

Why isn't there nothing?

Researchers
hope to solve one of the
greatest mysteries

SHARP

Revealing the shape
of proteins

SNAPPY

How plants deal
with stress

INTENSE

How rewards can
improve ADHD



Cress tests

What impact does lighting have on the growth of garden cress? This is what 11-year-old Flynn Fehre tested using three different types of lamps. He presented his results at the regional heat of the “Jugend forscht” science competition at Forschungszentrum Jülich – as one of more than 50 school students. He was awarded third place in the junior category for school children. First places in the various categories went to young algae researchers, a budding astronomer, a computer specialist, and a biologist who looked at how sight changes as we grow older. Forschungszentrum Jülich has hosted the “Jugend forscht” competition for the last fifteen years. This year marked the fiftieth anniversary of the competition.

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Clear the ring!

Why is nothing not nothing? Let's be honest, a normal person probably wouldn't ask this question – but for particle physicists, it's one of the biggest mysteries. For them, theoretically matter shouldn't exist at all. Matter and antimatter should have completely annihilated each other after the Big Bang. But there's no denying it: the universe, the Earth, living beings – they're all matter.

One possible explanation is that somewhere in the far reaches of the universe – still undiscovered – the same quantity of antimatter exists. This is what the accepted laws of physics postulate. The Alpha Magnetic Spectrometer on the International Space Station (ISS) is searching for traces of this antimatter in outer space and will continue to do so until at least 2020. Our scientists are also involved in this project together with researchers at RWTH Aachen University via the JARA-FAME research alliance.

However, Jülich researchers are also considering a second possibility that our knowledge of the accepted laws of physics is incomplete and must be extended. But first, they have to find evidence supporting this theory. How the Jülich scientists intend to provide this evidence is what the cover story of this issue is all about: clear the ring for protons and unrivalled precision!

We hope you enjoy this issue!

Your *effzett* editorial team



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PHYSICS

Sticking power

Geckos' feet can stick to even the smoothest and most vertical of surfaces. This is possible because of the van der Waals forces, which act like a quantum glue on all types of matter.

All of the key details of how strongly these forces bind single molecules to a surface have been determined experimentally for the first time by Jülich researchers.

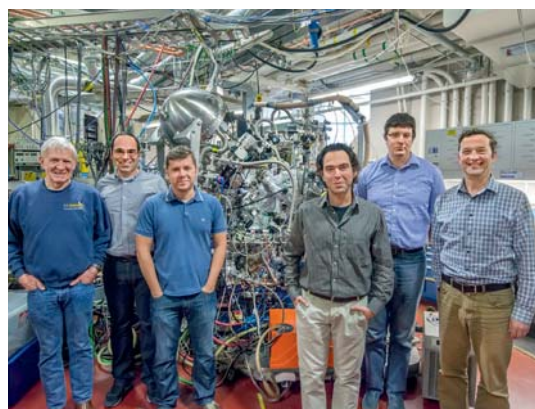
– PETER GRÜNBERG INSTITUTE –

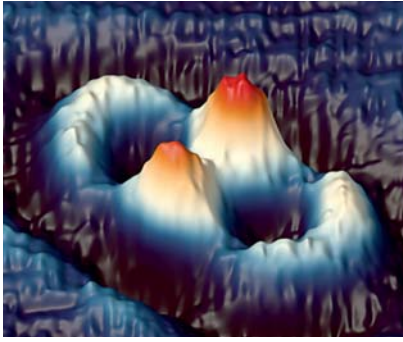
MATERIALS SCIENCE

A look at interfaces

A German-American research team (photo) has developed a new method for a more accurate analysis of chemical processes at interfaces. This enables researchers to analyse the interaction between electrolytes and electrodes in batteries with subnanometre precision – and thus develop more effective batteries as well as fuel cells and photovoltaic cells. Their new technique is a combination of two common methods used in X-ray spectroscopy which were conventionally applied independently of each other: ambient pressure X-ray photoelectron spectroscopy and standing waves.

– PETER GRÜNBERG INSTITUTE –





NANOELECTRONICS

Guests in metal

Embedded foreign atoms alter the properties of metals more than was previously thought. Jülich researchers verified this for two systems at low temperatures. With their colleagues in Göttingen, they introduced magnetic iron atoms into non-magnetic copper. All around the “iron guests”, the order of the electrons changed (image) – and so too did the electrical resistance. This “Kondo effect” reached ten times farther than was previously thought. In another project, they selectively altered variations in electron density – referred to as Friedel oscillations. Computer simulations of oxygen atoms in iron demonstrated that the density of the iron layer extended the range of the oscillations. Both findings can be used for new nanoelectronic components.

– PETER GRÜNBERG INSTITUTE –

BIOLOGY

Starting Grants awarded

Two scientists from Jülich have been awarded a Starting Grant by the European Research Council (ERC). Each grant is worth more than one million euros in funding. Microbiologist Dr. Jan Marienhagen (photo, left) will use his funding of € 1.5 million to customize biosensors for the detection of particularly efficient bacterial strains. Up to now, this was a difficult and expensive process. Biochemist Dr. Pitter Huesgen (photo, right) was awarded € 1.8 million for his research on proteolysis, a metabolic process in plants. He is investigating how this process helps plants to deal with stress, such as bacterial infection or strong light (see p. 14).

– INSTITUTE OF BIO- AND GEOSCIENCES –

– CENTRAL INSTITUTE OF ENGINEERING, ELECTRONICS AND ANALYTICS –



Bringing things to light

Jülich researchers were the first to directly examine the propagation of light trapped in solar cells. In the past, this was only possible using indirect methods. The trick?

Jülich researchers exploited the quantum mechanical tunnelling effect. When a light-conducting component is brought close to the surface, light that had been directed into the solar cell is emitted out of the solar cell. This method will accelerate the development of nanostructured light trapping in solar cells.

– INSTITUTE OF ENERGY AND CLIMATE RESEARCH –



134

million euros ...

... is the sum that Forschungszentrum Jülich will receive out of the Helmholtz Association's new research programme entitled Storage and Cross-Linked Infrastructures. The focus is on developing energy storage systems and infrastructures to integrate renewable energy – two key challenges associated with transforming the energy sector. Over the next five years, the Helmholtz Association will provide a total of € 310 million for the programme.

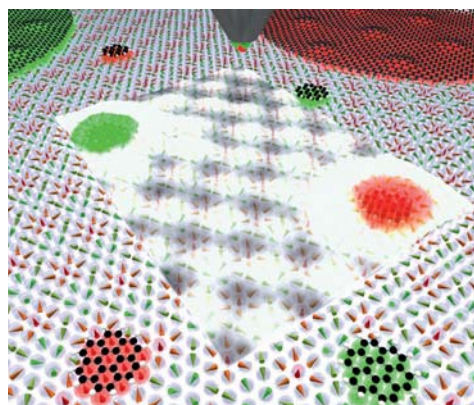
– INSTITUTE OF ENERGY AND CLIMATE RESEARCH –

MATERIALS SCIENCE

Molecules in magnetic vortices

Scientists at Jülich and Hamburg have developed a new approach for faster and more energy-efficient processors and data storage. The researchers coated organic molecules on a magnetic vortex structure known as a skyrmion lattice (image). This combination forms hybrid compounds that can be switched at will – a prerequisite for use in information technology.

– PETER GRÜNBERG INSTITUTE –



FIRST-EVER AUTHORIZATION

Switzerland is the first country to authorize the use of a radioactive amino acid developed at Jülich as a radiopharmaceutical for diagnosing brain diseases in humans. Positron emission tomography (PET) with 18F-fluoroethyl tyrosine (FET) provides important additional information on the size and metabolism of brain tumours compared to other techniques.

EXCELLENT CLIMATE PROTECTION

The climate change initiative KlimaExpo.NRW has listed the research and development of solid oxide fuel cells at Forschungszentrum Jülich as an exemplary contribution to climate protection. These activities have been integrated into its “qualified projects” which aim to promote climate protection in the federal state of North Rhine-Westphalia.

COOPERATION WITH AUSTRIA

In mid-January 2015, the new Christian Doppler Laboratory was officially opened at Jülich's Institute of Energy and Climate Research. In the lab, which is funded by the Austrian Ministry of Science, researchers are working on new fuel cells for auxiliary power supply in trucks. Cooperation partners are Austrian enterprises as well as Vienna University of Technology.

Why does the universe exist? When it came into being, matter and antimatter were created simultaneously – and they should have instantly annihilated each other. Why they did not do so is one of the greatest mysteries of physics. Jülich researchers are planning a unique experiment to solve it.

New ways of explaining the world



It all began with the Big Bang: the hot, thick energy soup thickened – and expanded faster than the speed of light. Within minutes hydrogen, helium, and traces of beryllium and lithium were formed. Our universe was born. At least, this is what physicists today imagine happened some 13.8 billion years ago. But it still remains an unsolved mystery. In the very first billionth of a second, there was a violent battle of annihilation: matter versus antimatter. For every particle of matter, a twin particle of antimatter was formed – with the same properties but a different charge. When the two collide, they annihilate each other leaving nothing behind but pure energy. Nothing should remain. Instead, planets, moons, and solar systems were formed – creating the cosmos as we know it today.

It is made up of the leftovers, the matter that remained after the annihilation. But where did this matter come from? Were unequal quantities of matter and antimatter formed after all? Was there an imbalance at the very beginning of the universe? Was there a disturbed symmetry?

Or is there antimatter hidden somewhere that would restore the balance? At the moment, there is no indication that there is.

These very questions are what Jülich researchers hope to answer. They are banking on a particle no bigger than around two trillionths of a millimetre – the proton, which is a stable building block of atomic nuclei with a positive electric charge.

But what can this minuscule thing tell us about the universe? To put it simply, accepted physical models say that what holds for the whole must also hold for the tiniest component (see symmetries and the standard model, p. 12). In other words, if excess matter is the reason why the world exists, then this asymmetry of the universe must also be reflected in the properties of elementary particles, such as the proton. Proof of such asymmetry in a proton would be a teeny tiny, but measurable, dipole moment, as this is an asymmetric charge distribution. In an electric dipole, the negatively and positively charged poles are spatially separated from each other.

A dipole moment of a proton or neutron shouldn't exist according to the laws of physics. But there are theories that claim that it does exist – and that the laws of physics will have to be adapted accordingly. Its existence would explain how the universe came into being.

“The existence of a dipole in protons or neutrons could not be verified in the past – probably because measurements were not precise enough to make the tiny poles which are located extremely close together visible,” says Prof. Dr Hans Ströher, director at Jülich’s Nuclear Physics Institute (IKP). “To give you an ideal of the scale involved, imagine the proton was as big as the Earth, what we want to measure would then be separated by a distance no bigger than the thickness of a human hair.”

SEARCHING FOR THE DIPOLE MOMENT

Ströher and the scientists within the Jülich Aachen Research Alliance (JARA) worked together with international colleagues and developed a concept to make dipole measurements on elementary particles at least a thousand times more precise. “Finding an electric dipole moment would mean identifying a symmetry violation,” says Ströher. “If this violation is large enough, it would explain the excess matter in the universe.” And thus our existence.

The planned experiment is based on the fact that protons possess a spin. In simple terms, this spin is a bit like a small bar magnet. Its orientation would alter in an electric field if the protons possessed an electric dipole moment.

A spin is a quantum mechanical angular momentum.

The COSY particle accelerator (Cooler Synchrotron) has a circumference of 184 metres and is used by researchers to accelerate protons and deuterons.

To measure this, the JARA researchers want to first produce a proton beam in which they can force the spins of all protons to turn in the same direction. Or to use the jargon: they want to produce a polarized proton beam. Jülich's existing particle accelerator COSY could be used for this – after necessary modifications.

Then, they will send the protons into a second ring where the electrostatic fields will keep the protons on track and – if a dipole moment exists – influence their spins. “Such an electrostatic storage ring does not yet exist anywhere in the world,” says Prof. Mei Bei, who joined IKP as a director last December. The opportunity to make this ring a reality is what convinced her to come to Jülich from Brookhaven National Laboratory in New York.

The planned ring is a track for protons, a bit like the 400-metre track in an athletics stadium. But while athletes aim to achieve as high an acceleration as possible, protons ideally move along the track as steadily as possible. In addition, protons should only alter their polarization direction due to a possible electric dipole moment and not because of any other factors.

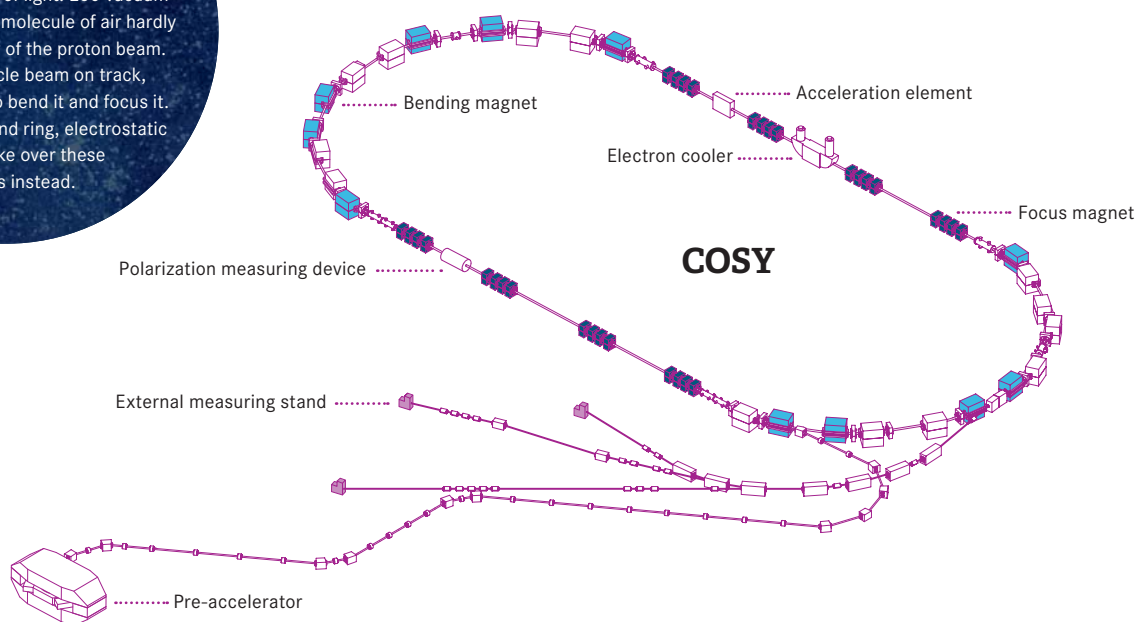
EXPERIMENTAL GAME OF PATIENCE

After the protons have moved around in the storage ring for about 15 minutes, the researchers will then direct them towards a block of matter. Based on the collision processes that occur in this target, researchers will be able to infer whether the direction of the spins altered during the circulation – in other words whether protons have an electric dipole moment and how large it may be. The puzzle is also a test of patience: the scientists expect that they will have to repeat this 15-minute experiment continuously over the course of at least a year. They then hope to have recorded sufficient reliable measurement data to explain the existence of the universe.

Race track for protons

In the COSY accelerator, protons circulate at almost the speed of light. 260 vacuum pumps ensure that a molecule of air hardly ever gets in the way of the proton beam.

To keep the particle beam on track, magnets are used to bend it and focus it. In the planned second ring, electrostatic fields will take over these functions instead.



Prof. Mei Bai and Prof. →
Hans Ströher from the
Nuclear Physics Institute
are working on realizing
an internationally unique
accelerator ring at Jülich.



Verifying that elementary particles have an electric dipole moment could also help to solve another mystery: the search for “dark matter”. Nobel laureate in physics, Frank Wilczek, wrote about this last year in an open letter. It is thought that dark matter makes up 25 % of our universe but it cannot be detected with optical telescopes. And it also remains hidden to all electromagnetic waves outside the spectrum of light, for example, X-rays. Despite the fact that dark matter is not visible, astronomers are convinced that it exists because there are indirect indications that it does, including the speed at which visible stars orbit the centre of their galaxy. This could only be explained by attraction due to the gravitational force of invisible matter.

In their painstaking search for the tiny charge separation, the JARA researchers benefit from international support. Under their guidance, researchers from ten countries are collaborating on the large-scale project JEDI – short for Jülich Electric Dipole Investigations and not an allusion to the superhuman or knightly abilities of the scientists. Although their research also touches on at least two of the three principles of the Jedi warriors in the science fiction world of Star Wars, namely discipline and knowledge. The researchers are exploiting these qualities to develop their design study for the novel storage ring, to draft its exact shape and size and the necessary electrostatic components, as well as the required measuring instruments. In addition, the JEDI partners hope to perform the necessary preliminary experiments in the next few years with COSY. Their aim here is twofold: they want to optimize the technique for measuring the electric dipole moment of the proton, and they want to determine the upper limit of the value of this dipole moment for the first time ever. For the necessary precision, they require the novel second ring, which will be completed in five years at the earliest.

The Jülich Aachen Research Alliance (JARA) is a research cooperation between Forschungszentrum Jülich and RWTH Aachen University.

The JARA researchers have a long way ahead of them. But what are one or two decades of research if a 13.8-billion-year-old mystery can be solved?



An ice crystal is a simple example of spatial symmetry:

If you swap the top with the bottom, it looks no different. And if you swap the left-hand side with the right-hand side, the ice crystal still looks the same.

Symmetries and the standard model

Symmetries play a decisive role in physics, particularly in the standard model of particle physics – “a grotesquely modest name for one of humankind’s greatest achievements”, as Nobel laureate in physics Frank Wilczek wrote. The standard model describes elementary particles and the forces between them. It summarizes everything we know about the fundamental laws of physics.

The model is based on the three symmetries of charge conjugation (C), parity (P), and time reversal (T). T-symmetry holds when a process runs the same way backwards as it does in the forwards time direction. If a process is C-symmetrical, then it runs the same way after the sign of the charges of the particles involved have been changed – for example, if a positively charged proton is replaced with its negatively charged counterpart, the antiproton. If a process is P-symmetrical, then its mirror image will be identical. If all three transformations – the symmetry operations of C, P, and T – are performed one after the other, this has no effect on the processes in the natural world. At least, this is the assumption made by all conventional physical theories.

On the other hand, there are natural processes, such as the Big Bang, where it does matter if particles are replaced with antiparticles and simultaneously all spatial coordinates are reflected. These are termed symmetry violations. Although the standard model does provide for mechanisms explaining such combined C and P violations (CP violations), they are insufficient and cannot explain why there was excess matter when the universe came into being. For this reason, particle physicists throughout the world are looking for another CP-violating mechanism beyond the standard model. This mechanism may be expressed as an electric dipole moment in a proton.

Precision instead of energy

Many, often expensive, experiments have already attempted to solve the mystery of symmetry violations in the universe. Jülich researchers are taking a very different approach.



Dr. Rathmann, the novel proton storage ring that you want to construct will cost an estimated € 50 million. That's a lot of money, isn't it?

Yes. But yet it's a small amount compared to how much some other instruments for basic research in physics have cost. The Large Hadron Collider (LHC) at CERN's accelerator complex in Geneva, for example, alone cost € 3 billion. Needless to say, the LHC is intended for many things: in addition to providing an answer to the question of the origin of the universe, it will also be used to address several other issues. The underlying principle here involves making particles collide with more and more energy – in bigger and bigger and thus more expensive accelerators. We are taking a totally different approach. Instead of an “all-rounder”, we want to build a comparatively cheap facility for a specific problem – namely for precision measurements in physics. We are convinced that our approach is promising.

For decades, activities have been under way worldwide measuring the electric dipole moment of neutrons. Why are you now proposing the same thing for protons?

Because we're not getting any farther with neutrons. The accuracy of the measurements over the last few years has not really improved. The precision that we have achieved failed to detect a dipole moment and solve the matter-antimatter

mystery. Protons are more suitable for a number of reasons. For example, as charged particles, they are easier to manage than uncharged neutrons. In actual fact, the two approaches don't really compete with each other. We will only be able to explain the reasons for a dipole moment, if it exists at all, by comparing the dipole moments of two particles composed of different quarks – as is the case in protons and neutrons.

Why should the storage ring be constructed at Jülich and not somewhere else?

If you were to look down at Earth from Mars to find a place for the ring, you would land in Jülich, which has experts with more than 20 years of experience in polarizing particles. And Jülich is already home to a particle accelerator – COSY – with the correct energy range that can be used for the necessary preliminary studies and indeed later as a pre-accelerator.

THE INTERVIEW WAS CONDUCTED BY FRANK FRICK

Jülich physicist Dr. Frank Rathmann is one of three spokespersons for the JEDI collaboration (Jülich Electric Dipole Investigations), which involves scientists from ten countries.



↑ Thale cress may not look like much but it's well researched: Pitter Huesgen is investigating how it deals with stress factors such as too much light.

Beating stress!

Potato blight led to the starvation of one million people in Ireland in 1845. Today, scientists around the world are investigating the reactions of plants to pathogens and environmental stress factors, such as too much light, in order to prevent such devastating crop failures. Jülich biochemist Pitter Huesgen specializes in molecular biological issues.

A plant doesn't have a choice: no matter how much sunlight it is exposed to, how dry it is, or what bacteria, viruses, or moulds attack it, it can't run away. Instead, it must deal with external conditions and use "on-site" defence mechanisms. If it fails to defend itself, the consequences can be disastrous. In the mid-19th century, for example, the potato blight pathogens caused widespread devastation of potato crops in Europe. In Ireland, the Great Famine cost one million people their lives. Even today, people still die of starvation due to crop failures. Pathogens are not the only reason. Other causes include periods of extreme weather such as drought or sunlight

that is too intensive. Against this background, scientists around the world are investigating the reactions of plants to stress factors.

Peter Huesgen from the Central Institute of Engineering, Electronics and Analytics (ZEA) is interested in how plants perceive such stress factors on a molecular biological level and how they react to them. A certain metabolic process, proteolysis, is at the centre of his investigations. In this process, enzymes known as proteases split long-chain proteins into smaller protein sequences. On the one hand, they destroy damaged, misfolded, or mutated proteins preventing them from causing

any further damage in the cell. “In this respect, proteolysis is like a shredder for proteins that are no longer needed,” says Huesgen.

On the other hand, the protein fragments can also take on completely new functions than the “long version”. For example, they can trigger signalling processes that prompt the plant to defend itself on the molecular biological level. Huesgen wants to learn which enzymes split which proteins where as well as how the plants adapt their metabolism to the changed conditions. When the biochemist understands how the proteases work at the molecular level, then he may be able in a second step to turn them on and off as desired. In the long term, the results could contribute to the development of new pesticides and stress-resistant cereal plants.

PROTEASES ARE MULTITALENTED

The 37-year-old has been working on proteolysis since early 2002 when he was writing his Master’s dissertation at Stockholm University in Sweden. Even during the six-year period he spent in Vancouver at the University of British Columbia, proteolysis was the focus of his research – although here he concentrated on the medical aspects, because proteases are a popular starting point for treatments. For example, it is known that two of these enzymes are involved in the emergence of the neurodegenerative disease Alzheimer’s.

“The idea is to inhibit these proteases and thus treat Alzheimer’s,” explains Huesgen. The researcher wants to maintain these medical ties with his Jülich colleagues at the Institute of Neuroscience and Medicine and the Institute of Complex Systems.

But his main area of work at the Institute of Bio- and Geosciences revolves around the some 800 different proteases in plants. Very little is known about these proteases. Too much light and pathogens are the two stress factors that interest Huesgen. He uses an undemanding, herbaceous plant for his experiments – thale cress or *Arabidopsis thaliana* to give it its scientific name. It is genetically related to many food and feed crops, such as broccoli and kohlrabi. Thale cress is extremely popular in science as a model organism for higher plants because its genome has already been decoded and it can be genetically manipulated very quickly – a decisive advantage for Huesgen. The short reproduction cycle of eight weeks helps him to verify his hypotheses fast. Huesgen hopes to gain new insights into the still largely unknown path from stress perception to the plant’s response. What proteases are involved? What tasks

do the proteolytically shortened proteins fulfil in comparison to the full proteins?

The excellent early-career scientist is in the first stages of his project for which he was awarded a Starting Grant by the European Research Council in November 2014. Huesgen will use the € 1.8 million to set up a new research group at ZEA. The group’s most important large-scale device is a new, ultrasensitive mass spectrometer. The scientists can use it to precisely analyse the proteins that exist in a cell or an organism. “We want to identify which proteases play a key role in the plant’s overall system. Based on this, we hope to create a list of protease targets on the molecular level,” says Huesgen. This could help to develop new pesticides and stress-resistant plants.

KATJA LÜERS

“Let there be light – but not too much!”

Winter is over and many an amateur gardener takes his potted plants out of their shady winter quarters and places them in direct sunlight. But no more than a few days later, the leaves develop their first spots. Light stress is the reason for this: oxygen radicals are produced in the chloroplasts, which are responsible for photosynthesis. These radicals damage and destroy many proteins. To rid itself of the radicals as quickly as possible, the plant mobilizes some of its around 60 proteases in the chloroplasts. These degrade the damaged proteins, and also split certain proteins, which when shortened activate defence mechanisms, which in turn prevent the formation of radicals.



Exposure specialist

A rather unwieldy name with a very bright future: computational structural biology is gaining ground. In 2013, three American scientists were awarded the Nobel Prize in Chemistry for simulating chemical reactions. Jülich's specialist in this field is Gunnar Schröder. The physicist heads a young investigators group and successfully develops his own atomic prediction models.

»We would be able to customize antibiotics that would target the bacterium at its most sensitive spot and ultimately kill it.«

Gunnar Schröder never really considered an alternative: he always wanted to be a physicist. As a child, he played with science kits and was fascinated by physical parameters such as force and velocity. As a 19-year-old, he constructed a “universal acceleration meter” together with a friend at the Felix-Klein secondary school in Göttingen. He was inspired by imprecise acceleration experiments in physics class. The two boys were awarded a special prize at the national “Jugend forscht” competition for school students, and upon completion of their school leaving certificate, their school awarded them the Felix-Klein prize for outstanding achievements in the natural sciences. Going on to study physics was for Gunnar Schröder the only logical consequence, even though the jobs market for physicists wasn't really rosy at the time. The young man briefly considered studying medicine. “But if you're passionate enough about something, then you really can't go wrong,” says the 40-year-old.

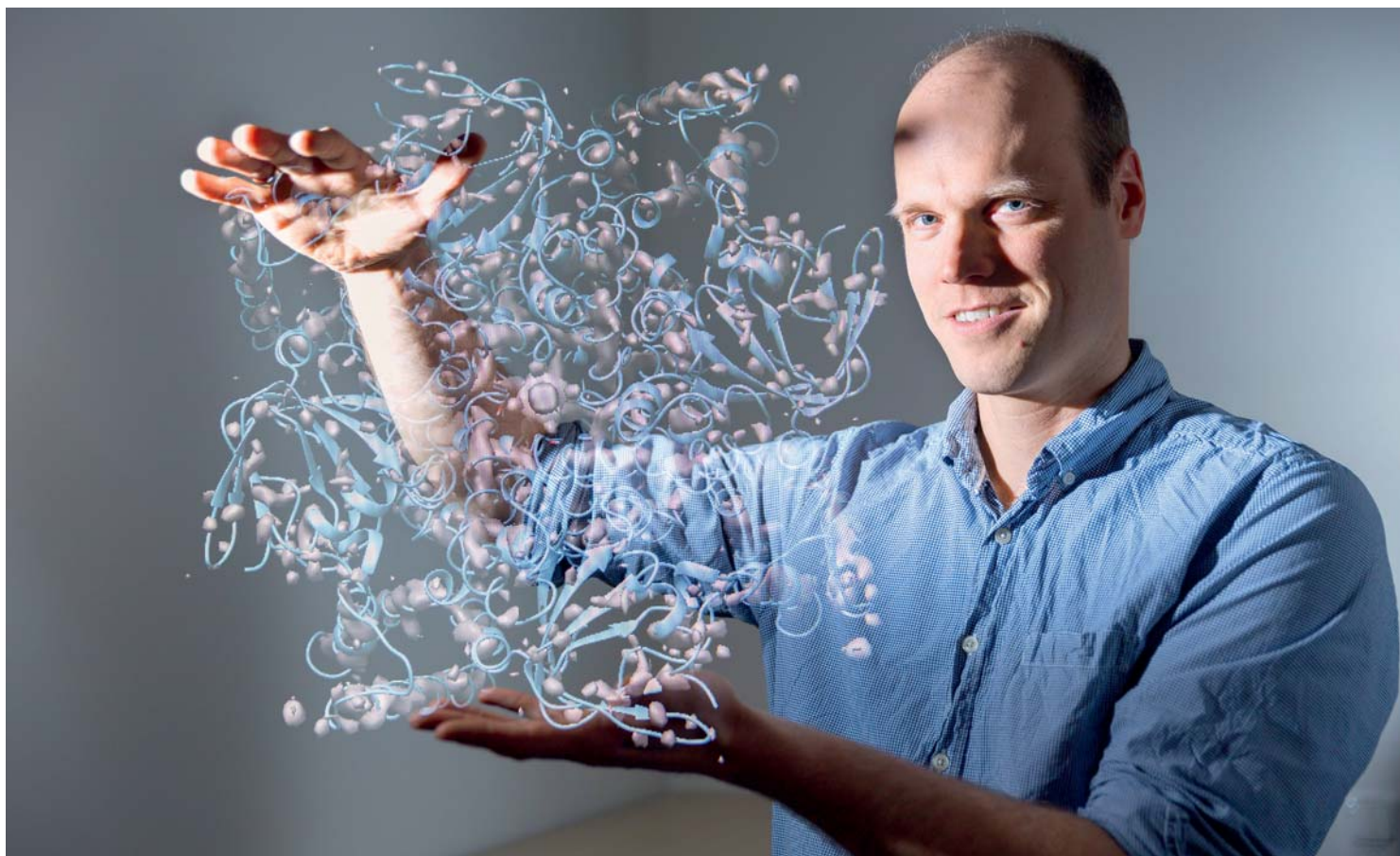
Success has proved him right: today, he is head of the young investigators group focusing on computational structural biology at the Institute of Complex Systems (ICS-6) and is also junior professor at Heinrich Heine University Düsseldorf. “Forschungszentrum Jülich, with its infrastructure and broad spectrum of fields, provides me with excellent conditions,” says the highly qualified physicist. After all, he tells us, computational structural biology is at the interface between various disciplines like chemistry, biology, computer science, physics, mathematics, and medicine – all topics that are pursued here at Jülich.

Even if the name is long and a bit unwieldy, and people don't really know what it's about, computational structural biology is becoming more popular: in 2013, Martin Karplus, Michael Levitt, and Arieh Warshel received the Nobel Prize in Chemistry for their computer models for complex chemical systems. “Computer models mirroring real life have become crucial for most advances made in chemistry today,” wrote the Nobel Committee about its decision.

PREDICTABLE FUTURE

For Gunnar Schröder, who conducted research as a postdoc with Levitt at Stanford University, the future of computational structural biology is not in doubt. Simulation programs can be used not only to recreate single molecules but also to understand chemical reactions that proceed in fractions of milliseconds. “Such procedures will become more and more important as computing power increases,” Schröder is convinced. Ten years ago, molecular dynamics could only be observed over a range of nanoseconds. Today's more powerful computers allow the movement of molecules to be traced over periods that are 1,000 times longer – that's when it gets interesting for biologists. Schröder concentrates on proteins: as a universal tool in humans, animals, and plants, they control metabolism, support the immune system, and pass signals on. They are anything but rigid: their spatial structure can change – in the jargon this is referred to as conformational change.

Many protein structures can be depicted with X-ray crystallography, but for larger complexes the resolution is often limited – for example, for a



cell's protein factories, the ribosomes. A ribosome is a bit like a huge molecular machine made up of more than 50 different proteins. It is constantly in motion and alters its state. Detailed examinations of such a biomachine are extremely laborious using experimental methods and they often provide no more than a rough picture of the protein. Many details remain unclear. Where are the individual atoms located? Where is a hydrogen bridge? How is the protein folded?

SHARPENING THE IMAGE

This is where Gunnar Schröder comes into play: "We combine experimental data with predictions and simulations of protein structures to develop good atomic models," says the researcher. He sharpens the virtual image of the protein structure using existing data as a basis. "In other words, we don't improve the data; we use the data to create atomic models that are much more precise than other models that have not been calculated with our simulation," he says. He adds the missing information using prediction calculations, for which he continuously develops and tests new algorithms. Computing time at the Jülich Supercomputing Centre (JSC) has therefore been integrated into his daily routine.

With his modelling technique "deformable elastic network" (DEN), he used electron micrographs as a basis to piece together the full sequence of motions in a ribosome for the very first time. A prime example of basic research. But it also has a practical application. Ribosomes in bacteria are preferred targets for antibiotics: "If the exact structures of the ribosomes are known, then we could customize antibiotics that would target the bacterium at its most sensitive spot and ultimately kill it," says Schröder.

The fact that biology and biochemistry are part of his job doesn't worry the physicist. "However, it's not easy to find physicists with the courage to tackle biology," says Schröder. Many are scared away when they begin to look at the literature. The members of his young investigators' group have taken the chance. After all, in keeping with Schröder's motto, if you're passionate enough about something, then nothing can stop you – not even biology.

KATJA LÜERS

↑ **Complicated molecular structures fascinate Gunnar Schröder: the physicist specializes in computational structural biology.**

Breaking through to the third dimension



↑ **Andreas Thust has been working with electron microscopes for 25 years.**



↑ **Chunlin Jia put forward the idea for the breakthrough.**

Atomic resolution images produced by electron microscopes should really only be two-dimensional. But researchers have succeeded in gaining information on the third dimension from a single “snapshot”.

“Imagine that somebody projects your shadow head-on onto the wall and claims that he can tell you exactly what size your chest is. This is just how fantastic many of our colleagues found our results to be,” says Andreas Thust. “But that’s exactly what we succeeded in doing on the nanoscale.” The physicist works at the Peter Grünberg Institute in the field of micro-structure research. A German-Chinese research team headed by Thust and his colleague Chunlin Jia from Xi’an Jiaotong University used a single “snapshot” taken by an electron microscope to reconstruct what is not obvious at first sight: the three-dimensional crystal structure of the sample as well as the exact structure of the surfaces.

“An image taken by a transmission electron microscope usually means a two-dimensional projection, like an X-ray,” says Thust. “And projections do not contain exact information on the surface.” In order to determine this information in the past, researchers had to use a CT process to create hundreds of images of the sample from all sides. However, this process damages radiation-sensitive samples, is not sensitive enough for light atoms such as oxygen, and

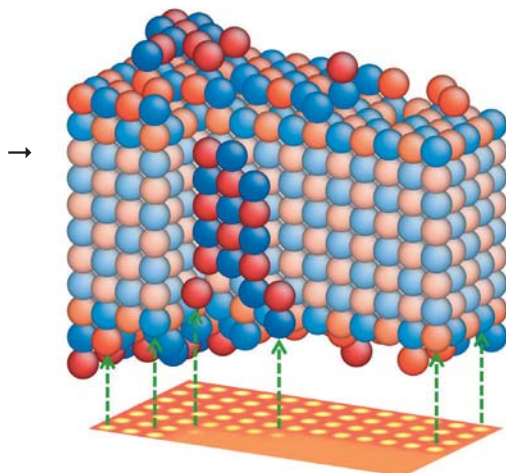
fast chemical processes cannot be imaged because it takes too long.

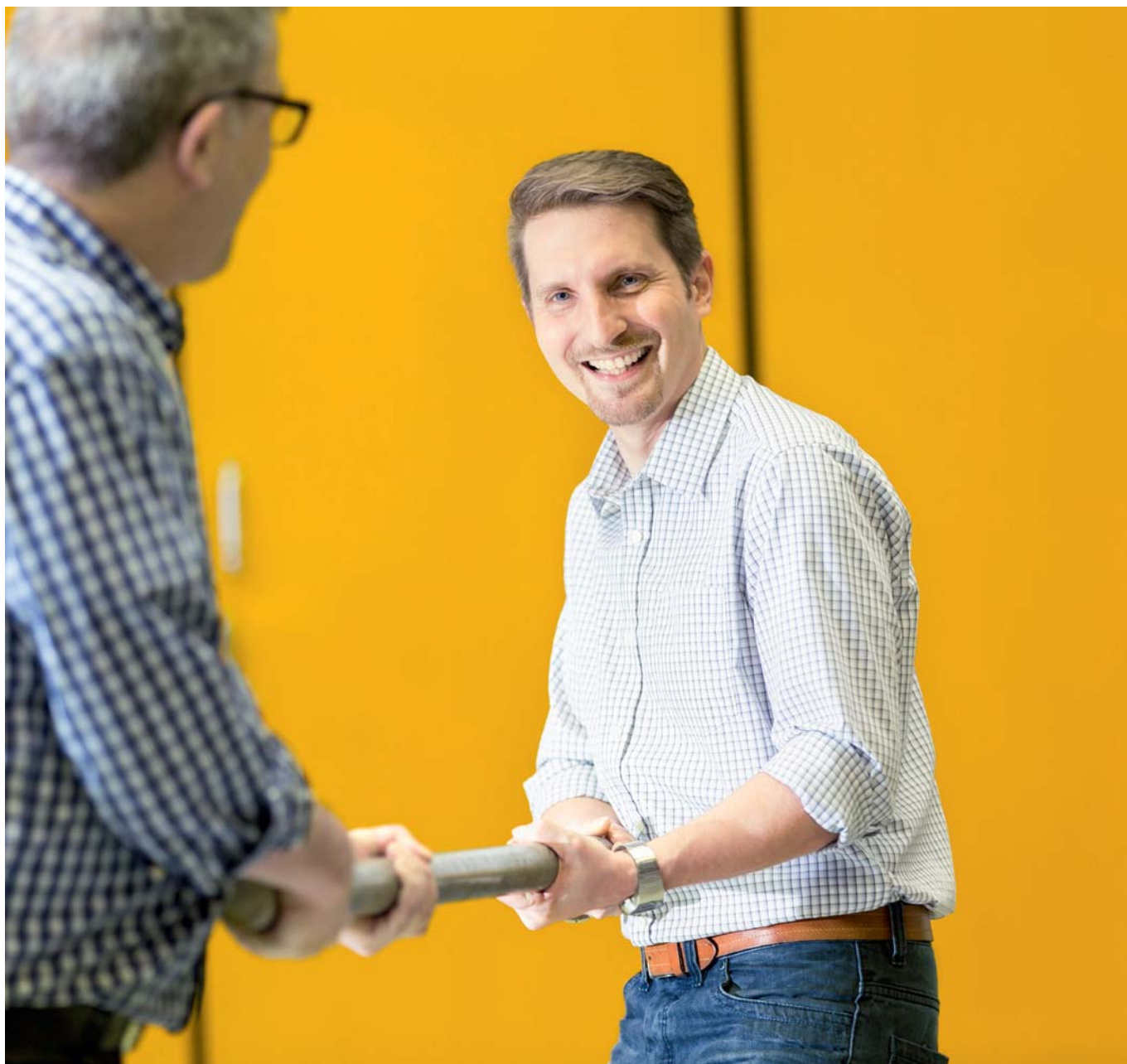
The new method does not have these disadvantages. The scientists identified extremely weak signals in the electron micrographs which provide information on the third dimension. The key is a quantum mechanical effect: wave diffraction.

“How an electron microscope functions on the atomic level is a bit like if sand were to trickle through a mesh onto a glass plate,” says Thust. “The mesh represents the atoms of the sample, the sand the some one billion electrons, and the glass plate is a film that shows the point of impact of the electrons.” If we imagine that electrons are like particles, then the film would simply show the density in which the atoms are arranged in the two dimensions of length and width.

But if we think along the lines of quantum physics and imagine an electron to be a wave, then a third dimension emerges: an electron wave making its way through the crystal lattice is influenced by each atom it passes. In the same way as when a stone is thrown into water, each atom creates a circular pattern in the electron wave. “This gives rise to characteristic differences in the intensity and shape of the points imaged at the atom sites, which can then be analysed. However, they are so tiny that they can only be registered and processed by computer programs. That’s why initially everyone put the effect down to random noise or wishful thinking. However, using statistical analyses and millions of simulations, we were able to conclusively prove that this was not noise,” says Thust. Under special conditions – the sample contains no foreign atoms and the atoms form perfect columns in the lattice – it is possible to clearly decipher information on the third dimension.

The intensity of a point indicates the length of the atomic columns, i.e. the sample thickness. The radius of the point shows the height at which an atomic column began. Combined, the two pieces of information can be used to reconstruct the sample atom for atom.

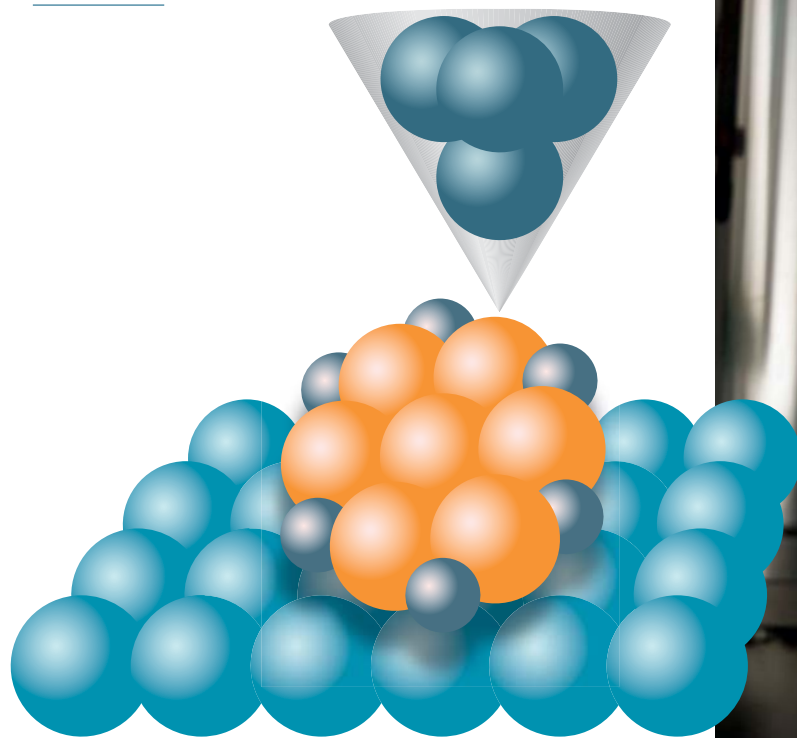




What's your research all about, Dr. Kuhn?

Dr.-Ing Bernd Kuhn, head of metallic materials and joining techniques at the Institute of Energy and Climate Research – Microstructure and Properties of Materials

“I develop particularly stable steels for steam power plants. The transformation of the energy sector means that power plants are no longer operated at temperatures of 600 °C continuously, but rather only when there is not enough wind or sun as an energy source. Frequent rapid heating and cooling means that steel must be made much more flexible and durable. We remove carbon from the steel, for example, and add tungsten or chromium. Why? Tungsten hardens the steel and chromium protects it against corrosion.”



Better by hand

MOBILITY: Some automobile manufacturers are already working on the hands-free control of several functions in cars. Examples include activating protection from the glare of the sun or turning on the windscreen wipers.

MEDICINE: Software allows surgeons to prepare for operations by working their way through the 3D image material of a patient, and, for example, to practise placing implants exactly where they are needed in the body. During an operation, surgeons can use gestures to leaf through the patient's X-rays and CT images, to magnify the images, or to mark them without having to leave the sterile area.

SPACE TRAVEL: In future, the US space agency NASA wants to be able to control robots on Mars and the Moon from the Earth using hand motions.

Real handiwork

Pressing buttons is a thing of the past! Today, scientists at Forschungszentrum Jülich control complex apparatus using gestures – a new tool with which they will create nanoelectronics in future “by hand”.

Completely focused, Matthew Green stands in a dimly lit room; only his arm is moving – downwards, upwards, and then sideways. On his hand, a shimmering silver sphere glitters. It reflects the light from two infrared cameras mounted on the wall and ceiling.

You might think that the PhD student at the Peter Grünberg Institute has immersed himself in the

virtual world of a games console. But Green is not manoeuvring game figures around dangerous obstacles. Instead, he is controlling the ultrathin metal tip of a scanning tunnelling microscope. When Green moves his hand five centimetres upwards to the right, the cameras register this and transmit the information to a computer. The computer ensures that the metal tip of the microscope instantly moves upwards to the right, but only by a tenth of a millionth of a millimetre, the typical size of an atom.

Green uses this tip to grasp molecules on the surface of his sample, lift them up, and deposit them somewhere else. “I suppose there is a certain amount of gaming involved – but it’s all in the name of a good cause,” says the young Briton laughing.

Being able to move tiny building blocks of matter at will could open up new opportunities in future.



↑ Using gestures, Matthew Green controls the tip of a scanning tunnelling microscope – and shifts single molecules.

The science community hopes to create miniature instruments where individual molecules would each function as a component. Electronic circuits, for example, could then be designed solely on the basis of the interaction between two molecules and thus on quantum mechanics. This concept promises even smaller, cheaper storage and logic circuits, as well as new, sensitive sensors.

PRECISION REQUIRED

“To make nanoelectronic instruments a reality, we must be able to move individual particles to a very specific position,” explains Green. At Jülich, researchers are working on understanding the interactions between molecules in order to move them as desired – for example, using a scanning tunnelling microscope. This instrument was originally developed to investigate surfaces. A thin metal tip moves slowly over a sample while a voltage is applied between the tip and the sample. The current that flows between the tip and the sample alters with the distance between the two, thus creating images of the sample surface. “You can even recognize the individual atoms,” says Green.

47

molecules were lifted one at a time by Green and moved elsewhere to create the word “Jülich”.



Today, researchers do not just use the instrument to look at the surface but also to change it. The metal tip can be used to lift individual particles and move them because a chemical bond is formed between the two. It all began with simple atoms. Recently, Green discovered how to move large flat organic molecules. But the motion sequences are complicated – and only manual control helps.

Exactly where the metal tip is positioned is particularly important in the case of large molecules. If the molecule is grasped incorrectly, it won't budge and will remain stuck to the surface. “You have to position the tip at the edge of this type of molecule and then slowly lift it upwards in an arc,” explains Green.

FLEXIBLE CONTROL

The researcher could program the computer to control the metal tip. But a programmed sequence of motions is very rigid. If an error occurs when the program has been executed, the sequence cannot be readjusted and corrected; the program runs as programmed until the end. “By using my hand, I'm much more flexible and I can control every step,” says Green. “As soon as I see that something is wrong, I can react immediately.”

As soon as you try out the manual control, you realize just how much body control is needed. “It takes a while to calibrate yourself,” says Green with a smile. “But you catch on fairly fast.” At the beginning, he needed 40 minutes to move a single molecule from A to B, but now he says he can manage it in 10 minutes.

Green's biggest project so far took four days. He lifted exactly 47 molecules off a monolayer one at a time and moved them elsewhere. In this way, he “stencilled” the word “JÜLICH”. “This shows just how precise our method is,” says the researcher. In contrast to any old pattern, a whole word can only be written with very careful planning and execution.

BRIGITTE OSTERATH

The power of a reward

**Two scoops of chocolate ice-cream in a cone.
The new football game for PlayStation. Or praise.
Rewards make us all happy. But this is particularly true
for children with ADHD.**

Another two smiley stickers and then John* will get the football game he has long wanted for his games console. He only has to do his maths homework properly, writing the digits carefully in the squares. Together with his mother, the 9-year-old has drawn up a plan that is affixed to the fridge in the kitchen with a magnet. And this plan also has squares. But these squares are not filled with numbers; they contain small stickers with smiling faces.

The smileys motivate John, who finds learning more difficult than many other kids of the same age. John has ADHD. ADHD stands for attention deficit hyperactivity disorder. A long name with a long list of symptoms that make it more difficult for children and teenagers affected by it to learn in school. “ADHD has very different forms. The most common symptoms are difficulties concentrating, motor restlessness, or sudden emotional outbreaks,” says neuropsychologist Prof. Kerstin Konrad, who works at the Institute of Neuroscience and Medicine at Jülich and University Hospital Aachen.

This impulsiveness also has a positive side. “Children and teenagers with ADHD are extremely enthusiastic and therefore easy to motivate,” says the scientist. But what reward is particularly attractive for the kids and teenagers? Is praise enough? Or does it have to be cinema ticket, a surprise, or money? And how can these motivation “goodies” be used for therapies? To find this out, Kerstin Konrad and her team conducted a combined behavioural and imaging study using a functional magnetic resonance imaging (fMRI) scanner.

For ADHD children like John, the test was anything but easy. “We had to lie perfectly still in the MRI scanner.” This is the only way that doctors can image the brain activity of children

and teenagers as they perform certain tasks. But rewards were on offer, at least most of the time. Stacks of coins, a woman smiling, or an empty white bottle in a red triangle signalled to the children and teenagers between the ages of 9 and 18 at the beginning of each series of tests whether they would get money, praise, or nothing at all.

“In addition to ADHD patients, a control group of healthy children was also involved in our study, allowing us to compare the results,” says project leader Gregor Kohls. The evaluation showed that the reaction times of healthy individuals and those with ADHD were always identical. But if money or praise was promised, the success rate for each task improved considerably.

DESIRE FOR RECOGNITION

Even though the groups behaved similarly, the neurobiological processes in the brain differed depending on the type of reward promised. “The prospect of money was much more enticing for the healthy individuals. We detected the strongest activity for this type of reward in the ventral striatum, which is the centre of the motivation system. Social rewards in the form of praise and recognition were not considered quite as desirable,” says Gregor Kohls summarizing the findings. The situation was completely different for ADHD patients: it didn’t matter whether words of praise or money was promised. A similar level of brain activity was detected for both types of rewards.

Kerstin Konrad can only speculate why this is the case – even though as part of her work at University Hospital Aachen’s Department of Child and Adolescent Psychiatry, Psychosomatics,

* name changed by the editors



CHILDREN WITH ADHD

NUMBERS

5% of children and adolescents in Germany between the ages of 3 and 17 are affected (most common mental illness in this age group); boys are four times more frequently affected than girls.

SYMPTOMS

Around a third of all children diagnosed with ADHD have it into their adult years. However, behaviour evolves over the years, and hyperactivity and impulsiveness often turn into under-performance and difficulties concentrating.

DIAGNOSIS

Specialists diagnose ADHD using tests, questionnaires, and behavioural observations based on information from parents and teachers.

and Psychotherapy, she sees many young and older ADHD patients every day. "One explanation might be that these children experience rebukes and negative feedback so often every day that they absorb everything that is positive," surmises the scientist. "This is where even a simple "well done" motivates."

Children with ADHD are a bit like roly-poly toys: they always manage to right themselves again and overcome adversity if they are encouraged and praised. In 2013, researchers investigated whether specific training given by parents and teachers could replace medications and demonstrably lead to improved cognitive performance. "The trainers surveyed – regardless of whether they were parents or teachers – all answered yes to this," says Kerstin Konrad, before continuing "but this could not be verified objectively."

Medications like Ritalin are therefore still part of the standard treatment for ADHD once the patient is above a certain age

and they are combined with parent training, specific measures to improve concentration skills, and other specially developed individual training measures. But what many people do not know is that in around 60 % of all cases, ADHD is accompanied by other disorders, such as antisocial personality disorder, phobias, dyslexia, or an arithmetic learning disability. These disorders, in particular, have been shown to respond to further training measures.

PRAISE IS ENOUGH

There's a lot of potential for frustration! The promise of a reward can soften this somewhat and also encourage the children and boost their self-esteem. "Our experience has shown that motivation-based agreements between teachers, parents, and the child concerned can be highly effective," says Kerstin Konrad about everyday treatment. And apparently rewards do not have to be material: words of praise are enough, and they can easily be integrated into the everyday school life. Naturally, this doesn't rule out chocolate ice-cream after school.

ILSE TRAUTWEIN

Cracking the molecular code

They're known as GABA_A, M₁, or M₂. The receptors are part of a code that characterizes language regions in the brain. Scientists have cracked it for the first time.



↑ When we speak or listen, different regions in our brain communicate with each other. They recognize each other thanks to a shared molecular code.

Encrypted communication has always been used – even in classical antiquity – to ensure that only a select circle could understand the messages. From the Spartans to James Bond: politicians, the military, and secret agents worked and work with codes. Our brain also makes use of the principle of exclusive membership: there is one single molecular code that characterizes the areas in our brain concerned with language. Only those regions that have the code can process and transmit signals that allow us to form and understand words and sentences.

“When we speak or listen, it is not just us people communicating. In our brain, different regions are also communicating intensively with each other,” explains Jülich brain researcher Karl Zilles. However, up to now, it was unknown why only certain regions could process language-related information. It was known that the brain regions had to be connected to each other via neural fibre tracts. But how were the signals processed in the receiver regions? How did the language code differ from the code in regions responsible for other tasks such as movement, sight, or feelings?

CODE DEFINES ROUTES

The new findings made by Zilles and a team of scientists from the Institute of Neuroscience and Medicine at Jülich, University Hospital Aachen's Department of Psychiatry, the Max Planck Institute Leipzig, and Aalto University, Espoo, Finland, show that the code shared by the language areas is based on their characteristic concentration of various transmitter receptors. These receptors are protein building blocks which basically serve as “docking stations” in the brain for neurotransmitters such as GABA, glutamate, acetylcholine, norepinephrine, serotonin, and dopamine. For each of these neurotransmitters, there is only one corresponding receptor – like the lock-and-key principle. All of them play an important role in signal transduction. Language-relevant information can only be “understood” and processed by a brain region if the corresponding concentrations of its receptors are precisely tuned – a bit like different instruments in an orchestra playing a polyphonic chord of a score.

MOLECULAR FINGERPRINT

Zilles and his team deciphered the molecular code shared by the language regions using a complex process to examine thousands of ultrathin slices of the brains of deceased individuals. The scientists were particularly interested in how fifteen different transmitter receptors were distributed in the language-related and language-independent brain areas. For this, the neuroscientists smuggled radioactively labelled molecules into the brain slices, which bonded with these receptors. By exposing films that were placed on the slices, the receptors that had been invisible up to then were revealed – a bit like a secret code. “With the aid of quantitative receptor audiography, we obtained a very good spatial representation on films of the distribution and concentration of the receptors,” says Karl Zilles. These films were subsequently developed and computerized using scanners. The intensity of the radioactivity was converted into real receptor concentration and imaged as different colour grades.

Then, the researchers compared the receptor architecture in the various regions using a statistical procedure called hierarchical cluster analysis. Computers perform complex calculations to identify the areas that share similarities – in other words, areas that form “clusters”. This reveals areas of the brain with the same balance between the various receptors – or to put in another way, that play the same chord – and can thus understand each other. The result: “The molecular fingerprints of the language-related areas resemble each other, enabling them to form a cluster. This cluster is very different to clusters of other brain regions such as those that process emotions,” says Karl Zilles. The molecular code has thus been discovered – and is the key for a select group of brain regions that make speech possible.

ILSE TRAUTWEIN



↑ **JARA senior professor Karl Zilles and his team analysed thousands of ultrathin slices of the brains of deceased individuals.**

Instantaneous messengers

GABA_A, M₁, or M₂ are receptors that dock onto neurotransmitters. These neurotransmitters are released quick as a flash between two neurons when an electric signal is received. They have to jump across a trench of sorts – the synaptic cleft – between the cells. When they reach the target neuron, the neurotransmitters dock onto certain receptors – a bit like a key that only fits a certain lock. Each neurotransmitter requires a system that has been customized for it to ensure that the flow of information is not impeded.

Language is on the left

When we speak, the left hemisphere of our brains is mainly active. The research project uncovered further evidence for this. The scientists identified the typical molecular code in more areas in the left hemisphere than in the right.

Sun, Stress, and Soya Beans

It's the end of January and the thermometer reads 35 °C. "In the shade, no less," says Dr. Anke Schickling. That the plant scientist is somewhere other than her home institute at Jülich is obvious.



Jülich's campus measures 2.2 km². But Jülich scientists are active beyond the campus. This section features brief reports on where they conduct research. This time around, we're headed to the south of Brazil.



↑ Travelling plant researcher: Dr. Anke Schickling is active in Brazil for Forschungszentrum Jülich.

Schickling is working in a city in the south of Brazil – Londrina. The main economic activity of the city with a population of 500,000 is the cultivation of soya beans. Logically enough, the state-owned Brazilian Corporation of Agricultural Research (EMBRAPA) has a unit here that is dedicated to soya beans, which are mainly used to produce cooking oil, animal feed, or biodiesel.

Schickling represents Labex Germany in Brazil – a virtual Jülich lab and an important part of Forschungszentrum Jülich's cooperation with EMBRAPA. In this function, she will work at more of the 48 EMBRAPA units over the next few years.

Shortly after her arrival, almost all of the 400 employees appeared to know the German scientist. "Even in the bus on the way to the institute, they addressed me by my name. Many of them had apparently read a report about me and my work on their intranet," says Schickling smiling.

She brought special measuring instruments with her from Jülich that allow plants to be studied without damaging them or having to remove them from the soil. She performed the first non-invasive measurements of her research stay in mid-January – on soya bean plants that bore their first fruit around the same time and were under stress due to the heat and lack of water. "In this reproductive phase, drought stress has a different impact than in the preceding growth phase," explains Schickling.

The scientists at EMBRAPA hope that the non-invasive methods will make it possible in future to identify the plants that will be the most pro-

2.2
plus

ductive even in extreme drought. Up to now, they had to wait until the end of the plant's life cycle in order to ascertain how well it could deal with drought stress. Schickling sees the measurements mainly as a method of learning more about soya bean plants and of analysing their structures and functions.

FRANK FRICK



↑ Soya experimental fields. The sliding roofs are used to protect the plants from rain and thus artificially create drought stress.



THUMBS UP

COMPETITION

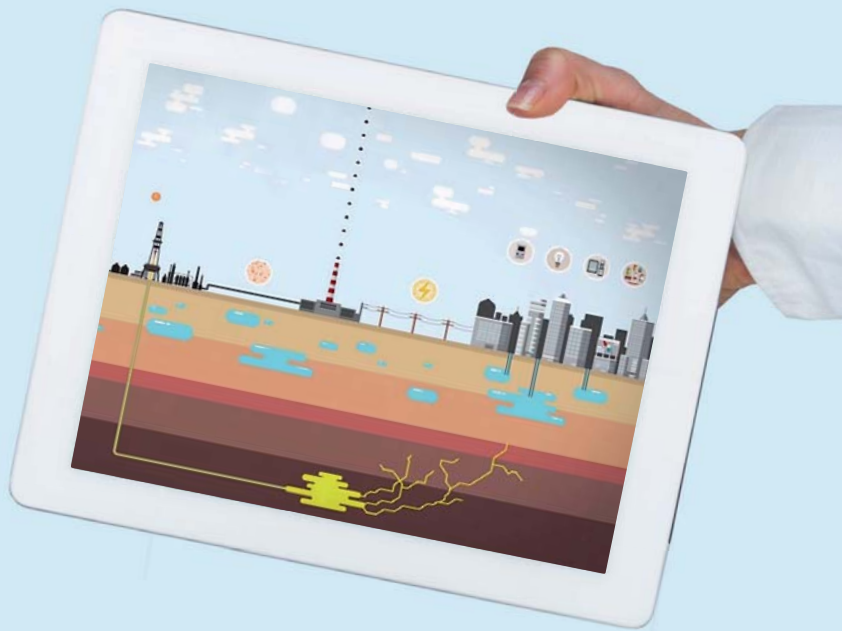
The best science videos

Dry and complicated science is off the mark here! The winning videos in Fast Forward Science, a competition for online videos organized by a German science network, are entertaining and fun and explain scientific issues almost in passing. An interdisciplinary jury selected nine videos last year from a total of 135.

The competition is running again this year.

Why not take part?

– WWW.FASTFORWARDSCIENCE.DE –



KNOWLEDGE PLATFORM

First-hand research data

How badly are oceans and the atmosphere affected by pollutants? What are the consequences of climate change? What dangers are inherent in nature itself? The Earth System Knowledge Platform (ESKP) focuses on the key environmental questions of our time and provides background information and research findings first-hand. For the project, eight research centres within the Helmholtz Association have joined forces to make up-to-date research data available online. Jülich climate researchers, for example, outline Arctic ozone depletion. Their calculations could serve as an early warning system for increased UV levels. But at the moment, there's no need to worry.

Winter in the stratosphere was warm and the researchers expect little or no ozone depletion and no increase in UV radiation.

– WWW.ESKP.DE –

SPEED FARMING

Farming high-rise buildings

In keeping with the theme of the 2015 science year – City of the Future – German broadcaster ARTE is taking a look at how agriculture will change in future.

One potential future scenario is that of “vertical farming”. Plants and animals will not be bred on land but rather in multistorey building complexes. The online game “Speed farming 2050” shows how this works and allows players to test it out for themselves. As a digital farmer, players manage a farm in a building. They have to cover the inhabitants’ demand for food. Food like tomatoes and corn must be harvested at the right time and production factors such as water and light must be controlled correctly. A somewhat mad scientist provides players with advice during the game.

– FUTURE.ARTE.TV/DE/STAEDTE-DER-ZUKUNFT –

RESEARCH IN A TWEET

Less platinum but the same performance. We use nano-octahedron to optimize fuel cells – and make them cheaper.



Dr. Marc Heggen

researches materials properties on the atomic level. With colleagues from Jülich and Berlin, he has developed novel catalyst particles for fuel cells. Using ultrahigh resolution electron microscopy, they showed how the crystalline, platinum-containing particles actually grow – an essential step towards selectively improving catalysts.

www.fz-juelich.de/nano-octahedron