Activity rooms for your events
- total area 2300 m²
- state-of-the-art room and conference equipment
- pleasant air conditioning
- individual lighting and stage equipment
- 250 parking spaces

Vogel Immobilien & Marketing GmbH
Horst Vollhardt
Max-Planck-Str. 7/9
97082 Würzburg
Germany
Phone: 0931 418-2211
horst_vollhardt@vogel-medien.de

---

Würzburg’s new top location...
for conferences, trade shows, culture, celebrations.

---

Partnership – Thanks to an initiative by Andreas and Thomas Strüngmann, a legally independent research institute is due to open in Frankfurt in cooperation with the Max Planck Society. The Ernst Strüngmann Institute (ESI), named after the father of the two brothers, will be dedicated to the cognitive neurosciences and will be located on the former premises of the Max Planck Institute for Brain Research as these are gradually vacated. We are breaking new ground in jointly setting up this institute: in contrast to our Max Planck Institutes, the ESI will be financed, not from public funds, but by the Strüngmann brothers, who are providing a sum of around 200 million euros. Decisions on important scientific issues concerning the ESI will be made by a Board of Trustees, which I will personally chair. The institute also fulfills the excellence criteria defined by our Society: from the choice of scientists to the evaluation of research results, our quality criteria will be applied, and the Directors at the ESI appointed Scientific Members. It is an exciting process for us to work together with a private research institute that will have maximum flexibility to explore new ways of working and offer competitive salaries to attract leading researchers from all over the world. Until the first Director is appointed, the management will temporarily be in the hands of Wolf Singer, who is currently Managing Director at the Max Planck Institute for Brain Research. The research carried out at the ESI will complement that of the Max Planck Institute for Brain Research, and will attempt to facilitate the translation of scientific findings from animals to humans. We can only hope that the generous patronage of the Strüngmann brothers will set an example in Germany.

Physics – The coming new year will see the opening of the poetically named new Max Planck Institute for the Physics of Light in Erlangen, a product of the existing Research Group for Optics, Information and Photonics. The excellent scientific prospects afforded by a new field of research are what clinched the decision to set up the new institute. The move was made possible by the commitment on the part of the Free State of Bavaria to contribute 60 million euros toward investment costs. By the time the development phase is completed, the institute will have four departments with 111 established positions. The Founding Directors are Gerd Leuchs and Philip St. John Russell, who have been studying fundamental aspects of the physics of light since 2004. With the opening of the new Institute for the Physics of Light, the Max Planck Society is complementing the work of other institutes, such as the MPI of Quantum Optics in Garching, which is expected to team up in research into photonic glass fibers. Further joint ventures are planned with the Max Planck Institute for Solid State Research in Stuttgart and the Max Planck Institute of Microstructure Physics in Halle. We hope that, in addition to our ongoing internal development, the future financial situation will enable us to continue to establish institutes that address new problems in science.

Pact – If we are to attract the best scientific minds to Germany in the long term, it is essential for us to offer them the same living and working conditions as are available abroad. The Five-Point Plan recently approved by the Federal Cabinet is a step in the right direction. We hope that negotiations for the Pact for Research and Innovation II will yield similarly positive results next year. With the increase in energy costs, the inflation rate and civil service pay rises, the 3-percent increase granted to us thus far will be largely eaten up before we are even able to implement the measures agreed in the Pact. To remain permanently competitive at an international level, we allied scientific organizations need an increase of 3 percent in real terms.

---

Working with the Best

Peter Gruss, President of the Max Planck Society.

NOTES FROM THE PRESIDENT
FOCUS

Wind experiments: With the help of a wind tunnel, ornithologists are keen to find out whether migratory birds occasionally sleep with one brain hemisphere during long-distance flights.

Obstructed healing: Mending broken connections between nerve cells in the spinal cord is one of the biggest challenges for neurobiology.

Measured beauty: Experts from various disciplines discuss whether what is widely perceived as beautiful can be expressed in universally applicable formulas.

Rampant hatred: Youth violence directed at those who are different or foreign has many root causes, and can hardly be combated with draconian punishment.

CONTENTS

NOTES FROM THE PRESIDENT 3 Working with the Best

RESEARCH IN BRIEF

6 Rafting to Better Memory
8 A Jet-Propelled Black Hole
9 Accelerating Plant Breeding
10 Shedding Light on a Methane Source
11 Barriers of Emptiness
12 A Gap in the Superconductor
13 Panorama

VIEWPOINT 14 Study of Societies
In Praise of Simplicity

FOCUS 19 Mathenatics

FASCINATING RESEARCH 46 Ornithology
Sleepless in Seewiesen

FIRSTHAND KNOWLEDGE 54 Neurobiology
Growth Treatments for Nerve Cells

FLASHBACK 60 The Roots of Genetic Engineering

CONGRESS REPORT 62 Cultural History
Beauty Beyond Measure

RESEARCH & SOCIETY 70 Criminal Law
Hatred Behind Bars

PERSONAL PORTRAIT 78 Meteorology
Dirk Notz

MAX PLANCK NEWS 83 Arena for Artists in Light
85 Visions of the Future
86 “We learn a lot from one another”
88 Technology Transfer Changing Lives
89 Murder in the Vegetable Patch
90 Pinboard

MAX PLANCK SITES 91 Research Establishments of the Max Planck Society
91 Imprint

IN THE SPOTLIGHT 92 Decomposing cells
Rafting to Better Memory

Nerve cells disintegrate, and forgetfulness becomes the order of the day: Humans lose their ability to remember and their sense of time and place. Alzheimer’s is an insidious disease of the brain. Researchers at the Max Planck Institute for Molecular Cell Biology and Genetics in Dresden have now inhibited the ß-secretase enzyme, one of the most critical proteins in the onset of Alzheimer’s disease. This enzyme is crucial in the formation of the peptide ß-amyloid, the culprit in the development of the disease. Alzheimer’s is the most common age-related dementia. It results in the progressive decline in memory and cognition, and ultimately leads to death. Clumps of protein fragments or plaques, known as amyloid deposits, are considered the most visible change in the brains of Alzheimer’s patients. According to the current school of thought, these accumulate over time and cause increasing damage to brain cells, until they eventually die. These deposits occur when the ß-secretase enzyme splits the ß-amyloid precursor protein (APP), which is a membrane protein. It is precisely this ß-secretase that researchers are attempting to block, with the aid of the right inhibitors. A group of scientists working with Kai Simons at the Max Planck Institute for Molecular Cell Biology and Genetics have now designed the inhibitor such that it blocks the enzyme directly in the cell where the target is located. Almost four years ago, Lawrence Rajendran, a post doc in Kai Simons lab, studied the cell biology of the processing of APP and found that the ß-secretase, though physically present on the cell surface, is not active until it gets internalized into intracellular compartments called endosomes. The enzyme and the amyloid precursor protein must therefore be transported into the cell, where the pH is so low that the enzyme can split the membrane protein.

“Previous approaches to finding a therapy neglected the exact site of enzyme activity and acted only non-specifically – that is, scattered over a broad area,” says Lawrence Rajendran, who played a crucial role in the present work. “This method allows us to increase the effectiveness of the ß-secretase inhibitor enormously.” This is a key to treating Alzheimer’s disease effectively – or at least slowing the course of the illness. How did they achieve this specificity in the inhibition? There are many ß-secretase inhibitors in the cell, but most of them either do not enter the cell and, even if they do, the inhibitor is all over cell interior. The Dresden-based scientists specifically targeted the inhibitor to the endosomes by linking the inhibitor to the lipid molecule called cholesterol. This makes the inhibitor readily attach to the membrane, and since part of the membranes continuously get internalized into the endosomes, this enables the lipid-linked inhibitor to reach the endosomes. The authors cleverly chose cholesterol to be the lipid to anchor the inhibitor because they previously showed that the enzyme is enriched in the regions of the membrane that also contained cholesterol. These regions, called lipid rafts, play functionally relevant roles in both physiological and pathological processes. It is interesting to note that Kai Simons put forward the raft hypothesis more than a decade ago, and it has been gaining increasing attention ever since. Now, using cholesterol as a lipid anchor, the scientists enriched the inhibitor not only in the endosomal membrane, but also in the vicinity of the enzyme. This strategy enormously increased the effective concentration of the inhibitor at the precise site of action. “The inhibitor travels into the cell as a stowaway on the little raft, so to speak,” says Lawrence Rajendran: “We thus use a cellular mechanism that transports the inhibitor into the endosomes, precisely where it is supposed to act.”

Initial experiments in both cell cultures and living organisms have shown that these endosome-specific inhibitors are many times more effective than the soluble preparations that have been available on the market to date. In an animal model in which Alzheimer’s was simulated, the new inhibitor reduced the formation of ß-amyloid by 50 percent in just four hours, whereas the previously available inhibitors showed no effect whatsoever. “The new ß-secretase inhibitors hold great potential for the development of new, effective medication to fight Alzheimer’s,” says Kai Simons. And he is already thinking ahead. “We believe that we will soon be able to apply this principle to other therapeutic inhibitors in other diseases.” In virus-mediated diseases such as Ebola and HIV, the viruses use rafts to move from cell to cell. In the future, drugs just might be able to block these routes. First, however, employees at JADO Technologies, of which Kai Simons is a co-founder, are trying to harness the stowaways on the membrane rafts as potential therapies for Alzheimer’s disease. In order to do this, one of the things they need to work out is how to introduce the ß-secretase inhibitor into the brain without directly injecting it. Before such effective inhibitors can become available as drugs, scientists must also find out more about the biological function of ß-amyloid. They know that ß-secretase helps wrap children’s growing nerve cells in an insulating myelin sheath. Blocking this in Alzheimer’s patients, who are predominantly older, is not expected to yield any undesirable side effects. However, neuroscientists at the Ludwig Maximilian University in Munich recently discovered that ß-amyloid is not just a useless or even damaging waste product. It might be involved in the construction and function of synapses, the contact points between neurons, which may also play a role in learning. However, even if a ß-secretase inhibitor should make learning more difficult, it at least prevents “the great forgetting.”

Contact: Lawrence Rajendran and Kai Simons Max Planck Institute for Molecular Cell Biology and Genetics, Dresden
tel: +49 351 235 23844 e-mail: rajendran@mpi-cbg.de; simons@mpi-cbg.de
It sounds a little like science fiction: Two black holes at the heart of a galaxy merge and create gravitational waves that catapult the super-heavy black hole out of the galaxy. A few years ago, theoreticians created computer simulations of just such a spectacular scenario. Now a team working with Stefanie Komossa at the Max Planck Institute for Extraterrestrial Physics has indeed found a gravitational rocket like this one – with far-reaching consequences for our understanding of how galaxies were created and how they evolved in the early universe, (ASTROPHYSICAL JOURNAL LETTERS, May 10, 2008)

The discovery by the Max Planck scientists provides evidence of one of these extreme events for the first time; up to now, they have only been simulated. According to the theory, enormous gravitational waves emanate at the speed of light when two black holes collide. As the waves are emitted mainly in one direction, the black hole experiences a recoil, similar to when a gun is fired or a rocket is launched. The black hole is prevented from remaining at the core of the Milky Way system and it starts to move away, eventually leaving the parent galaxy.

The astrophysicists’ attention was drawn to the black hole in the Sloan Sky Atlas by its very high speed: the gas around the black hole exhibited strong shifts in the spectral lines. This led the researchers to conclude that the cosmic heavy-weight – it is equivalent of several hundred million solar masses – was moving at almost 3,000 kilometers per second. To put this into perspective: a person leaving Munich at this speed would be in Africa in less than a second. The enormous force of this recoil catapulted the black hole out of its parent galaxy.

In addition to the spectral lines of the gas bound to the black hole, the physicists also noticed unusually narrow lines from the galaxy itself. This gas is not linked to the black hole, but is illuminated by its hot accretion disk.

When a black hole is ejected from the center of a galaxy, it takes most of the matter immediately surrounding it along with it, which provides it with fuel for many million more years. It continues to absorb gas from the disk, and this gas shines in X-ray light. The team headed by Stefanie Komossa also discovered the X-ray light around the black hole, which is ten billion light years away. By chance, this area of space was scanned by the ROSAT satellite; at the very edge of its field of view, there was a source of X-rays whose position corresponded to that of the distant galaxy.

Astrophysicists are strongly interested in gravitational waves, which were predicted by Albert Einstein. They bend space-time almost like a stone thrown into a lake ripples the surface of the water. In 2006, researchers first merged black holes in computer simulations and calculated the signal from the gravitational waves created in this way.

The latest discovery proves indirectly that black holes do indeed merge, for which there was previously no clear evidence. Another conclusion from the observation is that there must be galaxies that do not have a black hole at their core – and, conversely, that there are black holes that drift in intergalactic space for all eternity.

A Jet-Propelled Black Hole

Shot from the core: For the first time, researchers have observed how a black hole is propelled from its parent galaxy by gravitational waves. This scenario is depicted in the illustration.

Accelerating Plant Breeding

Rice is the most important staple food for around half of the world’s population, and its many different varieties are constantly being improved through breeding. Scientists at the Max Planck Institute for Developmental Biology in Tübingen, working with colleagues from the International Rice Research Institute in the Philippines, are now making use of small, artificially created RNA molecules to accelerate this breeding process significantly. (Pius Ous, March 19, 2008)

Many varieties of rice are very well adapted to the region in which they grow. Transferring a single gene to these varieties without affecting the genes that ensure their adaptation to their location normally takes years of conventional breeding. Researchers at the Max Planck Institute for Developmental Biology in Tübingen, working with colleagues from the International Rice Research Institute in the Philippines, have now developed a tool that could enormously accelerate the development of rice varieties with specific characteristics. Norman Warthmann and his staff have switched off genes using artificial microRNAs. A genetic modification in a plant often requires the inactivation of a single gene. The loss of the gene that makes rice plants grow tall and thus topple over under the weight of many heavy grains of rice is an example of this. Rice breeders are therefore very interested in transferring inactivated genes.

This process has now been successful with microRNAs: RNA molecules consisting of 20 to 22 base pairs that assist in gene regulation. As the microRNAs bind to the complementary base sequence of messenger RNA – scientists refer to this as RNA interference – they stop these base sequences from being translated into a protein. This silences the gene. “Using artificial microRNAs, we can quickly transfer reduced gene function to other varieties and even species,” says Norman Warthmann.

The research group working with Detlef Weigel, Director at the Max Planck Institute for Developmental Biology, developed this technique using the model plant Arabidopsis thaliana. They have now tried out this method on rice plants, including the variety Eul1. When this gene is inactivated, the uppermost part of the rice plant and parts of the flowers grow taller and the plants can more easily pollinate neighboring plants. Breeders use this genetic trick to produce hybrid seeds.

Originally discovered as a spontaneous mutation, eul1 has been transferred to Indica varieties through years of breeding. With artificial microRNA targeting the messenger RNA of the Eul1 gene, researchers at the International Rice Research Institute were able to create plants of two rice varieties with the desired characteristics within weeks. One of these was the Indica variety IR64, one of the most important varieties grown in southeast Asia. The stable integration of the gene that carries the information for the microRNA in the plants’ genome allows it to be passed on to future generations.

“Artificial microRNAs will also accelerate the identification of important genes and the discovery of new gene functions,” says Norman Warthmann. They could also improve immunity to pathogens and pests, by switching off pathogen-derived genes. “We have found microRNAs in all the plant varieties examined so far. It is therefore possible to apply this technique to other crops as well,” says Detlef Weigel.

Contact: Dr. Stefanie Komossa
Max Planck Institute for Extraterrestrial Physics, Garching
Tel.: +49 89 30000-3577
e-mail: skomossa@mpe.mpg.de

Contact: Norman Warthmann
Max Planck Institute for Developmental Biology, Tübingen
Tel.: +49 7071 601-1419
e-mail: norman@warthmann.com

A boost for rice cultivation: Small pieces of RNA accelerate the breeding of new varieties that exhibit new characteristics.
Shedding Light on a Methane Source

Plants store one greenhouse gas, but emit another. While they absorb carbon dioxide, they release methane – albeit in small quantities. Scientists from the Max Planck Institute for Chemistry, the University of Utrecht and the Agri-Food and Biosciences Institute in Belfast have now confirmed this. They have also discovered that some of the greenhouse gas comes from pectin, an important component with which plants build their supporting structures. (New Phytologist, May 9, 2008; Biogeosciences in press)

The announcement caused considerable controversy two years ago: Frank Keppler and his colleagues at the Max Planck Institute for Nuclear Physics in Heidelberg had observed for the first time that plants release methane under aerobic conditions – that is, in the presence of oxygen – and not the anaerobic conditions under which bacteria usually produce the methane that bubbles up out of bogs and marshes. This study further indicated that plants could contribute a substantial proportion of all the methane in the atmosphere. The global significance of these methane emissions was not the only issue that subsequently gave rise to intense debate: doubt was even cast as to whether plants released methane – a greenhouse gas – more damaging to the climate than carbon dioxide – at all. However, Frank Keppler, who is now conducting research at the Max Planck Institute for Metals Research in Stuttgart and his colleagues have now proven the existence of this mechanism by replacing certain hydrogen atoms in pectin with deuterium. “We still have no idea what percentage of the methane emissions from plants, it is difficult to estimate their true extent on a global scale.”

A methane source in sunlight: Plants create the greenhouse gas under UV radiation, which is part of sunlight. A large percentage of the gas is released from pectin – a biopolymer from which the supporting structures of flowers and leaves are made.

Because he and his colleagues were unable to reproduce them, however, they had grown plants in greenhouses under artificial light that did not emit UV radiation.

Frank Keppler and his colleagues, some of whom are now working at the University of Utrecht, examined both dry and fresh material from more than 20 different plants. “This time, we deliberately used only parts of the plants, such as leaves, because it is possible that there are processes taking place in living plants that distort the result,” explains Keppler. In one series of experiments, the researchers irradiated the specimens with different UV light energies; in another, simultaneously irradiated and heated the plants to 100°C, and in a third, without UV light, examined the plants at temperatures ranging from 20°C to 100°C. In the process, they established that the more energetic the light shine on the specimens, the more methane the plants emitted. Production reached even higher rates when the temperature was simultaneously increased. Without UV radiation, the emission rate rose to levels comparable with those reached with UV radiation only when the temperature was around 80°C.

One plant component from which UV light forms the greenhouse gas is pectin, a plant structural material. Keppler and his colleagues have now proven the existence of this mechanism by replacing certain hydrogen atoms in pectin with deuterium – the heavier form of hydrogen. They subsequently found the deuterium in the methane again. This does not, however, explain the presence of all the methane, as some is also formed without deuterium. “We still have no idea what this alternative mechanism might be,” says Frank Keppler. He adds that, “since we currently understand only some of the processes that underlie methane emissions from plants, it is difficult to estimate their true extent on a global scale.”

In itself, a cell membrane is impermeable to ions. In order for sodium and potassium ions to be able to slip through the cell membrane, there are special proteins called ion channels, which are proteins in the membrane that have microscopically small pores. Depending on their structure, they are open only to certain ions; they can distinguish, for example, between sodium and potassium ions. Their narrowest point functions as a filter: in the ion channel investigated here, this point has an approximate diameter of just 0.3 nanometers.

At 1.2 nanometers, the diameter of the pore that is adjacent to this selectivity filter, which scientists call the gate, is much larger. In response to a change in the membrane potential, ion channels increase or decrease the diameter of the gate. However, this conformational change is not necessarily sufficient to halt the flow of ions. An important detail here is that, in most cases, the gate is slightly water-repellent. When the gate is wide enough, the mutual repellence of water and protein is barely significant, as each water molecule is surrounded, on average, by several other water molecules.

However, if the gate becomes narrower and its diameter is reduced to less than a certain value, then it is very unlikely that there will still be water in the gate. The repellent effect between the water molecules and protein stops this from happening and the space remains empty. This emptiness has a function: ions prefer to be in water, and if they are in the gate, the bar is raised, the water in the gate is repelled, and the gate is closed.

When we have a cup of coffee for breakfast, and lift the cup to our mouth, our brain processes information about the weight of the cup and the position of our hand. It issues commands to the arm muscles to coordinate the cup-to-mouth movement. This dialog is conducted via nerve fibers in the form of an action potential. The action potential constitutes a change in the electrical potential across the cell membrane, which results from sodium ions flowing into the cell and the subsequent outflow of potassium ions from the cell.

In itself, a cell membrane is impermeable to ions. In order for sodium and potassium ions to be able to slip through the cell membrane, there are special proteins called ion channels, which are proteins in the membrane that have microscopically small pores. Depending on their structure, they are open only to certain ions; they can distinguish, for example, between sodium and potassium ions. Their narrowest point functions as a filter: in the ion channel investigated here, this point has an approximate diameter of just 0.3 nanometers.

Ion channels play an important role in organisms’ communication systems: These proteins form tiny pores in the cell membrane of nerve cells. Scientists at the Max Planck Institute of Metals Research in Stuttgart and their colleagues from Rush Medical School in Chicago and the Miller School of Medicine at the University of Miami have now identified, for the first time, a physical mechanism that might be responsible for opening and closing these ion channels. (Biophysical Journal, June 9, 2008)

When we have a cup of coffee for breakfast, and lift the cup to our mouth, our brain processes information about the weight of the cup and the position of our hand. It issues commands to the arm muscles to coordinate the cup-to-mouth movement. This dialog is conducted via nerve fibers in the form of an action potential. The action potential constitutes a change in the electrical potential across the cell membrane, which results from sodium ions flowing into the cell and the subsequent outflow of potassium ions from the cell.

In itself, a cell membrane is impermeable to ions. In order for sodium and potassium ions to be able to slip through the cell membrane, there are special proteins called ion channels, which are proteins in the membrane that have microscopically small pores. Depending on their structure, they are open only to certain ions; they can distinguish, for example, between sodium and potassium ions. Their narrowest point functions as a filter: in the ion channel investigated here, this point has an approximate diameter of just 0.3 nanometers.

An invisible barrier: Ions surrounded by water flow through the open gate (left), when the gate closes (right), the channel wall repels the water molecules, creating a barrier.

In itself, a cell membrane is impermeable to ions. In order for sodium and potassium ions to be able to slip through the cell membrane, there are special proteins called ion channels, which are proteins in the membrane that have microscopically small pores. Depending on their structure, they are open only to certain ions; they can distinguish, for example, between sodium and potassium ions. Their narrowest point functions as a filter: in the ion channel investigated here, this point has an approximate diameter of just 0.3 nanometers.

At 1.2 nanometers, the diameter of the pore that is adjacent to this selectivity filter, which scientists call the gate, is much larger. In response to a change in the membrane potential, ion channels increase or decrease the diameter of the gate. However, this conformational change is not necessarily sufficient to halt the flow of ions. An important detail here is that, in most cases, the gate is slightly water-repellent. When the gate is wide enough, the mutual repellence of water and protein is barely significant, as each water molecule is surrounded, on average, by several other water molecules.

However, if the gate becomes narrower and its diameter is reduced to less than a certain value, then it is very unlikely that there will still be water in the gate. The repellent effect between the water molecules and protein stops this from happening and the space remains empty. This emptiness has a function: ions prefer to be in water, and if they are in the gate, the bar is raised, the water in the gate is repelled, and the gate is closed.

When we have a cup of coffee for breakfast, and lift the cup to our mouth, our brain processes information about the weight of the cup and the position of our hand. It issues commands to the arm muscles to coordinate the cup-to-mouth movement. This dialog is conducted via nerve fibers in the form of an action potential. The action potential constitutes a change in the electrical potential across the cell membrane, which results from sodium ions flowing into the cell and the subsequent outflow of potassium ions from the cell.

In itself, a cell membrane is impermeable to ions. In order for sodium and potassium ions to be able to slip through the cell membrane, there are special proteins called ion channels, which are proteins in the membrane that have microscopically small pores. Depending on their structure, they are open only to certain ions; they can distinguish, for example, between sodium and potassium ions. Their narrowest point functions as a filter: in the ion channel investigated here, this point has an approximate diameter of just 0.3 nanometers.

Contact: Dr. Roland Roth
Max Planck Institute of Metals Research, Stuttgart
Tel.: +49 711 689-1907
E-mail: Roland.Roth@mpip-mainz.mpg.de
A Gap in the Superconductor

For more than 50 years, the problem had been considered solved — but apparently only be- cause it had not been fully recognized: as early as 1957, John Bardeen, Leon N. Cooper and John R. Schrieffer explained why metals below certain temperatures conduct electricity without any losses. However, physicists at the Max Planck Institute for Solid State Research have now examined electrons in this superconduc- tive state more closely and discovered a previ- ously hidden detail in their energy distribution that had been explained with the theory as it currently stands. (SciAm, March 14, 2008)

At the same time, physicists observed a phe- nomenon in the two metals that, until then, had been considered completely separate from supercon- ductivity. Using readings from spin-echo neu- tron scattering, a particularly sensitive method, they were able to draw conclusions from the de- tails of the metal’s Fermi surface. The scientists drew a relief map in which electrons with a cer- tain momentum or a certain speed are assigned an energy level — mountains represent many elec- trons, valleys just a few. Previously unknown hills now appeared on this map where no one had ex- pected any to be.

Some doctors claim that there are no healthy people — only those that have been poorly examined. There may well also be physics theories that are ailing unnoticed as long as they cannot be exam- ined closely enough. This is clearly the case with the BCS theory. This theory received its name from the initials of the three physicists Bardeen, Cooper and Schrieffer, and describes conventional superconductivity in metals. It states that, below a specific, very low tempera- ture, their free conductive electrons save energy when they come together to form Cooper pairs. These are drawn together by the resonance of the crystal lattice. As pairs, they can move through the metal lattice without colliding with its atoms.

A certain energy is required to break the bond in a Cooper pair. Physicists speak of electrons hav- ing to jump over an energy gap — a gap that opens only at the critical temperature at which a metal loses its resistance. “Lead and niobium provided a good illustration of how the energy gaps open,” says Bernhard Keimer, Director at the Max Planck Institute for Solid State Research, who also headed the study.

Physicists call these hills Kohn anomalies. At these points, it is particularly easy to nudge electrons away from vibrating atoms, as they carry a matching mo- mentum — similar to the way a child on a swing needs to move its legs in the same rhythm in or- der to begin moving.

According to the physicists’ measurements, the energy gap in the superconducting state grows only to a degree at which electrons with exactly these momentum or energy levels are incapable of forming Cooper pairs. “It can’t be by chance that the Kohn anomalies coincide with the energy gaps, because they occur in both lead and niobium,” explains Bernhard Keimer. “Without the Kohn anomaly, the metals would perhaps be- come superconductive at higher temperatures.”

The scientist explains further: “Our particularly accurate method of taking measurements has de- livered new findings about materials that we thought we knew through and through. We can only speculate as to why Kohn anomalies and energy gaps coincide so unexpectedly.” In the final analysis, physicists will probably have to broaden the BCS theory to explain this connection.

A RING AROUND RHEA, Saturn’s second-largest moon, has been detected by instruments on board the Cassini space probe – making it the first ring system ever to be found around a moon. An electron detector from the Max Planck Institute for Solar System Research in Katlenburg-Lindau and a dust detector from the Max Planck Institute for Nuclear Physics in Heidelberg supplied important information about this ring. Both of these instru- ments have been orbiting Saturn with Cassini since 2004. They have also set their sights on Sat- urn’s moons, including Rhea, which has a diame- ter of 1,528 kilometers and orbits its parent plan- et at an average distance of 526,000 kilometers every four and half days. Numerical simulations show that it is indeed possible for dust particles to circle around Rhea in a stable disc. However, there has, as yet, been no visual evidence of this dust ring, as the Cassini probe must first reach a position from which its cameras can point directly at the ring’s edge.

BATS HEAR PLANTS and can, on the basis of their ultrasound echo, distinguish between deciduous and coniferous trees, as well as identify certain flowers as sources of nectar. Scientists at the Max Planck Institute for Biological Cyber- netics in Tübingen and at the University of Tübingen have been investi- gating these amaz- ing feats. Using so- nar, they imitated key elements of the bats’ sensory appa- ratus. They also used machine- learning technol- ogy to analyze the vegetation echo they received. It was discovered that, irrespective of their complexity, these echoes can be precisely matched to individual plants using surprisingly simple time and frequency identifiers. According to the researchers, the combinations of identifiers would also probably be easy for the bats’ auditory system to analyze. They therefore supply a “biologically plausible” explanation for this previ- ously elusive feat.

A SHORT CIRCUIT IN THE SIGNAL PATH be- tween scent receptors and ion channels allows the stimulus to be conducted biochemically via spe- cial proteins that activate a messenger sub- stance that eventually reaches the ion channels. Conversely, where the concentration of scent molecules is high, there is a short circuit between the receptor and the ion channels, so that the scent stimulus acts directly on the ion chan- nel without the biochemical diversification, thus trig- gering an immediate behavioral response.

PRIMITIVE ROCKS FROM THE OCEAN FLOOR have been brought to light from the Gakkel Ridge – an extension of the mid-oceanic ridge in the Arctic Ocean – during an expedition on the Ger- man research vessel FS Polarstern. The samples are of peridotite and originate in the upper sec- tion of the Earth’s mantle. Researchers at the Max Planck Institute for Chemistry in Mainz have used isotope analysis to establish that these rocks formed from a melt two billion years ago and have remained unchanged ever since. In 1998, the scientists to conclude that this “fossilized” pe- ridotite from the Earth’s mantle lost its metamorphic components two billion years ago, which is why it has remained unaltered. Unlike other parts of the ocean floor, it was unable to remelt and become one of the common, younger basalts. These are often found in layers of several kilometers’ thick- ness, forming the oceanic crust over the mantle. The primordial peridotite on the floor of the Arc- tic Ocean has provided the geoscientists with a new look at the history of the Earth’s mantle.
We would be lost without it today – and nothing would work. Specialization is the way of the world: in industry, science, culture – everywhere, really. It is the means by which to stand out and to find an economic niche. A country such as Germany owes its success as a world-class exporter to its thousands of specialized equipment manufacturers that produce goods that few are likely to know of, but that are needed the world over in countless factories.

In the field of science – but not only there – to make a name for oneself, it is essential to be identified with one subject or another. Consultants pocket hefty fees by virtue of their expertise in solving highly specific problems. Even artists and composers must follow the path of specialization if they want to be successful, whether by developing a particular painting technique, subject or musical style that ultimately becomes their trademark. For Max Weber, the whole process of modernization was a process of differentiation, not only in the economical and political fields, but also in science. Describing his own profession, he wrote: “The true scientist of the present and future is a specialist.” He believed that the time to indulge in flights of intellectual fancy was over and gone.

Evolution has smiled on specialization as a recipe for success. It is mostly the case that specialists have the advantage over generalists in their given field. The unseen hand of nature busies itself to ensure the efficient use of resources. The process of natural evolution is decentralized and self-organized. There is no central coordinating function. The Austrian economist Friedrich von Hayek (1899 to 1992) was not alone in believing that the economy, if not indeed society as a whole, works in just the same way. Order is created “spontaneously” – an idea that occurred to British-Hungarian chemist and philosopher Michael Polanyi (1891 to 1976).

Until the fall of the Berlin Wall, the belief was prevalent that a society could also function, and even function better, if it were centrally controlled. Hayek demonstrated early on that such a concept would fail primarily because of the difficulty in meaningfully processing and coordinating the sheer variety of information in the world. The administrative machinery of those countries that favored centrally planned societies was manned and controlled by specialists. Central planning did not mean that any one individual had an overview.

In Praise of Simplicity

Mankind owes its prosperity and its fund of knowledge primarily to the division of labor. It is this phenomenon that has brought both industry and science to their present peak of productivity. However, specialists alone cannot steer society – generalists are required as decision-makers at the forefront of politics and business. Hubert Beverle discusses the skills that are needed.
In contrast, perhaps, to days of Leibniz or Goethe, today, a perspective on entirety is something more than what we can manage. The path of specialization is not just useful, but also psychologically understandable. One might even say that we find, in garden, in our own little realm that we control; a place in which we know our way around, and understand the criteria that govern sense and nonsense.

In the view of Hayek, specialization is extremely attacked, for all his belief in the idea of spontaneous organization. In the real world, one plan is always in competition with another and can be implemented only at the expense of another. “In order to see that, one must consider factors other and can be implemented only at the expense of his belief in the idea of spontaneous organization. In the governance sense and nonsense.

Yet Hayek vehemently attacked specialization, for all his beliefs in the idea of spontaneous organization. In the real world, one plan is always in competition with another and can be implemented only at the expense of another. “In order to see that, one must consider factors other and can be implemented only at the expense of his belief in the idea of spontaneous organization. In the governance sense and nonsense.

Hayek concluded that “it is hard to imagine anything more unbearable – and more irrational – than a world in which the principal specialists in every field are permitted to realize their ideals without impediment.” Max Horkheimer (1895 to 1973), a contemporary of Hayek writing in common with him, once noted that “specialism is one of the tricks by which we prevent ourselves from thinking.”

Society needs generalists

Human societies evidently do not function without generalists. Every organization needs them, including those engaged in competition. Wherever there are major decisions to be made, whether at the corporate or government level, information must be amassed, weighed and reduced to the essentials – to the point that turns the balance. The reason ultimately lies in our limited brain capacity. It is impossible for us to consider all the information available – just as it is impossible for a chess player to compute little more than the possible series of moves in his mind.

So we must, of necessity, simplify and estimate, and it is here that the specialist comes up against his or her limitations. Even to determine good science from bad demands the perspective of generalists who can draw comparisons and look beyond the end of their nose. And if science is not something that can be controlled, the extreme alternative of a complete absence of coordination makes little sense. Michael Polanyi basically raised the question: “Would a society of specialists not unavoidably appear unrestrained, irresponsible, egotistical and patently change?” Polanyi proposed the concept of supervision – quite short of planning, but a function that requires a certain generalist perspective.

However, there is a much more far-reaching need for generalists. The first five places on the Alienschift Institute’s scale of professional prestige are as follows: trade union leader, television presenter, politician, bookseller and professor. The rest of thought is that much harder to falling well behind nuclear physicists, engineers and university professors. Heading the list are doctors of medicine, themselves often specialists. Thus, in our society, the generalist tends to be held in poorer regard than the specialist.

In a society that is aware that it owes its prosperity to the and society is less appropriate – the generalist is ideally concerned with maintaining a perspective on entirety. The criticism leveled at an expertocracy, in which political power is based solely on technical knowledge, underscores the fact that specialists are ill-prepared to make important political decisions.

The verdict of one specialist on the discipline of another is seldom fair. Rational discourse across disciplinary boundaries evidently follows a different pattern than internal discussion, for suddenly a pluralism of methods applies. This is where the generalist can help, by simplifying things to the point at which the problem is fundamentally understood by all. Particularly in the political field, decisions must be understandable; otherwise – almost by definition – they lack legitimacy. Specialists are often opposed to such policies, but also banks – effectively cultivate a language that consciously makes it hard for outsiders to understand just what is meant. Simplicity counts for nothing here.

There is also another reason why the term simple has a bad name. Simple statements conceal the risk of violence and terror, as Armatya Sen, for example, writes in his latest book, Violence, it is argued, can be the consequence of the “undifferentiated and one-dimensional construct of identity.”

The poor image enjoyed by simplification has a long tradition. As long ago as 1889, Swiss cultural historian Jacob Burckhardt (1818 to 1897) warned against the terrible simplifiers, in what was later interpreted as an admonition against Hitler and Stalin. For Jacob Burckhardt, simplification was obviously extremely problematic. He perceived the fundamental evil to lie in the claim that every opinion is of equal weight. That is a view that no scientist today would argue with. And of course it is quite correct: in matters of knowledge and scientific findings, not every opinion is equally valid.
But is “simple” always a negative concept in science? The situation is by no means clear. There is a strong tradition in the philosophy of science that perceives simplicity as an ideal. That dates back to Occam’s razor, a centuries-old principle according to which – plainly stated – everything that is not necessary to explain a phenomenon should be shaved away. Today, that has been reduced to KISS – Keep it simple, stupid!

The philosopher Karl Popper (1902 to 1994) adopted this ideal when he poked fun at the language of Jürgen Habermas. Habermas is quoted as saying: “System and detail are reciprocal and are to be understood only in the context of their reciprocity.” Which Popper rendered as: “No relationships in society can be understood without reference to the others.” Habermas again: “Theories are ordering schemes that we construct at will within a syntactically binding framework.” Which Popper translated as: “Theories should not be formulated ungrammatically, but otherwise you can say what you like.” Popper also went on to conclude: “If you can’t say something clearly and simply, it is better to keep quiet and keep working until you can say it clearly.”

Simplicity is regularly recognized as an ideal, the acceptance of which, however, is evidently more pronounced in some philosophical traditions and cultures than in others. Attempts have repeatedly been made to counter the triumphant advance of the specialists, and yet all that is left to remind us of these movements are fine words – the ruins of terminology whose meaning has paled into insignificance: words such as holistic and interdisciplinary. They failed to have any sustained effect because they were unable to furnish us with criteria to distinguish between sense and nonsense.

An appeal to superior wisdom

Back in the mid-1990s, catchwords such as contextualization, transdisciplinarity and reflexivity were common parlance. Terms such as Mode 2 and post-normal science were coined to describe new forms of knowledge production that respond more directly to burning social problems and pay greater attention to social effects. These concepts were intended to sidestep normal, internally oriented science that seeks exclusively to answer questions of its own asking. On the other hand, it would appear highly dubious as to whether these concepts genuinely concern the production of new knowledge, or merely the dissemination of knowledge in the gray area between science and politics.

The indications are that, deep down in the scientific knowledge factory, specialization rules. The concept of post-normal science resonates with a “conspicuously romanticist appeal to the superior wisdom of participating groups,” says sociologist Peter Weingart. He is critical of the idea that those who are affected or feel affected and, for example, become involved in a citizens’ group of some kind should know more than an expert in the field. This attitude may be supportive of democracy, but the extent to which it advances the cause of science is, in Weingart’s view, questionable.

Simplification is evidently a creative achievement, the technology of which cannot be entirely deciphered. We cannot, for example, define rules for it. Nor is it imaginable that the task of simplification could be performed by a computer. Consider the effect when an issue or problem is neatly and succinctly put. This achievement is entirely dependent on a prior understanding of the problem. And conversely, the ability to neatly simplify a problem is proof that one has understood it.

In the natural world, it is possible for a generalist to become a specialist, but not the other way around. In society, things are different. There are many examples of scientists who, having once become successful, go on to glimpse the big picture. It would seem that attaining a certain age entitles the specialist to attempt answers to the really big questions. In doing so, he uses, as it were, his authority as a scientist, casting aside the ladder of his specialist career when he has no need to ascend it further.

The conversion of specialist knowledge into its general counterpart can take other forms: for example, an interview between an expert and a journalist. The latter’s job is then to translate the expert’s knowledge. Here too, specifically, the task of the journalist is one of simplification. But he can perform it only with the aid of the scientist. So the scientist, too, must engage in simplification. Under present day conditions, the distinction between generalist and specialist is often purely temporary. In many professions, it is essential to be both: one day a specialist, the next a generalist – the transition prompted by the situation. Each needs the other, their roles fluid rather than fixed. That of the specialist need not necessarily be confined to the realms of functional rationality. On ethical matters, as well, the specialist can occasionally have more to say than the generalist.

Hubert Beyerle is a Berlin-based freelance journalist for economic affairs. In the early part of the year he participated in the “Journalist in Residence” program through which the Max Planck Institute for the Study of Societies offers scientific training during educational leave.
Mathematics is persuasive in its clarity and impressive in its beauty – particularly when a complex relationship can be expressed in a simple equation. This suggests that mathematical laws exist independently of our awareness of them. So do we merely discover them, rather than inventing them? An answer eludes definitive proof. There is, however, some evidence: non-Euclidian geometry, for example, was considered a purely theoretical construct until Albert Einstein used it as the basis for his general theory of relativity. The following articles show some of the practical aspects of what mathematics accomplishes – whether in medicine, materials science, or education.
**Spotting Cancer in the Genes**

When tissue starts to grow uncontrollably, it is often because defective genes are sabotaging cell division. Or the genetic control system has failed. Christoph Bock, scientist at the Max Planck Institute for Informatics, is searching for the biochemical patterns that could shed light on such aberrations in the processing of genetic information.

Cancer is Christoph Bock’s subject. He’s been working on it for almost five years now. But unlike most other cancer researchers, he doesn’t work with microscopes, centrifuges, test tubes or large DNA sequencing machines – his laboratory is a stark office, equipped with two desks, two computer screens, a filing cabinet and a whiteboard on the wall, covered with mathematical formulas and figures.

Christoph Bock conducts his research at the Max Planck Institute for Informatics in Saarbrücken. Inside his computer, cancer mutates to become mathematical tables, dense clouds of figures and multidimensional computing spaces. The scientist uses all of this to bring order to something that is difficult to comprehend: the dizzying complexity with which biochemical reactions direct and conduct 25,000 genes when they come together to play in the chorus of life. Bock is keen to find out what goes wrong in this huge biochemical concert when cancer develops – and to come up with ideas for new therapies on this basis.

Biologists long believed that the sequence of bases in the DNA was enough to determine how an organism developed. Even when it came to the genetic factors that cause many cells to proliferate wildly, the medical professionals focused on the DNA sequence. But there’s more to it than that. For instance, it is now known that a whole range of other genetic traits influence the activity of genes, including those that cause cancer.

**Virtuoso Music on the DNA Keyboard**

The genome alone, which would be a two-meter-long string of DNA if it were unraveled, is thus nothing more than a mundane keyboard. Music rings out only when it is played. The discipline concerned with studying this virtuoso music calls itself epigenetics – the area in which Bock specializes. In recent years, the scientist has focused on one specific epigenetic trait: DNA methylation. This involves methyl groups – little hydrocarbon attachments – that sit at certain points in the genome. They prevent genes from being read and their information translated into a protein. DNA methylation is a very natural process and occurs in all people at similar points in the genome. However, sometimes important genes are aberrantly methylated, leading to their deactivation. In some cases, a tumor develops as the result of inappropriate gene silencing.

The fascinating thing about epigenetics is that DNA methylation is not fixed and unchangeable like the genome; it is, in fact, modified by the environment. And that’s not all: these modifications are even passed...
down to children! This insight is only about 20 years old, and caused quite a stir in the scientific world. What it ultimately says is that traits that are not manifested in the genetic code are actually passed down to the offspring. A sensation.

Experiments on mice, for example, prove that even diet has its part to play. If fat, gold-yellow lab mice are fed large quantities of folic acid – a substance that women take during pregnancy – the mice give birth to small, brown babies and these, in turn, produce small, brown grandkids. One of the reasons for this is that the folic acid provides many methyl groups and thus strengthens the DNA methylation. It also blocks the specific gene that causes the golden coat color and obesity. This effect was found to last between five and ten generations – even if the mice are no longer fed with folic acid.

Experts agree that methylation also plays a major role in cancer development. Nevertheless, how tumor diseases, it is still completely uncertain where exactly the cells’ epigenetic control system goes out of control, and why aberrant methylation occurs in specific areas of the DNA. After all, the genome is a broad field: many millions of base pairs are changing daily in a row, and on them sit thousands of methyl groups. In this molecular universe, finding the ones that cause disease is like trying to discover a new planet in our galaxy.

“For me, though, searching through enormous volumes of data is part of the attraction of the job,” is where mathematics can make a real contribution to medicine,” says Christoph Bock, who works in the computational biology department of the Max Planck Institute for Informatics in Saarbrücken. With the help of software programs that he developed himself, the scientist wanders through the labyrinth of experimental genetic data looking for suspicious structures – such as methylation patterns that are characteristic of certain types of cancers. Experts call these structures biomarkers, as they are indicators of a certain state in the cell – different biomarkers are relevant for different diseases.

Fever and a high temperature may be important indicators of a cold or the flu, for example, and the PSA protein has been used as a biomarker for prostate cancer for years. Cancer specialists are intensively searching for new biomarkers that can be used to detect many different types of tumors – ideally in the early stages of cancer development, when the chances of curing it are still high.

In a pilot study published two years ago, Bock already demonstrated how effective his computational methods can be when applied to cancer. At the tumor reference center of the University Clinic in Bonn, immunologist Andreas Waha was looking for a quick and easy way to identify malignant glioblastomas, a dangerous type of brain tumor. Waha’s job was to analyze tissue samples from patients and determine which molecular changes had taken place in the tissue, as this is the key to choosing the best therapy.

Glioblastomas are among the most aggressive tumors, and they grow extremely fast. Without treatment, glioblastoma patients usually die within three months of diagnosis. Operating to remove the tumor, administering radiation and reinforcing it with chemotherapy can prolong the lives of sufferers by about a year on average. However, the energy-sapping chemotherapy is effective in only a quarter of the patients. This is because cancer cells make use of a DNA-repair gene known as MGMT to fix the damage its genetic makeup caused by chemotherapy. Only the one-quarter of patients in whom MGMT is methylated, and thus deactivated, will experience the full effect of the therapy cocktail.

Once doctors diagnose a glioblastoma, they first need to decide whether therapy is the appropriate road to take. Theoretically, MGMT is an excellent biomarker that could be of considerable help to doctors in making this decision. However, Waha determined that classic analytical methods were too intricate for use in routine clinical practice, and that they were also not particularly reliable. So he asked Christoph Bock to look for alternative testing methods that could provide a certain indication of the methylation state of the MGMT gene. Bock then fed his computer data from healthy tissue and tumor tissue that originated through thorough analyses of methylation surrounding the MGMT gene.

The computer scientist was looking for changes in DNA – methylation – that always occur in combination with the deactivation of the MGMT gene. He hunted down the information through statistical learning methods and mathematical simulations that compare the different data records automatically. And he was successful; his learning method did, in fact, uncover criteria that clarify, with a high probability, whether the MGMT gene is methylated and thus whether chemotherapy is an option.

The software has been running for some time now on the computers in Waha’s lab. “It makes our job easier on a daily basis,” he says. Today, all they need to do is read out the few relevant sections of DNA in a patient’s tumor tissue to get a reliable reading of the methylation status of the gene. In a matter of seconds, the clinicians know how likely it is that the MGMT is methylated and how they should treat the patient. “The program gives us additional certainty. Ultimately, we here at the refer- ence center are helping to decide on the treatment and the fate of a patient,” says Waha.

MGMT is a small success story in the fight against cancer, which is, after all, the second most common cause of death in Germany, after heart disease. But in the case of many other cancer types, scientists do not know which genes are even relevant for tumor growth and response to chemotherapy. And the situation is even grimmer when it comes to biomarkers.

Computer-Aided Search in the Genome

The scientists in Saarbrücken are thus gearing up for their big coup – a genome-wide computer-aided search for epigenetic aberrations. Bock and his colleagues, working together with researchers from various countries, are charting the DNA methylation patterns for leukemia and colon cancer in the EU’s new CancenChip project. By again comparing healthy and diseased tissue, Bock’s goal is to identify methylated sections in the genome that come up suspiciously often in conjunction with cancer. He is interested in areas that contain genes that, like MGMT, have a direct impact on the cancer, as well as in parts of the genome that, for reasons that are still unknown at this stage, always occur together with the disease pattern.

The data originate from cooperating clinics in Naples and Madrid, where tissue samples are taken from the patients. The samples are then sent on to a biotechnology lab at Radboud University in the Dutch city of Nijmegen. The researchers then have a biotechnology lab in the lab that can precisely chart the position of all methylation in the genome. To do this, they must cut the genetic material into tiny snippets. The ‘snippet solution’ is then poured over plastic chips the size of postage stamps, known as microarrays. These have DNA fragments on their surface, each of which a specific DNA snippet fits like a key in a lock.

The trick: before the patient’s DNA is placed on the array, it is marked – red for methylated DNA and green for unmethylated DNA. The marked snippets then dock on to the corresponding DNA fragments on the array. Under UV light, the scientists can see exactly which parts of the DNA are methylated and which are unmethylated. Of course, the researchers also test the methylation patterns of healthy people for comparison.

Around 40 microarrays are needed to accommodate a complete human genome. An analyzer measures the different colors and brightnesses at the different genome positions and stores them as a simple number. This jumble of numbers then travels on to Saarbrücken. The window-dowell in Bock’s office is already home to a sizeable stack of data DVDs. In the course of the coming months, the researchers will feed the information they house into his latest programs.

Comparing the methylation patterns of healthy and sick patients is particularly difficult, as the methylation changes in more than just the cancer cells. It also changes as a person ages – regardless of whether that person

Scientists usually study tumors in the lab (lft). Christoph Bock (right) uses nothing more than his PC to identify which genes are deactivated in certain types of cancers.

Computer-Aided Search in the Genome

The scientists in Saarbrücken are thus gearing up for their big coup – a genome-wide computer-aided search for epigenetic aberrations. Bock and his colleagues, working together with researchers from various countries, are charting the DNA methylation patterns for leukemia and colon cancer in the EU’s new CancenChip project. By again comparing healthy and diseased tissue, Bock’s goal is to identify methylated sections in the genome that come up suspiciously often in conjunction with cancer. He is interested in areas that contain genes that, like MGMT, have a direct impact on the cancer, as well as in parts of the genome that, for reasons that are still unknown at this stage, always occur together with the disease pattern.

The data originate from cooperating clinics in Naples and Madrid, where tissue samples are taken from the patients. The samples are then sent on to a biotechnology lab at Radboud University in the Dutch city of Nijmegen. The researchers in the lab there can thus precisely chart the position of all methylation in the genome. To do this, they must cut the genetic material into tiny snippets. The ‘snippet solution’ is then poured over plastic chips the size of postage stamps, known as microarrays. These have DNA fragments on their surface, each of which a specific DNA snippet fits like a key in a lock.

The trick: before the patient’s DNA is placed on the array, it is marked – red for methylated DNA and green for unmethylated DNA. The marked snippets then dock on to the corresponding DNA fragments on the array. Under UV light, the scientists can see exactly which parts of the DNA are methylated and which are unmethylated. Of course, the researchers also test the methylation patterns of healthy people for comparison.

Around 40 microarrays are needed to accommodate a complete human genome. An analyzer measures the different colors and brightnesses at the different genome positions and stores them as a simple number. This jumble of numbers then travels on to Saarbrücken. The window-dowell in Bock’s office is already home to a sizeable stack of data DVDs. In the course of the coming months, the researchers will feed the information they house into his latest programs.

Comparing the methylation patterns of healthy and sick patients is particularly difficult, as the methylation changes in more than just the cancer cells. It also changes as a person ages – regardless of whether that person

Scientists usually study tumors in the lab (lft). Christoph Bock (right) uses nothing more than his PC to identify which genes are deactivated in certain types of cancers.
drugs could, for example, specifically target disease-causing genes, dissolving the whole body. Bock’s programs have to take all of these imponderables into account and cannot let themselves be confused by random differences in the data records of healthy and diseased tissue.

The Saarbrücken-based researchers hope that the genome-wide analysis of DNA methylation will help them find new biomarkers that can be used to diagnose cancer faster and better than before. When the characteristic methylation patterns of different tumor types are known, doctors will be able to better assess the risk associated with any known tumors in the patient’s body. Ultimately, telltale methylation patterns could also enable doctors to spot unrecognized tumors based on the patient’s blood. This is possible because many cancer cells are being destroyed during tumor growth, shedding their characteristic DNA into the bloodstream.

Despite its clinical potential, the search for epigenetic tumor biomarkers is only a first step toward epigenetic tumor biomarker research for the rest of his days proved to be not enough for him in the end. “When I’m working on cancer, the benefit for all of us is much clearer to me.” He therefore changed over to biology, genetics and medicine. After all, the statistical and mathematical models from business informatics work just as well for searching the genome. “You could say that biology has adapted more mathematical.”

Bock is confident that he will find new cancer biomarkers in the Cancerdip project, and maybe even possible starting points for developing new cancer drugs. “It would be a great shame, though, if our work improved the early diagnosis of cancer, but people did not have any better therapies to turn to,” he says. Because without suitable therapy options, all the diagnosis in the world is worthless. Dangerous, even. But small successes in the fight against cancer – like the work on the MGMT gene – give him reason to hope that mathematics and epigenetics will take cancer therapy a step forward.

The data that Bock generates from tests with genetic chips (right) takes up a lot of space on the institute servers.

is healthy or sick. Moreover, it also changes from one cell type to the next. To complicate matters even further, various factors that affect the experiments, such as humidity, also cause the measured findings to fluctuate. Bock’s programs have to take all of these imponderables into account and cannot let themselves be confused by random differences in the data records of healthy and diseased tissue.

The Saarbrücken-based researchers hope that the genome-wide analysis of DNA methylation will help them find new biomarkers that can be used to diagnose cancer faster and better than before. When the characteristic methylation patterns of different tumor types are known, doctors will be able to better assess the risk associated with any known tumors in the patient’s body. Ultimately, telltale methylation patterns could also enable doctors to spot unrecognized tumors based on the patient’s blood. This is possible because many cancer cells are being destroyed during tumor growth, shedding their characteristic DNA into the bloodstream.

Despite its clinical potential, the search for epigenetic tumor biomarkers is only a first step toward epigenetic tumor biomarker research for the rest of his days proved to be not enough for him in the end. “When I’m working on cancer, the benefit for all of us is much clearer to me.” He therefore changed over to biology, genetics and medicine. After all, the statistical and mathematical models from business informatics work just as well for searching the genome. “You could say that biology has adapted more mathematical.”

Bock is confident that he will find new cancer biomarkers in the Cancerdip project, and maybe even possible starting points for developing new cancer drugs. “It would be a great shame, though, if our work improved the early diagnosis of cancer, but people did not have any better therapies to turn to,” he says. Because without suitable therapy options, all the diagnosis in the world is worthless. Dangerous, even. But small successes in the fight against cancer – like the work on the MGMT gene – give him reason to hope that mathematics and epigenetics will take cancer therapy a step forward.

The data that Bock generates from tests with genetic chips (right) takes up a lot of space on the institute servers.

is healthy or sick. Moreover, it also changes from one cell type to the next. To complicate matters even further, various factors that affect the experiments, such as humidity, also cause the measured findings to fluctuate. Bock’s programs have to take all of these imponderables into account and cannot let themselves be confused by random differences in the data records of healthy and diseased tissue.

The Saarbrücken-based researchers hope that the genome-wide analysis of DNA methylation will help them find new biomarkers that can be used to diagnose cancer faster and better than before. When the characteristic methylation patterns of different tumor types are known, doctors will be able to better assess the risk associated with any known tumors in the patient’s body. Ultimately, telltale methylation patterns could also enable doctors to spot unrecognized tumors based on the patient’s blood. This is possible because many cancer cells are being destroyed during tumor growth, shedding their characteristic DNA into the bloodstream.

Despite its clinical potential, the search for epigenetic tumor biomarkers is only a first step toward epigenetic tumor biomarker research for the rest of his days proved to be not enough for him in the end. “When I’m working on cancer, the benefit for all of us is much clearer to me.” He therefore changed over to biology, genetics and medicine. After all, the statistical and mathematical models from business informatics work just as well for searching the genome. “You could say that biology has adapted more mathematical.”

Bock is confident that he will find new cancer biomarkers in the Cancerdip project, and maybe even possible starting points for developing new cancer drugs. “It would be a great shame, though, if our work improved the early diagnosis of cancer, but people did not have any better therapies to turn to,” he says. Because without suitable therapy options, all the diagnosis in the world is worthless. Dangerous, even. But small successes in the fight against cancer – like the work on the MGMT gene – give him reason to hope that mathematics and epigenetics will take cancer therapy a step forward.

The data that Bock generates from tests with genetic chips (right) takes up a lot of space on the institute servers.
Anja Schlömerkemper often sits at her desk and ponders geometric structures, formulas and proofs. When she plays with a paper clip while doing this, and bends the small organizational tool out of shape, it will not necessarily have outlived its usefulness. If immersed in hot water, it quickly reassumes its original form – if it is made of a shape-memory alloy. Such a paper clip can be found in the scientist’s office at the Max Planck Institute for Mathematics in Leipzig – to demonstrate what she is pondering: the mathematical models for such materials and how to use these models to improve the materials.

Materials scientists do not fully understand why memory alloys behave in this way, so developing similar materials for other applications requires laborious tests. The Leipzig-based mathematicians want to change this. And that is not all they want: the mathematical methods they are searching for can also be used to describe, for example, how magnetic materials are used in storage media. They also help us understand how bubbles form in a layer of paint. The scientists are ultimately solving mathematical problems that are impeding progress in other, completely different areas of the sciences.

“Whereas engineers look for formulas that apply to the data from specific measurements, we try to find generally applicable mathematical models,” says Anja Schlömerkemper, who heads a research group at the institute in Leipzig. This assertion touches on a philosophical question: Do people impose mathematics on the world, or does the world have a mathematical structure that merely awaits revelation? In any case, mathematicians penetrated into curved spaces, apparently with no specific purpose in mind, when they developed non-Euclidian geometry. Barely a century later, in his general theory of relativity, Albert Einstein discovered that space is actually curved. “It is ultimately impossible to say whether the laws we use to describe the world are universally applicable,” says Stefan Müller, Director of the department in which Anja Schlömerkemper works: “But a certain degree of regularity in the world would appear to be a precondition of our understanding.”
Stefan Müller and Anja Schlömerkemper rarely deal with such large-scale questions, however; the problems they tackle are usually smaller – even microscopic in nature. They are looking for the laws that can be used to describe microstructures. “Microstructures are responsible for the special characteristics of memory alloys,” explains Anja Schlömerkemper. Materials scientists understand microstructures as structures that exist in the microscopic range. These include the scales on shark skin and trabeculae in human bones, as well as the structure formed by data points in a magnetic memory.

In the microstructure of memory alloys, the regions where the alloy atoms are differently oriented alternate. These differently oriented regions can also be found in Anja Schlömerkemper’s paper clip, but only at room temperature. They disappear at higher temperatures, and with them, the microstructure: the material is then left with only one order. Because the paper clip experiences this structural change in warm water, it “remembers” its original form.

To explain what happens when metals remember their structure, Anja Schlömerkemper uses a simple example and a sketch: she draws a square lattice. This is what the structure looks like at high temperatures – in a two-dimensional model, at least. In three-dimensional space, the squares become cubes. There is an atom at each point in the lattice, and each square or cube corresponds to an elementary cell in the crystal. This is the structural unit on which the composition of a crystal is based – and metals are crystals, too.

Nature Wants to Conserve Energy

The technical term for the cubic structure is austenite, coined in honor of the British metallurgist Sir William Chandler Roberts-Austen. Any attempt to bend something in the square lattice would deform the elementary cells, which the material does not like at all. The alteration of the atoms from their usual state costs energy, and nature avoids any process that costs energy.

At high temperatures, at which the material forms only a square lattice, the paper clip springs back into its original, fully functional shape. The material is actually trained into this shape: the paper clip with the capacity to remember actually originates from a piece of wire. It is bent into the shape of a paper clip when cold, clamped this way and then heated until the atoms have changed into the new state. Some memory alloys are also trained through several heating and cooling cycles. While all this effort is worthwhile for cardiac valves, it is less so for mass-produced goods like paper clips – Anja Schlömerkemper’s paper clip is ultimately for demonstration purposes only.

The fact that memory alloys can easily be bent at room temperature is due to the structure their atoms form at this temperature. Materials scientists refer to the arrangement as the martensite phase. To demonstrate this, Anja Schlömerkemper draws two lattices based on rectangles with two sides of different lengths. In one case, the longer sides are horizontally aligned; in the second, they are vertically aligned. In a three-dimensional memory alloy, the rectangles expand to form possible microstructures, the more possible microstructures, the more flexible the material. If the material is forced to accept a prohibited microstructure, it may tear or break.

The reason why not all microstructures are possible can be clearly illustrated, at least for the model of differently oriented rectangles: the rectangles must match up where the two orientations meet. This means that they must share lattice points. The atoms located at the boundary actually belong to both lattices and must be at home in both. This is possible only if they fit quite precisely into the structure in question. Anything else would, again, cost too much energy.

“I like to begin by imagining the geometric appearance of the possible structures,” says Stefan Müller: “Only when we have done this do we try to develop a calculation.” However, the end product must constitute a mathematical statement or formula and, if possible, a formulation that provides materials scientists with an indication of suitable materials. In other words, one that contains easily quantifiable parameters. “Energy provides a starting point here,” says Stefan Müller.

As the energy level of the allowed microstructures must be as low as possible, a problem arises that mathematicians in Leipzig would not have much more to do. However, this is not the case, as only certain microstructures are allowed. “What we would like to discover mathematically is precisely which microstructures are allowed,” says Anja Schlömerkemper. A function of a shape-memory alloy is in no way as simple as a discussion of curves at school. First, the energy is a functional – the mathematical two influences vie with each other in a microstructure: elastic energy and interfacial energy. The less the preferred structure of the atoms is deformed in the bent paper clip, the lower the elastic energy. If the microstructure is as fine as possible, the regions with differently oriented atoms are as small as possible and the structure is very flexible. This is very similar to a game with building blocks: the smaller the stones, the more varied the structures that can be built with them.

However, a fine microstructure also has a disadvantage: there are a lot of interfaces in it at which the differently oriented lattices must align with each other. This costs energy, as the atoms must shift somewhat from their preferred positions. Thus, from this perspective, the fewer interfaces there are, the closer the structure and the better the energy balance. The compromise formula for obtaining the optimum of elastic energy would be as low as possible, a problem arises that mathematicians in Leipzig would not have much more to do. However, this is not the case, as only certain microstructures are allowed. “What we would like to discover mathematically is precisely which microstructures are allowed,” says Anja Schlömerkemper. A function of a shape-memory alloy is in no way as simple as a discussion of curves at school. First, the energy is a functional – the mathematical two influences vie with each other in a microstructure: elastic energy and interfacial energy. The less the preferred structure of the atoms is deformed in the bent paper clip, the lower the elastic energy. If the microstructure is as fine as possible, the regions with differently oriented atoms are as small as possible and the structure is very flexible. This is very similar to a game with building blocks: the smaller the stones, the more varied the structures that can be built with them.

However, a fine microstructure also has a disadvantage: there are a lot of interfaces in it at which the differently oriented lattices must align with each other. This costs energy, as the atoms must shift somewhat from their preferred positions. Thus, from this perspective, the fewer interfaces there are, the closer the structure and the better the energy balance. The compromise formula for obtaining the optimum of elastic energy...
At high temperatures, the atoms of a shape-memory alloy form a cubic structure (above, austenite phase). If the material is bent to form, for example, a paper clip and then cooled down, the atoms arrange themselves in cuboids and form a microstructure (martensite phase), thus the external form of the paper clip is maintained. It is possible to bend the wire thanks to the variety of possible microstructures. The reasons for this behaviour are energetic (below). At high temperatures, there is an exact minimum for energy $W$, which is due to the cubic structure. At low temperatures, there are two variants that can connect with each other in a way that in-between orientations in which four of the elementary cells consist of a deformed cuboid and resemble an unstable shell that has ended up tilting to one side: “For such materials, we are looking for the quasiconvex hull,” says Schlömerkemper – which means that they must focus on the goal of systematically understanding such equations. This is helpful because, to date, computers have generally had to test all possible solutions and, as a result, are hopelessly overburdened when faced with the task of, for example, predicting microstructures.

However, the search for the energetic compromise formula that can help with this task is not exactly easy and, what is more, it is rendered significantly more complex by the fact that the microstructure is three-dimensional. In order to describe the spatial orientations of the elements of such a material whose orientation does not belong to one and the same group. There thus exist between these groups geometric relationships that Anja Schlömerkemper also wants to get a handle on mathematically. Instead of keeping her hands busy with a paper clip while pondering this problem, she constructs a paper model of the intergroup law: she sticks nine paper triangles together to form an unusual structure.

At the energy low point: Anja Schlömerkemper explains the quasiconvex hull (blue) for microstructures. This describes combinations of the two variants of the parallelogram (right and left).

However, zones can also be found besides each other in the microstructure of such a material whose orientation does not belong to one and the same group. There thus exist between these groups geometric relationships that Anja Schlömerkemper also wants to get a handle on mathematically. Instead of keeping her hands busy with a paper clip while pondering this problem, she constructs a paper model of the intergroup law: she sticks nine paper triangles together to form an unusual structure.

**The Search for the Essential**

Each rectangle stands for a group of differently oriented structures that are compatible with each other. The corners of the pieces of paper have numbers on them that correspond to the twelve variants of the elementary cells. Wherever the variants from different groups match, the triangles are connected. This gives rise to a kind of tiling of the intertwined bands of paper wind.

“Sometimes it helps to change the perspective,” says Anja Schlömerkemper: “We project the problem in three dimensions to obtain a geometric impression.” Anja Schlömerkemper and Isaac Chenchiah then have to express this in a formula. This also means that they must focus on the essential. “It is always a question of understanding the really essential information and not all of the details,” says Stefan Müller.

This is a problem that Anja Schlömerkemper must overcome in another project, as well. Together with Kaushik Bhattacharya from Caltech in Pasadena in the US, she is looking for the allowed microstructures that can form in polycrystalline memory alloys. Polycrystalline ma-
Arts and crafts in the service of mathematics: Using a paper model, the Leipzig mathematician show how the variants of a monoclinic lattice can be combined to form microstructures.

Materials make up the bulk of the natural minerals and everyday materials we encounter: cast-iron frying pans, automotive sheet metal, roof tiles and artery-widening stents. Unlike monocrystals, as considered by Anja Schlömerkemper in model form for monoclinc structures, they consist of a myriad of densely packed crystal grains. Materials scientists refer to the way these crystallites align themselves as texture. It is a function of the manufacturing process and is often a matter of chance, yet sometimes it also follows certain rules. In most cases, the texture limits the shape memory of the corresponding alloys. Anja Schlömerkemper and Kaushik Bhattacharya want to find out how the grains least obstruct themselves and thus display good shape memory. The mathematicians ultimately want to predict the characteristics of the material with a law that takes into account both the microstructure and the order of the crystallites. Furthermore, the long-term objective is a law that requires the input of nothing more than the crystal data – the dimensions of the elementary cells and information on the texture – and that can then calculate the possible microstructures. Based on this, they want to make it easier for materials scientists to find suitable alloys for all applications.

This law, on which the Leipzig scientists are working together with Dirk Raabe’s department at the Max Planck Institute for Iron Research in Düsseldorf, creates something very big from something very small. Mathematicians call this “multiscale”. Predicting the microstructure from an unlimited number of elementary cells that can be more complicated than that of a stretched cube or distorted cuboid is only a first step toward the fulfillment of this objective. “But we are just starting out with this,” says Stefan Müller. And this provides so much material to ruminate over that the scientists are sure to bend some more paper clips while deep in thought. They will definitely be happy then to have paper clips that can remember their functional shape.

Peter Hugisbergs

Memory at the push of a button: In the cold spring, the atoms form cuboids that can be oriented in different ways – the stone expands the spring. In the heated metal, the atoms group together to form an inflexible lattice of cubes: the spring contracts. In the heated metal, the atoms group together to form an inflexible lattice of cubes: the spring contracts.

Arts and crafts in the service of mathematics: Using a paper model, the Leipzig mathematician show how the variants of a monoclinic lattice can be combined to form microstructures.
Wave patterns on sandy ocean beds look as though they have been modeled. However, physics is the only force at work in the formation of these sand ripples. Similarly, the formation of sand dunes in the desert is based on the laws of physics: the initially flat surface of the sand is physically unstable – both above and below water. As a result, small irregularities increase in size under certain conditions. Thus, sand accumulates behind the shelter of a stone or shell, the dune or ripple starts to grow, and so on. As a result, more sand is deposited. However, once it settles, the sand cannot contribute to the formation of dunes or ripples elsewhere. The counter-reaction consists in the removal of the sand particles, which are carried away by the wind and waves. The likelihood that new dunes will form or existing sand ripples on the ocean floor will continue to grow declines once the sand is removed. The formation of a pattern is thus based on a local, self-reinforcing reaction. This is coupled with a counter-reaction that limits the extension of the self-reinforcing reaction.

**PATTERNING AS EXPLAINED BY RUDYARD KIPLING**

Every pattern found in nature presents a – usually profound – puzzle. Mathematics is particularly suited to helping us solve such puzzles. It helps us uncover, in a more or less systematic way, the rules and structures that lie hidden behind the observed patterns. These rules and structures can then be used to explain what is happening. Mathematics helps scientists calculate natural processes. “We would like to understand how and why certain patterns form, and to be able to predict how nature will behave,” says biologist Thomas Schlake, who was fascinated by the phenomenon of pattern formation during his post-doctoral studies at the Max Planck Institute for Immunobiology.

Ripple-like patterns, such as those we see when strolling along a beach, occur frequently in nature: the coat of a zebra also has such characteristic line patterns. But what pattern formation process lies behind this kind of coat pattern? Jungle Book author Rudyard Kipling tried to provide an answer to this question in his entertaining essay “How the Leopard Got His Spots.” According to Kipling,
Hair growth on the computer: During hair follicle formation, large primary follicles form first (blue spots) and smaller follicles (red spots) emerge later in the intervening spaces during a second wave of development.

The leopard, in contrast, got his spots close together (there was plenty of black left on his new skin still) and pressed them all over the Leopard, and wherever the five fingers touched they left five little black marks, all close together. You can see them on any Leopard’s skin [...] if you look closely at any Leopard now you will see that there are always five spots – off five fat black finger-tips." What this tongue-in-cheek attempt at explaining the origin of the patterns shows is that we cannot necessarily rely on intuition when it comes to explaining pattern formation processes.

In his model, Turing examines two substances that react with each other. The activator, a substance that acts over short distances, stimulates both its own production – a process chemists refer to as autocatalysis – and that of its rapidly spreading opponent, the inhibitor. The concentrations of both substances can be in a state of equilibrium. However, this state is locally unstable. As a result of autocatalysis, the concentration of the activator rises with each local increase. Yet, this also triggers an increase in the amount of inhibitor. As the inhibitor moves (diffuses) faster and thus rapidly spreads from the source of the activator, it cannot inhibit the further local increase of the activator, but arrests its autocatalysis in the environment: a halo forms around the areas in which the activator is formed. This is how, for example, a spot pattern forms. If the different parameters, such as the production rate, degradation rate or diffusion speed, are altered, it is easy for one substance or another to gain the upper hand in different areas on the surface. Almost any pattern can be formed in this way.

In the mathematical model, the specified parameters are entered into what is known as a partial differential equation. This is an indispensable tool in creating mathematical models, and we have Newton and Leibniz to thank for developing it in the second half of the 17th century with the aim of calculating rates of change. And this is what pattern formation is all about: With the help of partial differential equations, it is possible to correlate the changes in concentrations of the two substances over a short period as a function of their current concentrations. If the changes in concentrations are added to the specified initial concentrations, the concentrations at a later point in time are obtained. Therefore, multiple iteration of this calculation makes it possible to obtain the concentrations of the substances involved over time.

Inspiration during an Italian Meal

Turing’s model inspired a series of successors, all of which are described as reaction-diffusion models. In the early 1970s, Alfred Gierer and Hans Meinhardt, two researchers at the Max Planck Institute in Tübingen, also grasped with models for biological pattern formation. They were particularly fascinated by the complex patterns on the shells of tropical marine snails. On an Italian in an Italian restaurant, Meinhardt noticed a pattern of red lines on a clam shell. “To my surprise, mathematical models that we had developed to describe elementary stages in the development of higher organisms were also able to explain the course of the red lines on my clam shell,” writes the physicist. Hence, this form of pattern formation is ultimately only a very special example of a vitally important general process: the formation of structures during the development of a multicellular organism. The starting point here is a single cell – that is, the fertilized egg – which contains in its DNA all of the information necessary for the formation of the complex structure of a higher organism. However, the genes themselves do not provide any explanation for the formation of structures. As a general rule, during cell division, the doubled genetic material is distributed equally among the daughter cells, which are, therefore, identical.

The question that arises then is how the development of different cell types unfolds and how certain tissues and organs are assigned to these cell types. And, in turn, how the latter are assigned to certain positions in the body. “Signaling molecules play a crucial role here,” says Thomas Schlake. Initially similar cells that are directly adjacent to each other exchange signals that cause them to develop differently. Or a group of cells with the same potential for development is prompted by a signal from cells outside the group to divide into two cell groups with different developmental paths.

In many cases, the signaling molecules diffuse away from its source and form a concentration gradient. As a result, cells located at different distances from the source react in different ways – depending on the strength of the signal they receive.

Morphogens – Signals with a Formative Effect

Thus, these signaling molecules do not trigger a simple yes/no response. A high concentration of the signal substance can point the target cells in the direction of a particular developmental path, a medium concentration will prompt a different outcome, and low signal strength will cause them to embark on a third path. Certain genes that control the further development of the cell are activated or deactivated, depending on the po-
activation inhibitor pair, particularly since the WNT molecules are between 20 and 60 percent larger than the DKK molecules and therefore – of which there are quite a few – are also known: members of a protein family that scientists call Dickkopf (DKK) directly block signal transduction at the receptor. These are also present during follicle formation.

As WNT signals are required for the emergence of hair follicles, they could, in principle, also control the pattern of distribution, says Schlake. Based on the assumption that pattern formation unfolds in accordance with the mathematical model proposed by Alan Turing, WNT and DKK could represent the corresponding activator-inhibitor pair, particularly since the emergence of hair follicles is, the number of hair follicles – is tentatively: the number of spots – that result in larger white spaces in between – fewer new spots formed.

When the inhibitor was increased moderately, ring-like zones formed between the primary follicles. The concentrations of these signaling molecules in an organism, in this case the mouse, can be modified to day using genetic technology methods. What happens when one increases the concentration of the activator (WNT) or inhibitor (DKK)? In principle, it should be possible to associate visible processes, namely the distribution of hair growth, with molecular processes, says Schlake. If the reaction-diffusion model is adapted to the biological system under examination, it should be possible to predict the results that can be expected from the mouse experiment. And that is precisely what Schlake and his colleagues did.

In the case of insufficient or poor regeneration of the genome, its reading rate fell, and with it, the production of the signaling protein,” says the biologist. As a result, the concentration of the inhibitor remained lower and the hair covering on the mice was correspondingly sparse.

**Proof of the Turing Hypothesis**

An examination of skin samples from these mice under the microscope showed that the number of hair follicles had been reduced by 30 percent as compared with the wild type. And instead of the usually regular distribution, there were clusters of hair follicles that were clearly separated from each other by hairless areas. The experimental data therefore confirm the predictions of the computer model, stresses Schlake. WNTs and DKKs actually fulfill the theoretical requirements of the Turing hypothesis and exercise considerable control over the spatial arrangement of hair follicles.

The work of Schlake and his team thus provided the first empirical corroboration of the Turing hypothesis. During his own time, Turing’s ideas applied only to the rules of pattern formation and not to the protagonists of diverse biological systems. However, Turing’s flash of inspiration provided an important condition for this insight, as aptly conveyed by Jean-Henri Fabre in his description of mathematics as “that wonderful teacher of the art of directing one’s thought ... it arranges what is confused, thins out the dense, calms the tumultuous, filters the muddy and gives lucidity.”

**Computer-Generated Samples of Patterning**

In order to simulate the effects of altered activator or inhibitor production on a computer, the cellular biologist sought expert support from physicists Jens Timmer and Stefan Reinker at the University of Freiburg. Together they honed the equations on which the reaction-diffusion model is based. Here, they had to take into account that hair follicle formation apparently occurs in several waves: large primary follicles form first and, as part of a second wave of development, smaller new follicles form in the free spaces that remain in between the primary follicles. The researchers simulated the patterning processes on the computer using different parameter settings. When they increased the concentration of the activator moderately, during both the first and subsequent waves, the number of colored spots on the screen increased. This corresponded to a higher density of hair follicles. In contrast, an increase in the concentration of the inhibitor resulted in larger white spaces in between – fewer new spots formed.

When the inhibitor was increased moderately, ring-like zones formed where the activator had accumulated around the spots that had formed during the first wave of development. In the biological model system, this would lead to the formation of new hair follicles. Thus, the inhibitor influences pattern formation both quantitatively and qualitatively: the number of spots – that is, the number of hair follicles – is reduced and their distribution changes. The question remained, however, whether the experiment would empirically confirm these theoretical predictions.

Schlake and Sick therefore generated transgenic mouse lines in which they injected the gene for the signaling protein DKK2 into the fertilized eggs and, in this way, adjusted the screw for the concentration of the inhibitor. If the gene was successfully integrated, the production of the corresponding signaling protein, in other words the inhibitor, was increased. The result: the mature mice were almost hairless.

“In the case of insufficient or poor integration of the gene, its reading rate fell, and with it, the production of the signaling protein,” says the biologist. As a result, the concentration of the inhibitor remained lower and the hair covering on the mice was correspondingly sparse.
Born to Teach?

Mathematics is considered difficult material to convey – and math lessons are typically unpopular. Could it be partly because of the teachers? At the Max Planck Institute for Human Development, a team working with Mareike Kunter is investigating what makes a good math teacher.

Teachers can be authoritarian or insecure, strict or patient, generous or pedantic. And then there are those who seem to be born teachers. Their classes are easy to follow, they explain things well, and they make learning fun. For Mareike Kunter from the Berlin-based Max Planck Institute for Human Development, however, the born teacher – especially the born mathematics teacher – is a myth. Instead, she prefers to talk about “good teachers” and clarifies: “There is no evidence for the hypothesis that good teachers are endowed per se with certain qualities that set them apart from other people. Nor is there any evidence for their personality being responsible for better student outcomes.”

At the Center for Educational Research, under Director Jürgen Baumert, Kunter collaborated on the COACTIV study, which focuses on mathematics instruction at the lower secondary level, or grades 5 to 10. She and her colleagues aim to provide a scientifically substantiated answer to the question of what makes instruction successful. What characterizes teachers who are successful in their profession? And how can the quality of instruction be improved? “Being a good teacher is not an innate personality trait,” says Kunter: “There are very specific, typical skills that teachers can learn, just as surgeons can learn particular surgical techniques.”

Between Competence and Performance

COACTIV stands for Professional Competence of Teachers, Cognitively Activating Instruction, and the Development of Students’ Mathematical Literacy. The study focuses on teachers whose students participated in the PISA study on mathematics in the 2003/2004 academic year. This allows the researchers to directly examine the link between teacher competence and student performance.

However, the idea for COACTIV first came about as early as the end of the 1990s in connection with the international TIMSS study (Third International Mathematics and Science Study), in which Germany placed in the lower midrange.

The TIMSS Video Study that was carried out in parallel provided first indications of possible causes. In this international benchmark study, approximately 100 hours each of mathematics instruction in Germany, the United States, and Japan were recorded and analyzed. Typical patterns in teachers’ approaches to instruction were found in each country. The German pattern consisted in structured discourse: the teacher presented a problem to the entire class and then walked students through a tightly sequenced...
The notion that mathematics instruction at German schools promotes independent thinking and the ability to solve problems was already revealed to be a myth in the TIMSS study. After a focus on reading skills in 2000, the 2003 cycle of the study concentrated on German students – findings that remained stable in the 2006 cycle of the study.

**Drilling Routines Rather than Solving Problems**

“This small improvement could be a first result,” Mareike Kunter speculates, “of the attempts seen in the wake of TIMSS to improve the quality of mathematics instruction through systematic teacher education and training.” For example, the SINUS program – a German acronym that stands for “increasing the efficiency of mathematics and science instruction” – has been introduced in schools throughout Germany, with researchers and teachers developing new lesson formats and materials. TIMSS and PISA also sparked a flurry of research activity. Why are German students so much better at following set routines than solving problems? It wasn’t even clear where researchers should begin searching for reasons. “Previously, empirical education research had largely ignored the teachers themselves – they were considered a given, and the focus was exclusively on instruction,” says Mareike Kunter. Empirically grounded studies of teacher competence were rare. Theoretical papers and everyday opinions based on personal experience predominated.

Yet students and parents are sometimes quick to place the blame on the teacher when a student is in danger of failing. To remedy the shortage of data, researchers from various disciplines are working on the CO-ACTIV study. Mareike Kunter, for example, is a psychologist, and project director Jürgen Baumert, an educational researcher. The two are working with experts in mathematics education, such as Werner Blum from the University of Kassel and Michael Neubrand from the University of Oldenburg. There are also math teachers on the CO-ACTIV team – and not only as study participants whose knowledge was assessed.

According to a model established by Kunter, Baumert and their colleagues, there are three main aspects to the specific professional skills that typically make a good teacher: the teachers’ underlying beliefs about how knowledge is communicated, their motivation and self-regulation skills, and their professional knowledge. The researchers were thus able to test the extent to which teachers differ in their success in the classroom.

Teachers’ beliefs about how knowledge is communicated are a key determinant of how they approach instruction, and of active student participation. Education research distinguishes two main views on the question of knowledge communication. The transmission view, in which learning is considered to be the result of knowledge transfer and frequent repetition, is reflected byendorsement of the statement: “The most efficient way to solve a given type of problem should be ingrained through practice.”

In contrast, those who tend toward the construction view, in which learning is considered the result of mental – that is, cognitive – activity on the part of students, endorse the statement: “Students should have the opportunity to explain their approach in detail, even if it is wrong.” And indeed, the researchers found that the students of teachers who tended toward the transmission view learned less.

To succeed in their jobs, teachers must not only be well versed in the subject they teach, but they must also be motivated to apply this knowledge and to continually refine it. The research team therefore took a closer look at one particular trait that many laypeople consider to be the mark of a good teacher: enthusiasm. As they discovered, a teacher’s enthusiasm does not guarantee good instruction. Only if they are enthusiastic about teaching will there be positive effects on the quality of instruction. Enthusiasm for math alone is not enough.

**Little Feedback from Colleagues**

Attempts to systematically improve the quality of instruction are further hampered by the fact that teachers receive little external feedback, for example from supervisors or colleagues. It is left to them to decide how much energy to put into their work and when they need to distance themselves from it. This aspect was analyzed on the basis of teachers’ self-reports.

The study found that precisely those students who work in teams and at school. At the same time, they wanted the problem set to go beyond the knowledge typically taught in school. This is where experts in mathematics teaching contributed their experience. The test items developed “cover background knowledge that...”
we assume teachers need in order to convey the material to their students,” as Mareike Kunter explains.

In addition, problems were devel-
oped that students could solve in dif-
ferent ways. Unlike the problems re-
lating to content knowledge, the
researchers were not looking for a sin-
gle correct solution here. Rather, the
more approaches the teachers sug-
gested, the more points they scored.

Teachers must also be able to put
themselves in the typical mindset of
students in order to recognize where
difficulties arise. People often seem
to think that only born teachers are
able to understand how their stu-
dents think. “But in fact, it’s simply
another form of professional knowl-
edge that can be acquired,” says Ma-
reike Kunter. She and her colleagues
tested this aspect using problems
such as the following: “The area of a
parallelogram can be calculated by
multiplying the length of its base by
its height. Please sketch an example
of a parallelogram to which students
were asked to outline as many differ-
ences, particularly in terms of pro-
fessional knowledge, depending on
whether they received less training in
this aspect than their younger colleagues. This
finding has influenced the direction
of future research in the COACTIV
project: “Teacher competence is not
an innate quality, nor does it seem to
be a matter of professional experi-
ence,” she says: “Instead, our find-
ings show that core aspects of com-
petence are acquired during formal
training.” Consequently, in their fol-
low-up study COACTIV-R, the re-
searchers are now focusing on the
compulsory two-year teaching place-
ment that follows the first, universi-
ty-based phase of teacher training in
Germany.

Radical Changes in
Teacher Training
Kunter and her team also want to
look at in-service teacher training.
They did not find any clear connec-
tions between teacher knowledge and
participation in continuing educa-
tion, even for teachers who had par-
ticipated in many such programs.
“This may be due, at least in part, to
the fact that most of these programs
do not cover specific aspects of con-
tent knowledge or pedagogical con-
tent knowledge, but deal with gen-
eral pedagogical topics or aspects of
school organization,” surmises Kunt-
er. Now she would like to find out
which teachers are particularly dedi-
cated to furthering their training.

Initially, however, research will fo-
cus on the first steps in the teaching
career. What skills and expertise
do future math teachers have when
they begin their teaching placement?
How do they develop their abilities,
knowledge, beliefs and motivation
during this period? Which factors,
both individual and institutional, in-
development? These questions will be addressed in the new study.

“Teacher training in Germany is
currently undergoing radical chang-
es,” says Mareike Kunter, “but the re-
forms are based largely on assump-
tions for which there is still too little
empirical evidence.” For example, it
is often said that the university phase
of teacher training is much too theo-
etical and that future teachers start
out more or less from scratch in
terms of practical competence when
they enter the classroom – or that
the teaching placement is so de-
manding that many beginning teach-
ers lose their enjoyment of the pro-
fession during this phase. With
COACTIV-R, the education research-
ers again aim to distinguish fact
from opinion.

Merle Porta, provides individual tutoring in math

In the Year of Mathematics, I hope to take math out of the chamber
of horrors. I don’t want my students to learn formulas by heart and forget
them again just as quickly; I want them to really understand math and
see that it is directly relevant to their lives.

Merle Porta, teacher

I hope to help the mathematicians of tomorrow see
beyond the basic mathematics taught in school, and I try
to convey to my students that math has more to do
with creativity and learning how to think and solve
problems than with applying routines.

Reinhard Schmidt, teacher

Steffanie Hense

mathematics

3/2008 Max Planck Research | 45

Max Planck Research 3/2008

44

45
Ornithologists have come up with novel ways of exploring when birds take a break.

**Sleepless in Seewiesen**
Every whistle, twitter and warble in such a variety of pitches that it’s a joy to the ear. An inconspicuous little bird flies through the shrubbery – and the camera zooms in and shows it close-up. But what does the pigeon make of it? At that moment, the TV screen is showing an episode of David Attenborough’s “The Life of Birds.” The pigeon watches it with its right eye; the left eye is covered with a patch. The experiment that Niel Rattenborg’s offi ce. The scientist picks up a maggot out of a knothole and next to it a chimpanzee – also with a stick to its hand – poking around for termites. Both are examples of the extensive cognitive feats that mammals and birds are both capable of performing.

**More Space in the Head**

Beneath this is a picture of a bird’s brain and a mammal’s brain in cross-section. Measured against their body weight and in comparison with other vertebrates, birds have larger and more complex brains. The same applies to mammals, and of course to humans in particular. “More recent theoretical and empirical studies indicate that SW sleep is directly involved in sustaining brain function,” explains Rattenborg.

He describes the “synaptic-homeostasis hypothesis” proposed by fellow researchers as particularly interesting: “During wakefulness, the large quantity of incoming sensory information increases the number and strength of synapses in the brain. “There comes a point when the head is full and unable to take in any more information,” says Rattenborg. In this case, SW sleep serves to reset the synaptic activity: the less-used synaptic contacts are effectively deleted and the overall strength of all synapses is weakened, thereby enabling the brain to take in new information during the next period of wakefulness.

“In mammals, there is a great deal of experimental evidence to back up this hypothesis,” confirms the scientist. This would mean that sleep was no longer merely an

---

**Fascinating Research**

48

---

**Ornithology**

The pigeon watches a video with its right eye, while the left eye is covered with a patch. It wears an EEG recording device on its head.

One-sided television viewing: A pigeon watches a video with its right eye, while the left eye is covered with a patch. It wears an EEG recording device on its head.

---

**Fascinating Research**

49

---

**Ornithology**

The pattern of sleep: John Lesku (left) and Niel Rattenborg discuss the EEG recordings. The slow, regular waves are evidence of a deep sleep phase.

---

**Fascinating Research**

48

---

**Ornithology**

The pattern of sleep: John Lesku (left) and Niel Rattenborg discuss the EEG recordings. The slow, regular waves are evidence of a deep sleep phase.

---

**Fascinating Research**

49
ergy-conserving rest phase, but that it had, in the course of evolu-
tion, taken on additional functions that go hand in hand with the de-
velopment of more complex brains, which can now fulfill demanding
cognitive tasks.

In any case, pigeons need their sleep, as the TV experiment showed.
But if sleep has such an important function for the brain, what about
birds that are active for long periods without a rest, for example when
they’re migrating between their breeding area and winter habitat –
what do they do then? Since many birds fly long stretches of their mi-
gration at night and also do not sleep during the day, they must build up a
considerable sleep deficit over several days – with the corresponding
negative consequences. However, they seem, in fact, to be able to func-
tion at full physical and cognitive capacity during their migration.
A paradox?

“Whether migrating birds manage to get enough sleep during their brief
rest phases, whether they sleep with a single brain hemisphere during flight
or whether they have an as-yet unknown ability to perform amazing feats of flying despite reduced sleep is something no one has studied yet,”
explains Niels Rattenborg.

The ability of birds to switch their sleep to just one brain hemisphere –
unihemispheric sleep is also known to occur in marine mammals such as
dolphins, but we humans are inca-
pable of it – would at least seem to imply that birds might be able to
employ this form of sleep during their long migratory flights. And that
is why Rattenborg, an American
from Madison, Wisconsin, came to
Seewiesen in Upper Bavaria: “Ever
since I first visited the institute in
2001, the thought of using the wind
tunnel they have here to study
whether birds sleep on the wing is a
thought I just couldn’t shake.”

STRONG WIND FORECAST
FOR THE TEST MOUND

We leave Rattenborg’s office and
walk along the corridor together. The
scientist opens a door, which leads
into the flight chamber. The birds are
as big as our native star-
lings and are also long-distance fly-
ers. Their natural breeding areas are
located in Eastern Europe, while their
winter quarters are mostly in north-
ern India. The birds are hand-reared
in Seewiesen, which makes them
very tame. Since they are familiar
with the wind tunnel, they are highly
cooperative during the experiment –
although they prefer to fly in small
groups of at least three birds. “Then
they are a lot more relaxed than if we
make them fly on their own,”
says John. After all, they form flocks
in the wild.

The flight chamber, constructed
outside of Plexiglas, is two meters long
and just over a meter wide, and gives
the rose-coloured starlings plenty of
room to maneuver. With an average
wing span of 35 centimeters, the
birds are as big as our native star-
lings and are also long-distance fly-
ers. Their natural breeding areas are
located in Eastern Europe, while their
winter quarters are mostly in north-
ern India. The birds are hand-reared
in Seewiesen, which makes them
very tame. Since they are familiar
with the wind tunnel, they are highly
collaborative during the experi-
ment – although they prefer to fly in small
groups of at least three birds. “Then
they are a lot more relaxed than if we
make them fly on their own,”
says John. After all, they form flocks
in the wild.

The biologist opens the door to
the wooden aviary, where three
starlings are waiting to be let out
into the wind tunnel. The birds are
between two and three years old.
One after the other they fl ap into
the flight chamber’s little outer
hatch, and land on a perch sus-
pended from the ceiling.

A STRONG WIND BLOWS IN

At 6 p.m., the group outing be-
gins. The trio will spend three hours
straight in the flight chamber; John
will keep an eye on them at all
times to make sure they do not in-
rupt their non-stop flight. A
drafty business – standing at the
front of the flight chamber’s entry hatch, the
young researcher must feel like a
passenger on a ship’s fordeck with
the cool wind blowing in his face.
And the wind machine isn’t exactly
quiet, either.

At 6 p.m., the group outing be-
gins. The trio will spend three hours
straight in the flight chamber; John
will keep an eye on them at all
times to make sure they do not in-
rupt their non-stop flight. A
drafty business – standing at the
front of the flight chamber’s entry hatch, the
young researcher must feel like a
passenger on a ship’s fordeck with
the cool wind blowing in his face.
And the wind machine isn’t exactly
quiet, either.

An Outing Is Tiring
for Starlings

“The birds lose about three grams of
body weight during a three-hour
flight,” he explains. John records this
data as background information, as
it provides a measure of the birds’
physical condition. What he’s actu-
ally investigating is whether the
birds need sleep to recover from long
flights. To enable him to find this
out, the starlings have a miniature
EEG recorder attached to them after
their outing. It records their brain-
wave activity during the following
hours.

Since it is impossible to distinguish
between REM sleep and wakefulness in
the EEG, the scientists use several
video cameras to record the birds’ be-
havior in the aviary during the period
in question. Only when a bird is in a
typical sleeping posture – eyes closed,
motionless and the head possibly rest-
ing on one of the wings – can they be
sure that the waves they are recording
reflect REM sleep. John can see that
his starlings sleep more intensely fol-
lowing an outing by the much greater
amplitude of the SW sleep.
There are other bird species that can apparently do without much of their sleep at certain times of the year. To this effect, Rattenborg and his team studied the sleep pattern of a North American sparrow, a small songbird. During the time when the birds in the wild would be migrating, the team found that their hopping to and fro in the cage increased. This migratory restlessness continued for as long as their migration would have lasted. During this time, the studies showed that the birds slept two-thirds less. "I wouldn’t be surprised if different bird species employed different strategies to manage the conflict between the need to sleep and the need to be awake," says Rattenborg.

The researchers now want to find out what the EEG of a rose-coloured starling looks like during the long-distance flight simulated in the wind tunnel. But there are a number of technical obstacles to be overcome first:

If the EEG recorders, already maximally miniaturized by colleagues at the University of Zurich, are attached to the birds’ heads, they lose all motivation to fly. So John Lesku fastened the recorders to their backs instead. Although they do stay in the air like this, wing flapping interferes with the EEG readings.

ONE WEEK NON-STOP IN THE AIR

But the Max Planck researchers have another iron in the fire: In the summer, they and French colleagues are due to start a cooperative field test with frigatebirds in the wild. With a wingspan of over two meters and a body around a meter long, these birds are much larger than starlings. "The ratio of EEG recorder to body size will then be better," explains Rattenborg. They are therefore justifiably hopeful that the frigatebirds will not be troubled by the little recorders on their heads.

Frigatebirds fish for food on the open seas. Unlike gulls, for example, they are unable to take off from the water. Indeed, recent tests have shown that they spend up to a week in the air before returning to their nest to feed their young. "Whether they sleep during such a flight or perhaps get through it completely without sleep, we do not know - either way, it’ll be exciting to find out," stresses Niels Rattenborg.

CHRISTINA BECK

With a mini-recorder on their heads, the rose-coloured starlings’ EEG readings are recorded by the scientists (left). The birds’ behavior in the aviary is recorded simultaneously on video cameras (right).
Depending on where in the brain the injured cells are located, many different impairments can result, most of which are permanent. Accidents involving head injuries, diseases such as multiple sclerosis or Parkinson’s, and strokes are frequent causes of cell death in the brain.

When nerves in the spinal cord are badly crushed or severed, lifelong paralysis can result. The closer to the neck the injury occurs, the more severe the paralysis. A study in the US showed that, in that country alone, there are 8,000 to 11,000 cases annually of spinal cord injuries that result in paralysis. In 47 percent of these patients, the legs are paralyzed, and in 52 percent, both the arms and the legs. Accidents are often the cause of injury to the spinal cord, which is why paralysis is frequent in 16- to 30-year-olds. As those affected have a relatively normal life expectancy, their number increases globally from year to year.

**STOP SIGNS IN THE NEURAL NETWORK**

With so many people impacted in this way, an urgent search is underway for an answer to why nerve cells in the central nervous system do not regrow after an injury.

For me and many of my colleagues, this is one of the most fascinating questions in modern neurobiology. In the past 10 to 15 years, intensive basic research has brought about considerable progress in this area. For example, a number of factors have been found in the nerve cell environment that can stop the nerve cell extensions from growing.

I have always been impressed by the body’s ability to heal itself. A cut on your finger destroys skin cells, injures muscles and blood vessels and severs nerve cell extensions. It is painful, but not a catastrophe. After a short time, nerve cells regrow, muscles and blood vessels are reconstructed and the skin closes over the cut.

Even more serious injuries usually heal without leaving significant traces, although the cells occasionally have to be persuaded to grow in the right direction with a bandage or a splint. But what’s wrong with this picture? If the body has these astonishing self-healing powers at its disposal, why doesn’t it use them to repair its most delicate systems, the brain and the spinal cord?

The nervous system is divided into two areas: the brain and the spinal cord form the central nervous system, while all other nerves, such as those in the arms and legs, make up the peripheral nervous system. One important difference between these two systems lies in their ability to regenerate. Unlike those in the peripheral nervous system, the cells in the central nervous system hardly ever recover from damage.

A damaged nerve in a finger will heal, but a damaged nerve in the brain or spinal cord will not. **Frank Bradke** and his research group at the **Max Planck Institute of Neurobiology** in Martinsried want to encourage nerve cells in the spinal cord to regrow after injury.

**Growth Treatments for Nerve Cells**

A damaged nerve in a finger will heal, but a damaged nerve in the brain or spinal cord will not. Frank Bradke and his research group at the Max Planck Institute of Neurobiology in Martinsried want to encourage nerve cells in the spinal cord to regrow after injury.
a cell extension stops growing when it reaches one of these stop signs. And this is precisely the problem: as soon as the nervous system is fully developed, these stop signs are put up throughout the central area. When the nerve cell extensions in an adult organism are severed, they are faced with a forest of stop signs. As long as these signs are present, the cell extensions can grow no further. This also means that once contact with partner cells has been broken off, it cannot be re-established. The consequence is paralysis.

But what would happen if the nerve cells could be turned into more daring road users that would simply ignore the signs and grow right past them, more or less the way it is in everyday traffic situations? This question has not only occupied my thoughts while driving, it is also the main subject of my work at the Max Planck Institute of Neurobiology. For example, it recently became possible to mark individual nerve cells or cell components and study them. The discovery of GFP was also fortuitous for my work, as it enabled us to visualize what was happening in the retraction bulb. My colleague Ali Ertürk discovered that a retraction bulb can be identified less than an hour after an injury. While it slowly swells during the ensuing hours, mitochondria accumulate inside it, which is similar to what happens in a growth cone. With these cellular powerhouse houses on the job, it is rather un-likely that the growth stop is caused by a lack of energy. Things became really interesting, however, when we looked at the microtubules. Nor-

When an injury occurs in the central nervous system, the damaged extensions of the cells do not regrow. However, when the same cell is damaged first in the peripheral section and then in the central section, it will also be able to regrow in the central nervous system. These observations show that nerve cells in the central nervous system can, in principle, recover from an injury. In order to understand why the cells nevertheless do not grow after being damaged, it is helpful to recall the structure of nerve cells and how they develop. A typical nerve cell consists of a cell body and a series of extensions. Depending on the cell type, they can develop into axons and/or dendrites. Like a long cable, an axon propagates incoming information to remote nerve cells; dendrites collect information from many different nerve cells with their fine branches. The separate pieces of information coming from the dendrites are computed and the result passed on to other cells via an axon. It is often the long axons that are severed when injuries occur, which means that the growth of these connecting cables is particularly significant. At the tip of a growing axon, for instance from a young nerve cell, there is a growth cone where, quite literally, everything goes on. This is home to special proteins that allow the axon to find its way to the correct partner cell among thousands of nerve cells. In addition, the growth cone contains many mitochondria, the cellular powerhouses, and parallel bundles of microtubules without which the axon could not extend. Microtubules are tiny protein tubes that lengthen the axon by means of a coordinated push forward. Thus, in our search for the brake in the cell, the microtubules seemed to be a very promising place to start our research. Perhaps it would be possible to use the microtubules to make a damaged axon grow past the stop signs.

**The Search for the Growth Brake**

When an axon in the peripheral nervous system is severed, a growth cone forms at its tip – exactly in the same way as in a young cell – and the axon grows anew. The tip of a damaged axon in the central nervous system also thickens. However, unlike the growth cone, this axonal bulb shows no inclination to grow. On the contrary: we observed that, in the weeks following the injury, the axonal retraction bulb continued to swell, but stopped moving forward to extend the axon for an indefinite period. What happens in this retraction bulb, and what prevents the axon from continuing to grow? These questions are key to understanding the growth brake in the central nervous system. For a long time, it was impossible to directly observe how the retraction bulb formed. Our research group was one of the first to attempt to get to the bottom of these fascinating questions. This was possible thanks to the great progress made in genetics in recent years, which has brought increasing numbers of new methods and analyses. For example, it recently became possible to mark individual nerve cells with green fluorescent protein (GFP). This has revolutionized neurobiology: scientists are no longer faced with a confusing array of thousands of identical nerve cells, but can precisely mark individual cells or cell components and study them. The discovery of GFP was also fortuitous for my work, as it enabled us to visualize what was happening in the retraction bulb. Thus, the microtubules in the bulb accumulate inside it, which is similar to what happens in a growth cone. With these cellular powerhouse houses on the job, it is rather unlikely that the growth stop is caused by a lack of energy. Things became really interesting, however, when we looked at the microtubules. Nor-

![Growth stop: Retraction bulbs, seen here as small green bulges, form where the nerve cells have been severed.](Image 84x456 to 319x729)

![An injured axon with microtubules in an orderly arrangement continues to grow (top), unlike one with its microtubules in disarray (bottom).](Image 329x455 to 563x730)
short time, we have found out a great deal about what happens in the axonal retraction bulb. We also now know one of the reasons why damaged axons in the central nervous system do not continue to grow. The next steps are to find out whether Taxol works in the same way in living organisms. We also need to find the correct dosage and a way of administering it. Too much Taxol suppresses the dynamics of the microtubules so that axons cannot grow properly. These problems need to be resolved, first in the laboratory and then in clinical studies.

However, I believe that, in the long term, microtubule stabilization is a promising approach to improving regeneration of axons in the central nervous system. Nevertheless, there are still many open questions, and it will take years before medicine will be able to heal paraplegia. The impact of other factors, such as nerve scar tissue, is still unknown. This nerve tissue initially protects the cells from further injury, but it also forms a barrier that prevents the regrowth of the cells. How to reduce this scar tissue and how to make the nerve cells not only ignore the growth stop signs but also break through the scar barrier are some of the questions we will be looking at next.

**Dr. Frank Bradke**, 38, studies the intrinsic cellular mechanisms that govern axonal growth. Together with his group, he characterizes the growth and the growth-inhibitory mechanisms in axons during nerve cell development, in the hope of being able to stimulate damaged nerve cells in the spinal cord into regrowth. He has headed the Independent Junior Research Group “Axonal Growth and Regeneration” at the Max Planck Institute of Neurobiology since 2003.

**Dr. Stefanie Merker**, 35, studied biology and researched the life of army ants and their insect guests for her doctoral thesis. While working with various museums, she discovered her enthusiasm for public relations work. As an “interpreter of science for the rest of the world,” she has been helping the public since 2007 to understand and appreciate the research undertaken at the Max Planck Institute of Neurobiology.
The notion that genetic engineering is mankind’s invention is misguided: even the bacterium A. tumefaciens has been known of genetic manipulation since 1885. Jeff Schell and his colleagues at the Max Planck Institute for Plant Breeding Research in Cologne were the first to appreciate that the cells already carry the instruction for uncontrolled cancerous growth. When Schell and his colleagues at the Max Planck Institute for Plant Breeding Research in Cologne discovered genetic manipulation by bacteria, and these bacteria were killed off by an antibiotic the day after the infection, the cancer continues to grow. It appears that the cells already carry the instruction for uncontrolled growth at that stage, and pass this on to their daughter cells. When the researchers examined the cancer cell cultures more closely, they discovered that these cells contained plasmids that met the bacterial parasites’ requirements for nitrogen, carbon and energy. It appeared that they forced the plants to produce these substances – in other words, they were able to alter the plants’ metabolism to produce bacteria-specific nutrients, in effect subjecting the genes to a kind of conscription. The mechanism that turns a normal cell into a tumorous one remains a mystery for some time until the research groups led by Jeff Schell and his colleague Marc von Montagu discovered large quantities of plasmids, ring-shaped DNA sections usually found only in the cell nucleus, in the bacteria responsible for the tumors. Such plasmids contain the genetic information that controls some of the cell processes, and can leave their original cells and enter into other cells.

The researchers in Cologne used the micro organism Agrobacterium tumefaciens as genetic engineering tool for potatoes, tobacco and wheat. Schell took the first successful step toward making his idea a reality in 1983: for the first time, he used the bacteria to transfer individual genes to the cells of higher plants, creating plants that could reproduce. He initially managed to create transgenic plants that were resistant to antibiotics. Some time later, plant pathogens from across the globe achieved further successes: they altered plants such that they were better equipped to protect against fungicides, viral infection or viral diseases. Genetically modified plants were later trialed in field tests. Schell said that there was no risk that these kinds of experiments would have unforeseen environmental consequences, a view now shared by most experts. Individual genes are also sometimes transferred to a plant in nature, even across species types. Schell also opposed the view that plants that are cultivated using genetic engineering and that are resistant to chemicals could foster uncontrollable growth in plants. In fact, the method would enable the development of environmentally friendly herbicides that specifically kill only plant organs and break down in the soil into completely harmless products.

Jeff Schell’s discovery of Agrobacterium tumefaciens makes him one of the pioneers of green genetic engineering. He has received various prestigious awards. He attained major scientific recognition when he was awarded the highly regarded Japan Prize in 1998. However, Schell’s discovery was not only celebrated, as a scandal came to light in the Cologne-based institute, sparking outrage in the research community. One of the technical assistants in Schell’s department had been falsifying results for several years.

Many of these studies had been published in leading scientific journals. Jeff Schell was never charged with scientific fraud, but it was later shown to be merely the customary honorary authorship. A committee set up by the Max Planck Society to examine the case found that Schell was blameless in all of the cases of falsification. The assistant and her group leader left the institute. Jeff Schell retired in July 2000 to pursue his hobby of sailing. However, he had little opportunity to do so, as he fell ill with a neurodegenerative disease and died in April 2003.

Lukas Wimmer, Director at the Max Planck Institute of Molecular Plant Physiology in Golm, recently explained science’s position on agricultural genetic engineering in view of the global food crisis in an interview with Berliner Tageblatt. Traditional production methods yield low returns. More must be produced. In order to do so, plants must be better equipped to cope with dryness and salt and to make better use of nitrogen and phosphate.

There are many examples from India and China where small farmers have increased their crop output by growing genetically modified plants, improving their situation economically and ecologically. The danger of dependence on companies that have protected their innovations through patents does not exist in many third-world countries, as these companies have not registered their patents there. Wimmer accepted the concerns of some critics that the genes of genetically modified plants could spread to other plants if they were plants normally pollinated. To prevent this from occurring, hybridized with related wild plants is also possible in principle. However, corn has no such relatives in Germany, and neither do potatoes, tomatoes or soybeans. This may mean that the promise of increased plant yields in developing countries is not as likely to be lower than with plants produced using traditional methods.
Beauty was the topic tackled by the participants at the 12th Berlin Colloquium of the Gottlieb Daimler and Karl Benz Foundation. “Is beauty measurable?” was the question explored by art historians, scholars of literature and music, car designers, mathematicians and lawyers under the direction of Wolfgang Klein, Director of the Max Planck Institute for Psycholinguistics.

Art lovers generally consider Botticelli’s Venus to be beautiful. However, opinions differ considerably when it comes to other works of art, as aesthetic judgments can be at odds with each other. Value judgments vary from person to person, and are bound to fashions and eras, which may explain why they seem to persistently elude sound scientific analysis. “It is no coincidence that science shies away from matters concerning values and value judgments,” said Wolfgang Klein, Director at the Max Planck Institute for Psycholinguistics, who chaired the conference on the question of whether beauty is measurable. “A colloquium like this is an excellent opportunity to examine this issue.”

Aesthetic value judgments are relative – the example of Botticelli’s Venus and the Venus of Willendorf from the Paleolithic Age makes this all too clear. Both embody the ideal of beauty of their times, but do not necessarily meet modern ideals.
In addressing the question of the measurement of beauty, the Berlin-based gathering of experts that met at the Academy of the Konrad Adenauer Foundation was in very good company and in keeping with a long and fine tradition. The search for the formula of beauty pervades the cultural history of man. Since ancient times, philosophers and artists have endeavored to solve this mystery using numbers, units of measurement and proportional ratios. Time and time again they came up with the ideal ratio of proportions, only to discard them again later.

However, there are now very different motives for the search, as the issues raised in Berlin reveal: for example, how does a car designer go about attracting buyers to his vehicle? How does a leading judge pass a verdict on the artistic merit of a composition? What lies at the heart of these issues raised in Berlin reveal: for example, how does a car designer go about attracting buyers to his vehicle? How does a leading judge pass a verdict on the artistic merit of a composition? What lies at the heart of these issues? Of beauty and its measurability is, in many ways, related to the interplay between man, the environment and technology – the foundation’s pro-fessed main area of interest for more than 20 years. “The more we know about what lies at the heart of these aesthetic consequences, the stronger the impact on the shaping of our environment through architecture, town planning, landscaping and product design.”

However, practical a general standard for beauty might be, and despite great endeavor, no satisfactory result has yet been produced as a generally applicable, timeless beauty formula. The golden ratio, body mass index and 90-60-90 (36-24-36) as the ideal measurements for the female figure are fine efforts in this respect, but they do not hold as normative specifications.

Max Planck researcher Wolfgang Klein believes that the failure to find the standard of beauty is not because this formula does not exist, but rather strictly because the right approach has not been used. “What has been lacking so far is an empirical analysis of aesthetic properties – that is, the search for arguments that establish an object’s aesthetic value scientifically – just as with physical laws that govern other natural phenomena.”

As an example, he cited the study of literature, which deals, among other things, with works that many consider beautiful. Goethe’s Faust and Rilke’s The Panther are typical examples. “I have often thought about how empirically proven methods could be used to tackle the problems of aesthetics – whether in literature or other forms of expression. I think there are a lot of possibilities here,” says Klein.

But in order to fathom the design principle of beauty, the humanities would have to narrow their focus. “They usually focus on great and complex works,” explained Wolfgang Klein. “Here, however, you have to begin small and not try to immediately explain why Goethe’s Marienbad Elegy, Beethoven’s piano sonata Appassionata or Rembrandt’s Night Watch are considered beautiful by scores of people, but not by all.”

**COURAGE TO TAKE THE LONG ROAD TO KNOWLEDGE**

Using the simplest possible texts, sound sequences and forms, one must “see how the principles apply.” However, this method, as with any empirical science that deals with variable occurrences, is “labo-rious, tedious and dull” – and thus exactly what “many scholars and academics working in the humanities do not like doing,” says Klein.

“But this is the only way to establish which factors and rules deter-
mine our aesthetic judgment.” This requires that scholars in the arts have the “courage to take the long road to knowledge.”

Ulrich Konrad from the Institute of Music at the University of Würzburg showed what form this empirical approach might take in the humanities using short extracts from Verdi’s La Traviata. He painstakingly analyzed the phenotype of the “beautiful sections” in the music, going over it bar by bar, and scrutinizing chords, metrically unstressed moments, strict regularity and other compositional elements of these sections that spark goose bumps – that is, that pleasant shower of emotion that manifests itself in an increased heart rate and changes in skin conductance that can be recorded with measuring equipment. Ultimately, however, even Ulrich Konrad was unable to explain what the mysterious formula of aesthetics might look like.

Klein claimed that empirical procedures were particularly well suited to imprecise or variable areas of research – and that is exactly what characterizes the aesthetic questions that he aims to address and resolve using the meticulousness of science. “It’s no coincidence that the phrase de gustibus non est disputandum – there’s no disputing taste – was often heard during discussions over whether something was beautiful or not.” He was referring here to the customary rhetorical restraint shown in controversial aesthetic matters. This contributes little to resolving the question in individual cases, but it does indicate something characteristic: the great relativity of opinions.

AESTHETICS IN THE LAB

Beauty is also just one of many aesthetic qualities that may distinguish a work of art or an item of everyday use, and have a certain effect on the recipients. Klein wants to examine these relationships using empirical methods: “Using objectively defined methods, we have to attempt to explain why a text has a certain impact on people, also with objectively defined characteristics.”

Hans-Dieter Futschik was quick to agree that aesthetic evaluation involves a complex combination of individual factors. As Director of Design at Daimler AG, he is responsible for ensuring that drivers find the cars he designs attractive – and that they purchase them. “Why people find a car attractive can be explained by the interaction of various aesthetic qualities and other factors that go beyond the object’s form.”

To determine what appeals to potential customers, the Daimler designers rely on just these empirical aesthetics, using various measurement methods to analyze the emotional impact of cars. Futschik explained that the findings of design studies also play a part in automotive design. However, the most important impulses for them are the results obtained from car clinics – test laboratories where trial participants evaluate car models prior to market launch. “These judgments clearly depend on a number of different aesthetic and social characteristics of the car that have a subconscious effect on the observer,” said Futschik, summing up numerous test analyses. Most people react to car models in the same way they do to works of art – directly, intuitively and with clear value judgments, such as “I like it” or “I don’t like it.”

The formula for beauty, the implementation of which would inevitably trigger great enthusiasm in customiers, would be the Holy Grail – and not only for designers like Hans-Dieter Futschik. Countless others from various professional groups would know just how to put it to best use. For example, it would also be in great demand with lawyers, according to legal expert Haimo Schack from the University of Kiel during his presentation. “Passing judgment on beauty” has caused a real conundrum for some judges, who usually have the task of applying clearly defined norms to a case.

“The more clearly defined the legal norm, the lower the risk of individual judges’ subjective feelings influencing a ruling, and therefore bringing arbitrariness into the courtroom.” Significantly, words such as...
University of Berlin and head of the Berlin Zuse Institute is not searching for the most beautiful algorithms. Rather, he operates with numbers – almost literally, as one of his research groups provides support for oral and maxillofacial surgeons in planning surgery and determining the measurements for a well-proportioned face.

Before the surgeon starts to use his scalpel to correct a patient’s facial disfigurements, Deuflhard and his team calculate how the face might appear most attractive after the operation. To do this, for each patient, they must revisit the question of what constitutes a beautiful face. “Is the distribution principle of the golden ratio a code for facial beauty, or is it the seventh rule?” he asked, outlining some of the questions he has to consider. He has yet to find a formula that works for every patient, and continues his research. “I apply the knowledge of a mathematician and a physicist, and explore what the arts have to offer here.”

**FRUSTRATION FOR THE MATHEMATICIAN**

Peter Deuflhard’s aim is to establish a “catalog of criteria on which the planning of oral and maxillofacial surgery can be based.” However, neither the old art and philosophy masters nor results from the laboratories of modern science have provided him with the measurement principle he has been looking for. His contribution to the forum, therefore, was only to provide a dismantling of common beauty formulas – such as the results of research into attractiveness, which show that ordinary faces that are very symmetrical are equally appealing in both men and women. For Deuflhard, this theory concerning the attractiveness of average faces derived from psychological and aesthetic experiments offers no basis for his work.

He is not convinced by the methodology of the experiments and pointed out obvious shortcomings in their interpretation. Disillusioned, he summed up by saying: “I hold out little hope of finding the beauty formula.”

However, linguist Wolfgang Klein is not content with that. “The fact that there is a wide range of variations with a clearly established phenomenon that anyone can understand cannot be a reason for not analyzing it scientifically,” he said, coming to the conclusion that “beauty, a generic term for various aesthetic values such as charm and elegance, must therefore be empirically determinable, and also measurable to a certain extent.”

Klein believes that the time has come for establishing an exact science of beauty, but anticipates opposition from within his own ranks. He believes that particularly his proposals on the empirical study of works of beauty will meet with resistance from the humanities. Yet he still hopes to gain their support, since it is especially the academics who specialize in literature, music and art who will be needed for the empirical study of beauty, owing to their deep understanding of the subject. After all, this is all about issues that are of no little social importance: “If it were not possible to discuss matters of aesthetic judgment rationally, we would no longer need any music, culture or art critics.”

Bouw Fauns

---

**Call for Nominations**

**Max Planck Research Award 2009**

The International Research Award of the Alexander von Humboldt Foundation and the Max Planck Society

The Alexander von Humboldt Foundation and the Max Planck Society jointly confer the Max Planck Research Award on exceptionally highly-qualified German and foreign scientists. The researchers are expected to have already achieved international recognition and to continue to produce outstanding results of research. The award is endowed with 750,000 Euros. Nominations of qualified female academics are especially welcome.

On an annually-alternating basis, the call for nominations addresses areas with the natural and engineering sciences, the life sciences, and the humanities.

The Max Planck Research Award 2009 will be awarded in the area of humanities in the field of

**History and Memory.**

History and Memory has in the past two decades become an internationally visible research direction stimulating theory and empirical research equally. In its broader sense, it approaches cultures in terms of social memory, i.e. the memory of social groups and communities. In its narrower sense, it is concerned with the history of individual and collective memory, with particular reference to its production and distribution through media.

The Rectors/Presidents of the universities or research organisations to the Administrative Headquarters of the Rectors’ Conference of the Alexander von Humboldt Foundation. Direct applications by candidates themselves are not possible. The deadline for nominations is 27 October 2008.

Further information can be found at http://www.humboldt-foundation.de or at http://www.mpg.de.

---

**Max-Planck-Gesellschaft**

Majesternstraße 3, 20537 Hamburg

telephone: +49-(0)40-2108-2267

telefax: +49-(0)40-2108-2260

E-mail: mpk@mpk.mpg.de

**Alexander von Humboldt-Stiftung**

Humboldtstraße 5, 10117 Berlin

telephone: +49-(0)30-3353-107

telefax: +49-(0)30-3353-212

E-mail: leihen-orate@avh.de

---

**Max Planck Research Award 2009**

The International Research Award of the Alexander von Humboldt Foundation and the Max Planck Society

The Alexander von Humboldt Foundation and the Max Planck Society jointly confer the Max Planck Research Award on exceptionally highly-qualified German and foreign scientists. The researchers are expected to have already achieved international recognition and to continue to produce outstanding results of research in international collaboration – not least with the assistance of this award. Funding for the award is provided by the Federal Ministry of Education and Research. Every year, two research awards are conferred on internationally renowned academics. One of the awards should be given to a researcher working in Germany and the other to a researcher working abroad. As a rule, each Max Planck Research Award is endowed with 750,000 Euros. Nominations of qualified female academics are especially welcome.

On an annually-alternating basis, the call for nominations addresses areas with the natural and engineering sciences, the life sciences, and the humanities.

The Max Planck Research Award 2009 will be awarded in the area of humanities in the field of

**History and Memory.**

History and Memory has in the past two decades become an internationally visible research direction stimulating theory and empirical research equally. In its broader sense, it approaches cultures in terms of social memory, i.e. the memory of social groups and communities. In its narrower sense, it is concerned with the history of individual and collective memory, with particular reference to its production and distribution through media.

The Rectors/Presidents of the universities or research organisations to the Administrative Headquarters of the Rectors’ Conference of the Alexander von Humboldt Foundation. Direct applications by candidates themselves are not possible. The deadline for nominations is 27 October 2008.

Further information can be found at http://www.humboldt-foundation.de or at http://www.mpg.de.

---

**Max Planck Research Award 2009**

The International Research Award of the Alexander von Humboldt Foundation and the Max Planck Society

The Alexander von Humboldt Foundation and the Max Planck Society jointly confer the Max Planck Research Award on exceptionally highly-qualified German and foreign scientists. The researchers are expected to have already achieved international recognition and to continue to produce outstanding results of research in international collaboration – not least with the assistance of this award. Funding for the award is provided by the Federal Ministry of Education and Research. Every year, two research awards are conferred on internationally renowned academics. One of the awards should be given to a researcher working in Germany and the other to a researcher working abroad. As a rule, each Max Planck Research Award is endowed with 750,000 Euros. Nominations of qualified female academics are especially welcome.

On an annually-alternating basis, the call for nominations addresses areas with the natural and engineering sciences, the life sciences, and the humanities.

The Max Planck Research Award 2009 will be awarded in the area of humanities in the field of

**History and Memory.**

History and Memory has in the past two decades become an internationally visible research direction stimulating theory and empirical research equally. In its broader sense, it approaches cultures in terms of social memory, i.e. the memory of social groups and communities. In its narrower sense, it is concerned with the history of individual and collective memory, with particular reference to its production and distribution through media.

The Rectors/Presidents of the universities or research organisations to the Administrative Headquarters of the Rectors’ Conference of the Alexander von Humboldt Foundation. Direct applications by candidates themselves are not possible. The deadline for nominations is 27 October 2008.

Further information can be found at http://www.humboldt-foundation.de or at http://www.mpg.de.
A ccording to the 2007 report by Germany’s Federal Office for the Protection of the Constitution, the number of right-wing extremists prepared to resort to violence has stabilized, albeit at a high level of around 10,000 individuals. “There is absolutely no cause to relax our vigilance,” says Martin Brandenstein, pointing to a circumstance that is often overlooked: “The fact that the development of right-wing extremism behind our prison doors has thus far been neglected by researchers means that particularly our juvenile detention centers are increasingly populated by a group of prisoners we know virtually nothing about.”

Martin Brandenstein has been working as a staff member in the Criminological Department of the Max Planck Institute for Foreign and International Criminal Law in Freiburg im Breisgau since December 2004. While at the university – he first studied psychology, and later law, as well – he specialized in aspects of clinical and forensic psychology. Many of the results of this work have found their way into his dissertation, which he expects to complete soon.

To obtain information, he developed an interview technique through which to investigate changes in identity, self-perception, adherence to right-wing extremist beliefs and groups, and the propensity for violence among young offenders in the course of their imprisonment. The object was that the prisoners themselves should supply the answers – but for that to happen, Brandenstein first had to find them. Describing the problems he faced in starting his research, he explained: “The fact that there was a xenophobic background to an offense won’t necessarily appear in the case files.”

He finally located the offenders he was looking for by examining the characteristics of their victims. “I looked at who was most likely to be targeted – foreigners, homosexuals, the homeless, junkies, punks, members of the left.” Typically, this form of violence is inflicted on those who the perpetrators identify as belonging to a minority group. “Even though there were times when the motive for the attack was not unambiguously xenophobic, this victim-based approach proved to be an ideal way of exploring the complexity and gray areas of xenophobic violence,” Brandenstein explains.

The random nature of the violence, the haphazard chance that it should have been inflicted on a particular person in a particular place – for Brandenstein, these are important indicators: “Perpetrator and victim would have had little or no personal connection with one another prior to the event. The victim simply had the misfortune to be in the wrong place at the wrong time.”

For his study, Brandenstein singled out young offenders who were serving their first term behind bars and who had been in prison for no more than six weeks when the interviews began. “That was important because I wanted the developments I recorded to be, as far as possible, the product of the new imprisonment situation faced by the offenders, not of their past experiences behind bars.”

He managed to find 11 juvenile inmates who met his strict criteria and were willing to take part. Brandenstein met them twice in prison, once shortly after their arrival, and again seven to nine months later. For comparison purposes, he interviewed two other groups of juveniles: 10 serving time for crimes of violence without a right-wing background and 16 who had been arrested for acts of xenophobic violence but had merely been put on probation.

With the aid of the first group, he wanted to compare the extent to which a xenophobic propensity to violence develops differently from its non-xenophobic counterpart. His preparatory research had indicated that xenophobia and a disposition toward violence do not necessarily go hand in hand. “Not least because xenophobia comes in many guises,” he discovered.

With the second group, those guilty of xenophobic violence but not behind bars, he investigated whether the changes that took place in prison were necessarily attributable to the effects of imprisonment per se, or whether conviction for a crime of violence was, in itself, sufficient to prompt a change in attitude or disposition.

“Unlucky to be in the wrong place.”

Hatred Behind Bars
It was with mixed feelings that Brandenstein approached his first meeting with the young inmates. “At the time, I seriously wondered how it would go,” he remembers. It wasn’t exactly a group of choirboys waiting for him in the prison visiting room. “By the time one of these teens ends up in jail, he most likely has quite a career behind him.” He was prepared to draw the answers out of his interviewees bit by bit, if need be. In most cases, however, it was not resentment he encountered, but an astonishing openness. “I had the impression that most of them were glad that someone was interested in them and willing to listen to them,” he states.

In order to discover how a stretch of time in prison affects young people, Brandenstein first had to answer a more fundamental question. His opening strategy was thus to discover the extent to which offences committed right-wing extremists who used violence for its own sake, because they enjoy getting into a fight – much like we see with hooligans.”

The processes involved in psychological development play into the hands of the extreme right in other respects, as well. Another typical feature of the time between childhood and adulthood is the search for an identity. The pluralism of our postmodern society does not make this search any easier, says Brandenstein: “Our present age is characterized by a steadily diversifying range of accepted takes on life.” In the process, individual values and ideas of accepted standards are becoming increasingly relative, leading in turn to a loss of security. This makes it substantially more difficult for young people to develop an identity of their own – a dilemma that can exert huge psychological pressure.

As a result, some adolescents attempt to establish and maintain an identity of strength and power by committing acts of violence. The emotional turmoil they experience in this phase of their development makes them susceptible to bombastic propaganda with pithy slogans. The hard right offers a strong attraction because its ideology simplifies the search for an identity. The plurality of our postmodern society does not make this search any easier, says Brandenstein: “Our present age is characterized by a steadily diversifying range of accepted takes on life.” In the process, individual values and ideas of accepted standards are becoming increasingly relative, leading in turn to a loss of security. This makes it substantially more difficult for young people to develop an identity of their own – a dilemma that can exert huge psychological pressure.

Violence and right-wing ideology simplify the search for an identity. "We were frequently surprised," says Brandenstein. "In many cases, we couldn’t be sure whether xenophobia was really a cause." One adolescent, for instance, related that, on the outside, he had been on quite good terms with a foreigner. But then, one day, he and his buddies passed the guy in the street and went after him. It was just the foreign guy’s bad luck.

For a psychologist, such contradictions between words and deeds are very revealing. They give an indication of the state of development of the individual concerned, since humans in specific development phases, such as puberty and adolescence, exhibit a greater propensity for aggressive behavior. According to Brandenstein, for a psychologist, such contradictions between words and deeds are very revealing. They give an indication of the state of development of the individual concerned, since humans in specific development phases, such as puberty and adolescence, exhibit a greater propensity for aggressive behavior. According to Brandenstein, acts of xenophobic violence are often committed by teens in order to let off steam. "In those cases, right-wing extremism serves as more of a smoke-screen for violence for its own sake, because they enjoy getting into a fight – much like we see with hooligans.”

Processes involved in psychological development play into the hands of the extreme right in other respects, as well. Another typical feature of the time between childhood and adulthood is the search for an identity. The plurality of our postmodern society does not make this search any easier, says Brandenstein: “Our present age is characterized by a steadily diversifying range of accepted takes on life.” In the process, individual values and ideas of accepted standards are becoming increasingly relative, leading in turn to a loss of security. This makes it substantially more difficult for young people to develop an identity of their own – a dilemma that can exert huge psychological pressure.

As a result, some adolescents attempt to establish and maintain an identity of strength and power by committing acts of violence. The emotional turmoil they experience in this phase of their development makes them susceptible to bombastic propaganda with pithy slogans. The hard right offers a strong attraction because its ideology simplifies the search for an identity. The plurality of our postmodern society does not make this search any easier, says Brandenstein: “Our present age is characterized by a steadily diversifying range of accepted takes on life.” In the process, individual values and ideas of accepted standards are becoming increasingly relative, leading in turn to a loss of security. This makes it substantially more difficult for young people to develop an identity of their own – a dilemma that can exert huge psychological pressure.

As a result, some adolescents attempt to establish and maintain an identity of strength and power by committing acts of violence. The emotional turmoil they experience in this phase of their development makes them susceptible to bombastic propaganda with pithy slogans. The hard right offers a strong attraction because its ideology simplifies the search for an identity. The plurality of our postmodern society does not make this search any easier, says Brandenstein: “Our present age is characterized by a steadily diversifying range of accepted takes on life.” In the process, individual values and ideas of accepted standards are becoming increasingly relative, leading in turn to a loss of security. This makes it substantially more difficult for young people to develop an identity of their own – a dilemma that can exert huge psychological pressure.

As a result, some adolescents attempt to establish and maintain an identity of strength and power by committing acts of violence. The emotional turmoil they experience in this phase of their development makes them susceptible to bombastic propaganda with pithy slogans. The hard right offers a strong attraction because its ideology simplifies the search for an identity. The plurality of our postmodern society does not make this search any easier, says Brandenstein: “Our present age is characterized by a steadily diversifying range of accepted takes on life.” In the process, individual values and ideas of accepted standards are becoming increasingly relative, leading in turn to a loss of security. This makes it substantially more difficult for young people to develop an identity of their own – a dilemma that can exert huge psychological pressure. The plurality of our postmodern society does not make this search any easier, says Brandenstein: “Our present age is characterized by a steadily diversifying range of accepted takes on life.” In the process, individual values and ideas of accepted standards are becoming increasingly relative, leading in turn to a loss of security. This makes it substantially more difficult for young people to develop an identity of their own – a dilemma that can exert huge psychological pressure.
Ideology, too, is important in offering juveniles a means of orientation within the group environment. “Given that we are talking here of an extreme – specifically a hard-right – set of views, there is no need for young people to bother about niceties and complex shades of opinion. On the contrary, the more they simply do what is asked of them, the better,” Of no less importance are the sense of community that comes with participation in frequent group activities, and the resulting feeling of strength and recognition.

Even the clothes they wear, the quasi-uniform, gives a sense of identity. “Just their boots, their clothes or their haircuts are enough to say: I’m one of them.” The practice of talking up their own group status by denigrating other groups is another factor that distinguishes xenophobic youths from other violent types, and one that justifies it all well and good to stand authority they have, by their very presence, as a barrier to any freedoms. While being convicted by a court against one’s fundamental constitutional rights, their general attitude toward the state. “Normal” prisoners generally accept their punishment as a normal reaction to their crime. With xenophobic offenders, in contrast, the possibility cannot be excluded that they will see their punishment as unjustified and as confirmation of their criticism of the state’s ‘failure to act’.

Explaining the social climate on the inside, he continues: “It’s also very macho, lots of boasting and bragging, and they often have to physically defend themselves. The conditions are just about as unfavorable as they get.” However, while being interviewed, some of the juveniles showed themselves to be quite capable of taking a detached view of their interactions with other inmates. They would say things like: ‘It’s a real kindergarten in here.’ But still they considered it all well and good to stand up for themselves physically. If they let people take too many liberties, they got no peace.”

Similarly, the function of their violence – whether for the thrill of it – is a decisive factor in determining whether a young offender will continue to attract attention as a hard-right fighter or not. In principle, observations indicate that, in the case of all juveniles, the propensity to violence de-
Their arrest is intended to serve as educational intervention. Brandenstein notes that few, if any, of their hard-right buddies are likely to show their face. But that does not mean that their xenophobic attitudes, insofar as they are of independent importance to them, will have changed while they were inside. Contact with other young people with affiliations to right-wing organizations can also make it harder for offenders to distance themselves from the hard-right scene.

In other respects, the young people report having become calmer in prison and wanting little or nothing more to do with the hard-right scene. And for almost all juvenile inmates, the people they are most attached to, such as family members, suddenly acquire great importance. They become aware of their pursuit of ideological goals and for almost all juvenile inmates, the people they rely on. “Few, if any, of their hard-right buddies are likely to show their face,” Brandenstein notes. But that does not mean that their xenophobic attitudes, insofar as they are of independent importance to them, will have changed while they were inside. Contact with other young people with affiliations to right-wing organizations can also make it harder for offenders to distance themselves from the hard-right scene.

Meanwhile, Brandenstein has largely finished evaluating his data and his dissertation is nearing completion. The facts revealed by his empirical survey do not show the response of the criminal justice system to juvenile right-wing extremism in a particularly positive light. In any case, punishment is ineffective as a deterrent. “It presupposes that they actually give a damn. In general, that is not the case; they don’t seriously think they’ll ever be caught.” This fact alone demonstrates what effect the discussions about raising the maximum term for young offenders from 10 to 15 years are likely to have. The imposition of long terms of imprisonment may be counterproductive, but in most cases it is true to say: Where the law fails, nature succeeds.

To improve interdisciplinary cooperation, optimize scientific exchange between PhD students and strengthen team spirit, we invite you to the 7th PhDnet Meeting

November 27th-29th • Bremen • MPI for Marine Microbiology

www.phdnet.mpg.de/meetings/bremen2008 • Register online!
There are many reasons why Dirk Notz, who was recently appointed head of a research group at the Max Planck Institute for Meteorology in Hamburg, loves all questions relating to climate – one of them being the nature experience he gains on his adventure-packed expeditions to the Arctic.

The photo is an eye-catcher. The shimmering bright blue icebergs in the image hanging next to the computer in Dirk Notz’s office are a reminder of one voyage to the Arctic. He is always joining expeditions there. This is due to the nature of his research: he wants to find out what role sea ice plays in the climate system. At the Max Planck Institute for Meteorology, he was recently appointed head of a research group dedicated to just this goal.

In the northern polar region, Dirk Notz collects not only data, but also impressions of a landscape of cold beauty – as well as the occasional tale of adventure. Like this one, from the winter of 2004: Notz and four other researchers had just moved into an isolated hut on a fjord on Spitsbergen, where they were to live for two weeks. "When our oldest team member, Jamie Morison, stepped outside to brush his teeth the first day, he found himself face to face with a mama polar bear and her cub," recounts Dirk Notz. But the bears were apparently just as surprised as the sleepy researcher, and turned on their heels and galloped away.

The next day continued in the same vein – as if the participants in the expedition didn’t already have enough respect for the risks of their undertaking. "When we returned to the hut in the evening after taking our measurements, a polar bear had completely demolished the toilet door," says Notz. Dirk Notz’s ‘him’ with a trace of grim humor in his voice. However, the door to the adjacent hut, where their frozen provisions were stored, and the door to the main hut, where the bears would have found even more edibles, remained untouched. "We were just lucky that no one was sitting on the toilet right then."

Such impudence on the part of the furry visitors could almost be called ungrateful. After all, Dirk Notz and his colleagues are trying to preserve the polar bears’ habitat. A first step toward this goal is a better understanding of how quickly the Arctic sea ice is melting in the ever-warming greenhouse that is the Earth, and how its disappearance may further intensify climate change.

Measurements taken from submersibles show that the ice has become an average of 40 percent thinner since the middle of the last century – and that doesn’t even take the heavy melting of recent summers into account. And satellite images show that the area that is covered by sea ice in summer has shrunk by nearly four million square kilometers since the 1970s. That is a decrease of more than ten times the surface area of Germany. Moreover, the dark sea that peeks out from beneath the dwindling ice stores the heat of the Sun’s rays much better than the light ice, which reflects most of these rays. This speeds up the warming, and even more ice melts. "The Arctic Ocean may even become largely ice-free in summer as early as mid-century," says Dirk Notz.

Oceanic Thermal Cover in Danger

If the atmosphere heats up so much that the ice starts receding even in winter, then the ocean will also lose its insulation layer: "Currently, the sea ice still functions like a lid on the ocean, and trapped in it is a great deal of heat that usually escapes into the atmosphere. "This is because, in winter, the temperature of the salty ocean water hovers around freezing, while the temperature of the air above the sea ice frequently drops below minus 30 degrees Celsius," says the researcher. The meteorologist is working on new models to predict this development more accurately and reliably. They are expected to account better for the physics of the sea ice than is currently possible with future-climate simulations. The tools of his trade: "Mathematics is a wonderful language," says Notz, smiling. "Reducing the complexity of the world to highly precise formulas simply fascinates me."

As a meteorologist, Notz can employ mathematics in the service of the sense of responsibility he feels for the world. This attitude is also a product of his connection with nature. Dirk Notz grew up with his three sisters in a single-family house in Hamburg-Harburg, not far from a nature preserve. He often wandered through the forests there with his friends. "Sometimes we also just spent a week in a hut in the forest and smoked salmon there."

His penchant for research was also clearly noticeable in his youth, and was likely inspired by his parents. The son of a teacher and a physicist, he already had a great interest in the natural sciences at school, and discussed physical phenomena with his father. "I enjoyed school," says Dirk Notz.

Today, the meteorologist can live out both his interest in the natural sciences and his love for nature on his research trips to the North Polar Sea: "Icebergs in the morning light. Snowstorms in which you can’t even remain standing. Hot cocoa at lunchtime. Hoar frost that pours off your sleeping bag onto your face." Those are fantastic experiences, he finds. And the animal encounters are particularly impressive. With beluga whales in a glacier-enclosed lagoon, for example. "There were seabirds everywhere, and in front of this backdrop, the whales spouted jets of water into the air." Just as moving
for him was the sight of a mama polar bear teaching her two playful cubs how they might be able to catch some lunch by jumping up and down on a seal cave.

Dirk Notz enthusiastically recalls his experiences: “In their immutable way, penguins stand on the ice and watch with curiosity as the research ship passes by.” When he also vividly describes the pastel colors on the horizon hours before the Sun rises over the Polar Sea, the polar regions are very present on this summer day in Hamburg.

His first encounter with the Arctic was in 1999, when he spent a year studying Arctic oceanography and Arctic meteorology on Spitsbergen. He was almost finished with his studies in meteorology at the University of Hamburg. He originally undertook the detour to Spitsbergen purely out of curiosity, as he has also undertaken the detour to Spitsbergen during his stay on Spitsbergen, and their collaboration continues to this day.

**BRINE AFFECTS WATER CIRCULATION**

During his stay in Seattle, Notz also met his future Ph.D. advisor, Grae Worster, from the University of Cambridge. What began as a chance encounter in Seattle likewise turned into an extended collaboration that culminated in Dirk Notz transferring to Cambridge after completing his undergraduate degree, and writing his Ph.D. dissertation there from 2002 to 2005. This time, his work basically focused on thermodynamic and hydrodynamic processes in sea ice, and especially on the salt in the ice.

Unlike ice in a freshwater lake, sea ice does not form a compact block. Rather, millimeter-thin sheets form, between which brine collects. The more water freezes, the higher the salt concentration in the brine. This salt content is a key determinant of the properties of the sea ice. For example, it determines how well the ice insulates the heat of the sea.

But what is even more important for the Earth’s climate system is that a large portion of the brine that is stored between the ice sheets flows into the ocean over time. Due to no small part to this flow of highly concentrated brine, seawater in the polar regions can become so heavy that it sinks to the ocean floor. From there, it spreads throughout the world’s oceans and sets their water masses in motion. Cold water flows into warm regions, where it takes up heat, transports it to cooler areas and creates milder temperatures there. To describe this cycle and predict how it will develop under different climate conditions, climate researchers must thus calculate the salt content in the sea ice correctly.

To this end, while working on his doctorate in Cambridge, Dirk Notz created a model, together with Grae Worster. According to this model, the ice directly at the interface to the ocean ought to contain just as much salt as the seawater. However, previous measurements had always painted a different picture: they showed there was considerably less salt in the ice than in the water.

“Normally in such a case, a quote from Richard Feynman would apply,” says Dirk Notz. The American physicist once coolly remarked: “It doesn’t matter how beautiful your theory is. It doesn’t matter how smart you are. If it doesn’t agree with experiment, it’s wrong.” According to that, Notz and Worster actually should have buriel their theory, but they didn’t want to. And for good reason: The theory they used to describe the ice and saltwater system is based on principles that hold quite well in similar mixtures.

“At minus 30 degrees Celsius, we laid cables in the frozen desert, connect- ed them to generators, and typed away on our laptops with clammy fingers, all the while regularly look- ing up from our work to scan the horizon for approaching polar bear,” recounts Dirk Notz. Their efforts under these hostile conditions paid off. The measurements now matched the theoretical predictions very well.

Nevertheless, the researchers were only mildly excited. The results indicate that, in the future, the sea ice may melt even faster than previously predicted. But Notz is still cautious about issuing any ardent pleas: “The most important task of science is to deliver sound findings. Citizens and politicians must decide how to counter climate change.” But it seems that many are not yet ready for that: “Society is still in the tar- get-definition phase.”

At least the EU has already de- fined a benchmark: “Limiting warming through the end of the century to an average of two degrees is a compromise between what may still be achievable and the attempt to avert uncontrollable consequences, such as the melting of Greenland’s inland ice.”

To achieve this goal, Notz does ultimately demand political action: merely continually pointing out that such countries as the US and China also need to do their part in reducing global greenhouse gas emissions will achieve nothing. “The Earth doesn’t care where the methane or carbon dioxide comes from,” says Notz, and stresses: “Every little bit each indi- vidual can save helps.”

It is clear that he finds it difficult to completely disengage from any political impetus. And why should he? After all, he wants his not-quite-one-year-old daughter to be able to grow old on an Earth that is worth living on. Indeed, Notz doesn’t just limit himself to producing scientifically sound findings behind the scenes of the political processes. It is very important to him to also com- municate his findings to the public.

“Not a proponent of convoluted scientific formulations,” he says, and this attitude has already won him multiple prizes for understandable science, such as the Klaus Tschira Award in physics last year.

But for Dirk Notz, that alone is not enough in the way of PR work for climate change. He would like to start informing young people about the phenomenon. That is why, to- her with expedition leader Arved Fuchs, who became known through
Solstice™. The new high point in ultrafast amplifier technology and a shining example of Spectra-Physics® innovation.

The earth’s solstice has always marked a turning point. With the new Solstice™ one-box ultrafast laser, Spectra-Physics has created a turning point for femtosecond (fs) amplifier stability and reliability.

The Solstice laser is a high performance, ultra stable, one-box Ti:Sapphire ultrafast amplifier—all integrated with a small footprint so it’s ideal for use in a variety of environments.

The Solstice amplifier’s unique combination of high power, unrivaled beam quality and ruggedness makes it ideal for the most demanding scientific and industrial applications. Just as the summer solstice marks the sun’s apex, our Solstice marks the highest point in ultrafast amplifier technology.

To learn more, call us or visit us at www.newport.com/solstice7. You’ll see why our Solstice amplifier is truly a reason for celebration.

Polar research in the lab: Dirk Notz examines how quickly saltwater from the green ice cubes sinks in the warmer red water.

“We are also targeting schools in Hamburg to invite them to participate in the competition,” says Notz.

There’s no doubt that climate research and climate change are more than just a research field that Dirk Notz simply chanced to stumble upon. Nevertheless, he can also imagine himself in an entirely different profession. For example, his eyes begin to light up when he considers the possibility of becoming a science journalist. He recently proved, with an article on his research that appeared in the German science magazine BILD DER WISSENSCHAFT, that he has the requisite talent. He has already amassed enough anecdotes for articles on his polar research. In one, he can report how he and his colleagues wanted to drive the moisture out of their clothes after a snowstorm. A nice, roaring fire was to help. “Unfortunately, in the process, we also dried the ceiling of the wooden hut so well that an oil lamp on the wall set it on fire,” recounts Dirk Notz, laughing. “With an outside temperature of minus 30 degrees Celsius, that actually did generate a bit of chaos. But quick, prudent action helped us avert any overly dramatic consequences. I hope the same is possible with respect to climate change.”
The lights are on in Erlangen: The Senate of the Max Planck Society resolved at this year’s annual meeting to establish a Max Planck Institute for the Physics of Light in Erlangen, effective January 1, 2009. By the end of the projected four-year development phase, the new institute is expected to comprise four departments with a total of 111 established posts.

From flying saucers of light and atoms that soak up individual photons to the world’s sharpest focal point – these are just a few of the tricks that scientists at the future Max Planck Institute for the Physics of Light have either already mastered or will soon be working on. They will be developing and using new optical structures, such as photonic crystals that reflect specific...
colors of light, and plasmonic ma-
terials in which light and charge
carriers interact with one another
in new ways. They will also be
studying metamaterials with un-
usual properties.

The research is a product of the
Max Planck Research Group for
Optics, Information and Photonics,
headquartered in Erlangen. It has
been based at the Friedrich Alex-
ander University of Erlangen-Nuremberg
(FAU). The institute’s founding
Directors, Gerd Leuchs and Philip St. John
Russell, come from the same
source. Both scientists have been
studying the basic phenomena of
the physics of light since 2004.
“This work will help shape the
future of information processing and
data transfer,” commented Max
Planck Society President Peter
Gruss.

Leuchs will head the Department
of Optics and Information that will
study the field of optics from the
macroscopic to the nanoscopic.
Under the auspices of the FAU, research-
ers already succeeded in focusing a laser
three times more sharply than ever before— an achieve-
ment that will contribute to the design of more
compact optical data memories and improve the
precision of the lithographic structures used in
electronic components.

An important tool scientists use for this is a ra-
dial polarizer, which filters the electromagnetic
field of light at right angles to the laser beam.
This causes the field in the beam’s center to dis-
appear, leaving only a ring of light, much like a
moon. This “butterfly ring” of the non-laser light is then gathered
into the focus of a lens, the ring field is super-
posed upon itself, creating a particularly small fo-
cal point.

The Department of Photonics and New Mate-
rials, headed by Philip St. John Russell, will study
the behavior of light in hollow fibers com-
posed of photonic crystals (PCFs). Fibers like these
confine and conduct light with extremely low lo-
sses. PCs are also solid with a core that is particu-
larly well-suited to converting light from one
color to another, a property utilized, for example,
by Thodor Hänsch, winner of the Nobel
Prize for Physics and Director at the Max
Planck Institute for Quantum Optics, to split laser light
into a frequency comb.

Russell, who first developed these fibers, has
great plans for the future: for example, he hopes to
use hollow waveguides to develop sensors
for medical use. By passing samples through the hol-
low fiber core and illuminating them with a laser
beam, it is possible to detect tiny quantities of
molecules thanks to the particular quality
of this laser light. He also plans to send “flying saucers”
through the fibers—albeit saucers of light. Using a nanometer-scale
network of fibers in the core of a PCF, the idea is to create packets
of light that, unlike conventional puls-
es, do not gradually spread apart, and thus
have unusual properties.

The institute’s new Department of Nanophotonics and Plasmonics
will study photonics ab initio and metamaterials, which, in contrast
to all natural materials, can have a negative index of refraction.
The scientists who will soon staff this department will use these charac-
teristics to investigate how light interacts with plasmons. Plasmons
are fluctuations in the electron density in metals. An improved
understanding of how they inter-
act with light could help in the
construction of sensitive micro-
scopes capable of scanning a sur-
face simultaneously with both
electrons and light. If the scien-
tists were to succeed in bringing plasmons under
control, they might possibly soon be able to de-
sign new types of microscopes.

The theoretical study of these phenomena is one of the tasks allotted to
the fourth depart-
ment, Theory of Light, which is likewise currently
being developed. This department will seek to cre-
ate new models for processes in nanostructure
materials. Methods that are fine for recording
macroscopic systems are too imprecise on
this scale. However, the scientists will also be
working to describe non-linear phenomena that
may aid in the development of a type of optical
invisibility cloak. In addition, the department
will also conduct research into relativistic effects in
the field of optics.

The planned institute will fit neatly into a net-
work of other Max Planck Institutes whose re-
search fields it both touches on and complements.
For example, plans are underway to cooperate
with the MPI for Quantum Optics in Garching in
a study of photonic glass fibers: Fernan Krausz
is keen to collaborate with Philip St. John Russell in
studying the spectral characteristics of these
fibers. The Erlangen-based physicists may also join
the MPI for Solid State Research in Stuttgart
in investigating the optical properties of semicon-
ductors, or it may work with the MPI for Micro-
structure Physics in Halle on the development
of novel micro-nanostructures that have inter-
esting optical characteristics, or perhaps with
the MPI for Biophysical Chemistry to develop new
methods of microscopy.
LINDA PARTRIDGE AND JAMES W. VAUPEL ON RESEARCH INTO AGING

“We learn a lot from one another”

Despite the fact that aging seems to be inevitable, some species have found a way to delay or even put off the aging process. Can we actually understand these exciting findings? What determines aging? Why are there differences between individual species and what role do cells play in this? On the island of Rügen recently, MaxNetAging (the Max Planck Society research network dedicated to aging) held a conference on the biology of aging. One of the speakers at the conference, geneticist Linda Partridge, who is also a Director at the newly established Max Planck Institute for the Biology of Aging, in Cologne represents the state of the art in its field. How will you and your co-directors be approaching the subject in the future?

PARTRIDGE: The institute will concentrate on the basic biology of aging and carry out interpretative work in association with the University of Cologne, between whose University Clinics the institute is located. The object is to use animal models as a means to understand the process of human aging. There are now clear indications that the mechanisms of aging have been preserved over vast evolutionary distances, and that intervention in the aging process itself is of decisive importance in avoiding age-related illnesses.

MPR: Professor Vaupel, age research has become an important topic in almost every discipline. The latest MaxNetAging seminar on the “biology of aging for non-biologists” was attended by cell biologists, as well as by researchers working in biodemographics, psychologists, historians and anthropologists, among others. How does MaxNetAging manage to reconcile these differing fields?

JAMES W. VAUPEL: Aging is a very complex process. In order to understand aging and help people enjoy a long and healthy life, and also to support society in coping with the consequences of an aging population, it is essential for our research to include many disciplines. That is, after all, why the Max Planck Society set up MaxNetAging. We have members working at 14 different Max Planck Institutes where they represent an even wider spectrum of research fields. We aim to encourage communication and cooperation in age research and provide the Max Planck Institutes with an opportunity to collaborate with one another. MaxNetAging has also initiated a doctoral program that allows young scientists at an early stage in their careers to benefit from a broad-based interdisciplinary outlook on aging. Each doctoral student has ties to one Max Planck Institute or another that participates in MaxNetAging. Over and beyond their interdisciplinary educational activities, the students remain in close contact with their scientific mentors and their own institutes, to which they later return after an initial period in Røstok. After all, any meaningful interdisciplinary research must build on the knowledge acquired in their original subject area. Overall, MaxNetAging has been very successful.

MPR: Con can quote an example of meaningful interdisciplinary cooperation?

PARTRIDGE: Let me give you an example of how it works. At the conference, we had an inspiring discussion with a young researcher, Annette Bau- disch. Her doctoral work has been supported by both James Vaupel and me, and includes aspects of biology, mathematics, economics and demography. This interdisciplinary approach was made possible thanks to her background in mathematics, economics and this interdisciplinary approach helped her familiarize herself with demographic methods and demographic thinking, and the interdisciplinary approach was thus essential if we were able to study one of the fundamental issues in biology – namely why we age.

MPR: To what extent do you regard the conference on the “biology of aging for non-biologists” as a success for MaxNetAging?

VAUPEL: One of the leading theorists on the evolution of aging, Thomas Kirkwood from Newcastle, gave a presentation. Other speakers included Adam Antebi, Nilis-Goran Larsson and Linda Partridge, the three new Directors at the Max Planck Institute for the Biology of Aging. These scientists are leaders in their field, at the cutting edge of research. The two Senior Fellows at MaxNetAging, Ursula M. Staudinger and Jean-Jacques Hublin, reflected on the biology of aging from the perspective of other disciplines. Another idea in MaxNetAging is that leading experts in their field meet young investigators specializing in aging research. In this respect, Annette Baudisch and Sebastian Jesberger made a substantial contribution to a high-level discussion on the research agenda for biologists with regard to age research.

We were able to learn a great deal not just from flies, worms and mice, but also from one another!

MPR: What were the most important messages to emerge from the conference?

PARTRIDGE: The increasing life expectancy of populations worldwide has far-reaching effects on legislation, the economy and architecture, as well as on biology and medicine, of course. An interdisciplinary approach is thus essential if we are to encourage communication between researchers in diverse fields.

MPR: What does the future hold for MaxNetAging?

VAUPEL: We are delighted that MaxNetAging has caught the attention of so many leading institutes working in the social sciences and humanities. Since the conference, I have had the impression that it would be well worthwhile to expand our interdisciplinary approach still further to include interested colleagues in the humanities, such as historians and anthropologists, and from the Max Planck Society’s technical institutes. Without a doubt, organizing a network on this scale will present a challenge. But MaxNetAging and the Max Planck Society have plenty of positive experience with interdisciplinary projects. We have a shared interest and a series of questions that will prompt comparisons and a stimulating dialogue between disciplines. I am highly optimistic that the broad-based interdisciplinary approach adopted by MaxNetAging will lead to some lively discussions, as well as to innovative research.
In its search for innovative drug treatments, the Lead Discovery Center GmbH is expected to break new ground in the fight against cancer, diabetes and heart disease. The latest off- shoot of Max Planck Innovation GmbH has now set up shop in Dortmund. The LDC is an important element in the Drug Development Center pioneered by Max Planck Innovation GmbH, which has already been awarded the high-profile IPTEC Prize for its contribution to the development of technology transfer in the public sector.

For the first time, we can now select the best projects being undertaken in basic research, and develop these through to initial proof-of-concept without subject to the usual constraints imposed by the capital markets,” said Joachim G. Heilig, General Manager of Lead Discovery Center GmbH. The investment horizon for the capital investors is “typically on the short side, and the standard models used to assess prospective risks and rewards are just not applicable to early-stage projects,” he added. “That’s why, in recent years, we have seen lots of fantastic projects come to nothing – irrespective of the potential for commercial potential. The new sustainable approach adopted by the LDC will help make the critical early stage in drug development more lucrative.”

Based on research results that offer new potential prospects for the specific use of substances for treatment purposes, the LDC team of experienced drug developers, scientists and project managers will identify chemical ingredients and formulate technology transfer experts to develop new ground in drug development. “We are delighted to receive this award in recognition of our commitment to professional technology transfer,” said Dr. Christian Stein-Gerlach, General Manager of Max Planck Innovation. “More than 30 years of technology transfer for the Max Planck Society have thus far demonstrated that the basic research has the potential to yield pioneering discoveries that can change our lives.”

Some familiar examples of successful technology transfer projects include the FLASH technology that has revolutionized magnetic nuclear spin tomography, the new cancer drug Sutent® and RNA interference technology, which is used to study the functions of genes, but could also lead to a new class of drugs. Overall, Max Planck Innovation has thus far handled more than 2,800 inventions, concluded over 1,700 licensing agreements and supported numerous spin-offs.”

“We have also learned that it takes a lot of patience and persistence to convert inventions into economically and socially useful products,” Stein-Gerlach added. For that reason, it remains a challenge to work jointly with investors, industry representatives and technology transfer experts to develop new models that will help close the oft-cited innovation gap between early-stage research and industrial application.

More than 10,000 young detectives took part in this year’s research competition. They investigated the alarm signals employed by plants, spied out deadly bioweapons and revealed who is responsible for the death of nerve cells. Under the motto “Long live curiosity,” this year’s 43rd annual junior research contest reached a climax in May, when 190 young investigators assembled for the final round in Bremenhaven, where there were awards to be won in seven disciplines, as well as special prizes. The Max Planck Society donated all of the prizes in the biology division.

“I was impressed with the deep insights and experimental skills the young people displayed – not to mention their enthusiasm and originality,” said Peter Fulde, Director of the Max Planck Institute for the Physics of Complex Systems in Dresden, who presented the biology awards.

When it comes to searching for clues, a researcher needs the same “sixth sense” and creativity as any detective. And it was these talents that won Lisa Schowe and Anja Masolle from Münster the first prize in biology and an award of 1,500 euros. The two girls, aged 17 and 16, found hidden clues in the ability of an unhealthy plant to give off light. If, for example, a plant is infected by a fungus, its photosynthesis does not function properly: the plant is unable to process all of the sunlight it absorbs and emits some of it in the form of a brief glow of red fluorescence.

With the aid of this light, the national winners were able to identify damage to the plant, and invented their own equipment and computer programs to do the job. What is the most exciting case for a detective? Investigating a murder, of course – which is what won Lisa Schowe and Anja Masolle from Münster second place and another 1,500-euro award. The 18-year-old discovered why certain nerve cells in epigynous flowers die off during treatment: it is not the illness that is responsible, but the medication. And the young researcher was able to prove her case with the aid of nerve cell cultures in the laboratory. A detective’s work involves a bit of close surveillance now and again, and such observation yielded third prize, worth 1,250 euros, for Alexandra Mannig from Jena. She borrowed a technique used in dentistry and testkit it on titanium, a material from which artificial implants are frequently made. To make sure for the body to tolerate the material, the 18-year-old silanized the surface of the titanium before testing with bone and connective tissue cells to see whether the samples were compatible as a biomaterial.

The amino acids studied by Binia de Cahan and Theresa Behling from Rostock were far from compatible. The two 18-year-olds won fourth prize, worth 375 euros, for their investigations into miniaturized bioweapons. They homed in on D-amino acids. Amino acids are commonly known as a component of all proteins, the basic substance of life. The D-variant, however, can be deadly, plants, bacteria and fungi use it to repel enemies! Who would otherwise eat them. To test plant beds, the two investigators discovered that some D-amino acids are not only hazardous to animals, but can also rescue the growth of flowering tobacco seedlings.

Tracing creatures that have “gone under” is one of the easiest tasks for Maria Noske, Juliane Herzig and Svenja Rosenberger of the Carl-Friedrich-Gauss-Gymnasium in Frankfurt am Oder. They shared fifth place for that coup to do the job. They investigated the alarm signals employed by aquatic creatures that have “gone under” as an entire submerged family – a population of freshwater clams in the Oder River. The three 19-year-olds spent three years tracking the development of these river denizens. This introduced species of Asian origin was decimated by cold winters, but subsequently recovered. As a result, the trio concluded that this was a creature to keep an eye on. If the mild winters continue, a mini-invasion can be expected.

Second place went to Celia Viernmann (above) for exposing the nerve cell killers, Alexandra Mannig (right) put implants on trial to win third place.
A RESTLESS SPIRIT – A gift that echoed throughout the day: For his 80th birthday, Hans Zacher requested harp music to please his wife – a request that was fulfilled by Sophia Steckel, who provided a musical accompaniment to the celebration. Max Planck President Peter Gruss recalled the achievements of his pre-predecessor, who headed the Max Planck Society from 1990 until 1996. As a legal specialist, Zacher was the only representative of the humanities among the presidential ranks. He was also the only one to be confronted with a unique challenge: the reunification of Germany. As a first step in an immediate action program, Zacher facilitated the founding of working groups at East German universities. Between 1991 and 1998, 18 Max Planck Institutes were created in the newly-formed German federal states with impressive speed. “A certain streak of Bavarian stubbornness,” as President Gruss put it, may well have helped Zacher withstand the then-prevailing pressures. The current President also praised the judicious manner in which Zacher simultaneously implemented the program to consolidate the West German Max Planck Institutes. To this day, Hans Zacher is actively involved in research as an emeritus member of staff at the Max Planck Institute for Foreign and International Social Law in Munich.

NEW FACES IN MANAGEMENT – At its recent meeting, the Senate of the Max Planck Society elected three new Vice Presidents: representing the Chemistry, Physics and Technology Section, Martin Stratmann (Director at the Max Planck Institute for Biophysical Chemistry) and Treasurer, along with two to four additional members and the President, collectively make up the Executive Committee. Together with the General Secretary, they constitute the Management Board of the MPS.

ADOPT AND ADAPT – “Nature has a head start of many millions of years, but we’re catching up.” The work done by Robert Langer – from whose laboratory in the US this maxim originates – and Peter Fratzl in the field of biomimetics seems simple at first glance, even if it takes staying power. The two recipients of the 2008 Max Planck Research Prize are engaged in an investigation of the structures of plants and animals in order to identify specific functions that can be carried over entirely to different systems. At the prize presentation held during the Max Planck Society annual meeting in Dresden, the 59-year-old American from the Massachusetts Institute of Technology and the 49-year-old Austrian Director at the Max Planck Institute for Colloids and Interfaces offered insights into their methods. These have, particularly in the case of chemical engineer Robert Langer, already resulted in numerous products – such as a dressing that stays in place without adhesive – which have helped him withstand the then-prevailing pressures. The current President also praised the judicious manner in which Zacher simultaneously implemented the program to consolidate the West German Max Planck Institutes. To this day, Hans Zacher is actively involved in research as an emeritus member of staff at the Max Planck Institute for Foreign and International Social Law in Munich.

Research Establishments of the Max Planck Society
IN THE SPOTLIGHT

Granulocytes might also play a crucial role in chronic inflammation that is not caused by infections, and also in autoimmune diseases. This is because two of the enzymes they release also split the body’s own anti-inflammatory protein and stimulate chronic inflammation, which destroys the surrounding tissue, as is the case, for example, with rheumatic diseases. It is hoped that these findings will lead to drugs that suppress the damaging effect of the neutrophil granulocytes in chronic inflammatory processes.

**Decomposing cells:** At the site of an infection, neutrophil granulocytes (dyed yellow) move out of the blood vessels (dyed blue) into the tissue. These neutrophil granulocytes are the largest group of white blood cells and form the front line in the defensive reactions of the immune system. They release enzymes that split proteins, causing invading pathogens to decompose and rendering them harmless. An international team working with Dieter Jenne and Kai Kessenbrock from the Max Planck Institute for Neurobiology in Martinsried has now discovered that granulocytes might also play a crucial role in chronic inflammation that is not caused by infections, and also in autoimmune diseases. This is because two of the enzymes they release also split the body’s own anti-inflammatory protein and stimulate chronic inflammation, which destroys the surrounding tissue, as is the case, for example, with rheumatic diseases. It is hoped that these findings will lead to drugs that suppress the damaging effect of the neutrophil granulocytes in chronic inflammatory processes.