Take a close look!
The human eye is a supercomputer

ENDURING
New type of steel for Energiewende

ENLIGHTENING
Soil influences our climate

ENDANGERED
Malaccensis trees need help
Huh!

Mouth gaping, eyes wide open: just what could this glowing green something be? A rare deep-sea jellyfish? Or an unknown life form? Neither. It is quite simply barley. To be precise: a cross section of a barley root. The large holes in the middle are vessels which transport water from the soil into the shoots. Jülich plant researcher Hannah Schneider was honoured for the most original root image at the meeting of the International Society of Root Research in Canberra, Australia. With her research, she wants to contribute to fighting world hunger. She will present her ideas at the Falling Walls Conference taking place in Berlin this November.
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Did you count the black and white dots on the cover? Apparently, this puzzle went around the world via email at Christmas in the year 2000 – combined with the task of counting the dots and then re-checking the result. The black dots were to be counted as votes for the US presidential candidate at the time, Al Gore, and the white ones for his competitor George W. Bush – a play on the ballot counting controversy in Florida that year. And it is an unrewarding, even unsolvable challenge. In contrast to the counting of votes, there is no clear solution in this case. The reason is an optical illusion: at the edges of our field of vision, the white dots suddenly become black.

How our visual organ filters and weights information before forwarding it to the brain is the issue being investigated by neurobiologist Prof. Frank Müller and his team. For this purpose, they look deep into the eye, right into the retina and its intertwined nerve fibre layer. But there are also other researchers at Jülich having a close look: for example at how the soil influences our climate, what Diabetes, Alzheimer’s, and Parkinson’s have in common, and what’s so special about one very valuable scent.

Enjoy reading!
Your effzett editorial team
NEWS IN BRIEF

A German–Australian research team has developed a bioelectronic sensor for the rapid and reliable detection of cancer cells. In laboratory experiments, the method revealed an individual cancer cell in a lymph node and uncovered tumour cells in the blood of bowel cancer patients. It took less than 30 minutes for the result of the analysis to be obtained after sample processing. The scientists from Forschungszentrum Jülich and the University of South Australia now want to develop a quick test from the method. For this purpose, the researchers have to prove that their method works reliably in humans.

– INSTITUTE OF COMPLEX SYSTEMS/PETER GRÜNBERG INSTITUTE –

BIOECONOMY

Replacing rapeseed and maize

Sida hermaphrodita is considered a promising alternative to the frequently used energy crops rapeseed and maize. The plant, which originates from North America, yields up to one third more biomass than maize, is frost-resistant, and also grows on soils that cannot otherwise be used for arable farming. Jülich scientists are cultivating the plant under various conditions. They want to find out when the perennial plant yields the best results for what application. Sida could be used, for example, to produce biogas or solid fuels.

– INSTITUTE OF BIO- AND GEOSCIENCES –

MEDICINE

Rapid detection of cancer cells

A German–Australian research team has developed a bioelectronic sensor for the rapid and reliable detection of cancer cells. In laboratory experiments, the method revealed an individual cancer cell in a lymph node and uncovered tumour cells in the blood of bowel cancer patients. It took less than 30 minutes for the result of the analysis to be obtained after sample processing. The scientists from Forschungszentrum Jülich and the University of South Australia now want to develop a quick test from the method. For this purpose, the researchers have to prove that their method works reliably in humans.

– INSTITUTE OF COMPLEX SYSTEMS/PETER GRÜNBERG INSTITUTE –
Giving Augustus a face

Jülich researchers have helped to reconstruct an approximately 2,000-year-old bust of the Roman emperor Augustus. The bust was found near Aachen in the 19th century – but only the back of the head was preserved. The researchers completed the missing face using state-of-the-art scanning technology and 3D printing. Other busts of Augustus from a Cologne museum and from the Louvre in Paris served as models.

– CENTRAL INSTITUTE OF ENGINEERING, ELECTRONICS AND ANALYTICS –

It’s a matter of time

For many years, scientists wondered whether red blood cells move of their own accord, or whether their motion is triggered by external forces. A team of Jülich, Münster, and Paris biophysicists has now verified that both theories are correct: on the one hand, fast molecules impacting on the blood cells make the cell membranes wriggle. On the other hand, the blood cells also become active themselves – if they are given enough time to trigger their own motion before being impacted externally. The researchers were able to determine these processes accurately by combining experiments using laser tweezers with computer simulations.

– INSTITUTE OF COMPLEX SYSTEMS –
Since April 2016, four new institutes have been enriching the Jülich Aachen Research Alliance (JARA). They are concerned with psychiatric and neurodegenerative disorders, energy-efficient computer and communications technologies, and quantum information. Scientists from RWTH Aachen University and Forschungszentrum Jülich work in close collaboration at JARA institutes.

JARA GROWING

Thirty years after the Chernobyl reactor accident, the population of the municipality of Volincy in Belarus, which was heavily contaminated at the time, is no longer subjected to extraordinary radiation exposure. Jülich radiation protection experts verified this by means of a long-term study. However, inhabitants should avoid mushrooms, berries, and venison from the region.

STUDY ON CHERNOBYL

The Helmholtz Association is establishing an Innovation Lab at Jülich: at the Microbial Bioprocess Lab, researchers together with industry partners will develop processes for production using microorganisms, for example to produce chemicals or food additives. Particularly the rapid analysis of the structural and functional properties of these microorganisms will play a major role.

LAB FOR BIOTECHNOLOGISTS

Jülich nuclear physicist Prof. Hans Ströher is seeking to find out the very foundation of our universe’s existence (see effzet 1-2015). In doing so, he will now receive support from Brussels: the European Research Council (ERC) has awarded him an Advanced Grant for outstanding established research leaders. The accolade is endowed with funding of around € 2.4 million. For Hans Ströher, this is already his second ERC Advanced Grant. The funding will flow into the search for electric dipole moments. These are differences in the distribution of the electric charge in particles. Hans Ströher and his German and Italian colleagues want to verify the existence of such dipole moments in protons and deuterons. The aim is to solve one of the greatest puzzles of physics: the imbalance between matter and antimatter in the universe.

ERC GRANT

Searching for the difference

… waiting for a flash of light: this is the plan for the world’s second largest but most accurate neutrino detector from 2020 onwards. It is currently being built in southern China with support from Jülich. The flashes of light will occur whenever neutrinos hit the special oil in the underground tank of the Jiangmen Underground Neutrino Observatory (JUNO). The objective of JUNO is to find out more about these electrically neutral and difficult-to-detect elementary particles. Jülich scientists are developing concepts to detect as accurately as possible and to process the signals produced by the photosensors.

— CENTRAL INSTITUTE OF ENGINEERING, ELECTRONICS AND ANALYTICS/NUCLEAR PHYSICS INSTITUTE –
Fix your eyes on the cross pictured on the right-hand side for around 30 seconds. Then, quickly, look at the cross shown on this page. You will see an eye, but in different colours. This is a negative afterimage. It occurs as a consequence of the retina adapting to the original stimulus.
Around 40,000 people in Germany are affected by the inherited disease retinitis pigmentosa. Patients suffering from it lose their vision because the photoreceptor cells in their eyes gradually degenerate. However, the neuronal network of the retina and the optic nerve are preserved. Researchers want to use this fact to restore part of their patients’ vision. Their approach is to implant a tiny electronic chip on or behind the retina. Controlled by a miniaturized camera that sends the image information, the chip stimulates the nerve cells with electrical impulses. In spite of intensive research during the past 20 years, patients with such implants are still far from being able to see clearly. Rough outlines, light and dark, strong contrasts – in most cases that’s as far as it goes. When looking more closely at the healthy eye, this doesn’t come as a surprise: our eyes along with the retina are absolute miracles. Inside them, 120 to 130 million photoreceptive cells feed their signals into a highly complex nerve cell network.

The retina is composed of several cell layers with various nerve cell types. What is significant is the large number of connections between the cells, made possible by long neurite fibres. The length of these retina nerve cell neurites alone can total up to 100 kilometres and have more than around ten billion synapses – these are contact points between two nerve cells. “We currently distinguish around 60 different cell types in the retina. According to the latest findings, however, we expect to have to adjust this number upwards by 10 to 20,” says Prof. Frank Müller in introducing his research field at Jülich’s Institute of Cellular Biophysics. This complexity is increased by the numerous messenger substances through which nerve cells communicate with each other.

Rods and cones, the photoreceptors, may be recognizable to most people from biology lessons. These cells are located in the outermost cell layer of the retina and they are also the cells that die off in patients suffering from retinitis pigmentosa. Rods are highly sensitive to light, permitting
macraine cells, transmit the signal laterally,” explains Müller. “These interconnections heighten the contrast in your vision, for example.” The signals are eventually pooled in the ganglion cells. Current estimates suggest the existence of up to 30 different types of ganglion cells. Each cell type has a different function, such as transmitting contrast or colours. But there are also ganglion cells which extract information on whether and how an object in our field of vision moves, or whether it is approaching us.

The multitude of cell types indicates that the retina carries out important interpretation work. “We are dealing with very different, highly complex circuits,” Müller explains. “During each transmission step at a retinal synapse, the signal is newly computed and changed.” With ten billion synapses per eye, there are thus quite a number of possibilities for signal modulation. The retina acts as a neuronal filter. It discards unnecessary information and thus minimizes the data flow from the eye to the brain. Primarily, however, it passes on the information which our brain is interested in: contrast, changes, movement. Our retina thus lays the tracks for our ability to quickly react to dangers in road traffic or for a goalkeeper to save a penalty.

Mach bands – each of these seven bands is evenly bright in itself. But where they touch, we perceive light and dark bands which do not exist in reality. The reason for this is that the eye increases the difference in brightness at the edges neighbouring a different band.

vision during twilight and in starlight. Cones, on the other hand, are less sensitive and permit vision in bright daylight and recognizing colours. The exciting part begins at the point where the knowledge acquired at school ends. Neurobiologist Frank Müller and his team aim for a much more detailed view into our eye’s confusing fibre and communication mesh. For this purpose, the researchers draw on the latest fluorescence microscopy to scan the retina cell by cell with a laser beam. “It’s about recognizing which cells are interconnected, and how, and what information is eventually transmitted to the brain,” doctoral researcher Stefan Esser summarizes.

THE FIBRES’ WHISPERINGS
To put it very simply, the fibres’ whisperings work like this: a cone is excited by light, transforms this stimulus into an electrical signal, and finally transmits the information to a bipolar cell via a chemical messenger substance. The bipolar cell in turn passes the signal on to another cell, a ganglion cell, which then transfers the signal to our brain via the optic nerve. What appears to be a simple relay is in reality the basis of a sophisticated information processing system. “Although the final analysis takes place in the brain, image processing starts in the retina, and right from the first synapse, the system relies heavily on parallel information processing,” emphasizes Frank Müller.

A cone transmits its signal not only to one bipolar cell but simultaneously to a whole set of different bipolar cell types. According to Müller and his team, there are at least ten types. “Two other classes of nerve cells, horizontal cells and amacraine cells, transmit the signal laterally,” explains Müller. “These interconnections heighten the contrast in your vision, for example.” The signals are eventually pooled in the ganglion cells. Current estimates suggest the existence of up to 30 different types of ganglion cells. Each cell type has a different function, such as transmitting contrast or colours. But there are also ganglion cells which extract information on whether and how an object in our field of vision moves, or whether it is approaching us.

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CELL LANGUAGE
This trip into the world of vision becomes even more complex when Müller starts talking about messenger substances and ion channels, the molecular basis of the nerve cells’ language. He sees an enormous need for research: “Our team showed, for example, that each bipolar cell type has a specific repertoire of ion channels.”
The retina – our eyes’ control centre

Seeing begins with an image of our environment being generated at the back of our eyes. But the retina is not a simple camera chip that transmits everything we see exactly as it is to our brain. Using its complex mesh of nerve cells and synapses, it extracts the part that our brain is interested in from the information flood. Such computing power is only possible because the retina itself is part of the brain. In the human foetus, it develops as early as four weeks after the fertilization of the egg cell, originating from outgrowths of the tissue structure that later on develops into the brain.

1. Incident light
2. Light receptors produce electrical signal
3. Signal transmitted in retina and first processing
4. Signal transmitted to brain via optic nerve

Simultaneous contrast – the band in the middle is evenly bright along its entire length. But the retina increases the contrasts so that the band stands out more clearly from the background. The brain re-calculates the brightness of the areas around it accordingly and we are tricked into thinking that the band in the centre changes in brightness.

Ganglion cells
transmit the signals from the retina to the brain via the optic nerve.

Amacrine cells
make up a second layer of cross connections, controlling the bipolar cells’ signal flow.

Bipolar cells
receive the signals from the light receptors and horizontal cells and then transmit them to the ganglion cells.

Horizontal cells
are cross connections between rods and cones and increase the image contrast.

Cones | rods
are light receptors which convert light stimuli into electrical signals.

Actual image of the retina, composed by the Jülich researchers from several micrographs: special staining techniques make the various cells and layers visible.
Ion channels are building blocks in the cell membrane. Through them, electrically charged particles – ions – find their way into and out of the cell. Since these channels can open and close, they act like a switch, controlling whether an electrical signal in the form of ions reaches the cell.

“Each cell type has its own specialized inventory of channels, and this characterizes the individual typical response behaviour of the cells,” Müller clarifies. His working group was able to verify an ion channel in rods, for example, which the researchers casually call “emergency brake”. It switches off the rod’s signal if there is a lot of light.

**BUILT-IN LIGHT PROTECTION**

In this context, it’s important to know that in darkness, the highly sensitive rods are active, while in bright sunshine, it’s the cones. The ion channel investigated by Müller and his team is activated when the signal in the rods becomes very large, i.e. in increasing brightness, for example if you step out of a dark room into bright sunlight. In order for the eyes not to be permanently blinded in such situations, the ion channel drastically reduces the rod’s signal. “Without this channel, we would practically be blind in certain lighting situations,” Frank Müller stresses.

But this miniaturized supercomputer – our eye – has further circuits: “The response behaviour of nerve cells is determined not only by their ion channels but also by a wide range of messenger substances. They help the retina to adapt its sensitivity to an enormous spectrum of light intensities,” says Müller. “In bright sunshine, 10 or 100 billion times more light reaches the eye than during a starlit night. Some of this adaptation takes place within the photoreceptors themselves, and some in the retinal network.” In addition, different nerve cell types react very differently to the same messenger substance. The researchers can observe this using fluorescence indicators, which they smuggle into retina cells as “glowing spies”. This is another indication of a complex system, comprising very finely tuned circuits, which scientists are not even close to fully understanding.

Given the enormous complexity of the eye, it may seem very bold to want to give blind people back their sight. But this is exactly what doctors and scientists want to achieve with retina implants. They want to use artificial impulses to stimulate the part of the retina that is still healthy. Prof. Peter Walter, director of University Hospital Aachen’s Ophthalmology Clinic and Frank Müller’s cooperation partner, has operated on eight patients suffering from retinitis pigmentosa.

“We use a chip manufactured by a US company and place it on the retina,” he explains. The chip stimulates the nerve cells by means of electrical signals from a camera that is integrated into the frame of a pair of glasses. This way, most people affected can at least make out sharp contrasts. Walter and Müller agree, however, that this system is far from being a proper vision aid. One central problem is that even the largest chips currently in use work with a maximum of 1,500 pixels. The field of vision produced in this manner is small – around the size of a tennis ball.
Deliberate deception

Optical illusions show that our perception sometimes differs from reality: straight lines seem curved, evenly bright squares appear as gradients. This deception can be useful: often, we have to rapidly classify what we see – for example to recognize dangers such as an animal on the side of the road or a person in a dark corridor. This is why the eye exaggerates and lets us see contrasts more vividly than they really are. From these phenomena, researchers can learn how and where the eyes and brain process information. The illusions on pages 8–11, for example, occur from information processing on the retina, while that on page 12 is produced by the brain. The optical illusion on the cover is a scintillating grid. It was developed from the Hermann grid (pictured on the right), where eye and brain produce dots where the lines intersect.

» When the light receptors die, the retina reorganizes itself – just as if someone were to keep plugging in and out cables inside a supercomputer. «

when viewed at arm’s length – and the resolution is roughly 100 times worse than that of a healthy retina.

IMPAIRED RECEPTION

“We also have to take into consideration that the retina heavily reorganizes itself during the course of the disease, just as if someone were to keep plugging in and out cables inside a supercomputer,” adds Frank Müller. His working group studied how the disease develops in mice. “We measured pathological series of rhythmic signals in the retina, which alternate with phases of normal activity.” Current retina chips don’t take these changes into account. They instead continue to stubbornly send their signals to the nerve cells. If the network is strongly changed due to the disease, however, the signal may no longer be of any use to the nerve cells. The teams of neurobiologist Müller and medical researcher Walter therefore teamed up with engineers and electrical engineers, with Jülich bioelectronics expert Prof. Andreas Offenhäusser among them. Together, they are designing a new generation of electrodes for retina implants.

The idea is that the electrodes not only send the signals in order to excite the existing nerve cells, but also measure what the state of the retina is and whether it efficiently converts the stimuli. “We hope that at some point, we’ll be able to recognize diseased activity using such bidirectional electrodes and use targeted impulses to reset them to their normal state,” says Frank Müller, looking to the future. One option would be to specifically target those nerve cells that react particularly effectively to the artificial signals. Within the scope of a project on bidirectional communication between retina stimulators and retina (BiMEA), funded by the German Research Foundation (DFG), the research unit wants to introduce the first functional electrode prototype by 2018.

BRIGITTE STAHL-BUSSE
The Jülich researchers have developed a novel type of special steel and given it the name HiperFer (high-performance ferritic steel). It unites two properties which preclude each other in conventional power-plant steels, at least at high temperatures: HiperFer resists corrosion caused by hot water vapour, which is produced in power plants in order to generate energy. And the material remains mechanically stable, even under these extreme conditions, i.e. it fatigues much more slowly. This means that not only frequent load changes can be borne: the steam turbines can also be operated at much higher temperatures than 600 °C. This increases the energy yield.

**CHROMIUM PROTECTS**

HiperFer owes its temperature stability to its comparatively large share of chromium: the metal protects the iron from corrosion. In conventional steels, the amount of chromium cannot be increased at will since from a share of around thirteen percent upwards, the mechanical stability of the components suffers. The researchers headed by Bernd Kuhn are meeting this challenge by mixing small amounts of other elements such as niobium, tungsten, and silicon into the hot iron melt during the production of the steel. While the steel cools, these materials form tiny particles of what is known as an intermetallic phase. They give the material particularly high durability of high-performance steels is practically exhausted. We are pursuing a new approach.”

German grid operators had spent months preparing for the day: on 20 March 2015, the Moon slid in front of the Sun and cast its shadow onto Earth. The partial solar eclipse caused the amount of power generated by photovoltaic facilities to take a plunge. Within moments, energy suppliers had to counteract this effect using conventional power plants. Such fluctuations occur daily in Germany’s electricity grids – on a smaller scale: sun and wind, which are being used more widely as part of the transformation of the energy sector, are not available around the clock. For the components of power plants, this frequent change in loads presents a special challenge.

Cold-starting a steam power plant used to take around ten hours just to reach the operating temperature of 600 °C. This time span has since shortened to three and a half hours, and for the first 500 °C, only 45 minutes are now required. “A few years ago, this was unthinkable. But these days, it’s an everyday reality,” explains Jülich scientist Dr.-Ing. Bernd Kuhn. “The power plants are not built for such operating strategies, however. The rapid switching on and off causes the steel components to fatigue quickly.” The engineer and his team working on metallic materials and joining techniques have therefore set themselves an ambitious goal: they want to use the most multifaceted metallic material known to man and make it fit for the new requirements posed on steam power plants. Bernd Kuhn is confident that they will succeed: “The potential of conventional methods to increase the durability of high-performance steels is practically exhausted. We are pursuing a new approach.”

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stability, as Bernd Kuhn explains. “The number, size, and distribution of the particles within the steel is decisive for the mechanical properties of the material,” he adds, pointing at his computer screen, which shows electron-microscopic images of samples. They are reminiscent of a starry night sky. “These little white dots are not stars but our special particles. They must not be too small, nor too large either. And they have to be distributed as evenly as possible so that the steel displays the desired properties.” In addition to the correct mixing ratio of all components, their processing plays a major role, including shaping and the speed of cooling during the production of the components.

WELDING AS A TOUCHSTONE
At the moment, Kuhn and his team are optimizing the steel’s processability. Their focus is how permanently the components can be joined by means of welding: “Welding is the most important process in building power plants. A new material that is difficult to weld will find it hard to establish itself on the market.” But the properties of the HiperFer steel are already convincing: starting from the middle of next year, the Jülich researchers together with their partners want to test how well the high-performance material can be produced on an industrial scale. Meanwhile, not only Germany’s Energiewende stands to benefit from HiperFer, with Bernd Kuhn convinced that the chemicals industry also has a great interest in such materials. “Due to its mechanical properties and excellent corrosion resistance, HiperFer is particularly suitable for the future production of gaseous and liquid energy carriers via thermal conversion processes using regenerative hydrogen and CO₂. And aside from this: good steel is always needed everywhere.”

But it will take at least another ten years before the steel can be brought to market. The requirements made of new materials in this field are extremely demanding. For example, they have to pass lifetime tests where they have to function for 100,000 hours. That’s a total of around twelve years. The Jülich steel has already achieved around half this time.

ARNDT REUNING

† If all goes according to Dr.-Ing. Bernd Kuhn’s and his colleagues’ plan, pipes such as these will be made from HiperFer in the coming years.
Small error, dramatic effects

Proteins are vital: these complex biomolecules ensure the smooth operation of our metabolism and immune defence, for example. However, small deviations in their molecular structures can lead to severe diseases such as Parkinson’s or Alzheimer’s. In our Interview, Jülich biochemist Prof. Dieter Willbold talks about the dramatic effects of these small errors.

Loss of memory due to Alzheimer’s, impaired movement caused by Parkinson’s, high blood sugar levels from diabetes – these ailments don’t have an immediately obvious connection. And yet, they are often mentioned in the same breath at your institute, Prof. Willbold – why is that?
The symptoms are different, but the causes are similar on the molecular level: the molecules of certain – generally harmless – proteins accumulate and form aggregates which then have damaging effects on the body. These aggregations are the beginning of the respective disease. Different proteins and organs are affected, but the underlying phenomenon of aggregation is always the same. We want to understand why proteins produced by the body itself thus become disease triggers.

Are there other diseases where this plays a role?
Yes, we know of many such diseases. Neurodegenerative conditions, which damage the brain and nervous system, are particularly prominent among them. Apart from Alzheimer’s and Parkinson’s, from which many millions of people suffer, there are also very rare but severe diseases caused by these conditions. Examples include amyotrophic lateral sclerosis (ALS) – the disease that physicist Stephen Hawking suffers from – as well as Huntington’s and Creutzfeldt-Jakob disease.
Is it known what causes these protein aggregations? They’re connected to malformed molecular structures. Proteins are precision tools in the body, with precisely defined functions and complex, three-dimensional structures suited to their exact purpose. Even very small deviations can cause an aggregation. What’s fatal is that the proteins not only lose their original function in their aggregated form, but frequently acquire new, damaging properties – for example, they can become toxic and then damage nerve cells. In order to understand what distinguishes the structures of healthy, correctly working proteins from that of pathologically altered ones, we need ultrahigh-resolution images of their molecular structures. At Jülich, we use methods such as NMR spectroscopy for this purpose, which – ideally – shows us the position of every single atom in a molecule.

Could this mean that there is a connection between the two diseases on a molecular level? We know too little so far to identify conclusive connections. But needless to say, indications such as these should be further pursued nonetheless. It’s important that interactions between the various disease-specific proteins now gain increasing importance in research – also for very practical questions on dealing with these diseases.

For example? For example the early diagnosis of neurodegenerative diseases. Unlike diabetes, where we can measure the higher blood sugar levels, we have yet to identify a biomarker for Alzheimer’s and Parkinson’s – a reliable indicator for the disease, measurable at an early stage. We are forced to go by the diseases’ symptoms – and they are not very reliable, especially in the beginning. This is why we have developed an extremely sensitive procedure for the detection and analysis of protein aggregates, with the aim of using them as diagnostic biomarkers.

And protein interactions would be a problem? Unknown interactions or overlaps between the aggregates could actually be detrimental. We have recently received funding from a joint initiative of the American Alzheimer’s Association and the Michael J. Fox Foundation for Parkinson’s Research to investigate these issues using our system.

If the basic principle of these diseases is similar, is it then conceivable that one drug could show effects on several of them? If the drug were to affect the process of aggregation itself, and not only the symptoms, then yes. Wolfgang Hoyer’s research group at our institute, for example, has developed a molecule which can shield certain areas of protein molecules. At least in laboratory experiments, the aggregation of the proteins relevant to Alzheimer’s, Parkinson’s, and type 2 diabetes was successfully inhibited. We are hoping that a new drug candidate against Alzheimer’s which we are developing at Jülich will also exhibit this effectiveness across diseases.

How far is this drug candidate in development? We know that the substance eliminates the particularly toxic aggregate forms and we have collected a lot of information on its tolerability and effectiveness in various model organisms. We are about to apply for the first clinical trials, during which its safety will be tested in humans. If it can later be confirmed in patients that our molecule is indeed effective against Alzheimer’s, then we’ll try to transfer the principle to Parkinson’s, Huntington’s, and ALS.

The interview was conducted by Peter Zekert.
Batteries: a breath of fresh air

Lithium–air batteries are potential successors to today’s energy storage systems. Jülich and Munich researchers have now found out why these batteries are only able to withstand very few charging cycles.

These days, an electric car can cover around 150 kilometres before its battery needs to be recharged. Larger ranges are viewed as critical for any future sales success of these environmentally friendly vehicles. But the battery cannot simply be enlarged because that would leave too little room for passengers and cargo. What is needed is a battery that requires no additional room but provides around 20 times the energy that today’s lithium–ion batteries do. A lithium–air battery can do this – theoretically.

In practice, however, the developers are combating problems such as the fact that these batteries can only be recharged a few times before they are capable of storing only small amounts of energy or even completely cease working. The effect is caused by degradation reactions that occur particularly during the charging process and which are not yet fully understood. These reactions are what Jülich battery researchers headed by Prof. Rüdiger Eichel together with scientists from the Technical University of Munich (TUM) have been investigating.

They based their research on the suspicion that singlet oxygen plays a decisive role in the degradation reactions. Singlet oxygen consists of oxygen molecules which are electrically excited. This means that they react much faster with the substances surrounding them than “normal” oxygen, making them more aggressive towards other materials, but also much harder to detect since they are so short-lived.

In order to get a hold of the alleged culprit, the researchers made use of a trick: “We basically lured the singlet oxygen into a chemical trap,” explains Eichel. This is made up of a complicated chemical compound. It reacts with the singlet oxygen and forms another compound, known as 4-Oxo-TEMPO, which is more stable than singlet oxygen. It is also easy to detect by means of electron spin resonance spectroscopy (ESR).

The scientists have thus developed an apparatus which is an ESR measurement cell as well as a battery at the same time. They were thus able to conduct ESR measurements while charging and discharging the battery.

It was revealed that 4-Oxo-TEMPO really is formed, and therefore singlet oxygen. “Now, we and other researchers can tailor lithium–air batteries in a targeted way to avoid processes in which the highly reactive singlet oxygen is formed. We thus have a starting point to make battery performance longer lasting,” says Rüdiger Eichel. Additives for the electrolyte or coatings for the electrodes could be used as tweaks.
What’s your research all about, Dr. Freimuth?

Dr. Frank Freimuth, Peter Grünberg Institute/Institute for Advanced Simulation – Quantum Theory of Materials

“I want to find ways to transfer information more efficiently. It’s about more rapidly writing and densely packing data to make computers considerably more powerful. For this purpose, I make use of the spin of electrons: with it, I want to control electric or light pulses – by means of the effects of quantum mechanics and the theory of relativity. My task is to theoretically predict what materials and methods are suitable for this. I also analyse the experimental implementations of colleagues from all around the world.”
Lost and found

This year, Forschungszentrum Jülich celebrates its 60th anniversary. A fitting occasion to delve into the depths of the archive and sift through some of the photos and videos. Here are some of the treasures we found. You will also find a look back on 60 years of research at historie.fz-juelich.de

ALMOST LOST

During a ceremony on 11 June 1958, the foundation stone for the MERLIN light-water reactor was laid in the Stetternich Forest near Jülich. The ceremony is viewed as the foundation of Forschungszentrum Jülich as a whole. The reactor itself was gradually decommissioned and demolished from 1995 onwards. It wasn’t until the last phase of dismantling – almost exactly 50 years after the ceremony – that the foundation stone was recovered. The dismantling company discovered it in the remains of the foundations.
CORE ELEMENTS

It took seven years to plan and develop Textor, an experiment on nuclear fusion. The image shows three core elements of the main coils – 16 in total. For 30 years, the facility permitted new insights into plasma physics and fusion energy. In 2013, the facility was switched off, and the scientists now focus on investigating the fundamentals of the continuous operation of fusion power plants.

VISITOR MAGNET

Almost all German Federal Presidents have come to visit Forschungszentrum Jülich; among them Gustav Heinemann (left) in October 1969. Leo Brandt (right), founder of Forschungszentrum Jülich and first Chair of the Board of Directors, guided Heinemann and his wife Hilda through the centre.

GROWING STEADILY

Shortly after the official inauguration of the then Nuclear Research Centre Jülich in 1961, numerous institutes and supplementary facilities developed: this is a view of the eastern part of the site (1969), with the DIDO heavy-water reactor (right) and the AVR high-temperature reactor (left) in the background.

COMPUTING MIRACLE

High-performance computing has a long history at Forschungszentrum Jülich. The first supercomputer was installed in 1983: a CRAY X-MP/22. At the time, it was viewed as Western Europe’s fastest computer.
Climate researchers going underground

It’s not just wind and high- and low-pressure systems that influence the weather and climate – soil, plants, and groundwater also play their part. What this role looks like in concrete terms is taken into consideration by a new simulation platform. It could refine future weather forecasts.
Weather and climate? They depend mostly on solar radiation, air mass movement, cloud cover, and precipitation — you would think. The reality is far more complicated: weather and climate are not solely dependent on processes in the atmosphere but also on the interaction between land and ocean surfaces with the atmosphere. This means that vegetation as well as deeper soil layers also influence temperatures and weather conditions. Let's look at an area with a high groundwater level as an example. In such an area, plants have access to plenty of water even during dry spells. They absorb it through their roots, pass it into the leaves, and from there it evaporates into the surrounding air. This affects air humidity and can have diverse consequences. Increased evaporation could mitigate heat waves but also intensify short and intense precipitation.

Researchers want to record and predict as accurately as possible brief weather caprices and long-term climate changes. They use complex computer models to this end. So far, these models have only considered the interactions between groundwater, land surface, and atmosphere in a very simplified manner. This contributes to the simulations deviating from reality.

**GAPS CLOSED**

Scientists from Bonn and Jülich have now developed a simulation model that is the first to precisely take into consideration such interactions: TerrSysMP, short for Terrestrial Systems Modeling Platform, can simulate and thus better predict systems such as the water cycle without gaps. The same also applies to the exchange of gases such as nitrogen and carbon dioxide, which also influence the climate.

The platform is run on Jülich’s supercomputers JUQUEEN and JURECA and interlinks existing individual models of the atmosphere, land surfaces, and groundwater: “This creates something completely new. The platform permits simulations for which the individual models really interact with each other,” says Prof. Stefan Kollet, head of the Centre for High-Performance Scientific Computing in Terrestrial Systems (HPSC TerrSys). In addition, TerrSysMP also calculates values ignored by other simulation programs, such as groundwater recharge and the amount of plant-available water in the soil. This information will help farmers decide whether a field has to be irrigated or not.

**DWD PROVIDES FORECASTS**

In order to calculate any simulations at all, TerrSysMP first needs some fundamental information such as physical properties which describe the nature of the soil, what rock there is, or how porous and water-permeable the subsoil is. In addition to these data, which do not change much over time, the modelling system is automatically supplied with current forecasts by the German Meteorological Service (DWD) as well as the European Centre for Medium-Range Weather Forecasts (ECMWF). These values include temperature, water vapour content of the air, and wind speed and direction, and they are the starting conditions for the partial model of the atmosphere. Based on them, TerrSysMP simulates how, for example, air pressure and temperature as well as the exchange of water and other substances between land surface, soil, and groundwater develop. “Every day, we calculate this for Europe and its river catchment areas for three days in advance – with a resolution of twelve by twelve kilometres. We have also run tests with three by three kilometres,” reports Dr. Klaus Görgen from Jülich’s Institute of Bio- and Geosciences (IBG-3), who is also active at the Simulation Laboratory Terrestrial Systems. The researchers also separately simulate the water and energy cycle for North Rhine-Westphalia. The supercomputers take around one hour to calculate the development for the next 24 hours.

The daily results are available on YouTube. The videos show, for instance, how the current groundwater level changes throughout the day. A website is also in planning, where users will be able to access the data interactively. According to the scientists, particularly the water management and agriculture sectors as well as research groups are the target group. If TerrSysMP runs as planned, meteorological services could also benefit from the forecast model. Currently, hydrologists and meteorologists are working on accurately reviewing the simulation results. In the long term, the researchers want to include current observational data in the simulations – and thus further improve the interactions of the subsoil with the weather.

**Daily updates**

The researchers post 25 new simulation videos on the Internet portal YouTube every day.

[www.fz-juelich.de/terrsys](http://www.fz-juelich.de/terrsys)
MORE EFFICIENT COMPUTING

An optimal distribution of tasks is the key to success when building a temple, just as it is in high-performance computing. It is in this way that supercomputers for scientific simulations are expected to become up to a thousand times more powerful than previously and use less energy at the same time. What’s new is that there are two different types of computers – Clusters and Boosters – united into one device. This way, the different tasks required for simulations can be tackled particularly efficiently. Coordinated by Forschungszentrum Jülich, 16 partners from eight European countries have implemented the Cluster–Booster concept in the DEEP project.

1 PLANNING
In order to simulate a process at the computer, scientists develop a physical–mathematical model. It consists of many calculation specifications to be carried out by the computer. It thus has to solve numerous tasks with different degrees of difficulty to come to a result – just like masons and sculptors have to manufacture many components of differing complexity to build a temple.

2 WORKING
The computation work is shared, just like work on different building components: the Cluster takes on the complex, particularly challenging tasks which can’t readily be divided into several similar subtasks. The Booster’s numerous processors, which are less powerful, work on the simpler tasks that can easily be divided into parallel subtasks.

3 RESULT
The tasks solved by the Cluster and those worked on by the Booster are combined into one result: the simulation is finished.
The tropical *malaccensis* tree really only wants to protect itself. Whenever it is injured and infested by a certain type of mould, it fights back by producing one of the most coveted raw materials in the world: a fragrant resin that is more expensive than gold. In Saudi-Arabia, Taiwan, and China, it is mostly used as incense due to its beguiling scent. In the perfume industry, the oil produced from the resinous wood is one of the most sought-after fragrances.

“In the past few years, demand for agarwood has exploded,” says Jülich plant researcher Dr. Claudio Cerboncini. The problem is that there are very low supplies to meet the high demand. As little as 1,000 tonnes of the raw material are produced in one year – and almost all of it by illegal harvesting. The market value of a high-quality piece of wood imbued with the resin can fetch up to $ 2 million per kilogram.

**STOCKS SEVERELY DEPLETED**
The hunt for the rare resin has severely depleted the population of this endangered deciduous tree: hunters of agarwood comb through the rainforests of Indonesia, Thailand, Vietnam, and Malaysia, and fell every *malaccensis* tree they can find – no matter whether it’s healthy or infected, although the resin is only produced in the heartwood of the *aquilaria* and *gyrinops* species, and the resin is only produced by every tenth specimen.

The race between extinction and reforestation has long since begun. As part of a three-year Vietnamese cooperation project, a Jülich team headed by Claudio Cerboncini has been looking for sustainable production alternatives. Launched in January 2016, Vietwood unites scientists from Vietnam University of Agriculture, Forschungszentrum Jülich, and a German aroma and fragrance producer, who work side by side to reveal the secret of the natural product. This is by no means a simple task, because more than 200 individual aromatic substances lend agarwood its unique fragrance.

“We are pursuing two approaches,” says Cerboncini, who has been investigating agarwood for several years and successfully mentored a programme in Indonesia in the past. On the one hand, the scientists want to find out what types of mould trigger the formation of the resin. For this purpose, they inject the tree species *aquilaria* and *gyrinops* with various types of mould. “We can thus determine what moulds can be used to produce resin of a quality that would be of interest for the industry,” explains Cerboncini. On the other hand, the researchers are also trying to develop a biotechnological method: they want to synthetically replicate the natural substance in order to curb illegal harvesting.

**KATJA LÜERS**

![From the jungle into the bottle: oil from the resin of *malaccensis* trees is a highly coveted scent for perfumes.](image-url)
With its shimmering silver metal skin, the award-winning building seems almost alien. The research facility :envihab – a portmanteau of "environment" and "habitat" – is all about mankind: about human health and performance under extreme conditions such as those in space. The various devices in the facility permit the consequences of zero gravity and lack of sleep, for example, to be examined. German astronaut Alexander Gerst also benefited from this after his stay on the International Space Station (ISS). When he returned to Earth in 2014, he was the first European to be looked after not in Moscow or Houston but at :envihab.

One of the devices available there is a combination of a positron emission tomograph (PET) and magnetic resonance imaging device (MRI), which makes functional and structural changes in the brain visible. Researchers from Jülich’s Institute of Neuroscience and Medicine (INM-2) use this device within the scope of a cooperation with DLR: “We and our partners from DLR have competences that perfectly complement each other," says Prof. Andreas Bauer from INM. "We contribute knowledge and experience in imaging techniques, and particularly PET-MRI, to the collaboration. But we also profit from the expertise at DLR concerning the examination and monitoring of bodily functions.”

Currently, Jülich medical scientist Dr. David Elmenhorst together with DLR colleagues is investigating why a lack of sleep affects people and their performance differently. For this purpose, a total of 36 test subjects spend eleven days and nights at :envihab, under strictly controlled conditions. By means of brain scans, the researchers want to verify that the messenger substance adenosine plays a major role in the individually different consequences of chronic sleep deprivation.

**Facts on :envihab:**

- 8 separate modules, equipped with a short-arm human centrifuge, a physiology laboratory, a baro laboratory (for decreasing pressure), etc.
- Area: approx. 5,400 m², of which 3,500 m² for research
- Height: approx. 9.25 m
Will the next winner of the Jugend forscht competition come from Africa or the Middle East? The chances of this happening are being increased by the “Physik für Flüchtlinge” project, by means of which Deutsche Physikalische Gesellschaft addresses young people in refugee accommodations. Volunteers help distract children and young people who have had to flee from their home by demonstrating hands-on experiments and kindle their enthusiasm for physics to aid their integration into our society. With more than 500 students, doctoral researchers, and scientists volunteering, the pilot project carried out in December 2015 was a huge success. The initiators are now looking for volunteers for the next event.

– WWW.DPG-PHYSIK.DE/PFF –

Summer is here, and with it one annoying pest: the mosquito. But the researchers from the Leibniz Centre for Agricultural Landscape Research (ZALF) are happy about each and every one of them. The experts are encouraging citizens to catch the little bloodsuckers for the good of science, and to send them in. They want to determine how widespread the various species are, for example specimens immigrated from Asia. Since 2012, they have been working on their mosquito atlas. If you want to participate, you should observe the following tip, however: squashed or flattened insects are of no use for science. The researchers recommend catching mosquitoes using a container, freezing them overnight, and also using a container to mail them.

– WWW.MUECKENATLAS.DE –

The results of our reader survey are in, and we would like to thank all participants. We were delighted to find out that you are fans of effzett! In almost all categories, you rated the magazine as “very good”. This reassures us that we are on the right track. Articles on energy are the most important topic for you. We will bear this in mind in future! For the next issue, we already have plans for hydrogen to be the cover story. Until then, the five survey participants who won in our prize draw can keep busy with the air propulsion system of their new model car – congratulations and have fun!

– WWW.EFFZETT.DE/SURVEY –
Dr. Dirk Witthaut developed the formula together with colleagues—also with a view to the transformation of the German energy sector because it causes increased loads on the electricity grid. If one power line fails, others have to step in. The formula immediately shows how the grid would react to a failure. This complements elaborate simulations and shows weaknesses. www.fz-juelich.de/power-failures