conventions, and that must be remedied.

**What is the role of the media in this development?**

The media is very important, especially when it comes to the public’s perception of the sexual homicide of children. Because of the media, there is a widespread belief that sexual homicide of children is on the rise. This perception is false. For the last 15 years, only two to three such cases have occurred in Germany each year. As abominable as these crimes may be, we will never be able to achieve a society in which no serious violent crime is committed.

**What do you think about the proposal to publish the domicile of ex-convicts and people released from preventive detention?**

This would lead to something that was actually abolished in modern criminal law: the disclosure of sentences. It represents an additional punishment which is neither covered in criminal law nor in the personality rights that German law guarantees even criminal offenders.

**How do you think that preventive detention should be regulated in the future?**

Subsequent preventive detention must be abolished; the government is of the same opinion. In addition, serious offenders should be included in special programs where they are specifically prepared for the problems they will face once released. The expensive surveillance schemes that have been put in place by certain German states because of the recent release of some individuals from preventive detention would then become superfluous. The probability that people in this group would commit serious offenses again is so low that preparatory programs would provide as much security as around-the-clock police surveillance.

**Interviewer:** Julia Merlot

---

Photograph: Szabolcs Csortos
Energetic Talks

Future Dialogue 2010 in Beijing attracts more than 450 guests

“Powering the future” – the subject of this year’s Future Dialogue – is probably the most daunting challenge facing humankind today. As the single largest consumer of energy and producer of greenhouse gases, China has a key role to play. Thanks to nine-figure investments, the People’s Republic will soon become a global experimental laboratory for new energy technologies, ranging from 4th generation nuclear power plants to CO$_2$ storage. All this made Beijing the perfect place to host the conference. More than 450 Chinese and international guests, together with senior executives from major companies, political decision-makers and top scientists, attended the conference to come up with ways to resolve the energy crisis.

Peter Gruss, President of the Max Planck Society, was one of the organizers and also spoke about basic research on the panel “The future of energy supply.” During the panel sessions, Günther Hasinger, Scientific Director of the Max Planck Institute for Plasma Physics, and Ferdi Schüth, Director at the Max Planck Institute for Coal Research, both gave inspiring talks about nuclear fusion and energy storage. Future Dialogue is a series of conferences organized by the Max Planck Society and Siemens in cooperation with Economist Conferences. Local organizers were the Chinese Academy of Sciences and the Energy Research Institute. The 2011 conference will take place in India.

Hans Schöler Lends His Name to Science

Top South Korean university names its new stem cell institute after the Max Planck scientist from Münster

Since the middle of August, “Hans Schöler Stem Cell Research Center” is the name of a new institute at the Ulsan National Institute of Science and Technology (UNIST). Naming the center after the Director at the Max Planck Institute for Molecular Biomedicine in Münster was a matter of personal importance to the President of UNIST, Moo Je Cho. “Dr. Schöler is an internationally leading stem cell scientist with high ethical standards. Moreover, we highly appreciate his long-standing dynamic support for young South Korean scientists in their careers.” The new institute will be dedicated to the use of stem cells in regenerative medicine. Scientists especially want to investigate how so-called iPS cells can be used in cell replacement therapy. Since no embryos are required for the production of these cells, they are widely considered ethically acceptable. The first department of the institute will be established by Jeong Beom Kim, who studied for his Ph.D. under Hans Schöler in Münster from 2005 to 2009.
A Pulsar in the Screen Saver

A German and an American couple discover a new star with the project Einstein@Home

The family on a mountain hike, a sunset by the beach or a colorful kaleidoscope; when the computer is idle, the screen saver kicks in. The fact that this is something that can be used for serious research has now been demonstrated by music computer scientists Daniel Gebhardt from Mainz and Helen and Chris Colvin from the United States. The three amateur researchers have been participating in the Einstein@Home project – and found the signal of a new pulsar in the data from the Arecibo radio telescope in Puerto Rico. The collapsed star, 17,000 light years away, is located in the Vulpecula constellation and rotates 41 times per second. The object is clearly a recycled pulsar, a neutron star that first acquires mass and momentum from a companion star, which it then loses. However, scientists cannot rule out the possibility that PSR J2007+2722 is a very young pulsar with an unusually low magnetic field.

The finding published in Science Express is the first discovery in deep space with Einstein@Home, a community project started in 2005 by the Center for Gravitation and Cosmology at the University of Wisconsin, Milwaukee, and the Max Planck Institute for Gravitational Physics in Hanover. It uses idle computing time volunteered by around 250,000 participants from 192 countries on their home and work computers. The original purpose of Einstein@Home was to search for gravitational waves, but since 2009 has also included signals from radio pulsars.
the most ambitious goal of modern social sciences is to develop theories that explain observed facts as the effects of their causes. Why have birth rates been declining for decades, why is voter participation dropping everywhere in Europe and why do large portions of Africa remain undeveloped? Politicians, however, as people of action, are interested in explanations only when what is being explained has practical significance for them, allowing the causes claimed by the theory to be influenced by political means in such a way that their effects are changed in a desired direction.

A theory that traces declining performance in school to accelerated biological development in youth may be true or false, but it holds no interest for political leaders (unless it could be used to release the government from responsibility). It would be a different story if the explanation were increased class sizes or, say, the elimination of grades for personal conduct: in these cases, the determined cause can be used as a lever – by the government, to improve student performance, or by the opposition, to hold those in charge accountable.

Unlike explanations, politicians are almost always interested in predictions. These, too, are based on theories and are, in principle, also explanations, but of future states rather than present or past states. Many scientists, including some social scientists, consider the ability to make predictions to be the defining feature of a good theory. Since politicians must continually bet on the future, they hold a similar view.

Thus, those who, as scientists, promise information about how much the economy will grow or shrink in the coming year, which occupations will see the highest growth rates in the next ten years, how many additional births extra parental benefits will encourage, or which new electoral candidate might propel his party forward, can expect not only an attentive ear, but also extensive financial contributions from governments and political parties.
Nevertheless, there are good reasons to suspect that the ability of the social sciences to predict the future is not only currently and coincidentally, but also fundamentally limited. “Why did no one see this coming?” asked the Queen during a visit to the London School of Economics in November 2008, referring to the global financial crisis. The researchers, as the representatives of their own interests, could have responded: Because too little was invested in research. But not even economists were that hard-nosed back then; the shock was apparently too great.

In early 2008, the six biggest German economic research institutes were still on average predicting economic growth of 1.6 percent for 2009. In April 2009, they revised their forecasts to minus 4.1 percent, with extreme values of “significantly more than minus 3.0” to minus 5.0 percent. A catastrophe? Today, forecasts are being merrily bandied about again – right down to the exact tenth of a percent, as always. And politicians gladly accept them and quote them as if nothing ever happened.

A better answer to the Queen’s question would have been: some did see it coming, as any event is always predicted by a few people if there are enough people making predictions about it. After all, someone usually wins the lottery, too – and twice a week, at that. In both situations, a person can be right without having known anything.

Not that actual knowledge would have hurt – such as a working short-term memory of history that included the LTCM crisis, the popping of the technology bubble, the Asian crisis and similar events that took place after 1972. Of course, scientists who rely only on theoretical, model-based knowledge, disregarding historical knowledge per se, will have difficulty accessing this memory. Perhaps their models simply shouldn’t have excluded the possibility that markets can, on occasion, also be inefficient. In the discipline’s groupthink, however, this would have made their authors outsiders. Still, despite the strong pressure among economists to conform, there are a few of them around. They knew good reasons for suspecting that there would be another crash sometime, because there is no such thing (yet?) as capitalism without a crash. But even they could not know what form the crash would take, where it would begin and how or whether it would end.

That they could not know this is not due to a lack of research, but rather lies in the essence of the matter: in the nature of the social world and the kind of knowledge we are able, in the best case, to obtain about it. The word is now spreading that the social sciences are incapable of making so-called point predictions – predictions about individual cases. Point predictions, however, are likely to be the only predictions that those in politics could be interested in.

For example, while it may be good to know that economic growth contributes to the creation of stable democracies, what policymakers really need to know is whether this will also apply to China or the Philippines in the first decade of the 21st century. But science can’t tell us this. All it can give us are statements of probability with no guarantees for individual cases, whether relating to democratization or election results, military coups, the outbreak and outcome of wars and – of course – financial crises.

There are solid and logical reasons why the social sciences cannot say much about individual cases. Nor can this be changed, even with the most ingenious refinements to their scientific toolbox. Research on social processes will always involve fewer cases than the number of factors that could explain these cases, thus inevitably leading to more than one valid explanation for any given state of affairs. And every future state comes about as a unique result of a unique interplay of many factors – a one-of-a-kind situation for which there is no normal distribution, and whose distinctive features thus can’t be derived from general laws.

This can also be expressed in a more pointed fashion: the essential historical actuality of the social world is proven in the impossibility of imagining a future adjusted for coincidences. History becomes what it is through events that could have also not occurred, and thus would have permitted a different history. With-

There is more than one valid explanation for any given state of affairs
out World War I and the Russian Revolution, which didn’t have to occur, the 20th century would have taken a different course and modern capitalism would have developed differently. Just how differently, no one can know. Without the extinction of the dinosaurs from the impact of a meteorite, there would be no mammals, and thus no humans. We can know this without being able to know what would have become of the dinosaurs if they had been allowed to go on (for example whether their present-day offspring would be eating with knives and forks or with chopsticks).

Historical events such as the collapse of Communism in 1989, the reunification of Germany or the current financial crisis can subsequently be reconstructed as probable or even declared inevitable; but until they have occurred, other events can prevent, delay or modify them, without anyone ever being able to know that they were just about to occur.

What politicians would like even better than predictions are technical instructions for controlling social developments. Politicians like to see society as a machine with set screws: adjust the right screw and the world works just the way you want it to. The task of science is to label the set screws legibly.

Where does this mechanistic world view come from, and the social utopias that feed on it? The dream of scientific methods for controlling behavior – methods that trigger no resistance because those who are affected don’t even notice them being applied – clearly persists. Many believe that their development is the real task of a truly scientific social science. For example, their colleagues from the natural sciences sometimes ask social scientists for measures they can use to turn off the public’s “hostility to technology”; after all, that is the subject they are supposed to be familiar with.

But unlike in the natural or engineering sciences, the field of social sciences consists of subjects who are capable of making observations and taking action, and who are not at all indifferent about what science claims about them and for what ends governments use their findings. People recognize attempts to steer their actions, and attribute intentions to such attempts. In turn, they respond with their own intentions. These include a fundamental need to be persuaded with reason rather than controlled by technologies of social engineering.

All democratic societies – societies whose members have a say – therefore strictly regulate the use of behavior control techniques. So for example, even if the research on neuromarketing were to deliver what its promoters promise, the application of its findings will inevitably be subject to strict legal limitations.

Just as the social sciences are incapable of predicting the future, the reactions of acting subjects to scientific attempts at control are unpredictable. Social science theories cannot be kept secret. Their use for behavior control will be noticed sooner or later. When that happens, they will be examined to determine their intentions, and responded to intentionally. For example, the researchers in the famous Hawthorne experiments (1924 to 1932) claimed to have found that female workers worked faster and better even without a pay increase if they were treated in a friendly manner and if the walls in their workshop were painted yellow. But after word had gotten out among the staff that the management merely wanted to save money through kind words and yellow paint, they demanded higher wages and went on strike.

A similar fate befell John Maynard Keynes, who knew better than any other economist of his time how important expectations are for behavior. When, in the 1970s, Keynesian global management of the economy by means of monetary and fiscal policies had become established practice, firms and consumers responded increasingly sluggishly to low interest rates; they believed that even lower rates could be expected if stagnation continued. In the end, the theory no longer worked because it had become generally known.

Many other facets of the relationship between forecasts relating to human actions and the actions themselves could be described, but all of them have
one thing in common: the fact that social science theories can be recognized in the world they analyze influences their validity in one way or another.

A special variant of this relationship is the use of forecasts in economic policy. When economists predict growth, participants in the economy gather up their courage and invest or consume — or at least that is what economists and governments believe. They become, in the jargon of what economists consider psychology, “optimistic.” If, however, the forecast is bad, then “pessimism” ensues, and investment and consumption decline.

Now it is true that the economy is a system of action. The expectations of actors in the system with respect to what will happen are thus — and no one understood this better than Keynes — of causal significance. Indeed, hardly anywhere has Robert K. Merton’s term “self-fulfilling prophecy” taken on such everyday significance as in economic policy.

If we think it all the way through, we arrive at the paradoxical possibility that a prediction that was originally and objectively wrong can become right as a result of being made known: When bad times are impending, the wrong prediction of good times can lead to the bad times not actually occurring, and everything turning out fine. Politicians who are at a loss when faced with an impending crisis in any case like to play it down or deny its existence, in the hope that it will then somehow go by. If, in contrast, other members of the political class (especially those who are in the opposition) express the fear that things could get bad, they will be accused of talking the catastrophe into existence — even if, according to all of the scientific criteria, it is objectively impending.

In or just prior to a crisis, economists may in this sense mutate into politicians and let themselves be persuaded to embellish their forecasts in order to avoid a panic and ease the job of economic policy. Their responsibility would no longer be to explain the world, but rather to influence it.

In the extreme case, as at the peak of the financial crisis, elite cartels can then emerge whose members undertake to be pointedly optimistic, regardless of how abysmal the outlook has been and still is. And what else can they do when, in a highly uncertain situation, they have no suitable instruments at their disposal anyway?

So politics and science — and the latter in its most positivistic variation — can transform into magic: into an attempt to prevent the worst from happening by forbidding any mention of it and invoking the best. As highly trained communications experts, politicians already have a natural tendency toward a magical world view that we can justifiably make fun of. But its rational core is the particular responsiveness of the social world: the fact that it sometimes really is influenced by symbols and can be healed by faith healing. Does that justify lying to it in its own supposed interests?

I will leave that question aside and mention merely that here, too, control can fail when its instruments are recognized as such. Positive forecasts must be taken to be scientifically true if they are to trigger the optimism they need to trigger in order to come true. If it were to become known that they were doctored for the sake of this result, then the outcome would not be optimism but a deep loss of trust — and a crash that could be far worse than anything that could have been expected.

In any case, the notion that a social scientist can truly have an advantage over experienced practitioners when it comes to the choice of suitable means for specific goals can be reasonably doubted. The gap between theory and intuition is smaller than many social scientists would like to believe. But that doesn’t mean that the social sciences have to be politically useless — only that it is not the theory-building research so highly prized by the scientists themselves that can contribute to improving politics. Although counting, measuring and observing social issues may seem trivial to some, it is anything but that.

The modern state and democratic discourse are in many ways dependent on information about the state of society that is not easily available, and the collection of which is often extremely complicated and requires extensive expert knowledge. Only a small portion of the data needed by politics is immediately evident from the state’s own administrative records: for example, the number of births and divorces or of recipients of social benefits of any kind, the average grades of high school graduates or the age structure of retirees. But more often, the state is not allowed or not able to collect key information itself — such as the number of newborns with a migration background or the actual extent of substance abuse.
Other factors that may seem entirely unproblematic have to be determined through complex estimation operations that require constant refinement. These include not only the GNP, but also the population, which has not been counted directly since the last censuses in 1981 (GDR) and 1987 (BRD), but only updated with complicated, more or less satisfying methods. The reason is that society is resistant to being counted – a further example of the active role that the subject of social science plays for it by responding to it.

Politically important issues, such as per capita economic growth, the birth and immigration rate or the unemployment rate are thus known with far less certainty than is normally assumed. In fact, there are examples of problems that governments have tried for years to solve, or problems for which voters called them to account, that, when the statistical data was later revised, turned out not really to have been problems after all.

The only possibility to make visible the decisions and interests that contribute to the official descriptions of social reality is an independent social science. Only it can ensure the necessary pluralism through which alone politically problematic issues can come to light, or how small changes in legal definitions or administrative procedures – for example in the definition of unemployment or in the classification of job applicants by the employment offices – can change what is presumably the case, like the rate of unemployment.

The same holds true for the measurement of poverty and inequality or in determining the performance level of students and schools or workers’ satisfaction with their working conditions. In short, without society having methodologically serious, critical information about itself, the political discourse would be even more void of content than it already often is.

**THE AUTHOR**

Wolfgang Streeck, born in 1946, works on political economy and economic sociology. He began teaching at the University of Wisconsin in Madison in 1988 and was a fellow at the Wissenschaftskolleg Berlin in 1993. Streeck also held visiting professorships at various international universities before being appointed Director at the Max Planck Institute for the Study of Societies in 1995.
The desert ant’s use of its own built-in GPS – consisting of a sun-compass-based path integration system and visual landmarks – in locating its nest is a known phenomenon. Researchers recently ascertained, however, that this system also includes a sense of smell. Even more surprising is the discovery that these animals learn to distinguish between different odors in the nest environment, and use these like a map. Markus Knaden and his team at the Max Planck Institute for Chemical Ecology in Jena set out to search for clues in ant country.
FOCUS: Orientation

Photo: MPI for Chemical Ecology

contained in the nest odor of desert ants. Does every nest have its own odor? Or do all nests smell the same? What odor emanates from the entrance, a roughly two-centimeter hole in the encrusted ground of a desiccated salt lake? This is the typical habitat of the subject of their research – the feisty, shiny black ant *Cataglyphis fortis*.

A TRAIL OF ODORS FOR THEIR CONSPECIFICS

For two weeks, Steck stood all day, every day, in the blazing sunshine in temperatures of up to 50 degrees Celsius. Bühlmann extracted the odors at the nest entrance while Steck pursued the long-legged ants on their journeys across the salty desert floor.

The olfactory orientation of ants has long been established – even if it is not obvious to everyone. The ants pick up the scent of their food and identify friends and foes in ant country. “When they meet one another or arrive at the nest, they touch one another extensively with their antennae,” says Knaden. Once a foraging ant finds a food source, it informs its companions in the nest by means of an attractant, a pheromone trail on the ground. The ants follow this odor trail to the food source and then carry the food back to the nest. The more animals use the trail, the more it becomes reinforced. The result is the familiar ant trails, teeming with insects.

However, the *Cataglyphis* genus does not deploy these types of ant trails at all. “They are lone warriors when it comes to food,” says the behavioral ecologist. In the salt lake, only individual ants are seen flitting around, sometimes zigzagging around while foraging, sometimes hot-footing it toward the entrance hole of the nest. “A pheromone trail would quickly disappear in the salt pan, where temperatures reach almost 60 degrees,” says Knaden. There are ant species that do leave odor trails in such territories,
Cataglyphis occupies a very special place in the world of ant research. It is known as a “navigational genius.”

Over the decades, researchers discovered that the insect actually uses several techniques to cross the salt pans in search of rich pickings and return directly to its nest. “They use a path integration system – based on a sun compass for measuring directions and a step counter for measuring distances covered – and landmarks, to find the nest entrance,” says Knaden, summarizing the ants’ repertoire. Their facet eyes are thus bigger than those of many other ants. They also have very large, mobile antennae.

Yet, until now, hardly anybody had bargained on their sense of smell for guiding them across the hot, hostile salt flats. Not even Knaden. It was only when he arrived in Bill Hansson’s department in 2006 that the use of the Formicidae nose as a homing device came to his attention. “I had hoped that the ants had learned not only visual landmarks, but also possibly odor cues,” says the Max Planck scientist.

Knaden and Steck first began systematically researching the substances that ants actually smell – or don’t smell. In a special laboratory such as the one operated by Bill Hansson they have all the equipment they need to systematically investigate odors. Steck tested a wide variety of substances from the odor libraries and, using ‘electroantennograms,’ demonstrated how the olfactory nerves in the antennae respond to odors.

The two researchers then concentrated on four odors on which they trained the ants for their experiments: methyl salicylate, decanal, nonanal and indole. “We took environmental odors that are not connected with food, but rather are produced, for example, by plants and are highly volatile at high temperatures,” says Knaden. Food odors would have been too attractive. And the ants are not supposed to be attracted by the odor – they are supposed to be able only to identify it and remember it.

Research on Dry Land

The odor researchers then wanted to find out whether the animals are capable of using these odors for orientation in the area around the nest entrance,

“but these are mostly species that are active in the evenings or at night.” This means that they engage in foraging when temperatures cool down.

Desert Ants with Built-in GPS

In addition, laying an odor trail is beneficial only if there are plentiful food sources to exploit, that is, for ants who are carrying in those seeds that are lying on the ground behind a bush. However, Cataglyphis fortis ants have a particular liking for dead insects. And they carry these back to the nest in one piece.

Markus Knaden has spent 14 years researching Cataglyphis, a genus with approximately 60 species, of which 6 can be found in the Sahara, its main habitat. Cataglyphis occupies a very special position in the world of ant research. It is known as a “navigational genius.” This is probably a slight exaggeration; many other animal species have comparable orientation skills, but only a few of them are as well researched as the Cataglyphis.

Since the 1960s, scientists have been investigating how ants get their bearings in the desert. Back then, the father of Cataglyphis research, neurophysiologist Rüdiger Wehner from the University of Zurich, pitched his tents in the Tunisian town of Maharès and began to examine the navigational ability of these long-legged, elegant desert runners, which are roughly the same size as the common wood ants.
above: Different strokes: The entrances to many of these nests consist of only an inconspicuous, thumbnail-size hole in the ground; other ants of the same species create striking nest mounds. One possible reason could be that returning ants use the mound as a landmark and therefore find their way back faster to the safety of the nest.

right: Kathrin Steck marks individual ants. Using checklists, the researchers can see how often the individual animals have already performed the relevant training.

for example, in the same way that they use visual landmarks, such as a bush or a stone, to pinpoint the small entrance hole. The area studied is a desiccated salt lake in Tunisia, six kilometers long, three kilometers wide, about one hour
from the coast and the town of Maha-
rès, where the scientists were staying. 
The mecca of *Cataglyphis* research. Rü-
diger Wehner discovered the coastal 
area in 1968 and set up his base there. 
Markus Knaden, who completed his 
doctorate with Wehner and worked 
with him as a post doc, also began 
working with desert ants in this area. 

When he moved to Bill Hansson’s 
department in Jena in 2006, he initial-
ly had some bad luck: his ant popula-
tion in Maharès was almost decimated. 
“We assume that it had something to 
do with the major use of pesticides in 
the nearby olive tree plantations,” says
Knaden. He and Steck were thus forced to search for a new population – and they found one at the said salt lake, 75 kilometers away. Knaden saw the advantage of their salt flat immediately on their first visit: “The nests there were literally exploding with ants.” The nests were much bigger than those in Maharès, which is beneficial for carrying out spot checks and performing statistical evaluations.

SWITCHING TO LANDMARK ORIENTATION

Even though research conditions are better at the salt pan, the scientists from Jena don’t want to move there lock, stock and barrel; their base camp continues to be in Maharès. “The coast is simply nicer,” says Knaden. Better climate, a fishing port, a few restaurants. And the locals know the researchers, as they spend entire days standing in the scorching heat, watching ants. “We are the crazy people who come every year with new equipment and a jeep,” says Knaden, smiling.

The scientists set up their experiment in the salt lake, which contains water only during the winter. For their first experiments, they needed only a round, five-millimeter-thick plastic and aluminum panel with a one-centimeter hole in the middle, which was placed over a nest entrance. Using this method, Bühlmann and Knaden were able to demonstrate that odor is actually a factor in helping the ants find the entrance when they return to the nest: once the sun compass and path integrator have brought the ant to within a meter of the nest, the animal then switches to landmark orientation. “The ant cannot actually see the hole itself, so it remembers a nearby stone or bush,” says Knaden.

In the experiment, the researchers can exclude such information by covering the nest entrance with the panel. The ants then have no clues as to where the hole is. Nevertheless, they find it – because the nest has a particular smell. The researchers know this because each time the ants on the panel reach the wind vane, which indicates the wind direction in front of the entrance, they turn and scurry to the hole. On the leeward side, however, they wander around, searching, even if they are only a few centimeters from their own home. A first important finding.

FORAGING TRIP IN THE ALUMINUM CHANNEL

For the subsequent, more complex tests, the field researchers needed aluminum channels measuring two meters long and seven centimeters wide, U-shaped and open at the top, which are placed on the ground. These channels are connected via a tube with an upturned bucket positioned over the

Large test fields painted on the ground allow the researchers to record the ants’ extensive search runs. This method was established by Rüdiger Wehner, the father of Cataglyphis research in the late 1960s, and remains a proven technique to this day.
entrance hole to the *Cataglyphis* nest. The scientists use this test channel to hide all visual cues and the horizon from the ants’ field of vision: “The animals scuttle out of their nest under the bucket. They go through the tube and arrive at the side wall of the aluminum channel through a tiny hole. There they look for the food that we have laid out and come back to this hole,” says Markus Knaden, describing the experiment.

Would the ants also be guided by an odor that does not emanate from the hole itself, but originates from its environment? When Knaden and Steck examined this issue in their channel experiment, they made an exciting discovery that once again illustrates the complex sensory abilities of these small insects. But something first had to go wrong before they realized the ants’ abilities.

The hole in the side wall of the aluminum channel is so small that it is very difficult for the insects to find unless it is marked. “It takes them forever to find it,” says Markus Knaden. They keep running by the hole. However, they find it immediately if the researchers paint a black spot, for example, on the wall opposite the hole. They evidently use the spot as a landmark and link this to the location of the entrance. Would the same thing work with odors?

Because Knaden and Steck were not sure whether even one (and if so which) of the four odors identified in the laboratory – methyl salicylate, decanal, nonanal and indole – could ultimately be important, they drizzled the four substances separately to form an odor square in the training channel in front of the entrance hole. The ants learned very quickly that their entrance could be found in this odor field. When they returned after their foraging trip in the aluminum channel, they just searched inside the square for the entrance and found it immediately.

**A MAP OF VARIOUS ODORS**

Unfortunately, the control experiments yielded no conclusive results; the researchers offered an odor field again, but this time without an entrance. The ants did remember the odor and initially systematically frequented the odor field, “but each time they hurried out again over the lines of the square,” says
Knaden, describing the ants’ behavior. And then the researcher realized they had made a serious error: “We had mixed up the odors. In the control channel, they were in the wrong locations in relation to where the entrance hole was supposed to be.”

The ants were visibly confused by this. When Kathrin Steck arranged the odors in the same order in the odor square as they were in the test channel in front of the entrance hole, everything was back to normal again: the ants looked for the nest entrance only within the odor field as they had learned to do previously. “We had not expected the odor array to be important for orientation purposes,” says Knaden.

The animals clearly navigate not only on the basis of one or two odors in the mix and link these in their memory with the entrance hole, but they actually remember the individual locations of the odor drops. Or, in a nutshell: *Cataglyphis* smells in 3-D – a completely surprising and conclusive result that nobody had reckoned with after 40 years of research on *Cataglyphis*’ navigational skills.

In order to be able to orientate themselves spatially in such an olfactory landscape, the animals need two separate sensory inputs – as they do for seeing – which means that they rely on both of their antennae. According to Knaden, “Ants that only had one antenna could no longer find their way around.” This type of stereo smelling among animals has been known for a long time; researchers are sure that rats and even humans use such a method. What they did not realize is that ants also have this facility.

Yet a number of questions remain unanswered: Which landmarks are more important for the ants – visual or olfactory? And does the distribution of odors at the nest entrance in the natural environment really play a role? After all, the experiment with the aluminum channels is an artificial arrangement. It is possible that the ants may use such an odor map less at the nest entrance but more when foraging. A typical smell of home could also be enough for an ant to find its own nest.

Following his latest field trip, Markus Knaden is somewhat skeptical about this: “It looks like there’s one general nest smell,” he says. Steck, Bühlmann and he already suspect what the smell – or perhaps one should say stink – is: carbon dioxide, or stale air. “The animals breathe in the nest, food is consumed there – all of this causes the level of CO$_2$ in the air to rise,” explains Knaden. That could account for the nest odor, but he isn’t sure.

To find out exactly, Cornelia Bühlmann and Kathrin Steck collected the nest odors mentioned at the start of this article using an aspirator. Here in Jena, Steck puts the odors back into the refrigerator, and now there is just one more thing to do: go home and go to bed.

GLOSSARY

**Electroantennograms (EAG)**
Electrophysiological discharge of so-called summating potential (superimposed action potential of several odor receptors) over the entire antenna when an odor is applied.

**Path integrator**
Desert ants use a path integration system. This consists of a compass, to determine where they are heading, and an odometer to measure the distances they have traveled. The compass uses a light phenomenon in the sky that is invisible to the human eye and stretches across the entire celestial hemisphere as a large-scale polarization pattern. *Cataglyphis* measures the distance it has traveled by integrating the steps it has taken on the journey. Rüdiger Wehner and his colleagues discovered this by artificially lengthening or shortening the length of the desert ants’ legs before they returned to the nest from a feeder. The result was that animals manipulated in this way over- or underestimated the return distance by exactly the amount by which the animals had modified their step length due to the change in the length of their legs.
Bats use echolocation for foraging and orientation. Greater mouse-eared bats (*Myotis myotis*) locate insects in the grass by the noise they make while crawling.
On the Move
with All Their Senses

As any child could tell you, bats see with their ears. **Björn Siemers** from the **Max Planck Institute for Ornithology** in Seewiesen and **Richard Holland** from the **Max Planck Institute for Ornithology** in Radolfzell have demonstrated that they also take their orientation from the Earth’s magnetic field, calibrate their internal compass by the sunset – and may hold even more surprises in store for researchers.

TEXT **SUSANNE WEDLICH**
mammal’s unique main sensory skill: as has been known since the 1940s, bats use echolocation for hunting and orientation. In short, these animals see with their ears. They emit calls in the ultrasonic range, which is inaudible to humans, and listen for the returning echo. If the call hits an obstacle, for example a prey, it is reflected. Bats can then derive important information from this echo. For example, the echo returns faster if the obstacle is close by. If the reflected sound is fainter at one ear than at the other, the bat can identify the direction in which the object is located.

However, echolocation only functions at short range. “Bats cannot use it to get a far-reaching overview of their three-dimensional environment,” says Björn Siemers, head of a Max Planck Research Group at the MPI for Ornithology in Seewiesen: “They usually locate insects at a distance of just one to five meters. Because they fly at speeds of up to 35 kilometers per hour, for us, this would be more or less equivalent to travelling along a highway with a flashlight.”

Nonetheless, some bats cover long distances in their search for food, around 20 or more kilometers every night. Distances in excess of 50 kilometers can also lie between their summer and winter roosts. In the case of some bat species that cover distances of over 1,000 kilometers, zoologists would go so far as to describe their behavior as migratory. Nathusius’s pipistrelle bats, which are born in Poland, mate in Germany and winter in Holland, are a striking example of this phenomenon. “The question is how these animals find their way to the different locations,” says Siemers. “It is difficult to imagine that the bats orient themselves over such distances solely by memorizing individual trees, bushes or other landmarks.”

In his search for an answer to this question, the behavioral ecologist found an important pointer in the research carried out a few years earlier by his colleague Richard Holland as a Marie Curie Research Fellow at Princeton University in the US: “Up to now, research on how animals find their way in unknown areas was carried out primarily on migratory birds,” explains

Vampires are pretty much unstoppable – a peril of which hardened fans of horror movies and stories have long been aware. Garlic provides only temporary help, and anyone aiming to drive a wooden peg into their undead hearts must first find the courage to get close enough to them. The arrival of the dawn is often the last hope because, if the myths are to be believed, vampires disintegrate into dust in sunlight. However, the human bloodsucker’s supposed animal counterpart not only tolerates the sun’s rays extremely well, it relies on them: bats adjust their internal compass with the help of the sunset. They can then orientate themselves using the Earth’s magnetic field.

ECHOLOCATION ONLY WORKS AT SHORT RANGE

This ability of bats to calibrate their magnetic compass by the sun was discovered only recently. One possible reason why it took so long to demonstrate this is that researchers previously focused their attention on the flying
Holland. “This research showed that these birds take direction from the Earth’s magnetic field. At some point it became clear to me that bats face similar challenges, so in collaboration with Martin Wikelski, I set out to determine whether they have a corresponding internal compass.”

Holland’s experiments appeared to confirm his suspicion. However, his experiments involved only a few animals and, as a result, his findings were received with a degree of skepticism – also on the part of Björn Siemers. The two researchers thus began testing for a possible magnetic sense in bats in the context of a larger study they carried out in Bulgaria. The bat colonies there are usually far bigger than those found in Germany. “If we catch and test a few specimens from thousands, it is less disruptive to the group than if there are only a few hundred animals altogether,” explains Siemers. After one or a few nights at the field station, the researchers release the bats again at the site of capture.

Together with their Bulgarian colleague Ivailo Borissov, Siemers and Holland aimed to initially establish whether bats can find the right direction in a place that is unknown to them and find their way home. It quickly emerged that this posed no problem for the greater mouse-eared bats. They were released in a harvested field around 25 kilometers away from their roost that provided the bats with very few clues for finding the correct orientation.

OUT AND ABOUT IN A REVERSED MAGNETIC WORLD

Using a radio transmitter attached to the back of the animal, the biologists were able to observe that most bats rapidly flew in the direction of their home caves after just a few kilometers: “The fastest animals needed only around two hours to get back to their roost,” says Siemers. “And I had had major doubts as to whether this test would even work.”

This did not, however, explain whether the bats took direction from the Earth’s magnetic field and adjusted their internal compass by the sunset. As was proven decades ago, this is precisely what migratory birds do. Researchers use devices known as Helmholtz coils to demonstrate this. The animals are exposed to an artificially generated magnetic field inside the coils, and the researchers can control the orientation of this magnetic field. Therefore, for the experiment in Bulgaria, the MPI scientists used Helmholtz coils to generate a rotated magnetic field for half of the animals, shifted from north to east by 90 degrees. The coils with the control bats were not switched on, so the natural magnetic field was accessible to these animals. One factor remained the same: all of the bats were placed under a transparent Plexiglas dome and were able to observe the sunset.

The animals in the control group found their way back to their cave immediately. However, the bats that emerged from the rotated magnetic world flew, in accordance with the artificial orientation generated in the coils, around 90 degrees in the wrong direction, to the east. “To test the effect of the sunset, we then repeated the experiment at night,” says Siemers. In this case, too, half of the animals...
were exposed for one hour to a magnetic field that had been shifted from north to east. Any trace of the post-sunset glow had already disappeared by this time.

THE SUNSET POINTS THE WAY

All of the animals then flew directly to their home caves from the release site. “The manipulation of the magnetic field was thus effective only at sunset,” comments Richard Holland, “because the magnetic compass is recalibrated on the basis of the position of the setting sun.”

As a result, irrespective of whether the magnetic field tells them otherwise, west is where the sun goes down, as far as the bats are concerned. This is a good strategy, as iron deposits in the Earth’s crust can cause fluctuations in the local magnetic field. The result is surprising, nonetheless, as nocturnal bats – and almost all of the 1,000-plus species that exist throughout the world belong to this group – would rarely get to see the sunset.

The mouse-eared bats start to fly only when the sun has long disappeared over the horizon. “An hour after the animals had flown out, we could still see from the brightness in the sky where the sun had disappeared to,” says Björn Siemers. This glimmer of light is clearly sufficient for the bats to find their way.

But what happens on days with heavy cloud cover? “The animals probably stick to their last calibration,” says Siemers. “We presume that they do not rely on daily calibration, but we will have to carry out more experiments to confirm it.” It is also very likely that the bats note conspicuous landmarks and take direction from them, although this too, remains to be proven. “This is probably why the incorrectly calibrated animals from our magnetic field experiments noticed their mistake and found the right direction that would take them to their caves,” speculates Siemers – despite the fact that the animals have rather poor eyesight. “Contrary to the common assumption, bats are not blind,” stresses the biologist: “Their eyes are entirely capable of providing them with this kind of information.”

Bats are an extremely successful group of animals that has produced numerous species over the course of evolution. In echolocation, they have a unique sensory system that they use primarily for orientation and foraging. Unlike birdsong and human speech, echolocation did not arise mainly as a means of communication.

YE SHALL KNOW THEM BY THEIR CALLS

Despite this, bats can recognize and differentiate other members of their species by their echolocation calls. As a project carried out by Siemers and his colleague Maike Schuchmann revealed, horseshoe bats also differentiate between echolocation calls from other species. This was even the case when their own frequencies overlapped with those of the tested animals.

These findings raise new questions: “We are not yet able to gauge the extent to which the animals actually make use of the capacity to identify other species on the basis of their calls,” says Siemers. It would be conceivable, however, that they avoid superior competitors in their
foraging grounds in this way. It is also possible that they use this skill to follow other species with similar roosting requirements in their search for new roosting locations.

ADAPTED TO A VERY SPECIFIC NICHE

However, it may already be noted that, despite being just one of several senses – bats can see, smell, hear, and can also take orientation from the Earth’s magnetic field – echolocation fulfills a wide range of functions. The researchers still must find out, however, how the animals perceive the magnetic field. As far as Björn Siemers is concerned, bats are without a doubt a perfect research object for sensory ecology: “I would like to better understand the role played by differences in sensory abilities for mediating resource partitioning in bat communities that share a habitat.”

He suspects that differential sensory abilities will give the individual species access to different prey, and may thus reduce competition between them. In this way, even small differences could play an important role. A good example here are the bat species that forage for insects in the forest. This task is far from simple, as every irregularity in the tree bark, every blade of grass and every leaf reflects a bat’s call. “The animals hear a lot of clutter echoes from the vegetation, in which a prey’s reflection can be easily lost,” says Siemers. In this situation, bats produce short, repeated calls. The frequency range and duration of the calls are adapted to the obstacle-rich environment, but are not identical in all species. For example, the Natterer’s bat specializes in foraging directly at the vegetation edge. Its sonar calls can generate clearly recognizable echoes from insects against this background, and it can even locate a spider in its web. Other species in the same habitat are adapted to foraging between the trees, and may overlook the potential prey of the Natterer’s bat as a result.

The greater mouse-eared bat, the largest bat species found in Germany, also recognizes its prey from the noise it makes and, initially, without using echolocation. As Björn Siemers has proven, the animals even fly toward the song of male bush crickets, who are aiming to attract females by singing, but may end up in the mouth of a bat instead.

It is known that this involuntary acoustic prey engages in its singing activities mainly from elevated locations so that it can be heard by females over a wide area. However, the male bush crickets also avoid very exposed locations. This may well be an adaptation to avoid exposure to their flying predators. The most important prey of the greater mouse-eared bat, the carabid beetle, also generally gives itself away by the rustling noises it makes on the ground.

Greater mouse-eared bats like to forage on dry ground or on mowed meadows because the beetles can hide easily in high grass. “We asked ourselves whether, perhaps, humans can also have a detrimental influence here,” says Siemers. Two years earlier, the researchers succeeded in demonstrating that the bats avoid loud traffic noise: “Then we wanted to know what happens when they cannot avoid the acoustic disturbance.”

The test involved the simulation of a highway roaring through the bats’ customary foraging area. To do this, Siemers and his colleagues recorded highway traffic noise and played it back to the bats. “And, moreover, at a realistically high volume, which made it sound like trucks and cars driving past them close by,” says the scientist. They also recorded the rustling sounds of carabid beetles in a sound chamber. The beetle rustling recording was
played at varying distances from the artificial traffic noise. The result: the closer the traffic noise, the longer the bats needed to locate the rustling sounds and the lower their foraging efficiency. However, even when the traffic recordings corresponded to a distance of just 7.5 meters from a road, the animals still succeeded in locating the beetle sounds half of the time. This proves that bats are extremely good at filtering out loud background noise. “These results highlight once again just how sensitive their hearing is,” stresses Siemers.

GLOSSARY

Ultrasound
Sound events above the human hearing range, between approximately 16 hertz and 20 kilohertz, are defined as ultrasound (1 hertz corresponds to one sound cycle per second). Most bat calls are very high frequency, typically above 20 kilohertz. Siemers and his colleagues succeeded in demonstrating the world record for a bat call of 250 kilohertz among Malaysian rainforest bats. Due to a phenomenon known as atmospheric attenuation, lower frequency sounds travel further than higher frequency sounds.

Echolocation
Despite its limited range, bats use ultrasound for echolocation because it provides relatively precise resolution. The physical principle at work here is that the higher the frequency, the smaller the wavelength and the smaller, again, the possible distance between two objects that still enables them to be reflected by two separate echoes. This means that they can be perceived by the bat as two distinct objects and not one (merged) object.

Vegetation edge
The edge structure of vegetation, for example of bushes or groups of trees.

Introducing the Mai Tai® SP, the most stable and first fully-automated, short-pulse oscillator for amplifier seeding. The Mai Tai SP laser delivers pulses in the <25 fs to 100 fs range, and features completely computer adjustable bandwidth. Our proprietary StabiLok® technology ensures that beam pointing and stability are always optimized – there is no need to realign the laser. Ever! That’s stability and flexibility beyond compare.

For detailed information, call us or visit www.newport.com/maitai-sp
Memorizing a Set of Maps

How do we orient ourselves when we’re in an unfamiliar city? What strategies do we use to get from A to B? These questions have been occupying the minds of scientists in the Perception, Cognition and Action Department of the Max Planck Institute for Biological Cybernetics in Tübingen. And they have discovered that our brains piece together our routes based on lots of individual bits of information, like tiny individual maps – always starting from our present location.

TEXT STEFANIE REINBERGER
Did you manage to find us alright?” asks Tobias Meilinger as he greets me. A routine everyday question, but one with a deeper meaning for this Tübingen-based scientist. The psychologist is working on a research project at the Max Planck Institute for Biological Cybernetics in Heinrich Bülthoff’s Perception, Cognition and Action Department. Meilinger is interested in how we orient ourselves in space, and what sensory and cognitive skills we need to do this.

As we move from A to B, our brains perform a feat of technical brilliance. Take my brain, for instance, on the day I visited Tübingen: I moved between bed, bathroom and breakfast table on autopilot, and the short distance to the train is a well-trodden route. The stations where I have to change are familiar from previous trips, and even when I finally reach Speimannstraße in Tübingen, I know roughly what direction to take, having visited the area a few years back. I make decisions about which direction to take in no
Our various sensory organs receive a wide range of impressions describing a place, a route or an environment. Without adequate sensory input, we lose our sense of direction.

NAVIGATION IS A MULTISENSORY PROCESS

A whole range of different details help us recognize a place and choose the right direction when we need to find our way somewhere in a specific environment, such as a building or a city. We use landmarks, such as high mountains or tall towers, to orient ourselves from a distance, but also distinctive roadside features, such as a red house or a bus stop. We also memorize whether we turned right or left coming from a particular street to get to the station.

“In addition to visual perception, our sense of balance plays a key role. But we also notice how much effort a particular route requires – for instance, whether it goes uphill, whether the ground is even or full of potholes and rocks,” explains Heinrich Bülthoff. Therefore, we usually manage to follow directions that go something like this: right at the first traffic light, then left at the church and up the hill. Navigation is a multisensory process. Our different sensory organs receive a wide range of impressions, describing a place, a route or an environment. If the bulk of this information is missing, things start to go wrong. During a sandstorm in the desert, for example, everything around us looks the same and we end up going around in circles, as the scientists in Tübingen discovered in 2009. Without sufficient sensory input,
we lose our sense of direction and our route quickly degenerates into random twists and turns to the right or left. Psychologist Tobias Meilinger is currently focusing on spatial orientation. “I’m interested in how we navigate in completely ordinary everyday situations, for instance when we’re walking through an unfamiliar town,” he says. How do we orient ourselves? What frames of reference do we use? What impressions help us? Psychophysics can provide the answers to these questions. It is an old scientific discipline dating back to 1860 and describes how the mind generates subjective perceptions from physical stimuli received from our surroundings.

The researchers in Tübingen are studying this with the help of state-of-the-art technology: virtual realities. Wearing video glasses, their test subjects walk through labyrinths, cybercities and computer simulations of real localities. In some experiments, they stroll along on a unique, specially designed treadmill on which they can move not just forward and backward, but also right and left, although in reality they are simply walking in place (MAXPLANCK-Research 2/2008, page 50 ff.).

**EXPERIMENTS IN VISUAL PERCEPTION**

“Working with virtual realities allows us to focus on several sensory responses simultaneously. This means that we can simulate an actual navigation situation very realistically,” explains Heinrich Bülthoff. “But unlike a real test lab, we can shut out disrupting influences – additional stimuli that might distract the test subjects from their task.” Until now, most spatial orientation experiments worldwide have used a static test setup with so-called vista spaces that can only be perceived from a single viewpoint. Or the test subject uses a joystick to stroll along a route on the screen. These tasks concentrate primarily on visual perception and ignore all the other sensory inputs that we use for navigation.

In the interest of research, Meilinger allows me to try out cyberwalking. He takes me into the test lab, the Cyberneum, and hands me the video glasses. I instantly find myself in a simple computer simulation of a city complete with streets, alleyways and houses of various sizes and colors. I can even make out the vague outlines of a shopping mall. Unfortunately, I’m not allowed to try out the CyberCarpet, as the research scientists have christened their special treadmill. This technological marvel is reserved for real test subjects. I only get to move the joystick and turn in the required direction. No
Tobias Meilinger prepares a test subject for an experiment.

Routes through an unfamiliar city: A bird’s eye view of the labyrinth of virtual streets through which test subjects must find their way.
Do we all walk around with a giant map in our heads, adding to it and expanding it with each new place we arrive at? Or do we store the information for different environments – each room or each street – separately?

matter. That’s enough to give me some idea of what Meilinger’s work is all about. “Take a look around first and then move forward,” the scientist instructs me. “Now along there,” he continues, as I look left at the first intersection. He deliberately avoids stock phrases such as “turn right” or “turn left.” This is to prevent test subjects from being influenced by his instructions during the experiment, instead of the visual and motor stimuli they receive in the virtual city.

WE TEND TO STORE LOCAL BITS OF INFORMATION

The Max Planck scientist uses his virtual city to investigate how people’s brains store a route that they take regularly. The first groundbreaking ideas on this subject were developed in 1971. John O’Keefe and John Dostrovsky of University College London discovered that rats had special cells in their brains – in the hippocampus to be more precise – which fired only when the animal was in a particular spatial position. And wherever the rodents were, at least one of these place cells was active. This discovery formed the basis for the later idea that our brains create cognitive maps that they use to store location information.

Meilinger is reluctant to use the term “map” in this connection. “It implies a map like the ones we’re used to seeing in a road atlas,” he says. He prefers “reference framework” or “system of coordinates.” But whatever you call it, the question the scientist is trying to answer is: Are these global or local systems? In other words, do we all walk around with a giant map in our heads, adding to it and expanding it with each new place we arrive at? Or do we store the information for different environments – each room or each street – separately?

A lot of evidence suggests that we tend to store local bits of information. Meilinger let his test subjects stroll through the virtual city several times – always the same route and always in the same direction – until they had memorized it. Then he teleported them to a specific location along the route and asked them to point in the direction of certain other positions on their walk, such as the starting point or their destination.

Most test subjects managed to accomplish this task faster when they were asked to indicate points that lay ahead of them rather than behind them. Test subjects also found it easier to orient themselves when they were aligned along a street – that is, positioned in such a way that they could have run straight along it. They could point to the required location more accurately in these circumstances than when they were, for example, staring at a wall. In other words, they used local landmarks for orientation rather than global reference points, such as points of the compass.

But this is not always the case, as the Tübingen-based scientists discovered to their great surprise during another experiment. Julia Frankenstein, a former graduate of the department, placed her test subjects in a photorealistic simulation of the old city center of Tübingen. At the time of the experiment, all of the test subjects had lived in the Swabian university town for more than two years, and seven years on average. So they knew it inside out and, unlike the walkers in Meilinger’s virtual environment, did not have to memorize the routes from scratch.

KNOWING A CITY LEADS TO A DIFFERENT STRATEGY

Just as in the experiment previously described, Frankenstein teleported her test subjects to certain positions in the town and asked them to point from that position to particular landmarks, such as places of interest. Astonishingly, these Tübingen residents managed this best when they were “beamed” to the aforementioned position in the old town and were facing north, exactly as the location would be shown on a town map. So in this case, the test subjects did not use local frames of reference for orientation – How do I get there? What route do I normally take? – but instead by using a compass point, a global reference point.

Rather than being built along a straight north-south line, the center of Tübingen is a typical “old town” of haphazard winding streets. This suggests that the “north alignment” effect is not restricted to Tübingen, but presumably also occurs elsewhere. The initial data gathered by Frankenstein using volunteers from other places indicates exactly this – people who are familiar with their town tend to use north as a reference point for gaining their bearings.
Almost real: The scientists used this photorealistic simulation of Tübingen to test how people orient themselves in their home town.

The experiments show that we locate destinations in a familiar town based on the points of the compass – apparently because we have a map of them (in this case Tübingen town center) in our heads – and that map is aligned to the north.
I assume that, wherever we happen to be standing, our brain creates a mental model of its surroundings, made up of different impressions.

The scientists in Bülthoff’s team believe this may be because, over time, we not only memorize our experience of different routes, but also the street map of the town itself. And that is always aligned to the north. “Ultimately, this means that the human brain is definitely capable of using different navigation strategies,” explains Meilinger. “And if we already know the map of a particular environment, have memorized the layout of a town we often visit for instance, we will refer back to it.” When we are new to an area, however, we learn it item by item, and store the information in small, local bits. And then we keep piecing these back together, depending on what we’re doing at the time. Meilinger cites an example: “Point toward the cafeteria,” he instructs me. I hesitate briefly before pointing in the direction where I think we got our coffee half an hour ago. “Pretty close,” the scientist says in praise. “You probably built a mental model in your head of the way there – from your present position and using landmarks you memorized as you went past them.”

Further experiments based on the psychologist’s virtual city suggest that this is, in fact, the case. When the test subjects were teleported to intersection number four, for example, it was relatively easy for them to point from there to the third, then the second, and finally, the first turnoff, and only after that to their starting point. Things became trickier when they were asked to leave out the intermediate points, and instead to point to their starting position right away and intersections one, two, and three only after that. The same applied when they had to point to stops on the training route that, theoretically, still lay ahead of them – in other words, when they were asked to point from the fourth intersection to the fifth or sixth intersection, and so on. Our brains find it easier to map a route starting from our own location than from any other position.

WHAT ROLE DOES OUR SENSE OF BALANCE PLAY?

Meilinger explains the results of the investigation. “This shows that we integrate information about a route incrementally – that is, one step at a time – and starting from our current location. I assume that, wherever we happen to be standing, our brain creates a mental model of our surroundings, or assembles a route made up of different impressions.” And this includes the sequence in which we noticed distinctive details, such as whether we saw the red house first, then a hydrant and only then a bus stop at the third intersection. Perhaps this directional thinking also explains why we sometimes choose a different route home than the one we took on the way there.

Visual impressions are certainly extremely important for orientation. But there’s more to it than that. Anyone who has strolled for hours through an unfamiliar city can probably remember if a certain street was really long. “We plan to investigate how we process information about distances in our navigation system,” says Meilinger, referring to a future research project.

Meanwhile, his boss, Heinrich Bülthoff, is keen to go one step further by adding another dimension. In the Cyberneum, right next to the room in which Meilinger’s test subjects stroll through a virtual city, stands a kind of flight simulator, a robot arm with a seat on the end. “We can use this to investigate how pilots orient themselves when flying. They process not only visual information but also information generated by their sense of balance,” explains Bülthoff. After all, spatial navigation is a multisensory process. Researching it means incorporating all of our senses, one step at a time.

GLOSSARY

Place cells
Specific neurons in the hippocampus that start to “fire” when an animal is in a specific location corresponding to the relevant environment, the place field of the cell.
What Makes Humans Human?

Human ancestors were already using stone tools to cut up meat 3.4 million years ago

Eating with a knife and fork is not merely an indicator of good behavior. Paleoanthropologists regard the crafting of tools to cut up meat as a criterion that distinguishes human beings, and ascribe it exclusively to the genus *Homo*. It appears, however, that the human ancestor *Australopithecus afarensis* was already using tools to eat. Shannon McPherron from the Max Planck Institute for Evolutionary Anthropology in Leipzig and an international team of researchers discovered 3.4-million-year-old bones in the Afar region in Ethiopia that bear unambiguous cut and percussion marks.

At that time, the only inhabitants of the area were representatives of the *Australopithecus afarensis* species, which also includes the famous “Lucy.” The researchers, however, have not found any tools and therefore do not yet know whether *Australopithecus afarensis* actually made tools or only collected and used sharp-edged stones. The oldest stone tools discovered to date are 2.5 to 2.6 million years old and were probably worked by early humans of the species *Homo habilis*. (*Nature*, August 12, 2010)

Carbon in a New Balance

Climate forecasts might become more precise and more reliable in the future thanks to new findings on the role of terrestrial ecosystems in the global carbon cycle. International teams of researchers headed by the Max Planck Institute for Biogeochemistry in Jena have presented two wide-ranging analyses of measurements from 60 stations distributed across the world. The results are precise assessments of how ecosystems might react to climate change. For example, the rate at which plants photosynthesize – that is, fix carbon dioxide from the atmosphere – hardly varies with temperature fluctuations in most ecosystems. On the other hand, on 40 percent of the Earth’s vegetated surface, photosynthesis reacts very sensitively to the amount of precipitation. Transpiration, whereby flora and fauna release carbon dioxide, increases less than previously assumed when the temperature rises. Furthermore, its dependence on temperature remains similar throughout the world, even in such diverse ecosystems as the tropical savanna and the pine forests of Finland. (*Science Express*, July 5, 2010)
Kicking is not restricted to football: When black holes collide and merge, the resulting black hole shoots on through space at speeds of up to several thousand kilometers per second. Sometimes, however, the speed decreases. Researchers working with Luciano Rezzolla from the Max Planck Institute for Gravitational Physics explain this using the gravitational waves that are radiated in the merging process. They simulated a frontal collision between two black holes, one fast-moving and small, the other slow-moving and large. Both radiated gravitational waves in the direction in which they were moving. As the larger black hole provides the stronger impulse, the merged black hole moves in its direction after the collision – which is the “kick”. The black hole thereby created is initially not completely round, however, but has a “bump” where the smaller black hole was submerged into the larger. A pulsing movement smoothes this asymmetry, while more gravitational waves radiate toward the bump than away from it. The gravitational waves exert an additional impulse which creates a recoil. This “anti-kick” causes the resulting black hole to slow down slightly. (Physical Review Letters, June 3, 2010)

Carbon could emerge as the silicon of the future. It might be possible to create very small and powerful microchips from this material if it were to take on the properties of a semiconductor. A team working with scientists from the Max Planck Institute for Polymer Research and Empa, the Swiss Federal Laboratories for Materials Science and Technology, have now achieved this. The researchers used a simple chemical method to create narrow ribbons of graphene – single layers of carbon atoms – on a metallic substrate. For this purpose, they manufactured molecules from which they fabricated the graphene ribbons. As these are no more than a few nanometers in width, they take on semiconducting properties, which makes them promising candidates for future applications in electronics, particularly since their properties – according to width and edge-type – can be manipulated in a targeted manner. (Nature, July 22, 2010)
The Phenomenon of the Opera

Cultural programs improve economic growth

When budgets are limited, authorities are quick to economize on cultural amenities. This might turn out to be counterproductive. A group of researchers at the Max Planck Institute for Economics in Jena has found that cultural events make cities and regions more interesting for highly qualified individuals – and thereby encourage economic growth in the area. The researchers evaluated regional data from Germany and determined that the number of highly qualified employees (defined as those with a university education) rose with the region’s proximity to a baroque opera house. These highly qualified people, in turn, are largely responsible for the stronger economic growth these areas experience.

The locations of the 29 baroque opera houses that formed the starting point for the study conducted by the Max Planck Institute for Economics

Pulsars for Weighing Planets

Even high school students learn how to weigh planets. They apply Newtonian mechanics and determine the masses from the orbits of the planets’ moons. Now, an international team led by David Champion from the Max Planck Institute for Radio Astronomy in Bonn has used a completely different method, which is not only accurate to 0.003 percent of the Earth’s mass, but also allows the planets to be weighed together with their rings and moons. Astonishingly, the technology uses pulsars – dead stars that rotate extremely rapidly around their axes while transmitting very regular radio pulses. As the Earth moves around the Sun, the rhythm of the radio signals is distorted on Earth. The researchers calculate from this when the signals arrive at the barycenter of the solar system. The sequence of signals is completely regular only if the researchers know the exact location of the barycenter. This, in turn, depends on the masses of the planets. In an iterative process, the researchers adjust the planet masses until their calculations yield a regular rhythm at the barycenter. The procedure could supply important data for future space travel missions. (Astrophysical Journal, August 23, 2010)

The Sun and the planets are embedded in a time-space grid. Researchers can now determine their mass with pulsar signals (blue rays).

Today Paris, Tomorrow Tokyo

Frequent fliers know all about it: When the internal clock is upset, the whole body is affected. This is because we have not just one inner clock, but an entire network of clocks in our organs. This network coordinates physiological processes in the body such as heartbeat, temperature, sleep requirements and hormone levels. Jetlag disrupts the rhythm of the whole mechanism. The inner clocks in the organs adapt to changes in the external environment at different speeds. According to scientists at the Max Planck Institute for Biophysical Chemistry in Göttingen, the inner
Expensive Defense

Plants must always pay a high price for resistance to disease

Every amateur gardener is familiar with the dilemma: The largest and most beautiful roses are the most susceptible. The small and insignificant ones, on the other hand, are more resistant to pests. The high cost of self-defense is the reason for this. Scientists working with Detlef Weigel at the Max Planck Institute for Developmental Biology in Tübingen have discovered a variant of the ADC6 gene with which mouse-ear cress, Arabidopsis thaliana, defends itself against bacteria, fungi and insects. The gene makes the plants resistant to different pests, but it also interferes with the growth of leaves and seeds. In nature, only some 20 percent of the Arabidopsis plants carry the variety of the gene that provides a defense against pests. In years or habitats in which enemies are rife, these plants have an advantage over fellow members of their species, but conversely, when there are few pests, most of the other individuals grow and reproduce faster. (Nature, June 3, 2010)

Arabidopsis with powdery mildew. The web of fungal hyphae forms rod-like reproductive organs with spores that are distributed by the wind. The plant’s immune system defends it against the powdery mildew. The purpose of the spines on the surface of the leaves is to protect it from insects.

Quantum Gas in Free Fall

A sensitive measuring device must not be dropped – because this usually puts an end to its precision. However, that is exactly what a team of researchers, which included scientists from the Max Planck Institute for Quantum Optics, did. Surprisingly, their intention was to make the instrument more sensitive. The team working with physicists from the University of Hanover allowed a device, in which they generated a weightless Bose-Einstein condensate (BEC), to plummet down a drop tower at the University of Bremen. The particles in a BEC lose their individuality and can be regarded as super particles. The researchers want to use such an ultra-cold quantum gas at zero gravity to construct a very sensitive device with which to measure the Earth’s gravitational field – in order to detect mineral deposits, for example. They could also use the procedure to test the equivalence principle. While every student is taught that it is irrefutable, proof has not been presented to date. According to the equivalence principle, gravitational mass corresponds to inertial mass, so that all objects in a vacuum fall at the same speed. (Science, June 18, 2010)

Fall height experiment: The capsule for the Bose-Einstein condensate
Immunity to Malaria

Antibiotics protect mice from malaria

An antibiotic against a non-bacterial pathogen – initially baffling, but it actually works. According to researchers at the Max Planck Institute for Infection Biology in Berlin and at the University Hospital in Heidelberg, antibiotics in tablet form could one day act as a vaccine against malaria. They have discovered that no disease-causing malaria pathogens appeared in the blood of mice which had been given the antibiotics clindamycin or azithromycin for three days. And there’s more: They also develop a lasting immunity to subsequent infection.

The scientists suspect that the active agents could work on humans in the same way. The antibiotics block an organelle of bacterial origin in the parasites, the apicoplast, which allows the pathogens to enter the cells. Although the apicoplast is blocked, the infectious stage of the malaria pathogens initially reproduces in the liver. This means that the immune system in the liver is confronted with all the markers of the pathogens and builds up immunity. The disease-causing stage, however, is subsequently unable to enter the blood cells and trigger the typical symptoms of the illness. (Science Translational Medicine, July 14, 2010)

The infectious stages of the malaria pathogen are transmitted by a bite from an infected mosquito. The vermiform sporozoites attack liver cells.

Ye Shall Know Them by Their Gestures

Media appearances by today’s politicians are meticulously planned. Political advisors even recommend that their charges gesticulate with their right hand, because in many cultures, “good” and “evil” are associated with “right” and “left.” An investigation by the Max Planck Institute for Psycholinguistics in Nijmegen in the Netherlands reveals, however, that humans do not associate positive messages with a certain side of the body, but with the side that is dominant for them personally. Consequently, right-handed people associate honesty or intelligence with their right-hand side, while left-handed people associate these characteristics with their left-hand side. Scientists at the Institute analyzed the spontaneous gestures made by the American presidential candidates in 2004 and 2008 in their speeches for their positive and negative content. According to this analysis, the right-handed candidates George W. Bush and John Kerry supported positive statements with their right hand, but they accompanied negative statements mainly with the left hand. This was exactly reversed for Barack Obama and John McCain, who are both left-handed. John McCain, for example, emphasized negative content with his right hand twelve times more frequently. (PLoS ONE, July 28, 2010)

Show me your gestures and I’ll tell you if you are lying: Right-handed George W. Bush associates positive messages more frequently with gestures by his right hand, but negative messages with gestures by his left hand. Left-handed Barack Obama uses his hands in the opposite way.
Quantum Transistors for Photons

In the future, light might do the job that electrons do today, processing huge quantities of data quickly and reliably in computers. Physicists at the Max Planck Institute for Quantum Optics have constructed an optical transistor using principles that could allow even the tiniest logic elements to work in a computer of the future. The researchers use a laser to control whether a single atom allows a test laser to pass between two mirrors, in the same way as a control voltage regulates the flow of current through a transistor. They draw on a quantum mechanical interference effect called electromagnetically induced transparency. As long as the controlling laser remains switched off, the atom interacts with the test laser in the space between the mirrors and prevents it from shining through the system. Then the control laser manipulates the atom and mirror system so that it no longer interacts with the test laser – it becomes invisible to the test laser and allows it to pass through again. Up to now, it has been possible to demonstrate the effect only with a large quantity of atoms. (NATURE 465, 755-758 (2010) doi:10.1038/nature09093)

The Proton – Smaller Than It Was Thought to Be

Sometimes, big problems can be very small. The problem physicists are now grappling with measures just 0.0350 millionths of a millionth of a millimeter. This is exactly how much smaller a proton, the nucleus of a hydrogen atom, is than was previously thought. Instead of 0.8768 femtometers, it measures 0.8418 femtometers. This measurement was made by an international team of researchers working with physicists at the Max Planck Institute for Quantum Optics in experiments at the Paul Scherrer Institute in Switzerland. These experiments are ten times more accurate than all the previous experiments. The researchers examined tiny subtleties in the atomic structure of muonic hydrogen in which, not an electron, but a much heavier muon orbits the nucleus. It is only with the heavier muon that the atom can be observed to assume states in which the electron (or the muon) sometimes resides in the atom nucleus, while in other states it avoids the nucleus. This leads to a tiny energy differential between the states that depends on the size of the nucleus or that of the proton. The physicists used a laser with an extremely precisely defined wavelength to measure the energy differential and calculated the size of the proton from it, leaving physics with some tough problems: at least one natural constant has now changed, and the calculations of quantum electrodynamics must be reviewed. This theory is considered very well proven, but its predictions do not match the current measurements. (NATURE, July 8, 2008)

Struck by a Comet

The large planets in the solar system are repeatedly the target of cosmic bombs – comets and planetoids. The projectile that probably resulted in the extinction of the dinosaurs on the Earth 65 million years ago is legendary. And in 1994, fragments of the Shoemaker-Levy 9 comet smashed into Jupiter’s atmosphere. Scientists at the Max Planck Institute for Solar System Research recently discovered that Saturn was hit around 230 years ago. Working with Max Planck colleagues in extraterrestrial physics and the French Lesia Observatory, this group has now made another find: 200 years ago it was Neptune’s turn to be a target. In data from the Herschel Space Observatory, they noticed a characteristic distribution of carbon monoxide in the atmosphere of the gas giant. There were higher concentrations of carbon monoxide in the stratosphere than in the troposphere below it. This increased accumulation can only be explained with an external source, such as the impact of a comet. When this happens, the “dirty snowball” breaks up and, over the years, the carbon monoxide fixed in the comet ice is distributed from the location of the collision throughout the stratosphere. (Astronomy & Astrophysics, online, July 16, 2010)
Klaus Blaum, Director at the Max Planck Institute for Nuclear Physics in Heidelberg, and his colleagues use clever tricks to weigh atomic nuclei to answer key questions in the field of physics – questions like how stars breed chemical elements. Or what makes up the dark matter that holds the universe together.
Weighing atomic nuclei – why undertake such a task? Klaus Blaum is obviously used to such questions. The young Director at the Max Planck Institute for Nuclear Physics in Heidelberg patiently explains why he is constructing what is probably the most sensitive balance to date for tiny objects. Close to 40 group members are working on these precision experiments in collaboration with partners from other scientific institutions. The conversation quickly turns into a journey of adventure from tiny atomic nuclei to the great questions in physics. It is amazing what insights the weighing of atomic nuclei can provide.

Breeding grounds for heavy nuclei: In the vacuum chamber, physicists produce heavy atomic nuclei by shooting an ion beam at a metal foil.

Time and again, Blaum jumps up and goes over to the large chart of nuclides on the office wall: a broad panorama of the diverse atomic nuclei with their physical properties. Blaum moves his finger over small squares that symbolize the chemical elements and their lighter or heavier isotopes with their varying numbers of neutrons; the heavier an element, the further to the right its position on the chart. To the extreme right, beyond uranium – the element with the atomic number 92 – for example is where the realm of the heavy and superheavy elements begins. These artificially produced nuclei do not remain stable – they decay after a few millionths of a second or a few seconds at most.
The physicists have already reached element 118, but the International Union of Pure and Applied Chemistry (IUPAC) has officially confirmed only the elements up to 112. Beyond these elements, the chart ventures into unknown territory. Physicists have long assumed there is an island of stability somewhere near element 120. “The nuclei there could live for years,” explains Blaum. Subtle quantum effects are assumed to form the stabilizing nuclear glue on this island, which also exerts a powerful force of attraction on the Max Planck researcher. He is not interested in holding weight records in physics, but in how atoms – the building blocks of matter – are formed.

“The exciting question for me is how the world came into being,” says Blaum, and promptly arrives at astrophysics because, after all, stars breed almost all the atomic building blocks of matter beyond hydrogen and helium. The scientist is particularly fascinated by the nucleosynthesis of heavy chemical elements. These are produced only under the extreme conditions that exist during a particularly dramatic death of a star – a supernova.

NUCLEI FUSE ONLY DURING HEAD-ON COLLISIONS

Astrophysics has even more problems in store, and Klaus Blaum wants to come closer to solving them by weighing atomic nuclei. The fundamental question concerns the mass of the neutrinos – the omnipresent, all-penetrating ghost particles of physics. The answer would, among other things, add a further, important piece to the jigsaw puzzle of the universe. Like any cleverly thought-out precision experiment, a balance for atomic nuclei is thus simultaneously useful in several basic research fields. But what does such an extreme balance look like? And how does it work? Blaum wants to demonstrate just this at the GSI Helmholtz Center for Heavy Ion Research in Darmstadt/Germany.

Two days later, we are standing inside a large experimentation hall in Darmstadt in front of Shiptrap. This seemingly chaotic jumble of tubes, cables and bright digital displays looks nothing like a scale, although in reality it has been thought through in great detail. Atomic nuclei are weighed in a completely different way than flour or people, of course. Dr. Michael Block provides a tour through the facility. The atomic physicist is the project leader of this experiment at the GSI, which is a collaborative effort between the Max Planck scientists from Heidelberg and other German and international research groups.

Block starts by pointing out where the heavy nuclei are created. This is where the Darmstadt physicists were the first to produce a total of six superheavy elements, including numbers 110 and 112, which they were then allowed to name darmstadtium and copernicium. The crucial element can be found in a vacuum chamber whose reinforced windows are reminiscent of an old-fashioned diver’s helmet. A metal foil clamped in a revolvable wheel gleams behind the window. “This is the target,” explains Block. A beam of ions, electrically charged atoms such as calcium ions, for example, strikes this target. Before impact, the electromagnetic fields of the GSI’s powerful accelerator have boosted their speed to tens of thousands of kilometers per second.

One of the many trillions of ions in the beam sometimes lands a direct hit: its atomic nucleus collides head on with the nucleus of an atom in the metal foil. This is an extremely rare event, however, as atomic nuclei are unimaginably tiny. Their diameter amounts to only a few femtometers: a few millionths of a millimetre. If a nucleus from the ion beam collides head on with a nucleus in the foil, they fuse together. This results in a heavy or even superheavy atom – albeit one that is also electrically charged.

The momentum tears the heavy ion out of the back of the metal foil. With Ship (Separator for Heavy Ion reaction Products), it initially passes a velocity filter that separates it from the beam particles. The ion then arrives at Shiptrap. Before the actual weighing can begin, it must first be slowed down from its high velocity to almost zero – and this happens over a distance of less than half a meter!

THE ATOM MEANDERS ABOUT IN THE TRAP

Another foil and an elongated cell filled with gaseous helium act as the decelerator: in the cell, the heavy ion collides with a cascade of helium atoms in a massive pile-up. Although the braking principle is simple, years of research have gone into developing the gas cell. Even with the technology used today, only a small percent of the heavy ions survive the deceleration process; most of them remain stuck in the foil or hit the cell wall, where they decay.

The ions that survive then arrive at the trap part of the Shiptrap. The name of the scale was actually chosen because it consists of a so-called Penning trap, named after the Dutch physicist Frans Michel Penning. It is positioned in a very strong superconducting magnet, and its magnetic field and the trap’s electric field together form a cage for the electrically charged ion. In the cage, the particle meanders about in an orbit resembling a spiral bolted together to form a circle.

“An ion circles a million times per second on this rosette-shaped orbit, for example,” explains Blaum. This circu-
lution frequency already contains the precise information on the weight or, to use the more precise physical term, the mass of the ion. There is, unfortunately, no simple way of just taking a reading. What is required is a trick that Blaum illustrates with an example: imagine that the ion oscillates to and fro on its orbit, as if on a swing. The particle is excited by an electromagnetic RF signal. The more accurately its adjustable frequency corresponds to the characteristic frequency of the ion in the trap, the faster the ion builds up its speed. Finally, it is ejected from the trap and ends up in a detector. The time it takes the ion to fly there tells the physicists the characteristic frequency and thus the mass of the ion. The researchers can ultimately use this to calculate the mass of the atomic nucleus with high precision.

Using this method, Blaum, Block and their partners recently succeeded in determining the mass of the atomic nucleus of nobelium, the element 102, with very high precision. “Our publication in the journal Nature caused quite a stir in the press,” says Klaus Blaum with pride. “In Spain, even El País carried the report of one of our Spanish group leaders on the front page,” recounts Michael Block.

The present measuring procedure has the disadvantage that each measurement destroys the valuable ion. Even in the case of nobelium, only very few ions per hour ended up in the trap on average. And in top accelerators, such as the one at the GSI, the even heavier nuclei are sometimes produced only once per day or per week. But the physicists need around 100 ions per mass measurement. This is a problem, because measurement campaigns lasting 100 weeks would be much too expensive at this very popular research facility.

Blaum and his team are thus now working on a particularly sensitive detection technology that does not destroy the ion, and makes it possible to conduct a mass measurement on a single ion. The trick is that the ion’s positive charge attracts negatively charged electrons in the trap wall. These circulate as a tiny mirror current in time with the ion. The researchers can measure the current — albeit only with extremely sensitive instruments. This new technology now makes it possible to weigh single atoms with a very high degree of precision.

THE MODELS OF THE ATOMIC NUCLEI ARE IMPRECISE

Klaus Blaum is developing the method with colleagues at the Max Planck Institute for Nuclear Physics and the University of Mainz. “The ion must survive in the trap for at least a few seconds if it is to be of use,” says the researcher. The method is therefore not suitable for ions that decay quickly. However, if superheavy nuclei that are long-lived or...
even stable again really do exist, then this balance would be the detection method of choice for new elements.

The current standard method can detect only ions that quickly decay again. It has been used for decades at all particle accelerators that produce heavy elements. Their detectors react only to the decay products, from whose data the physicists can reconstruct the original nucleus. The nuclear mass can also be derived from this, but this can lead to errors. One reason is that the nuclear fragments can surreptitiously carry with them a portion of the energy that is released in the decay – precisely what happens when protons and neutrons in the nucleus jump to higher quantum states, similar to the electrons in the atomic shell.

The nuclei absorb excitation energy in the quantum jump, although this energy remains virtually invisible to the standard method. This causes a certain error when the nuclear physicists calculate the mass of the decayed heavy nucleus from the decay products detected, as energy and mass are equivalent – that is, two sides of the same physical coin. Albert Einstein recognized this back in 1905 and expressed this fact in his famous equation \( E = mc^2 \).

The theory is still a challenge in modern nuclear physics. Although physicists can now calculate the behavior of the electrons in the shells of atoms and molecules quite accurately, they still have difficulties with the protons and neutrons in the tiny nuclei. Their theoretical models on the structure and internal cohesion of the nuclei are significantly less accurate than the precision that can now be achieved in experiments. This is because the nuclear building blocks form a system comprising many particles. Unfortunately, there is no exact mathematical solution for such systems with more than two particles. Theoretical physics must thus find clever approximative solutions.

NUCLEI WITH FILLED SHELLS MIGHT REMAIN STABLE

This presents a special challenge in relation to the complex nuclei. With the exception of simple hydrogen, the electrons in atoms also form many-particle systems; however, they are better behaved, as only the electromagnetic force binds the negatively charged electrons to the positive nucleus. This is the second strongest of the four known fundamental forces in physics. It is also effective in atomic nuclei, but in a destructive way, forcefully driving the identically charged protons apart.

The existence of our material world is owed to a further force that comes into play in the nucleus, but that also makes it more complex. This strong force forces the protons and neutrons together, but it has only an extremely short range. In very large nuclei, the weaker but longer-range electromagnetic force thus gains the upper hand and causes them to decay.

This can be prevented by a stabilizing effect from quantum mechanics. It also plays an important role in the shell of electrons around the atoms. Electrons, protons and neutrons belong to a type of quantum particles that are extreme individualists: each one of them claims one quantum state for itself. However, there is only a strictly limited number of these quantum positions
in both the electron shell and the nucleus. They form shells, similar to rows of seats in the theater.

In the electron shells, a full row of electron seats gives the noble gases their properties. The filled shells have very low energy and are thus very stable. Nuclear physics expects the same for atomic nuclei with their shell-like structure: each stable shell that is completely filled with protons or neutrons corresponds to a magic number of nuclear building blocks.

It is thought that this magical quantum property will glue together even superheavy nuclei, which should actually explode. Blaum points to the chart of nuclides and to the mass region around 120 protons and 184 neutrons: “Do such magical shells also exist around half of the elements beyond iron – if it exists at all.

Thus far, however, the physicists have not succeeded in producing such superheavy nuclei with large numbers of neutrons. It therefore remains to be seen whether the models of nuclear physics apply to predictions of this type at all. Highly accurate weighing of slightly lighter nuclei can reveal which of the competing nuclear models best describes nature. It should then be possible to determine in more detail whether the hypothetical island of stability exists and, if it does, where it is.

The stability of nuclei has already led Blaum to the novae and supernovae in a long-standing cooperation at the CERN European Research Laboratory in Geneva. These stellar events are assumed to be the breeding grounds for the heavier elements. Although, in contrast to the GSI, the Isotope facility there can produce only lighter atomic nuclei, some of them play a decisive role during the stellar death throes.

**BREEDING PROCESSES IN STARS MAKE GOLD VALUABLE**

These so-called waiting point nuclei act like stop signals on the way to even heavier elements. In supernovae, this path is provided by a process to which around half of the elements beyond iron in the chart of nuclides owe their existence. It involves a nucleus capturing one of the neutrons that race through the dying stars in enormous quantities. A radioactive decay, so-called beta decay, then converts a neutron in the nucleus into a proton, thereby releasing an electron. The new proton increases the atomic number by one and the new nuclide moves one place to the left and up in the chart of nuclides.

The waiting point nuclei can be imagined as gluttons that have eaten their fill standing in front of a buffet that is heavily laden with tasty neutrons. They have the choice – either swallow another neutron and become even heavier, or explode. Since the waiting point nuclei find it difficult to choose between the two, the formation of even heavier elements must wait for a while – which can significantly delay the breeding process. “We now understand why so little gold is formed, for example, and is thus so valuable,” explains Blaum.

Although current nuclear models allow one to guess which atomic nuclei act as waiting point nuclei, only the precise mass measurements of Blaum and his colleagues provide accurate information on the candidates’ shell structure. They recently used the Isolde facility at CERN, which operates according to the same principle as Ship trap, to successfully prove that a stable shell of 50 protons and 82 neutrons in the very heavy nucleus of the tin-132 isotope (tin is element 50) plays such a prominent role in supernovae.

Klaus Blaum is also interested in the “flyweight class” of the particles. Together with physicists from the Karlsruhe Institute of Technology, the Heidelberg-based scientists are on the trail of the neutrino masses. In addition, there is the Karlsruhe Tritium Neutrino experiment “Katrin” whose task it is to measure a specific radioactive decay with extreme accuracy: the beta decay of the heavy hydrogen isotope tritium.

Searching for the island of stability: This chart illustrates the known atomic nuclei between uranium and the element 18 (gray). The masses of three nobelium isotopes (red) have recently been determined with extreme precision. The physicists expect long-lived atomic nuclei to be in the region where the lines intersect.
PHYSIK & ASTRONOMIE

GLOSSARY

Neutrinos
Electrically neutral elementary particles with very low mass. Physicists distinguish between electron neutrino, muon neutrino and tau neutrino, each of which exists as a counterpart to electrically charged particles (electron, muon, tau particle). Neutrinos interact very little with matter and therefore also penetrate the Earth practically unhindered. They are produced in radioactive beta decay and nuclear fusion processes in stars, for example. Just as antiparticles exist for other building blocks of matter, there are also antineutrinos.

Characteristic frequency
Every object that can oscillate has at least one characteristic frequency – no matter whether it is an electron, pendulum, violin string, suspension bridge or skyscraper. If it is pushed or excited with this frequency, it oscillates with particular strength.

Standard Model of particle physics
This describes the elementary particles and the interactions between them, but includes only three of the four fundamental forces; gravitation is not taken into account. It also assigns a rest mass of zero to the neutrino, a fact that has since been proven to be incorrect. Physicists are thus trying to expand the model – one of the large unsolved problems in physics.

During this process, the tritium nucleus with its proton and two neutrons decays into a helium-3 nucleus; this consists of two protons and one neutron. Consequently, one of the neutrons has transformed into a proton in a beta decay. This is caused by the weak force, the third fundamental force in physics. In order for the balance of the electric charges to be correct, the electrically neutral neutron must produce a negative electron in addition to the positively charged proton. However, there is another gap in the balance sheet of a second physical property: the total angular momentum (spin) before and after the decay. This deficit is balanced by an electron antineutrino that is released as a further particle. Its mass is what the physicists are aiming for.

To this end, “Katrin” records with a high degree of accuracy how much energy the electrons released in the decays carry away with them. “We, on the other hand, want to use a device in Heidelberg to measure the difference in energy between the tritium and the helium,” explains Blaum. Since, according to Einstein, energy is equivalent to mass, it must be possible to calculate the neutrino mass from the two measured values. The Heidelberg scientists are thus building a particularly precise scale that will measure to within one million millionth of the nuclear mass.

This research project could cause a sensation. Although the Standard Model of particle physics, a mainstay of modern physics, allocates zero mass to the neutrinos, it is now clear that they must have a mass. However, the question as to how heavy the different types of neutrinos are remains unanswered. If the Karlsruhe Katrin researchers, together with the Heidelberg Max Planck physicists, succeed in weighing one type of neutrino, this would have far-reaching consequences. For the first time, it would be possible to estimate whether and to what extent these ghost particles contribute to the mysterious dark matter in the universe.

The precision balance for atomic nuclei thus helps answer key physics-related questions. No wonder, then, that Klaus Blaum summarizes as follows: “I believe that the new methods have led to a renaissance of nuclear physics.”

A source of heavy elements: The crab nebula is proof of a supernova. The heaviest natural elements are produced in such stellar explosions.

Neutrinos
Electrically neutral elementary particles with very low mass. Physicists distinguish between electron neutrino, muon neutrino and tau neutrino, each of which exists as a counterpart to electrically charged particles (electron, muon, tau particle). Neutrinos interact very little with matter and therefore also penetrate the Earth practically unhindered. They are produced in radioactive beta decay and nuclear fusion processes in stars, for example. Just as antiparticles exist for other building blocks of matter, there are also antineutrinos.

Characteristic frequency
Every object that can oscillate has at least one characteristic frequency – no matter whether it is an electron, pendulum, violin string, suspension bridge or skyscraper. If it is pushed or excited with this frequency, it oscillates with particular strength.

Standard Model of particle physics
This describes the elementary particles and the interactions between them, but includes only three of the four fundamental forces; gravitation is not taken into account. It also assigns a rest mass of zero to the neutrino, a fact that has since been proven to be incorrect. Physicists are thus trying to expand the model – one of the large unsolved problems in physics.
Monkeys have been living with their immunodeficiency virus for thousands of years; humankind with HIV for less than a century. That’s not much time for adapting to one another, so it’s no wonder that the relationship is fraught with conflict. Matthias Geyer of the Max Planck Institute of Molecular Physiology in Dortmund is studying the dangerous virus to discover how it co-opts its host’s cells for its own purposes.
The threat has receded into the background and it no longer seems to be such a burning issue. And yet, last year in Germany alone, some 3,000 new cases of HIV were identified—and 2.7 million cases around the world. According to estimates issued by the World Health Organization, 33.4 million people now carry the human immunodeficiency virus. Two million died from AIDS-related diseases in 2008, including 280,000 children. These numbers are those of a pandemic, not an easing of the situation.

However, the HIV retrovirus, which belongs to the lentivirus group, has a different effect on Matthias Geyer of the Max Planck Institute of Molecular Physiology in Dortmund: it fascinates him. As a scientist, he sees it as a highly developed biological system that possesses an astonishing ability: it gets human T immune cells to replicate its viral genotype about 100 times faster than their own. How on earth does it do that?

Scientists hope that the solution to this puzzle will yield benefits over and above new therapeutic interventions for the treatment of acute HIV infections and AIDS. Many new discoveries about molecular processes in human cells will be made along the way, helping us to understand what makes the difference between healthy and ill, young and old.

This is why the 45-year-old scientist does not see the deadly virus as merely “lean and mean,” but also extremely refined and highly efficient. “It clearly doesn’t want to kill its human hosts. In Darwinian terms, it wants to live with us in mutually stimulating coexistence,” says Geyer.

Burgeoning HIV viruses under the scanning electron microscope: Activated T-cells (blue) produce up to ten billion virons (red) each day.
RNA polymerase
Coding DNA region
Initiation region
Termination region

Transcription unit

Transcription – that is, the rewriting of DNA to messenger RNA – consists of three phases: initiation, elongation and termination. During this process, the genetic information is read by a special enzyme, an RNA polymerase.

Of course, it has no choice, because like all 4,000 or so known virus species, HIV is between a rock and a hard place: without a host, it can neither replicate its genes nor survive for long in the harsh outside world. It consists of just a shell or capsid and its genotype – a very small single strand of RNA with barely 9,500 base pairs. Lentiviruses (from the Latin lentus = slow) generally cause slowly progressing diseases. In the long run, killing their host would mean suicide – so symbiosis is their only option.

RAW BUSHMEAT A SOURCE OF INFECTION

“Most monkey species have been living with the virus for some 10,000 years, so they have a long history of coevolution.” It may sound cynical, but it could be said that it’s just our bad luck that HIV selected humans as new hosts only a few decades ago. It wasn’t even a deliberate choice. In the early 20th century, the virus was transferred to humans in several independent instances, first from chimpanzees (HIV-1), then from a type of long-tailed monkey (HIV-2). In both cases, it is thought that the infection occurred through the consumption of raw bushmeat or as a result of hunting accidents. It is now very rare for a monkey to die from the HIV-like simian immunodeficiency virus (SIV). When the pathogen infects another species, however, it is fatal, since changing hosts necessitates a process of adaptation.

“It’s a constant challenge: the immune system defends itself against the intruder, and the virus develops escape mutants to evade the antibodies. This process is an important part of evolution and has advantages for both sides, because viruses challenge our immune system in the same way bacteria do, prompting it to become more highly tuned.” In fact, it is thought that up to 8 percent of our genome is made up of the remains of former infectious retroviruses. Optimistic estimates suggest that it will take another 200 years for us to achieve this balance with the tiny pathogen, while pessimists put the figure at 500 years. At that stage, it will be about as threatening as a herpes virus. Two hundred years – that’s a mere blink of an eye in evolutionary terms. Yet scientists like Matthias Geyer don’t see that as a reason to slacken their pace. They are working away feverishly to discover strategies that will put the brakes on HIV propagation.

SCIENCE WITH MOLECULAR BUILDING BLOCKS

Matthias Geyer is from East Friesland in northwest Germany, and achieved school grades that would have paved the way for him to study dentistry. Instead, he chose physics and musicology in Kiel. He dropped the musicology after three semesters. “What was I going to do with it? Become a music critic or archivist? No, thanks.” His physics studies were also fairly bleak, generally speaking. Geyer moved to Bonn University,
and later to Heidelberg. There he heard a lecture on something that was still quite new – biophysics. That was the thing! He wrote his thesis at the Max Planck Institute for Medical Research, on NMR spectroscopy in the analysis of biological reaction mechanisms. “The playful aspect of it really appealed to me. A construction kit full of molecules: that was right up my alley!” he enthuses. It isn’t much different from the construction kits of his childhood, but this time the building blocks are much smaller and have even more knobs. Which fits with what, and how? And what effect does that have on the whole?

The biophysicist stands at the board in his office, anxious to outline his research. What makes the virus such a threat at present is its efficiency at a very specific point. “Ultimately, it’s all about transcription, the rewriting of viral RNA to DNA by the reverse transcriptase enzyme, and the subsequent propagation of the HIV genes once they have become embedded in the host genome.” In humans, the principle is the same, but in reverse: DNA is transcribed to RNA, called messenger RNA (mRNA). Transcription can be broken down into three steps: initiation or kick-off, elongation, when the nucleotide sequence is built, and termination, the final whistle.

While human DNA contains the plans for some 24,000 different proteins, HIV’s RNA has instructions for just 15. Some of these occur in other viruses, but 5 of them – the accessory proteins – are highly specific. These “accessories” are responsible for the pathogen’s refined behavior, making them particularly interesting for researchers. “Nothing is in the HIV genome by chance,” stresses Geyer. “If anything were superfluous, evolution would have thrown it out by the third round, at the latest.” These “hot 5” proteins include Nef, or negative factor. As soon as the virus finds its way into a T helper cell, it uses this intracellular protein to ensure that the cell does not deploy any further CD4 receptors on its surface. HIV docks only to immune cells that bear these receptors, and if further viruses were to enter an infected cell, it would cause a superinfection, thereby inducing cell suicide, known as apoptosis, and putting an end to the dream of long-term, “peaceful” symbiosis with the host – us.

Although Matthias Geyer’s research does include Nef, here he tells a different story. Right now, the star of the show is the accessory protein Tat – transcription activation factor. The virus uses this protein to crank up its propagation exponentially. Matthias Geyer explains the process of transcription in human cells in order to clarify the differences with the HIV virus.

It is a play with many subplots and a very large cast. Act One: Initiation. Some 100 different proteins come to...
At the start of the transcription of DNA to mRNA – in addition to the enzyme RNA polymerase II, the universal reader-writer. These proteins hunker down piggyback on certain recognition sites (promoters) in the gene sequence. Part of the DNA uncoils and the polymerase moves in, reads and connects about the first 30 mRNA nucleotides. Then the machinery stops. “It’s a feedback mechanism, a way of saying, ‘Do we really want to do this?’” explains Geyer.

**FESTIVE FIREWORKS AND VERBAL SPARKS IN JULY**

Act Two: Elongation. If the answer is yes, P-TEFB, the positive transcription elongation factor, gives the go-ahead. It loads one end of the polymerase chain (known as the C-terminal domain, CTD) with phosphate groups, and the process continues: the 100 proteins of the initiation complex fall off, the DNA uncoils further, and the polymerase continues its work and completes its transcript – mRNA.

Act Three: Termination. Finally, the “immature” mRNA is trimmed and – voilà! – the template for the desired protein is ready.

It is one of those sweltering July days. The heat hangs in the small office and the air gets heavier by the minute. P-TEFB! Hexim! Nef! 7SK! Cdk9! Cdk2! Cyclin! Tat protein! TAR! Tat-TAR! Names and abbreviations are flung into the air, one after another, exploding under the ceiling and showering the room with verbal sparks. It is clear that the speaker is on fire with enthusiasm for his research. Matthias Geyer talks fast, passionately and without any conceit. Let’s continue, this is no time to falter!

The “go-ahead” factor P-TEFB possesses a natural brake: a small protein called Hexim1. Its function in human cells is to switch off this factor when no more proteins are required, such as when the cell is not undergoing division. Geyer has now discovered where the fatal effect of HIV’s Tat protein lies: it is an activator and replaces P-TEFB’s Hexim1 brake. Consequently, the cell starts to produce the corresponding protein type endlessly.

The detailed explanation is rather more complicated. P-TEFB is a complex comprising two subunits: the cyclin T1 protein and its enzyme, cyclin-dependent kinase, Cdk9. First, Tat binds to a particular sequence of viral RNA: TAR. Then this nasty double-act (Tat-TAR) hooks onto cyclin T1, thereby occupying pole position – the very

---

**ORIGIN OF HIV**

It is now assumed that the disease was transmitted in four separate instances, which may have taken place on several occasions. The most important is from chimpanzees and probably took place between 1910 and 1930. By far the largest group, that of the HIV-1 M allele (M for major), arose from this transmission. The outlier group (HIV-1 O), also representing long-term non-progressors in part, was probably also initiated by chimpanzees. The HIV-2 variant arose from the mangabe monkey in West Africa.

The newest variant is HIV-1 P (HIV-3), which is thought to have transferred from chimpanzees to gorillas and then from gorillas to humans. In other words, it, too, originated with chimpanzees. This variant was first identified in 2009. Since this virus, like HIV-1 O, is not pathogenic, or only slightly so, it was categorized using the next letter of the alphabet: HIV-1 P.
place where the Hexim1 brake normally docks. This is also how the virus cranks up the transcription of its gene – or “upregulates its expression level,” in biochemist-speak.

The fact that Cdk9 is (normally) put out of action by Hexim1 binding to cyclin T1, thereby putting a stop to elongation, was only discovered in 2003. “It is interesting that misregulation of transcription elongation, such as that which occurs with HIV, also occurs in other diseases, like myocardial hypertrophy,” says Geyer. This causes heart muscle cells to keep producing more and more protein, leading to extreme enlargement of the heart and, ultimately, to death.

Certain types of cancer tell the same story. Hexim1 mutations can be demonstrated in ovarian, testicular and bowel cancer, among others. This either prevents the cell from producing enough protein, or causes point mutations that give rise to defective operation of the protein. Take breast cancer: it is now known that Hexim1 inhibits the growth of mammary cells. This function is controlled by estrogen, but it is weakened in tumors. Researchers have recently discovered that a very aggressive form of childhood leukemia is also dependent on the Cdk9 function. “However, this cell regulation mechanism was discovered in HIV,” stresses Geyer. Reason enough, as far as he is concerned, to take a very close look at all participating molecules – the “good” and the “bad.”

Bromodomain 4 is a case in point. This molecule activates the P-TEFb complex to give the go-ahead for polymerase II to continue reading and writing until the transcript is ready. “But how does specificity arise?” says Matthias Geyer smiling, as he approaches the whiteboard once more. Of course, we guessed it – there are plenty more questions to answer! A pivotal one is this: Why is one gene read and not another? The virus has only a small number of genes, but we have 24,000! “The cell could use different marks to identify each gene that is to be read, but
that would mean having 24,000 different marks – far too many for one cell. Then again, it could have a small set of marks that could be constantly combined in unique new patterns.”

A CRYPTIC CODE AT THE END OF THE ENZYME

Two molecules are hot candidates for this type of marking pattern. One of them is the above mentioned Bromodomain. Not only does it activate P-TEFb, but it also interacts with the histones, those small, knobby proteins where the DNA is coiled up so that it doesn’t get tangled. Each histone has small “hairs” of amino acid chains at the side, where hydrocarbon particles sit in particular patterns. Could these chemical modifications on the histones be a recognition pattern to prompt gene reading?

The other candidate is CTD – remember? It’s at one end of RNA polymerase II, and it bears a cryptic code called a “repeat” consisting of seven amino acids – tyrosine-serine-proline-threonine-serine-proline-serine. And this sequence is repeated 52 times – in humans, that is. In baker’s yeast, only 26 times; in some other organisms even more. It is a kind of “Da Vinci Code” – only no one really knows what it means, just yet.

What is known, though, is that transcription cannot continue until the heptad repeat is “embellished” by phosphate groups that settle onto serine (and do so in a different sequence than previously thought, as Geyer recently discovered). This could be the second part of specification for gene reading. Matthias Geyer and many of his colleagues around the world are working to solve riddles such as these – partly, but not exclusively, to enhance their understanding of HIV.

Back to immune deficiency. With current treatments, a person who is infected with HIV at the age of 20 will live to an average of 69.4 years of age. Of course, this applies only if they live in a country with optimal healthcare provision, such as Germany. In other words, they may wind up dying of something other than AIDS. Mostly, treatment involves a combination of several agents whose functions include the inhibition of reverse transcriptase or protease, which trims immature proteins. It attacks enzymes that occur in a very similar form in humans. Consequently, lifelong treatment is associated with many adverse reactions.

A NEW TOOL TO CURTAIL VIRAL PROPAGATION

Where could a new tool be applied effectively and with less collateral damage? “If we could switch off Tat-TAR, we would have a great tool for reducing viral propagation, because that particular system plays a role only in HIV,” says Geyer. The viral load increases one to three weeks after the initial infection; that is, the number of pathogens swimming around in the body rises steeply, and at the same time, the number of CD4 helper cells drops dramatically. “If we could gain an advantage for the body at this point by curtailing viral replication, antibodies would recognize all HIV-infected cells and switch them off, because the virus is fairly uniform to start with.” Afterwards, though, it changes with each round of replication.
– not out of “malice,” but because its reverse transcriptase is a sloppy worker; it functions on the basis of quantity, not quality. The enzyme has an error rate of 1 to 1,000 nucleotides, so there is a constant flow of incidental changes that lead to slightly modified proteins. In some cases, this causes no damage: these proteins are called silent mutants. In others, an important site might be affected, such as an envelope protein. Consequently, an escape mutant is formed, and there we have a new variant of the virus that is practically indiscernible to the immune system’s watchdog cells, as if it were clad in an invisibility cloak. “Even if just 5 out of 1,000 new viruses get through, it’s enough!”, as they then replicate unhindered. Sloppy work, but unfortunately not sloppy enough. “If the transcriptase error rate were a little higher, the following generations of the virus would lose track of what it’s about. It would lose its functions and therefore its effectiveness,” says Geyer.

Each new discovery raises new questions. Yet if even viruses are such complex entities, how much more sophisticated must a highly developed cell be? Each individual body cell integrates functions such as genotype reading, transcription, protein production and much more. Depending on the “location” and demand, it may perform these functions dozens, hundreds or even thousands of times a day – and all this in a coordinated, largely error-free manner. The fact is, it’s almost a miracle that there are any higher life forms than single-celled organisms, not to mention human beings. Matthias Geyer laughs. “That’s one of the reasons why we’re working on the HIV virus. It’s small and neatly arranged, and many of its processes have hardly changed during the course of evolution, so it’s an ideal model for us to study.”

**Glossary**

**CD4 helper cells**
Subgroup of white blood cells that have special molecules called CD4 receptors on their surface. The HIV virus uses these as entry gates into the cell.

**Co-evolution**
A process of mutual adaptation between two species that can take place over long periods of evolutionary development and history.

**Retroviruses**
A group of viruses that attack animal cells. Their genetic information, encoded as RNA, is transcribed to DNA and integrated into the host cell’s genome.

**Reverse transcriptase**
An enzyme that catalyzes the transcription of RNA to DNA. Incidental errors occur constantly during this process, giving rise to new virus variants.

---

**Mai Tai® eHP DeepSee™**
Tunable Ultrafast Laser

Designed specifically for high-resolution multiphoton biological imaging, the Mai Tai eHP DeepSee laser delivers 65% higher peak power than the closest competitive system. Combined with integrated dispersion compensation, this peak power advantage results in the maximum sample fluorescence at the maximum imaging depth.

- Highest Peak Power: 380 kW
- Tunable Pulse Width (70 fs to >500 fs) at the Sample
- Fully Automated and Computer Controlled

Based on proven technology, the new Mai Tai eHP DeepSee laser is the latest addition to the Spectra-Physics Mai Tai series of ultrafast lasers, with the industry’s largest installed base. For more information visit [www.newport.com/deepsee](http://www.newport.com/deepsee) or call us.

Newport Spectra-Physics GmbH
Guerickeweg 7 – 64291 Darmstadt – Germany
Phone: +49 (0) 61 51 / 708 – 0 • Fax: +49 (0) 61 51 / 708 – 217 or – 950
E-Mail: germany@newport.com

© 2010 Newport Corporation.

MaxPlanckResearch 61
View over the rooftops of Shanghai – Philipp Khaitovich enjoys the skyline of the megacity. He has been doing research at the CAS-MPG Partner Institute for Computational Biology for the past four years.
When Philipp Khaitovich opens the door, he is greeted by a draft of fresh air. In the small room, it is noticeably cooler than outside in the hallway that, on this beautiful spring day, is bathed in sunlight. Inside, machines are humming. The room is packed with white cabinets and deep freezers. The freezers are covered with digital displays; a temperature recorder controls the degree of coldness inside: -80°C or lower. “Actually, it’s a waste of space,” says the young researcher, who heads a research group here in the Chinese metropolis of Shanghai. He would like more room for his students or for the small laboratory next door.

Inside the freezers are the treasures of his research team. There are dozens of brain samples from humans, chimpanzees and rhesus monkeys of different ages that Khaitovich has painstakingly collected. Using the pieces of tissue stored here, the scientists are seeking to discover more about the differences between humans and monkeys. By comparing the activity of genes and the concentration of various molecules in the brain samples, the team can determine how the development and aging progresses in the different species on the molecular level.

**SO WHAT IS IT THAT MAKES HOMO SAPIENS SO SPECIAL?**

The research conducted should help provide answers to some of the fundamental questions in biology: Why do *Homo sapiens* live so much longer than closely related primates? What makes our species so special? “These are, of course, major questions,” says Khaitovich in his office, a bright room where he looks out of the window onto a street lined with sycamore trees. “And
Khaitovich gained significant impetus for his later work in the group headed by Swedish evolutionary geneticist Svante Pääbo.

we are only a small research group.” He smiles a little apologetically, almost like someone who is trying to find the answer to an insoluble puzzle – and who knows that he can actually succeed.

With a slightly faltering Russian accent, Khaitovich explains his project, his hands describing wide arcs in the air. He gesticulates and laughs a lot, rolls his eyes, and never takes himself very seriously. But he is serious about his work. For almost four years, the Russian has been carrying out research at the Shanghai center, at the CAS-MPG Partner Institute for Computational Biology, which has been run jointly by the Chinese Academy of Sciences and the Max Plank Society since 2005.

CHIMPANZEE REACH PUBERTY AT THE AGE OF EIGHT

During this time, Khaitovich has built up an international team of scientists. The researchers are young and ambitious, and many of them come from China. This is a group that does not shy away from difficult problems. Not even from problems that many great minds have wrestled with in vain in the past.

Such as the mysterious longevity of our own species. “Humans can live to be 100, in some cases even longer,” explains Philipp Khaitovich. “In contrast, rhesus monkeys, for instance, live to at most 40 years, even with the best medical care.” Humans do differ, even from their closest living relatives, chimpanzees, simply in development of their intellectual capabilities. Physical development is also dissimilar in the two species. For example, sexual maturity in female chimpanzees begins at the age of 8 or 9 years, whereas in Homo sapiens it is more like 13 or 14.

Why there is such a dramatic difference in the development of man and apes has long been the subject of research. “For a very long time, scientists have been puzzling over this question, including big names like Konrad Lorenz and Stephen Jay Gould,” says Khaitovich. “Every conceivable hypothesis has already been considered.”

There is, for example, the idea of neoteny. According to this theory, which has been debated over and over again since the beginning of the 19th century, human development is considerably delayed compared to any other primates.

The basic idea is that the adult human, with its sparse hair development, on the outside resembles the small face and big head of a baby monkey. At the same time, the human brain retains its plasticity longer, which might explain the special cognitive capabilities of our species. Up to now, however, such theories have been nothing more than just that – theories – because they cannot be validated, as such. It was only a few years ago that rapid technological development made it possible to put them to the test.

In the 1990s, when Philipp Khaitovich was studying molecular biology at the Moscow State University, this kind of research had not yet even been thought of. At that time, it took several years just to investigate the structure and function of a protein. After studying in Moscow, he went to Chicago to do his doctorate, then on to Germany where he worked at the Max Planck Institute for Evolutionary Anthropology in Leipzig.

There, in the group headed by Swedish evolutionary geneticist Svante Pääbo, he gained significant impetus for his later work. “Svante is a true pioneer. He was one of the first to use new genetic methods to investigate human evolution,” says Khaitovich. “My current subject is based largely on his ideas.”

A CITY ON FAST-FORWARD

After six years in Leipzig, the young Russian finally got the chance to form his own research group in Shanghai in 2006. “China is developing very rapidly, and that was something that attracted me,” says the scientist. He was, however, not prepared for Shanghai, the largest city in China, which has gone into fast-forward mode. Shiny new high-rise buildings are springing up everywhere, intertwining asphalt roads and colorfully lit bridges are being built. And after almost four years, Khaitovich is still sometimes taken aback by the breakneck speed of the city with a population of 19 million people. For example, when five new subway lines are opened within the short span of just a few months. Or when a new airport terminal that did not exist a few months earlier suddenly appears.

“There aren’t many cities that are as big and have changed at such an unbelievable rate,” says Khaitovich. But the young researcher enjoys life in the modern metropolis. He wanders with friends through the lively areas of the city, visits new cafes and art galleries. And from Shanghai he can also explore the rest of the country with its deserts and mountains, and visit historic sites, like old Buddhist monasteries. On his travels off the beaten track, Philipp Khaitovich has also stayed in simple farmhouses.
The researcher has been learning Chinese for two years, but his language skills are still “quite poor” in his opinion. He talks to his Chinese friends who he has gotten to know in Shanghai in a mishmash of Mandarin and English. Together they indulge in the truly greatest Chinese passion – food. They visit restaurants where very few foreigners stray, sample delicacies from all over the country, including, for example, “stinking tofu” – a fermented soya dish that gives off a pungent smell. Khaitovich goes into raptures about a “whole universe of dishes” tucked away in the streets and alleyways of the big city.

However, Shanghai is virtually the ideal site not only for culinary exploration, but also for his research project. The dramatically changing metropolis is a little like modern biology, Philipp Khaitovich finds. Because in his discipline, too, developments have experienced a meteoric rise during the past few years and technological progress has constantly opened up whole new avenues. Therefore, it is only logical that Khaitovich has set up his research group here.

**COMPUTER SCIENTISTS AND BIOLOGISTS IN ONE GROUP**

And Shanghai has a number of locational advantages. “In Germany, it is difficult to encourage students with good computer skills to join a group like this,” says the Russian. “Here it is much, much easier.” His team does around 70 percent of its work on computers; for his research, however, Khaitovich needs not only excellent computer scientists, but also talented biologists – and he can find both in Shanghai. In his group, he has to bring together experts from both fields and then motivate them in the other discipline.

China’s funding policy also benefits his research, as the country is investing in less well established areas of science: “It supports rather unusual projects that are simultaneously very promising,” explains Khaitovich. “Naturally, I hope that our work will be part of this,” he says with a smile.

Anyone who, like Philipp Khaitovich, is working on research in Shanghai must, however, be able to embrace a different mentality. “Those who think that their own brand of problem-solving is the only right one will have problems in China.” Instead, flexibility and empathy are needed, and people must be prepared to adapt to the different culture. Khaitovich reserves judgment about the subtle rules of etiquette and the fine differences in
International study group: Philipp Khaitovich has been conducting research at the Shanghai center since 2006. The CAS-MPG Partner Institute for Computational Biology is run jointly by the Chinese Academy of Sciences and the Max Planck Society.

thinking. “Four years in China is not enough to understand these things.”

Before important discussions, he seeks advice from Chinese friends, asking about the right strategy, the right behavior. However, the cultural differences do not present real problems. “There’s no such thing as an invisible barrier,” Khaitovich emphasizes. And the cliché of collective Asian thinking whereby personal well-being is always subordinate to that of the community is not something the researcher has encountered. “My students all have very strong personalities, sometimes stronger than I would like,” he says and laughs.

What the young team does have in common, despite all the potential cultural and character differences, is the type of work. Research in China is no different than anywhere else in the world. “Science is a universal language,” he says. “You analyze data and obtain results, then interpret them – that is exactly the same here as it is in Europe or America.” Perhaps what also unites the scientists is their research object: mankind itself. Because nothing is more fundamental than this. The riddle of our longevity, the origin of our intellectual capabilities – these are subjects that concern us all.

NEWBORNES AND THE ELDERLY PROVIDE THE ANSWER

To get to the bottom of these peculiar human characteristics, Khaitovich and his students are comparing the brain samples of humans, chimpanzees and rhesus monkeys – all at different ages. To be able to gain knowledge on the development of the brain, the team needs pieces of tissue both from newborns and from the very old. And from individuals in a number of different age groups in between.

Finding the right pieces of tissue is a real challenge. Time and again, Khaitovich must persuade other institutes to cooperate, because the samples not only need to be from a human or animal of a certain age, but they also need to come from a specifically defined area of the brain. From the prefrontal cortex, for example – the area behind the brain where inherently human capabilities, such as rational thinking, are located.

The human samples cause Philipp Khaitovich the least problems. He orders them from ‘brain banks’ – facilities where brain tissue from various donors is archived for research purposes. For chimpanzee samples, he is still on good terms with his former professor in Leipzig, where Svante Pääbo several years ago began to archive the brain tissue of apes of various ages; however, it is difficult to get hold of viable brain samples from old macaques. “Rhesus monkeys can live to about 35 years of age, but there are perhaps only a few dozen animals of this age throughout the world.”

The scientists then send the samples from the various elderly humans and monkeys for analysis in partner laboratories to determine gene expressions and other data. For this, they ignore the complicated structure of the brain tissue – the samples contain different types of neurons, glia cells and gray matter. “It is as if two ecosystems, together with all the animals and plants living in them, are being compared with one another.”

Khaitovich is the first to admit that there are weaknesses in this procedure. “This is all still very primitive,” he admits. And at the moment, the technology to investigate the brain comprehensively and look at all the different cell types separately simply does not exist. Nevertheless, Philipp Khaitovich is proud of exploring new avenues: “At least I can say that we are working at the cutting edge of research.”

FEELING AN ELEPHANT WITH YOUR HANDS

For the scientist, the technical development of biology cannot advance fast enough. Sometimes he feels like a blind man trying to feel an elephant with his hands – and instead of the trunk, thinks he has found a snake; instead of a leg, a tree. All the same, he has at his disposal the most state-of-the-art measuring methods to answer his questions on the development of the human brain. “It’s like looking at things for the first time under a microscope that you’ve been able to examine before only with a magnifying glass,” enthuses the researcher. And he can’t wait for the day when he can swap his microscope for an electron microscope.

He also takes rather unusual routes in some of his analyses. For example, he is working with a research facility that, at first glance, has nothing to do with the human brain – the Max Planck Institute of Molecular Plant Physiology in Golm, where a new measuring method has been developed to determine how much oil and other metabolic products different plants produce – a method that can also be used just as effectively to measure the different molecules in brain samples, such as neurotransmitters or lipids.
Khaitovich receives vast amounts of data from the partner institutes, which must then be evaluated. “This requires students who are not only very talented, but who are also obsessed with their work,” says the molecular biologist, only half joking. Among the wealth of information, the scientists attempt to recognize biological signals – certain patterns in the data that indicate peculiarities in the development of the various species. “Sometimes we fail miserably,” Khaitovich admits. “And quite simply because there is no established procedure to point us in the right direction.”

INCENTIVE AND CRITICISM FROM HIS MOTHER IN MOSCOW

The first results, however, are encouraging, although the data has not yet been fully evaluated. “We can already see very clear molecular differences between the brains of humans and apes,” One of the results confirms the old idea of neoteny – but only to some extent. According to this theory, the gene expression in the brain of a juvenile human is roughly equal to that of a chimpanzee a few years old. For several hereditary features, this is actually the case. “But for other genes, the picture is completely different,” says Khaitovich. His interim assessment: “The reality is much more complicated than we previously imagined.”

The young researchers can get closer to an answer only step by step, theory by theory. This is sometimes frustrating, not just for the scientist himself, but also for his mother in Moscow, who, says Philipp Khaitovich, is very interested in his research. So far, though, she has not been disappointed by the progress: “She believes that there are so many interesting things to find out about the brain and the longevity of humans,” says Khaitovich with a wide grin: “And she says that we are concentrating on far too small an area. But we’re really just a very small research group.”

GLOSSARY

Neoteny
Biologists talk about neoteny if plants or animals retain externally youthful features. In terms of humans, this could explain, for example, the lack of body hair and the long life. Accordingly, a human is a monkey whose development has been greatly retarded.

Glia cells
For some time, these were assumed to be cells in the brain that support the neurons, provide electrical insulation for one another, and provide nutrients. According to more recent findings, however, they also play an active role in the processing of nerve impulses (cf. MaxPlanckResearch 2/2006, page 42 ff.).

Gray matter
This substance forms predominantly the external brain tissue and is actually pink, although it turns gray in formalin. In it are the cytosomes of the neurons. The nerve fibers, in contrast, form the white matter that is found inside the brain tissue.
überzeugend

Die auflagenstärkste hochschul- und wissenschaftspolitische Zeitschrift Deutschlands. Leseprobe unter: www.forschung-und-lehre.de oder per Fax 02 28 902 66-90
Creation of a nanosensor: A voltage is applied to the needle-like electrodes that trap nanotubes from the solution onto electrodes on the silicon wafer.
Handy, quick and very sensitive – that’s how Kannan Balasubramanian imagines a device for carrying out blood analyses. At the Max Planck Institute for Solid State Research in Stuttgart, his team is developing nanosensors with which it would be possible to carry out a blood count or to detect pathogens.

TEXT CHRISTIAN MEIER

Often it’s just a nuisance, but sometimes it’s actually dangerous. Currently, if you have a blood test, the doctor’s parting words will usually be: “You’ll get the results in a couple of days.” Kannan Balasubramanian wants to change all that. The physicist at the Max Planck Institute for Solid State Research in Stuttgart is pursuing the visionary objective of creating a diagnostics laboratory that can fit on a chip the size of a fingernail. Working with just a droplet of blood, the minuscule laboratory would be able, within minutes, to determine a patient’s blood count, estimate risks of disease and even detect sinister virus infections.

Doctors could carry out the test in their practices, or patients could even do it in the comfort of their own living rooms simply by taking a drop of blood from their fingertip. A device the size of a mobile phone would quickly deliver all of the relevant measurements from this drop.

“In just five to ten years we would like to have developed mature chips with which such portable diagnostic laboratories can be made a reality,” says Kannan Balasubramanian, who heads the “Nanoscale Diagnostics” Junior Research Group, which is funded by the German Federal Ministry of Education and Research. Over the past three years, the scientists have already cleared some of the major hurdles they were facing. Others still remain to be overcome.

VIRUS DETECTION STILL TAKES TOO LONG

Above all, it is the examination speed with a portable laboratory that would be a big step forward in medicine. Just one example: “In a hospital, it often takes days to detect a viral infection,” explains the Max Planck researcher, who is originally from India. This is because the pathogen’s genetic material, namely its DNA or RNA, is present in the patient’s blood at only a very low concentration. And it cannot be detected using conventional analytical methods. As a result, any viral genetic material suspected of being present in a blood sample must be enriched to a level above the detection limit using
polymerase chain reaction, or PCR for short. The entire test, from taking the sample to getting the result, thus takes several days.

“Doctors want testing to become faster so that they can treat the infection as quickly as possible,” Balasubramanian says. This is why his team is developing sensors that can forego PCR and are capable of detecting minuscule concentrations of viral RNA. Using a highly sensitive diagnostic chip, it would be possible to get closer to the end user, as analysis would be much simpler. “In an epidemic situation, rapid mass testing would be possible,” says the 32-year-old researcher. Moreover, a patient would no longer have to have ten or more milliliters of blood taken for a blood analysis.

NANOTUBES FOR SENSITIVE SENSORS

To achieve his goal, Balasubramanian needs sensors that respond to single or very small numbers of molecules of a specific substance – for instance, to one molecule of viral genetic material or to one protein indicative of a risk of heart attack. The researcher’s five-member team focuses on a material that is currently used for reinforcing ultra-light tennis rackets and bicycle frames: carbon nanotubes (CNT).

These tubes have one fascinating property that makes them ideally suited for use as highly sensitive sensors: they are nothing but surface. Their walls could not be any thinner because they consist of a single layer of carbon atoms. The entire nanotube is thus ex-
posed to its environment; not a single one of its atoms is protected inside it. And if foreign molecules bind to the surface of a carbon nanotube, this influences its overall characteristics.

In particular, its electrical resistance changes sharply if molecules attach themselves to its surface. This is explained by the structure of a nanotube: its carbon atoms form a regular lattice reminiscent of a honeycomb. This regularity means that each carbon atom contributes an electron to an electron cloud that extends over the entire CNT and allows electrons to move through it unimpeded. The nanotube thus conducts electricity very well.

Should a foreign molecule bind to one of the nanotube’s carbon atoms, it interrupts the honeycomb pattern at this spot. In this way, the attachment disrupts the free passage of electrons over the surface of the tiny carbon tube. Figuratively speaking, this puts a baffle in the track the electrons are racing around, and the tube’s electrical resistance increases. The more foreign molecules stick to the nanotube, the more the resistance rises.

The change in resistance, and thus the concentration of foreign molecules, can be measured if the nanotube bridges the gap between two electrodes. This is the fundamental idea behind the carbon nanotube sensors that Balasubramanian’s team is developing.

However, if a CNT sensor is to yield usable information, the nanotube has to be choosy – after all, it isn’t intended to respond to just any old molecule in the blood, but only to specific molecules, such as viral RNA or the blood sugar molecule glucose. In specialist circles, this characteristic is known as selectivity. At first glance, it would seem impossible to give a carbon nanotube this property, since a CNT exposes its surface to all the molecules in a blood sample.

RECEPTORS TAILOR NANOTUBE PROPERTIES

However, nature gives the researchers a helping hand in making the nanotubes more selectively perceptive. Many biomolecules have a kind of companion, a second molecule into which they fit, like a key in a lock. DNA, for instance, the carrier of genetic information, consists of two single strands that together form a double helix. One of the single strands fits like a jigsaw puzzle piece with the opposite strand – and with no other. Another example: on the surface of foreign bodies in the bloodstream are proteins, known as antigens, that the body combats with the help of antibodies. An antibody is a protein that can be slipped over the antigen like a mold. Researchers generally call a molecule that selectively binds a sought molecule to itself a receptor.

“We make the CNTs selective by attaching a receptor to them, for instance a receptor for blood sugar,” explains Balasubramanian. The presence of the receptors themselves increases the nanotube’s resistance. The researchers define this increased resistance as the new baseline. If the substance sought – called an analyte – then binds to the receptor, the distribution of electrons on the carbon nanotube changes more strongly than due to the receptor alone, and conductivity falls further.

In this way, the researchers can make sensors for specific substances. Balasubramanian, however, would like to build a chip that simultaneously tests for several analytes in one drop of blood, for example to carry out a complete blood picture in a single test. To achieve this, the chip needs several pairs of electrodes connected by carbon nanotubes, the current flow between which can be separately measured. The nanotubes between the electrodes would in each case have to carry different receptors.

But how can the nanotubes be provided with different attachments in such a way that the ultimate location of each kind of receptor is still known? Immersing the chip in a solution containing all the receptors at once would be pointless, as the receptors would react at random with the carbon nanotubes and no one would know where each one is located. As a result, it would be impossible to tell which analyte is bringing about a change in resistance. Balasubramanian and his team, however, found a surprisingly easy way to arrange the receptors at a specific location.

The researchers immerse a chip comprising numerous pairs of electrodes that they have already bridged with nanotubes into a solution of one receptor. They then touch one of the electrodes with the tip of an electrical-
Balasubramanian's researchers have thus been looking for a method to achieve this. Electrochemistry again provided the solution, as it makes it possible to control whether electrons are supplied or removed during the reaction between CNT and receptor – that is, whether it is a reduction or an oxidation reaction. "If we provide the receptor with a diazonium salt and have the reaction proceed as a reduction, a covalent bond is formed between the receptor and the metallic CNT," explains Balasubramanian. Using electrochemical methods, the scientists have already built a nanosensor that measures the pH value of a solution and another that measures blood sugar concentration. The latter serves primarily as a demonstration because easy-to-use test strips for measuring blood sugar levels are already commercially available. "However, the search is still on for sensors that can monitor blood sugar levels over an extended period," says Balasubramanian. This could then be built into devices that automatically inject insulin as required. "So far, only test systems that work for less than a week are available," explains Balasubramanian. This is because the sensors are based on enzymes, which do not have long-term stability. Nanosensors made from CNTs, on the other hand, last significantly longer. They may thus possibly be suitable for continuous insulin monitoring.

Mass-producing blood testing devices, however, means more than just being able to build laboratory demonstration models. "We wanted to develop our process further so that it is suitable for industrial nanosensor production," says Kannan Balasubramanian. The first step is no problem in this respect. Platinum electrodes can be placed on a silicon wafer using standard chip production methods. After that, however, the process enters new technical territory: at least one CNT must be located between each pair of electrodes so that there are no dead sensors. Industry expects a process that has the lowest possible reject rate. According to Balasubramanian, "100 percent throughput is absolutely essential for industry."

Placing the CNTs is similar to hunting with a shotgun: like a hunter shooting a spray of pellets at the prey and hoping that one will hit its target, the...
researchers try to place nanotubes between the electrodes. The “shot” corresponds to the mixture—a dispersion—of carbon nanotubes and water, while the “gun” the researchers use is a method known as dielectrophoresis. A non-uniform electric field generated in the solution drives the nanotubes toward the electrodes. By chance, some of them are caught between the electrodes in such a way that they exactly fit into the gap.

Since the nanotubes are not uniformly distributed in the dispersion, but instead have a tendency to clump together, not every pair of electrodes receives a nanotube. “Until a short time ago, a throughput of only around 30 to 60 percent could be achieved with dielectrophoresis,” says Balasubramanian. In other words, at least one third of the sensors were dead. “But then we found a way of producing a dispersion without nanotube agglomerates,” explains the researcher. This allows the nanotubes to be distributed so uniformly that at least one is guaranteed to land between each pair of electrodes.

In this way, 100 percent throughput can routinely be achieved. At present, up to 40 sensors can reliably be produced on a 10 centimeter diameter wafer without any rejects. This means that the nanosensors have made an important step toward mass production.

“Each sensor must be individually calibrated,” says Balasubramanian. However, this may well be less troublesome than it sounds. “I estimate that it will be feasible to produce a diagnostic device using CNT sensors for around twice to three times the price of today’s systems that operate with lasers,” says the researcher. Such a device would, on the other hand, be small and highly sensitive, would operate quickly and work with only a little blood. Moreover, it would be easy to operate, as the analysis is based on a simple electrical measurement.

These advantages of devices with nanosensors could be of benefit not only in medical practice, but also in basic research, for instance for testing enzyme activity. This is because conventional methods investigate the effect of a very large number of enzymes in a solution. Using nanosensors, it is now possible to investigate the level of activity of individual enzymes. The conductivity of a carbon nanotube to which an enzyme is joined changes when a molecule attaches itself to the
enzyme. “It is thus possible to observe in real time when molecules bind to the enzyme,” explains Balasubramanian, “thus making it possible to determine the activity of an individual enzyme.”

JUST HOW IS THE SIGNAL PRODUCED?

The Stuttgart-based team nonetheless has some important tasks to tackle before nanosensors can be used in practice. While it has been found that nanosensors function and can be produced in processes under near-industrial conditions, the researchers have not yet gained a detailed understanding of the physical processes that take place during signal generation on the nanotubes. “We need a theoretical model to explain the dependency of the sensor signal on analyte concentration,” says Balasubramanian. Only then will it be possible to prove that what is intended to be measured is actually being measured. Not least, developing the diagnostic devices to market maturity means that the scientists must look beyond their own horizons. “It’s not enough to build a nanosensor,” says Balasubramanian. “We have to ask ourselves today what system our sensor will be working in tomorrow.” And the technology must be flexible, and allow subsequent addition of interfaces.

Turning a vision into reality thus means tying up a lot of loose ends. As long ago as the 1990s, when Kannan Balasubramanian was studying computer science at the Birla Institute of Technology and Science in the northeastern Indian city of Pilani, he already had a dream: he wanted to work on building a nanocomputer. He was fascinated by the vision of a computer consisting of molecular-scale switches – a computer that would be visible only under a microscope, but that would still have the performance of a personal computer.

That’s why he went to Germany and became a physicist at the Max Planck Institute for Solid State Research. Here, he has fine-tuned his original dream so that it can be turned into a reality within a decade. But who knows: perhaps there will be nanocomputers in a few decades. Perhaps they will contain nanosensors so that they can communicate with their environment. And perhaps some of these nanosensors will bear the signature of these Stuttgart-based Max Planck researchers.

Mixture with and without lumps: Ashraf Ahmad and his colleagues have found a way to make a fine dispersion of nanotubes (on the right), thus increasing the yield of functioning sensors.

GLOSSARY

Superposition
Particles do not adopt a single state, but rather all possible states simultaneously, until measurement destroys the superposition.

Entanglement
Two or more particles form an overall system and measurements made on one particle have an instantaneous effect on the entangled partners, irrespective of how far apart the particles are.

Superconductivity
Below the “transition” temperature, which is usually below minus 260 degrees Celsius, many metals conduct electricity without resistance. Physicists have a very good understanding of this form of superconductivity – but not of the unconventional form of superconductivity. This occurs in, among other things, copper oxide ceramics, the record holder losing its electrical resistance at a temperature as high as minus 110 degrees Celsius.

Superfluidity
This phenomenon was first observed in two isotopes of helium. Quantum mechanical effects result in a liquid or gas flowing without friction.
Für Forscher, Entdecker, Wissenschaftler - und solche, die es werden wollen:

Junge Wissenschaft

Das einzige europäische Wissenschaftsmagazin mit begutachteten Beiträgen junger Nachwuchsforscher.

Wissenschaftliche Erstveröffentlichungen und das Neueste aus Mathematik, Informatik, Naturwissenschaft und Technik.


Vorteilsabo sichern!
abo@verlag-jungewissenschaft.de
Stichwort: „Vorteilsabo“

Leseprobe anfordern!
leseprobe@verlag-jungewissenschaft.de
oder per Fax 0211/385489-29

www.verlag-jungewissenschaft.de

Vorteilsabo
nur 20,-€*

für Schüler, Studenten, Referendare und Lehrer
(4 Ausgaben für 20,00 EUR statt 30,00 EUR)*

*zzgl. Versandkosten
Bacteria can live on almost anything – some even on oil. Friedrich Widdel, Director at the Max Planck Institute for Marine Microbiology, is studying microbes that break down oil hydrocarbons without oxygen, deep down in the sediment. Could they be useful in oil spills?
hey may not look like much, aesthetically speaking,” says Friedrich Widdel, placing some black and white photos on the table. One photo shows a heap of thin black bars, another contains small grey blobs. Physically, the bacteria do not appear to be much more than an abstract, milling mass. To Widdel, however, they are so interesting that he has spent over 30 years studying them. “Their metabolism is truly fascinating. The bacteria can do things that more highly developed life forms are unable to do.”

Indeed, some of them have real hidden talents: they can degrade substances that are indigestible for animals and people (such as cellulose), or that are toxic, such as hydrogen sulfide. The organisms absorb nitrogen from the air and make it available to plants.

IT ALL BEGAN WITH HYDROGEN SULFIDE IN AN OIL TANK

No one knows how many types of bacteria there are, and it is quite likely that most of them have yet to be discovered. There is probably no place on Earth where some form of bacteria doesn’t feel right at home. The single-celled organisms colonize soils, tombs, waste treatment plants, hot vents at the bottom of the ocean and even the Arctic sea ice. Many billions of these microscopic creatures romp around in and on our bodies, in the digestive system or on our skin. This is a good thing, as microbes improve our defenses and provide us with essential substances.

Friedrich Widdel is interested mainly in the specialized bacteria that survive in the complete absence of oxygen – the “anaerobes,” which take in sulfur or nitrogen compounds from their surrounding environment in order to breathe. The scientists from the Max Planck Institute for Marine Microbiology in Bremen are particularly fascinated by the oil-degrading bacterial strains that thrive in exotic habitats: underneath oil slicks on the shoreline or in anoxic oil sediment on the seafloor.

The subject grabbed Widdel’s attention years ago, in 1982, when an engineer friend gave him a tour of an oil storage site. There had been problems with a crude oil tank that was used to separate the oil/water mix from the drill holes; in the containers, a toxic hydrogen sulfide, stinking of rotten eggs, had accumulated. This “sour gas” is a corrosive substance that can even damage steel pipes.

Hydrogen sulfide is found in many oil reservoirs. It was generally known that it is generated by chemical reactions at high temperatures deep in the ground. However, why hydrogen sulfide would form in the lukewarm tank was a mystery. It soon became clear to Widdel that anaerobic bacteria must be responsible for the process in the anoxic tank, as hydrogen sulfide is a typical degradation product of anaerobiosis. But what were the bacteria feeding on?

At the beginning of the 1980s, it was still believed that crude oil could be degraded only by “aerobic” bacteria, organisms respiring oxygen. Crude oil consists of hydrocarbons, mainly so-called alkanes: long chains of carbon atoms with which only hydrogen atoms bond. The metabolism of aerobic bacteria, in which the alkanes are decomposed, is similar to the workings of a car engine. The long chains are torn into pieces and then react with oxygen, leaving only carbon dioxide and water.

OIL COMPONENTS DEGRATED EVEN WITHOUT AIR

The amount of energy released in the reaction with oxygen is enormous. This is why a liter of gas will get you pretty far. For aerobic bacteria, utilizing alkanes with the help of oxygen is thus a sumptuous meal. But what about the anaerobes? Many scientists assumed that anaerobic utilization of alkanes was impossible. Otherwise, surely the bacteria would have finished off the oil reservoirs of the planet during the course of the millennia?

As it turned out, this hypothesis was plausible, but incorrect. Friedrich Widdel brought water with oil residue from the tanks to the laboratory and placed it in air-tight containers. Then he waited. Sure enough, slowly but surely, hydrogen sulfide formed in the test tube. The only possible source was the degradation of the crude oil using the sulfur compound sulfate. To this day, scientists have only partly understood what happens in the metabolism of bacteria. Widdel is thus also trying to find the proteins that are involved in degradation.

It looks as if the anaerobes first extend the chains and then pick them
apart, piece by piece, in order to finally respire them. Instead of oxygen, the anaerobes use, for example, sulfate, which is present in much higher concentrations in seawater than oxygen. Even if the oxygen in the oil separator tank has been used up, the anaerobes can still find quite a lot of sulfate. The end product of the reaction of the sulfate with the alkanes, through a complex sequence of metabolic processes in the bacteria, is hydrogen sulfide. To reduce these and other undesirable bacteria in oil production, antibacterial substances are added to the water, which is pumped into the reservoir.

So far, there has been no real explanation for why bacteria have not long since devoured the planet’s crude oil reservoirs.

GROWING BACTERIA TO COMBAT OIL SPILLS?

Each time a large oil spill occurs, experts argue about how such disasters could be avoided in the future and the best ways to tackle the pollution. Time and again, the use of laboratory-grown bacteria is brought up – bacteria that supposedly could devour the oil with lightning speed – much more quickly and efficiently than naturally occurring microbes. From a microbiological perspective, however, such a huge deployment of bacteria is hardly feasible. Even if the bacteria should survive the abrupt transition from the laboratory environment to the ocean and would begin to feed on the oil, the degradation would soon slow down because the microorganisms also consume essential minerals from the surrounding seawater. Another problem is that the aerobic bacteria, which break down oil very efficiently, require a lot of oxygen to do so. This leads to a lack of oxygen, often within a millimeter of the surface of an oil layer on the shore – and this in turn hampers the degradation process. The anaerobic bacteria, on the other hand, work too slowly to be able to eliminate the oil before it becomes a dense, tarry mass. To make matters worse, the bacteria are active only in the boundary layer between water and oil. Hardly any degradation takes place in the middle of the oil layer, so as the oil slicks become thicker, the degradation rate decreases.

So far, there has been no real explanation for why bacteria have not long since devoured the planet’s crude oil reservoirs over the millennia. It is possible that some oil reservoirs were very hot and therefore remain almost free of bacteria to this day. In other cases, it is clear that bacteria have been at work. The tiny things are gourmets. From the hundreds of different alkanes present in crude oil, they look for the ones that are easier to digest, such as hexadecane, a molecule comprising 16 carbon atoms.

If such an oil sample is analyzed using a gas chromatograph, a device that
can trace specific substances, it becomes clear that certain alkanes are missing. The varying properties and qualities of crude oil from different reservoirs may, in part, be due to the “feeding habits” of the anaerobes.

People who work with anaerobes need a lot of patience. Many anaerobes belong to the “sloths” of the microorganisms. They grow and reproduce in slow motion. Nobody is quite sure why this is. In contrast, the famous laboratory bacterium *Escherichia coli*, the biotechnologists’ workhorse, is a true sprinter. It stays alive and functions using oxygen. When in good shape, it splits once every 20 minutes. In 10 hours, one such bacterium creates billions of successors.

In that period, Widdel’s bacteria have not even started growing. They may take days or weeks to split. “They live and die slowly,” says the scientist. This makes growing such microbes a tedious task. Microbiologists aim to create pure bacteriological cultures of bacteria to understand their function. However, a sample of water or sediment contains a whole host of different bacterial strains. In order to find the exact bacterial strain that degrades the oil in this microscopic soup, the sample is diluted over and over until, finally, statistically speaking, only one bacterium is left floating in the laboratory receptacle.

During this process, the bacteria must keep reproducing so that the scientists can establish whether there are still any oil-degrading bacteria left in the diluted sample. This takes time. So much time that, Widdel says, in the first years, he was rarely able to get even a doctoral student to work on his oil-degrading anaerobes. Thus, for a long time, the dilution series was more of a side job for him and his colleagues.

The team in Bremen has now managed to isolate a range of pure strains, but so far they have not found a real winner among the anaerobes. These bacteria are simply not good enough to clean up a major oil spill, according to the scientists. They are much too slow. In cases of oil tanker damage or accidents like the one in the Gulf of Mexico, thousands of tons of crude oil are spilled in a matter of days. Against such volumes, even the quick aerobes, the oxygen-devouring cousins, are powerless. The tide brings the oil and tar masses onto the shore, where often lumps of oily mud and sand form. Widdel’s bacteria are active wherever the oxygen becomes scarce, for example underneath the black oil layers on the beach, or in places where oil seeps naturally from the seafloor, or in the oil reservoirs.

**HYDROGEN SULFIDE CAUSES MORE PROBLEMS**

Sometimes during an oil spill, anoxic zones will even appear directly in the water, since the aerobic oil-degraders draw the essential oxygen from the seawater. In order to break down one drop of 0.2 millimeters of oil completely, aerobes require the oxygen from up to 80 liters of water. In the case of large amounts of oil in the environment, the aerobes themselves...
The degradation of thick crude oil masses in anoxic or near-anoxic conditions takes years or decades, and even then the oil is probably incompletely degraded.
increases the pressure. Still, he underestimated the unicellular organisms.

One day when he checked the incubator, one of the phials had burst and its contents were spread out everywhere. Widdel still remembers the loss of a productive bacteria colony that he had taken care of for a long time with a bit of sadness. In a complete “microbial alkane gasification,” the volume may increase a hundredfold. Such bacteria may have contributed to the gas in the oil reservoirs.

Naturally, oil-degrading bacteria are not Friedrich Widdel’s only subject of study. Anaerobes can do so much more. The shelves of his incubator hold tightly sealed phials containing metal strips. The metal is the food source of anaerobes that directly utilize and corrode metallic iron. Widdel wants to use them to understand the problem of biocorrosion in iron pipelines.

However, the area of hydrocarbons is definitely the one that has thus far occupied him for the longest period of time. Friedrich Widdel continues to search for new strains of bacteria with interesting properties in samples that he himself collects from mudflat sediment or in phials brought back by his colleagues from scientific surveys. He is convinced that some bacteria will still display new, surprising properties. There is just one thing that he does not believe in: “Superbacteria that will clean up oil spills in the blink of an eye. Because degradation performance and bacterial metabolism also operate within natural limits.”

GLOSSARY

Anaerobes
Organisms whose metabolism works without oxygen, in contrast to that of aerobes. To many of them, oxygen is even toxic.

Gas chromatograph
A device that separates the substances of a mixture. Using a carrier gas, the mixture is sent through a thin, 10- to 50-meter-long column that is wound into a coil. The capillary column is coated with a material to which substances will be absorbed for varying periods of time, depending on their polarity and their vapor pressure. The materials will thus exit the column after varying lengths of time.

Alkanes
Compounds consisting of carbon and hydrogen that contain no double bonds. The carbon atoms thus form a chain that may be branched or joined up in a ring. A hydrogen atom is bonded to any free bonding point. They are obtained primarily from crude oil.
"Sex offenders should be put behind bars – forever!" This opinion, though widespread, is untenable in a country subject to the rule of law. A team working with Gunda Wößner of the Max Planck Institute for Foreign and International Criminal Law in Freiburg is conducting a study on criminal recidivism and the effectiveness of social therapeutic measures.

TEXT KLAUS WILHELM
On a research mission: Gunda Wößner (right) and her colleague Elke Wienhausen visit inmates in the Waldheim correctional facility. Wößner, who holds a doctorate in psychology, is leading an evaluation study on the treatment of sex offenders.
Our carefully tended plants in very special planters – margarine tubs – are waging a lone campaign to counteract the monotony of the room. The room is small, not even 15 square meters. A chair, a bed, a small television set. The toilet is toward the front, near the door. Two shelves. Everything spick and span. There’s a feeling of order – two or three books, a couple of document folders. And an impressive model of the “Admiral Graf Spee,” a warship of the German Navy in the Second World War. “I enjoy making things with my hands,” says Frank S. Although 35 years old, you’d think from his appearance that he was 25. He sits upright on the chair and talks calmly.

Frank S. has abused children, mostly boys, sometimes girls. More than 100 times, for years.

The room is a cell in the Waldheim correctional facility, just under an hour’s drive west of Dresden. As he talks, Frank S. appears relaxed, alert, at times somehow liberated. Just occasionally his eyes shift away and look troubled when he talks about the past. “The thing I thought about most was self-confidence,” he says. He didn’t have any. Almost every adult unknown to him was unapproachable. “How was I supposed to get to know a woman?” S. was shy and timid in a way that other people cannot even imagine.

“There is a big connection between that and what I did,” he says, “I longed for security and love.” The extremes of emotions were tearing him apart. All that remained were children, incompa-

rably friendlier and more uncomplicated than any adult. And the loss of control. The complete lack of understanding that he was destroying the souls of his young victims. And what he was doing to parents and relatives.

SOCIAL THERAPY AIMS TO PROMOTE RESOCIALIZATION

He uses psychological terminology, such as “cognitive distortion,” as naturally as other people mention “car” or “handbag.” Something he has learned to do during social therapy in the Waldheim facility – in other words, in treatment composed of a variety of therapeutic means and social aids designed to resocialize prisoners. The goal of the treatment is to show Frank S. how and why he came to do what he did, how he can change his behavior, how to establish himself once he’s been released, and how to work and function on the outside.

The treatment is made up of different strands – training in social skills needed for communal living, developing empathy and conflict management, acquiring self-confidence, working through disordered thought and interpretation patterns, and relapse prevention specifically for sex offenders.

For a variety of reasons – political, emotional, populist – lawmakers decreed, with effect from January 1, 2003, that sex offenders sentenced to more than two years of imprisonment must be treated in an institution offering social therapy, provided such treatment is indicated. This proviso has created a certain amount of discretionary leeway for those responsible for implementing the law, namely the federal states and individual institutions.

The treatment would seem to be especially relevant for offenders with a significantly disordered personal and social development giving rise to the fear that they might commit dangerous criminal acts in the future. Treatment lasts for one and a half to three years, or up to four or five years in exceptional cases.

“We start by taking everyone, at least for a three-month trial period,” says Michael Brinkmann, director of social therapy at Waldheim and deputy director of the correctional facility – even offenders who initially are not motivated at all. There is a good reason for this. A preliminary assessment of the ongoing study being conducted in Waldheim by the Freiburg Max Planck Institute of Criminal Law in cooperation with the Saxon Ministry of Justice and the Institute for Criminology and Business Criminal Law at the University of Freiburg demonstrates the following: even prisoners who are totally unwilling at the outset may gain something from the treatment. Moreover, “Usually we would expect that the child abusers are the offenders who succeed because of their conforming social conduct. But these very rapists with antisocial tendencies, unwilling at the beginning of the social therapeutic intervention, drop out of the treatment far less than the former,” says project director Gunda Wößner.

As a psychologist in the department of criminology at the Freiburg-based Max Planck Institute, she knows how
socially destructive child abuse and rape can be. “The topic keeps flaring up when people get together to talk in bars and also on TV talk shows,” she says. This is particularly true if an offender abuses or rapes again after release – and then all the more so if he has had social therapy while in prison.

The result is demands such as that recently made by the German FDP (Liberal Democratic Party) politician Christian Ahrendt, that “whenever an offender is convicted of a sex offense or of being in possession of child pornography,” he must be forced “to take sexual medical treatment.” In other words, treatment with medication that inhibits the sex drive. Alternatively, that all individuals with a single conviction should be “locked away” permanently, as former Chancellor Gerhard Schröder put it in 2001.

From the point of view of victims and their families, these demands are more than understandable because they are driven by pure fear and quite possibly also by the desire for retribution. “I don’t want anything to happen to my children, either,” says Gunda Wößner. Even so, for the researcher, such radical opinions smack of ignorance and a lack of detailed knowledge. On the one hand, “they contradict the tenets of a country founded on the rule of law and liberty,” whereas on the other, “reality is always more complex than any popular opinion.” Yes, a small number of sex offenders do benefit from medical treatment. Yes, social therapy can reduce the rate of offense-specific recidivism, depending on the study cited, by 12 to 20 percent.

PERSONAL INTERVIEWS AS THE BASIS OF THE STUDY

But the questions currently being asked by researchers in criminology regarding social therapy go far beyond this. How successful is this treatment really? What exactly are the effective measures? Which types of offenders benefit from social therapy? And which don’t? What lies behind a relapse, and how can its likelihood be influenced? Can the rate of recidivism be further reduced by gearing the social therapy better and more specifically to the individual? Is the focus on sex offenders justified at all?

At present, the question of whether every sex offender should be required to undergo social therapy is still open, at least from the psychological point of view. “Treatment works somehow,” says Wößner, “but we have not determined precisely what works how and for whom.”

The purpose of the ambitious study – planned to last 15 years – of the Max Planck Institute in Freiburg and the social therapy departments of the Free State of Saxony is to provide new answers and to shed light on the confused mass of speculation. In this spirit, Gunda Wößner has been making regular trips from Freiburg to Saxony since 2006 in order to gather information, monitor the ongoing study and provide solutions for emerging issues. There she meets local colleagues, including Elke Wienhausen, who recruit prisoners receiving social therapy for the study and conduct interviews with the inmates. “They are usually friendly and glad that someone is listening to them,” says the sociologist, “no problems so far.”

The team working with Gunda Wößner has thus far conducted in-depth interviews with 106 sex offenders and 55 violent offenders before the start of their social therapy in the Waldheim correctional facility. The questions focus
on all manner of personality, biographical, emotional and socio-economic issues. With standard psychological tests, but also with information gathering tools of their own design. Of the study participants, 69 have already been interviewed a second time - just before the end of treatment. In addition, another 150 prisoners who are serving their sentences in a regular correctional unit and are not undergoing social therapy have also been interviewed.

**IN THE HUMANE PRISON, A GOOD SOCIAL CLIMATE PREVAILS**

One year after their release, the subjects are interviewed a third time, if they are willing and can be traced. Additionally, the researchers evaluate their personal files and include the assessment of the therapists on each individual prisoner. Five years after release, the Freiburg-based researchers consult the data on the interviewees contained in the criminal records of the central federal register. Thus, the officially registered reoffenses can be traced.

Frank S. can only dream of release at the moment: his earliest release date for probation for good conduct is 2012. His cell is located in the renovated Building 1 in the correctional facility. When he peers through the bars, he sees a small town lying in a hollow surrounded by higher ground. On this summer’s day, the town magnificently confirms the publicity slogan “Pearl of the Zschopau Valley.”

The prison blends seamlessly into this image, almost as if the two had grown together. Were it not for the discreetly placed barbed wire coils on the white walls, it would scarcely be recognized at first for what it is. A lime tree and a church give the area the feel of a village green, and the simple strung-out buildings are more reminiscent of an old boarding school than a prison. Since its foundation nearly three centuries ago, the prison has been regarded as a model institution, as a contemporary of the time remarked back in 1791.

The interior of House 1 looks like a model, contemporary humane prison.

“We no longer have gangways complete with railings outside the cells, as we did in the past, when the different stories were not separated by partition walls,” says security officer Steffen Rost, “you can hear the difference.”

And it is true, it’s almost perfectly quiet – even at 5:00 p.m. when all the prisoners have returned to the wing. They gather together in light wells. They cook together. “They get along together without much trouble,” explains Rost. This is despite the fact that almost all of the approximately 300 prisoners are serving many years in custody owing to serious violent offenses or sex offenses.

Michael Brinkmann attributes this to the social therapy, among other things. “We see positive effects in the day-to-day life of the facility,” he says, “The social climate is improving appreciably.” He has been working with dangerous criminals in his capacity as a psychologist for 15 years “because I can really make things happen here,” he explains, “for people that really need it.” He is a committed champion of social therapy.

“Believe in this concept,” he says with conviction, “doing nothing at all is not an alternative.”

Frank S. was sentenced to a total of eight years of imprisonment and wanted to get out of regular imprisonment in Dresden “as soon as possible” and into social therapy at Waldheim – maybe because he saw it as a real opportunity to do something positive about his situation. Or perhaps because he hoped he would be released earlier. Perhaps because, as someone convicted of child abuse, he was the “lowest of the low” in the prison hierarchy and his life could be made a living hell. However, at first there was no room for him at Waldheim. The whole situation, the guilt feelings and black despair, culminated in 2007 in a suicide attempt. “They had to act quickly,” he says laconically. Early in
2008, he was transferred to Waldheim and started receiving social therapy.

Susann Gebhardt is a young social worker in the Waldheim social therapy team. She is small in stature and speaks with a decisive but empathetic tone. She needs both of these attributes when she works with a dozen prisoners, as she does now. Some seem extremely interested, whereas others seem nervous or stressed. Just like every week, today’s program includes training in social skills.

Gebhardt is standing in front of a board and is asking the group, “How can I be likable to people I don’t know? And speak to them?” She is asking for their thoughts that could get in the way of doing that. And also for feelings that give them a sense of confidence or uncertainty. Feelings! Some of them are confused and look away. This is a basic course dealing with the (most) elementary things that we normally learn as a child or a young adult. The fundamental principles of friendliness.

Sessions like this have been Frank S.’s first experience of hearing about his disordered relations with empathy, and of learning in role plays what empathy means. It is his first realization of how he came to commit his acts. For the very first time, he perceived the concept of cognitive distortion – the way he internally plays down and justifies his acts. “But the children were willing, I taught them something new.” Eliminating this sort of false reasoning from the ground up is one of the central themes of psychotherapy in social therapeutic treatment: blame should not be sought in others.

Together with the prisoner, the therapists develop an individual model of an offender’s delinquent behavior or disorder without dwelling too much on analysis. “It is important for them to understand the dynamics of their own actions,” says Max Planck Institute researcher Gunda Wößner, “but what the offenders need above all else are specific strategies related to their own situation for combating their disorders.” In the sense of cognitive behavioral therapy.

Practicing self-control, even in stressful situations. Accepting responsibility for their actions. A hard path that not all follow to the end. Some 10 to 15 percent withdraw from social therapy. There is something very odd going on here, in that dropouts, on average, become recidivists more frequently than offenders who do not even begin the treatment. “We don’t know why,” says Wößner, “and we want to get to the bottom of it.” Have the needs of this group not yet been addressed at all?

Frank S. wants to succeed. “My eyes have been opened,” he says. His upbringing was strict, and both his father and mother drank. He was teased at school for being overweight. As an adult, he lived with his mother for a long time. An extremely small circle of friends, not sexually active. The psy-

**MORE DISORDERS**

Alcohol abuse and dependency, impulse control disorders and paraphilias – disorders involving severe sexually deviant conduct – are significantly more often a trait of the prisoners at the Waldheim and Bautzen correctional facilities than in the general public. The researchers working with Gunda Wößner have established this in a subsidiary project of their long-term study on social therapeutic institutions in the Free State of Saxony. In addition, in comparison to the general population, there are significantly more compulsive, insecure, narcissistic, antisocial, schizoid and paranoid personality disorders. The insights gained could help develop disorder-specific therapeutic concepts for the sex offenders concerned.
duct, culminating even in the murder of their victims.

- Low-ability offenders who, because of their lack of intelligence, do not know how to approach someone and how to experience intimacy.
- Offenders who at first glance do not stand out socially, but who tend to go to extremes in crisis situations: either incestuous acts with their own children (or children brought into the relationship by their partners) or rape of the (ex-) partner.

Initial evaluations confirm the typology, including those from the ongoing Waldheim study. An additional type is the offender, also antisocial, who commits his sex offenses almost exclusively in the family. “We are only now beginning to recognize this group properly because victims have recently become more confident about reporting the abuse,” emphasizes Gunda Wößner.

An important aspect of more individualized treatment in the sense of type-specific intervention are so-called “coping mechanisms,” – the inner resources that an individual develops to deal with negative feelings. “At this point, it is important to gear interventions to each offender type,” she says.

The Waldheim study suggests that there are different types of violent offenders, “something that is often not brought out in the literature.” For example, there is the type who – at first glance – is quite normal, but in a crisis exhibits acts of severe violence and killing. Or a type of professional, highly antisocial offender who has specialized mainly in crimes involving robbery.

It is elementary especially for the aggressive, antisocial offender types to hold down a job in prison – this has much to do with the fact that these inmates are generally not used to full-time work. “They often do not know how to structure a day,” says Wößner. Work simplifies this enormously, and there is a large supply of work and production halls to do it in at Waldheim. Everywhere, men in blue trousers and striped shirts are busy working. Some seem to be rather reluctant, others seem to be concentrating. They are constructing lattices, binding books, making wood briquettes, drilling, sawing, operating lathes, milling. They make wiring looms for Mercedes for good money – about ten euros per day. Others are training to be welders, which will be a valuable qualification.

“No less important – especially for the ‘antisocial types’ – is the use of free time. For many of them, sports are their number one interest. Others paint, while some cook. “If they can’t learn how to use their free time sensibly, they are only a step away from dropping back into the criminal environment or their peer groups who hang around and become involved in shady activities,” says Rost. Reoffending is then more or less a certainty.

For Michael Brinkmann, “each percent” counts – that is, each percentage drop in the relapse rate attributable to social therapy. It is a matter of human suffering. A matter of the cost of enforcement. Yet, as Gunda Wößner em-
phasizes, it is not easy to say how often sex offenders without therapy relapse. Numerous figures are bandied about in the literature, depending on the particular design of the studies cited. Recidivism rates depend on the definition of successful treatment, on the length of time between treatment and the measurement of outcome, and on the offender types under investigation; therefore, results may diverge widely.

**RECOGNIZING THE EARLY INDICATIONS LEADING TO ABUSE**

If only offense-specific relapses – meaning a repeat of the sexual delinquency – are considered, the rate is between 6 and 33 percent. However, for relapse in the sense of any other offense, the rates go up to as high as 70 percent. Jutta Elz of the Center for Criminology found that the frequency/recidivism rate for child sexual abuse is around 22 percent; for offenses with sexual violence, the rate is around 19 percent. The relapse rates established in various national and international studies are between 15 and 20 percent for rapists and between 6 and 24 percent for various forms of child sexual abuse.

The few studies conducted in German-speaking regions quote relapse rates of approximately 12 percent for serious child sexual abuse. According to studies so far conducted, offenders with a social therapeutic treatment are 8 to 20 percent less likely to reoffend with an offense-specific crime than offenders without such an intervention.

“Therapy achieves something,” stresses Wößner. However, preliminary results from the current study vary. According to some of the interviewees, they gained little or nothing from social therapy – whereas others say they benefited a great deal. As regards evaluation, the psychologist does not want to concentrate solely on the relapse rate. “Relapse is a very severe criterion, one that is not used in any other medical or psychological field – for example in treatment for depression – to determine whether or not treatment is meaningful.” What she also regards as important is whether a relapse is less serious than the original offense. Is there a very long delay before it occurs? Or can the former prisoner maintain a job?

The psychologist knows that it is very difficult to convey such views to the general public, and she says that “some are so much at risk of relapse that they can never be released.” But there will always be recidivists among the ones not obviously at risk of relapse. The only 100-percent-certain alternative is to keep every person ever convicted of a serious offense in preventive detention for the rest of his life. But: “Do we want to do this in a country based on the rule of law, such as ours?”

Frank S., a trained metal worker, has had further training in Waldheim as a machine cutter. And now he has started a course in technical drawing. He ought to be able to make a go of working again. But that is not necessarily the problem for him. He hopes that the therapy will help him overcome his disorder. The fact that he can engage in conversation with “a complete stranger, a journalist” is confirmation for him of his newly acquired confidence. “That would have been impossible before the therapy.”

Therefore, S. hopes that the prevention strategies he has learned will work. And that he will always remain aware of “how it used to be.” That he will recognize the thoughts and warning signs that lead to abuse. That he will then be able to use the resources that give him self-control. And that he will find friends to help him “lead a new life.”

**GLOSSARY**

**Cognitive behavioral therapy**
A form of psychotherapy that aims to modify dysfunctional cognitions – one’s attitudes, thoughts, evaluations and beliefs – through special therapeutic techniques. The underlying premise is that a particular manner of thinking determines how we feel and behave and how we react physically.

**Preventive detention**
A measure involving deprivation of liberty intended to protect the general public from dangerous offenders after they have served their normal custodial sentence. The degree of danger must be established in an expert opinion report. Preventive detention is still carried out in correctional facilities, although detainees are granted more privileges than are regular prison inmates. The German federal government intends to pass a new law on preventive detention.
Even back in ancient times, this was an area that beckoned with exceptional pleasure: on the southern slopes of Monte Pincio, the Roman general and gourmet Lucius Licinius Lucullus invited his guests to lavish feasts at his garden villa. However, the affluent Roman not only provided for the physical well being of his guests: with his extensive library, he created a place of intellectual pleasures and a meeting point for scholars. In so doing, he established a tradition that continues to this day. At the Palazzo Zuccari, which was built on the foundations of the ancient garden villa, the Bibliotheca Hertziana serves art historians with a unique collection of books and photography. This important art institute was named after its founder Henriette Hertz, the daughter of a Jewish family from Cologne.

Henriette Hertz was born on January 5, 1846. As a precocious young girl, she showed great interest in art, literature and languages. Her classmate Frida Loewenthal was her kindred spirit who, in turn, sang the praises of her new friend “Harry” who fluently spoke English, French and Italian, and who was a great art enthusiast.

The two women worked tirelessly to complete their knowledge of art, literature and philosophy. They learned ancient Greek in order to read Homer in the original. In addition, they attended lectures about Greek mythology and history. Their evenings were often spent with a group of friends who translated the works of Shakespeare, Dickens and Dante. They declared their thirst for education to be their purpose in life: “For living purpose!”

Henriette Hertz’s love of Renaissance art inspired her, starting in 1882, to undertake regular journeys to Italy, often accompanied by her childhood friend Frida and Frida’s husband, the chemist Ludwig Mond. The scientist had established the ammonia soda industry in England, and was thus one of the country’s leading industrialists. The profits from the soda empire enabled the triumvirate to enjoy a feudal lifestyle. The Palazzo Zuccari in Rome not only became their winter residence, but their second home.

The Renaissance palace, whose main portal is in the form of a monstrous orifice, looms above the Spanish Steps, wedged between the Via Sistina and the Via Gregoriana. In line with the concept of its builder, the painter and architect Federico Zuccari, the monster-like gateway was intended to “swallow up” visitors and then “disgorge them” in a hidden, paradisiacal garden behind the façade. The palace that Zuccari built at the end of the 16th century was intended to serve as both his residence and studio – in an area that was, back then, still undeveloped, as the street names, Capo le Case (“where the houses end”) and Via delle Fratte (“street of brambles”), indicate.

In his will, Zuccari decreed that his studio was to be used as a “meeting place for painters, sculptors and architects of the Academy, as well as for distinguished scholars of fine literature.” The other chambers, conversely, should serve as “quarters for poor students of my profession (…) And these poor young men, if they so desire, should pursue their studies here, and not be forced to leave for six months and one year (…)”

Unfortunately, however, the young students were not to enjoy this privilege, as the building and associated costs drove the extravagant artist to ruin. At the time of his death, the building was still unfinished; later, prominent figures such as the archaeologist Johann Joachim Winckelmann and Johann Wolfgang von Goethe, would be frequent guests here.
Henriette Hertz, initially tenant and, from 1904, owner of the Palazzo Zuccari, turned the lavishly furnished rooms into the social hub of Rome's artistic world. Her salon played host to a "colorful crowd of (...) foreigners from all nations," united by their love of the city and for the fine arts. Every week, scientists, artists, collectors and Italophiles gathered for discussions and to attend lectures, readings and concerts.

"Evening, 21:30 h at Miss Hertz," wrote archaeologist Ludwig Poljak in his diary. "A large, illustrious crowd. I met Siegfried Wagner. Extraordinary similarity to the old man (Wagner). Tremendously enjoyable evening."

The hostess' social events were also devoted to the tradition that Lucullus had established here almost 2,000 years earlier: Theodor Mommsen, classical scholar and literature Nobel Prize winner, greatly appreciated not only the intellectual delights, but also the outstanding food and superb wines served at the Hertz residence.

Henriette Hertz's role was, however, in no way limited to that of a witty salonière. Together with Frida and Ludwig Mond, she supported students, scientists and artists, and invested in educational opportunities for women and in childcare. Early on, she developed a passion for collecting and, in addition to paintings, amassed a comprehensive collection of art historical books and photographs. Furthermore, she was a translator and was also devoted to writing.

As early as 1878, her novel Alide was published under the pseudonym Harry Hertz. It contained the words: "The most fateful moment in life. The life of a woman is marriage, and like the crisis of a protracted illness it rarely develops into good, stable health, but often into wretched wasting away." For the author of these lines, the risk was obviously too great – she would remain unmarried.

Henriette Hertz's close friendship with the art historian and Michaelangelo specialist Ernst Steinmann, who she had met in Florence in 1894, was of decisive importance for the founding of the Bibliotheca Hertziana. In a letter to Steinmann she wrote: "The establishment of this library is the fulfillment of my life-long wish (...) to maintain and support, also for the future, art historical research, especially of the Renaissance period." In keeping with the tradition of her salon – where what counted were mutual interests, rather than background, gender or social standing – men as well as women, regardless of their nationality, should come together "in total freedom and independence" and dedicate their efforts to the research of art and culture, starting with the Renaissance. Her own difficult situation was a pivotal factor here: Henriette Hertz often lamented the fact that women encountered difficulties in accessing libraries.

During the founding phase of the institute, Ernst Steinmann served as consultant and took on diverse organizational tasks. Henriette Hertz discussed book acquisitions with him, and left negotiations with third parties to his discretion. She ultimately appointed Ernst Steinmann as lifetime director. There was one point, however, where he did not live up to the founder's expectations: with the allocation of user passes, the "administrative body proceeded with a certain severity and sought to ward off, when possible, dilettantish elements." For the director, this meant above all the large number of "female art history students."

In October 1912, on the occasion of the 10th international art historian congress, the Bibliotheca Hertziana opened its doors for the first time to scientists from all over the world. The following January, the institute began its research activities. Henriette Hertz, who had already been ill for a long time, died on April 9, 1913 at the age of 66. According to the terms of her will, her painting collection went to the Italian government; the Palazzo Zuccari and its annex, the entire library holdings, the Fototeca (photographic collection) and endowment capital in the form of securities passed to the Kaiser Wilhelm Society.

Thanks to her endowment, Zuccari's wish to foster young academics finally became a reality: the Bibliotheca Hertziana, which is one of the institutes of the Max Planck Society, offers future art historians the ideal conditions to pursue their doctoral or postdoctoral work.

The foundation for the Bibliotheca Hertziana included around 5,000 books and 12,000 photos from the founder's estate. In the meantime, the library's inventory has grown to over 250,000 books and 800,000 photos – and continues to grow. The new building by the Spanish architect Juan Navarro Baldeweg, which is currently being erected in the courtyard of the Palazzo Zuccari, is expected to be completed in 2011, thanks to the generous support of several patrons, and will provide ample space for the abundance of art historical treasures.

The building is also intended to be a reminder of the 2,000-year history of the location: during construction, a mosaic-covered wall of a Roman nymphaeum was discovered – part of Lucullus' legendary garden villa. A glass wall in the book stacks will allow visitors to inspect the mosaic – and call to mind the famous gourmet and founder of the first library on Monte Pincio.
A SMALL MISSING PIECE MAY MAKE A BIG DIFFERENCE.
MAKE A BIG DIFFERENCE BY YOUR SUPPORT.

Most basic research is government-funded, worldwide. Max Planck research is top, worldwide, with more Nobel Laureates* than any other research institution anywhere. But others are accelerating the pace with private funding, which Max Planck research largely misses.

Since 2006, the Max Planck Foundation has had a good start in closing some gaps, with €350 million of capital gifts and €17 million project gifts. 100% for research: All gifts go into Max Planck research; none of them substitutes government funds. Your support makes the difference.

* 32 Nobel Laureates, including the Max Planck Society’s predecessor, Kaiser Wilhelm Society, founded in 1911.
Hairy Donuts

Junior scientists shine in the first Munich Science Slam – with some unusual metaphors

When the Max Planck Institute for Physics organized the first Science Slam in Munich, the tickets were gone in next to no time. In brief presentations, six young scientists introduced the subjects of their research – and delighted the audience with their enthusiasm, wit and easy manner.

What do Mahatma Gandhi, provocative swimwear and positrons have in common? Gandhi went on a hunger strike, Prussia banned “revealing” swim suits and Carl David Anderson discovered the positron – all in the year 1932. So began doctoral student Andreas Moll’s winning presentation at the first Munich Science Slam at the MPI for Physics. The title: “Hunting the missing antimatter.” Six participants – five doctoral students at the International Max Planck Research School and one young post doc – attempted, in just 12 minutes, to explain in layman’s terms how they spend their working day.

Andreas Moll described how it came to be that, since the Big Bang, there has been more matter than antimatter, even though both actually derive from energy in equal parts and immediately revert back in equal pairs. Researchers are using particle accelerators to create matter and antimatter in order to demonstrate that there is always just a little more matter that is unable to pair off with an antimatter partner to form energy. “The surplus matter becomes visible, rather like the audience at a Science Slam.”

An audience of around 200 followed the action on stage with enthusiasm and turned up the volume as the clap-o-meter measured their appreciation. The device measures the loudness of the applause in decibels. “Next time we are going to need a bigger space,” noted Silke Zollinger, who organized the Science Slam. “We didn’t quite expect such a crowd.”

Second place went to Peter Graf, whose Bavarian dialect and self-mocking delivery added much to his description of “The dark side of the universe,” or dark matter. “If, for example, a planet is not to fly away, then, according to theoretical physics, its weight must be equal to the centrifugal force. Unfortunately, experiments fail to confirm this,” he explained. “So to make sure that everything still works, physicists have invented a fancy new particle: the axion.”

How do I come across as relaxed as possible, and not tense? A week before the event, the participants received a few tips from a drama coach. “But the biggest challenge for the presenters,” said Dieter Lüst, Director at the MPI for Physics, “was to find comparisons that could hold their own with respect to the theme, right through to the end.” Third-placed Thorsten Rahn came up with a particularly original image: He gave an explanation of string theory, which attempts to overcome contradictions in gravitation and quantum physics. He illustrated this in his PowerPoint presentation using donuts that grew hair, around which the strings then wrapped themselves like spaghetti. “Then we package the whole thing in mathematics and software.” On the screen, a complex picture emerged to illustrate the computational processes, to the accompanying sound of “A Kind of Magic” by Queen.

“I would like to see whether I could generate such enthusiasm among less science-friendly listeners,” pondered winner Andreas Moll at the end of the evening. He received a cup that echoes the logo of the Institute for Physics. All of the participants also received cuddly toys – antimatter particles with a friendly face, and even a hairy donut.
MAX PLANCK COMMUNITY

Have You Met ELENA?

The Max Planck Society is among those required to transmit employee data at irregular intervals. All public bodies and companies that automatically process the personal data of more than ten employees are required to appoint a Data Protection Officer. The MPS is no exception. Apart from their formal duties, these specialists have also become the general contact for matters relating to the broader aspects of IT security, and they are happy to pass on information. They can also explain the contents of the MPS Data Protection Handbook, in which the essential rules and regulations are outlined. For those who prefer to have it on screen, the Handbook, which has so far been available only on paper, can now, with immediate effect, be found on the intranet as a PDF file in German and English.

Data protection is also an issue for ELENA. The abbreviation stands for the Electronic Pay Statements Act that is intended to close the gap between the employer’s electronic HR management systems and the programs used by the authorities. At present, the gap is bridged only on paper – the 60 million or so paper statements issued every year by around 3 million employers. Employees need these statements as proof of entitlement to various benefits provided by public-sector bodies. Unemployment benefit claims, for example, are assessed on the basis of the proofs of employment issued by past employers.

The MPS is required by law to transmit its employees’ pay details to a central data storage point. This has been happening since the July salary statements were issued. Starting in 2012, the data is due to be called up via ELENA procedure. At present, however, due to the immense cost, the government is considering cancelling the scheme – to the delight of the data protection community. According to Rainer Gerling, they are understandably concerned that the scope and scale of the data are unlawful and have already lodged a constitutional objection. “Despite this, we have to supply the data,” Gerling explains, “because the law is in force and must be complied with.”

Employees can also learn more about data protection by taking part in the Max Planck online IT security training. The course is intended for computer users with minimal experience. A short test at the end of each lesson enables participants to check what they have learned. However, there is no need to worry about getting an answer wrong. “Using the IT security training is, of course, not something we keep a record of,” says Rainer Gerling.

Everyday Science

PhDnet workshop reflects on everyday phenomena

One of the by-products of crude oil, coal or wood processing is a tarry substance called pitch. It is as brittle as glass, as hard as stone, and yet flows like a liquid. But how fast does pitch drip? How long can a cookie be dunked in hot tea before it breaks? And what, actually, is a candle flame? At their fifth Interdisciplinary Workshop, the doctoral students who make up Max Planck PhDnet got down to discussing just such everyday science.

The meeting held in Bonn in early June was the fifth time that the network members had gathered to talk about aspects of science that went far beyond the bounds of their own disciplines. With “Everyday Science” as their theme, they reflected on a wide variety of day-to-day phenomena. Each contribution stemmed from their individual perspective developed through their studies and Max Planck institute training. The presentations took the form of either posters or brief lectures. The framework for the workshop was consciously modeled on that of conventional conferences. But anyone expecting dry theory or dreary lectures would – depending on their point of view – have been either disappointed or surprised: each of the 16...
The first meeting of the new MPS-wide research managers’ network was a complete success. Junior scientists with management responsibility joined with guests to discuss matters of common interest and share ideas for joint research projects. The next meeting of LeadNet is planned for 2011.

The network is an initiative prompted by Max Planck Society (MPS) research managers who are keen to develop scientific topics and discuss organizational issues beyond the bounds of their individual institutes. All junior scientists with management responsibility are invited to join the network. The object is to encourage cooperation and boost the exchange of information between group, team and project leaders within the MPS. A website already exists with a mailing list in which over 150 scientists have enrolled (www.leadnet-mpg.de).

The first network meeting in May was held at Schloss Waldfrauen near Mainz. Initiator Mario Albrecht (MPI for Informatics) and co-organizer Nicole Dubilier (MPI for Marine Microbiology) began by presenting the results of a brief survey of the 60 or so participants, drawn from around half of the total number of institutes in the three Sections of the MPS. The questions were designed to reveal their motivation for networking. Max Planck Vice President Herbert Jäckle then described the organization of the MPS and replied in detail to questions that had been submitted in advance. This, in turn, led to an intensive discussion of topics ranging from career opportunities to organizational problems, which reflected the participants’ differing experiences at the MPS and at their own institutes. One of the conclusions to emerge was that a lack of communication within and between institutes could unnecessarily impede the successful work of the scientific staff of the MPS. There was agreement that LeadNet will improve the exchange of information.

Benjamin Bowman (MPI for Biochemistry) began the second day of the meeting with a presentation of the various information and data search services available at the MPS, before handing over to Gabriele Gebhardt, who led a short workshop on conflict resolution – as an appetizer for the management seminars the MPS offers for research managers. Patrice Wegener from the Max Planck EU Regional Office at the MPI for Biological Cybernetics illustrated some of the opportunities for research sponsorship at the European level and gave some valuable hints on how to apply to the European Research Council. Nikolai Raffler of the German Research Foundation described the project sponsorship funding available from his organization and explained the evaluation procedure and the features to be expected in successful project applications. Finally, the meeting concluded with scientific workshops devoted to bioinformatics and microbial host interactions. By the end of the day, the first ideas for joint projects were already being discussed.
Online Help to Get Started

Information Retrieval Service offers “remote-controlled” search courses

“Back in 2006, we began offering our courses for scientists and visitors to the MPS, not just locally at the BM Section institutes, but also online for all of the Sections to use.” To take part in an online course, all you need, apart from a PC with an Internet browser, are headphones and speakers. Questions to the course tutor are typed in via the keyboard, using the chat function.

Taking part is an experience: as if by magic, a mouse moves across the screen, starts a program, and through the speakers, Bowman’s voice asks: “Can you hear me?” An answer is now required via the chat function to confirm that the system is working. During the next hour and a half in front of the screen, users are introduced to the most important databases and their contents, and have the chance to open a few pages and browse the information offered.

The MPS currently has a larger collection of digital information resources than any other German research institution. Given the international nature of the users, the courses are normally conducted in English. “But we’re flexible,” Benjamin F. Bowman says. “We’re happy to offer the course in German, if that’s what all of the participants want,” he adds.

In fact, the Information Retrieval Service does even more, offering courses on managing literature resources and bioinformatics programs – with great success. Since 2006, around 2,000 participants have improved their knowledge in nearly 300 courses, Bowman reports. With the aid of Berlin-based molecular biologist Nicola Gaedecke, a Bioinformatics Support Network has been developed at the MPS. The Bioinfo Wiki that went live in mid-2010 describes more than 250 special programs that were developed by Max Planck scientists.

“It was often the case that staff in one institute department didn’t even know what their colleagues on the next floor were doing,” Bowman explains. Now no one can say they weren’t informed – not just Max Planck scientists, but also their professional colleagues worldwide are benefiting from the new collection.
GS Junior System

Next Generation Sequencing for Everyday and Everyone
Introducing the GS Junior Benchtop System

Simplified Workflow and Bioinformatics

Perfectly sized for labs that require:

- Direct, clonal sequencing of amplicons (PCR products)
- Targeted human resequencing
- De novo sequencing of microbial genomes
- Metagenomic characterization of complex environmental samples
- Pathogen detection

...and many more applications, all for a price with extraordinary value!

Learn more at www.gsjunior.com

For life science research only.
Not for use in diagnostic procedures.

454, 454 LIFE SCIENCES and 454 SEQUENCING are trademarks of 454 Life Sciences Corporation, Branford, CT, USA, a Roche company. GS FLX TITANium and GS JUNIOR are trademarks of Roche.
We’ve done our research.
Now you can do yours.

» The latest job opportunities
» Opportunities in research: at entry-level and above
» Profiles, interviews and advice on career options
» Salary prospects in research and development
» Grant programmes in overview

FOCUS
Orientation
Strategies for Reaching Destinations with Confidence

SOCIOLOGY
Between Theory and Intuition

AIDS RESEARCH
Lost in Transcription

ENVIRONMENT
Oil-Eating Bacteria

CRIMINAL LAW
Building Blocks for a New Life