Why?

Plaques in the brain have long been regarded as the trigger of Alzheimer’s disease – probably wrongly. But what exactly is the cause, then? And where does research stand today?
In a moment, it will be “Blast off!” Jülich climate researchers examine the outer shell of their research balloon one last time before it sets off on its inaugural flight. It is to climb to an altitude of 35 kilometres, right through thunderclouds. The researchers want to find out how thunderstorms influence the climate. For this purpose, devices on the balloon record temperature, ozone content, air pressure, air humidity and aerosol particles. They will send the data to Earth by radio. After a few hours, the balloon will burst, letting the valuable cargo safely return to Earth with a parachute. The flights are part of MOSES, a mobile measurement system for earth observation.

Video of the test flight at: effzett.fz-juelich.de/en
NEWS IN BRIEF

Starting over?
No cure, unknown causes, false assumptions – why research into Alzheimer's disease gives cause for hope all the same.

RESEARCH

A force of nature with two faces
How the Asian weather phenomenon purifies the air and at the same time distributes pollutants over the earth.

Reading in primordial dust
What a meteorite reveals about the magnetic field in the early solar system.

The secret glow of plants
Instruments of start-up JB Hyperspectral Devices capture it.

A true jewel
JUWELS: start of a new generation of supercomputers

Spellbound by the channels
Christoph Fahlke researches transport processes in cell membranes.

Model kit for atomic nuclei
New computer model calculates exactly how stable a core is.

Inclusion in an emergency
SiME is looking for safe escape routes for people with disabilities.

Mapping the brain
Advances in medicine: from Brodmann's map to the modern brain atlas
Everything all right?

Our next door colleague’s grandmother was very special. She lived to be almost 100 years old. Physical infirmity was usually treated with a shrug of the shoulders: “As long as I’m still in my right mind!” She was – even when she was sitting in a wheelchair at well over 90 years old. This is not a given because on average, every third person suffers from Alzheimer’s disease at this age, the most common form of dementia. So far, it has been neither possible to stop the disease, nor possible to cure it. Jülich scientists have also been working for years to understand Alzheimer’s disease, to diagnose it early on and to specifically develop drugs. Our cover story summarises the current state of research, provides an explanation for why there are no drugs for the disease so far, and illustrates the approach that the Jülich scientists are focusing on.

JUWELS, the new Jülich supercomputer that we present to you here, is already on the road to success. We travel into the South Asian monsoon with our climate researchers and the fragment of an ancient meteorite tells us something about the beginnings of the solar system.

We wish you new insights on all topics of this issue, a clear mind and good health for years to come!

Your effzett editorial team
Early warning system for blackouts

The failure of even single lines in large power grids can lead to fatal chain reactions in just a few seconds – as in Europe in 2006, when large parts of the power supply were unintentionally knocked out when one line was switched off. In an international team, Jülich researchers have now developed a computer model to find such critical lines. It can detect weak points both in the planning of the power supply and during operation. Large-scale blackouts can affect millions of people – and would have catastrophic consequences in our highly technological and networked society.

Genes at work in the brain

Jülich researchers have developed a digital tool which allows for a better understanding of the influence of genes on the functioning of the brain. JuGEx combines genetic information with the anatomical data of preselected brain regions. The researchers have already been able to characterise two genes that are particularly active in a brain region that is altered in patients suffering from depression. JuGEx is part of the European Human Brain Project – started in 2013, this is one of the largest neuroscience projects worldwide. In June 2018, the European Commission provided the funds for another two years.
PLANT RESEARCH

Dodder decoded

Scientists from Norway and Jülich have decoded the genome sequence of a parasitic plant: *cuscute compestris* – or alfalfa dodder – is responsible for sometimes devastating crop losses of, for example, potatoes or rapeseed. The parasite wraps itself around the stem of its host plant and extracts water and nutrients from it. The results could help make crops more resistant to *cuscute*.

- INSTITUTE OF BIO- AND GEOSCIENCES -

BIOELECTRONICS

High-tech gummy bears

Jülich and Munich researchers have succeeded in printing an arrangement of microelectrodes, a so-called array, onto gelatine – in this case on a gummy bear with mechanical properties similar to those of the brain. They used a high-tech version of an inkjet printer filled with carbonated liquid.

Until now, it had only been possible to attach electrodes to soft surfaces with great effort. In the future, microsensors of this kind could be used to measure electrical signals directly at the brain or heart.

- INSTITUTE OF COMPLEX SYSTEMS -
Forschungszentrum Jülich will receive € 3.2 million from the ATHENA project for the expansion of its short pulse photon centre JuSPARC. In the future, experiments on the acceleration of short electron pulses will also be conducted in order to generate even higher photon energies. These are important for information technology, for example.

Together with an international team of researchers, Jülich scientists have developed a method that for the first time maps the magnetic structure of individual atomic layers inside a material. For their measurements, they used the ultra-high-resolution electron microscope PICO, which even shows positional shifts of individual atoms.

The Jülich campus is becoming a real laboratory for the energy transition: the “Living Lab Energy Campus” project focuses on intelligent supply systems for heat and electricity as well as chemical energy storage and mobility. Interactions between technology, IT systems and consumers are investigated in live operation.

It usually lies flat. With the aid of a scanning probe microscope, Jülich researchers have now succeeded in making an extremely thin PTCDA molecule stand up – on silver atoms serving as a “pedestal”. Building such nanostructures from complex molecules is still a challenge for scientists because molecules are difficult to control. The work is an important step towards the production of any molecular architecture and could enable a multitude of new applications in the future – even quantum computers.
"Alzheimer’s disease shows us human existence without any decoration, heartbreakingly bright, fragile, and delicate in all its details," writes Dutch photographer Alex Ten Napel. The Alzheimer patients shown here are part of a series photographed in an Amsterdam nursing home between 1996 and 2001. For more information, see: [www.alextennapel.nl/copy-of-about-hens-and-roosters-1](http://www.alextennapel.nl/copy-of-about-hens-and-roosters-1)
The disease has been known for over a hundred years, yet there are still no effective drugs against Alzheimer's – despite enormous efforts in research and industry. One reason is: time and again, new findings require different approaches. As a result, two major assumptions recently turned out to be wrong. Starting over, then? Not quite.

Our visit had been scheduled. We ring the bell. My mother opens the door. She beams at us: “Visitors! How lovely! Whom do we have here?” She has absolutely no idea who we are.

Auguste Deter is only 51 years old at the time of her admission to Frankfurt’s municipal mental asylum in 1901. She is confused, forgetful and unable to cope with everyday life – all symptoms that are more likely to be observed in older people. The neurologist Dr. Aloïs Alzheimer records Auguste Deter’s medical history. After her death, he discovers astonishing changes in her brain: under the microscope, he not only spots numerous dead nerve cells, but also conspicuous protein deposits. These are distinguished into two types: one is of flat coatings between the nerve cells, which are today known as amyloid beta plaques; the other of a structure of fine fibres in the nerve cells known as tau fibrils.

Aloïs Alzheimer gives the disease its name. Since the 1960s at the latest, the protein deposits have been regarded as the cause of the destroyed cells and forgetfulness. Typically, however, people fall ill much later than Auguste Deter: for those aged 65 to 70 years, the figure is merely three out of a hundred, while for those over 85, it is one in five (see also p. 11).

Alzheimer’s disease is not the only form of dementia, however, although the most common: in Germany, it affects two thirds of the 1.6 million dementia patients. “We speak of Alzheimer’s disease when both deposits, amyloid beta plaques and tau fibrils, occur together,” explains Prof. Dieter Willbold, Director at Jülich’s Structural Biochemistry (ICS-6) division.

“We’re having soup,” my mother says, radiant with joy. I look inside the pot. A piece of meat floats in the cold water.

In the search for an antidote to this insidious disease, research has long focused on one of the two deposits: on amyloid beta plaques. One reason was genetic findings. With the help of enzymes, every human being produces amyloid beta proteins from a so-called precursor protein. However, gene mutations of the precursor protein or enzymes may occur. This can result in the formation of a particularly large number of amyloid beta proteins. Those affected fall ill with Alzheimer’s very early in their lives. A small Icelandic population, on the other hand, has developed a mutation through which the body hardly produces any amyloid beta proteins. This apparently makes these people almost resistant to Alzheimer’s.
She has meanwhile recognised us by our voices and is happy that we are with her.

On the basis of these findings, an excess of amyloid beta proteins was long regarded as the main cause of plaques and, thus, of the disease. Hence, two ideas were at the centre of attention: if, using imaging methods, the plaques can be visualised early, the disease can be reliably diagnosed. If an active substance can be found that either destroys the amyloid beta proteins responsible for the plaques or prevents them from developing in the first place, the disease is defeated. Unfortunately, both ideas turned out to be wrong. Although some drugs that are currently being developed and tested reduce deposits in the brains of those affected, none of them has been able to stop mental deterioration.

“How was your trip from Aachen?” she asks. We haven't lived there for over six years.

Another indication that counts against the plaques as a cause was provided by the much-noticed Nun Study. Since 1986, the American epidemiologist David Snowdon and his research team have been continuously documenting the mental and physical condition of almost 700 nuns aged between 75 and 107. The nuns decided that after their deaths, the brains of the deceased are to be donated to science. It turned out that numerous participants of the study showed the typical deposits in the brain and were mentally fit up to old age all the same.

After these setbacks, several large corporations have thrown in the towel, either completely withdrawing from Alzheimer's research or discontinuing studies, as did the Eli Lilly Group in 2016 – after more than 27 years of research and development and an investment of around USD 3 billion – and the companies Pfizer and Merck at the beginning of 2018. Yet research does not have to start from scratch. The previous findings continue to form the basis. However, potential active substances might have to set in one step earlier.

“She asks me dozens of times a day what day of the week it is.” My father is visibly struggling to retain his composure.

Physicians and scientists by now assume that a precursor of amyloid beta plaques is the true culprit. “It is obvious the so-called amyloid beta oligomers impair brain function by disrupting the processes at the synapses, the contact points between the nerve cells,” explains Dieter Willbold. The oligomers are formed when the molecules of the amyloid beta protein randomly combine to form small molecule groups. The flat plaques that Alois Alzheimer discovered only develop when these molecular groups are grouped further. These are insoluble and accumulate between the nerve cells. The oligomers are different: they are smaller than plaques, soluble and can therefore move freely in the fluid of the brain. “However, it was only modern technology that made it possible to discover the oligomers about 15 years ago. They are now regarded as an important driver of Alzheimer’s disease,” says the Jülich expert.

Medicines against forgetfulness

Of all the drugs that have been tested against the progression of Alzheimer’s dementia, not a single one has made it into clinical routine. More than 100 drugs for Alzheimer’s dementia are currently in clinical trials, i.e. they are being tested on humans. Approximately 30 of these studies have already reached Phase III. In this phase, they have to prove their effectiveness against the malicious disease. If successful, the active ingredients can be approved as drugs. Many years, even decades of research and development have already gone into the active ingredients up to this point. “Unfortunately, Alzheimer’s research is like a super tanker that moves very slowly,” confirms Prof. Willbold and adds, “The principle that it is not about the formation of amyloid beta itself, but about its aggregation into oligomers, has already been known for several years, but the translation of these results into clinical application will still take years.”

This is why most of the compounds or antibodies in Phase III, some of which were developed decades ago, are directed against amyloid beta plaques only. Some of them also recognise amyloid beta oligomers. Other drugs are aimed at stimulating the brain’s metabolism by influencing the release of messenger substances or the growth of nerve cells. Only a small fraction of the drugs that are currently being tested is aimed at aggregates of the modified tau protein found in nerve cells.
46,800,000 people worldwide suffer from dementia*

60–65% of all cases of dementia are due to Alzheimer’s disease **

$ 818,000,000,000 is what care for dementia patients all over the world costs every year *

Sources: * World Alzheimer Report 2016, ** Federal Ministry of Health

What exactly are ...

... Plaques?
Insoluble amyloid beta deposits between nerve cells

... Fibrils?
Tau protein entanglements in nerve cells

... Oligomers?
Small soluble aggregates of a few amyloid beta molecules

Proportion of patients with Alzheimer’s disease aged ...

65+

85+

Source: Federal Ministry of Health
It appears that they also have an influence on the other deposits that Alzheimer had discovered: the tau fibrils. Their formation can be triggered by amyloid beta oligomers, among other things. The oligomers dock to the surface of nerve cells, triggering a momentous signal inside the cell. It activates an intracellular enzyme that alters another protein: tau proteins. Normally, these help to stabilise the structure of nerve cells and their transport pathways. But the alterations make these proteins “sticky”. They accumulate and form insoluble fibres, the fibrils. The result: the affected cell dies.

And things get even worse. Fatally, nerve cells exchange tau proteins with each other. They do not differentiate between normally structured tau and the altered, sticky variant. The result is a snowball effect in which more and more altered tau proteins are passed on and more and more of them become entangled. The irreversible mass death of nerve cells begins. At this stage, the first mental impairments become apparent in those affected.

“Yesterday she took her entire medication for two days at once,” my father says.

Combinations of active substances targeting both amyloid beta oligomers and the altered tau proteins are therefore considered promising. Dieter Willbold and his team have initially tackled one of the two possible targets. They developed a protein molecule – a peptide called PRI-002 – that destroys the amyloid beta oligomers.

The active substance had the effect that the spatial orientation of mice with symptoms similar to Alzheimer’s disease improved again. They were able to remember the position of a rescue platform in a pool. Without the active substance, they kept swimming around erratically in all experiments without finding the rescue platform hidden below the surface – in contrast to healthy mice, which always headed purposefully towards the platform after the first experiment.

In September 2017, Priavoid GmbH was spun off from Forschungszentrum Jülich in order to develop a marketable drug from the active substance. Following successful preclinical safety and tolerability tests, the Phase I clinical study began in April 2018, in which around 40 healthy test subjects take the active substance to find out how well they tolerate it. “The tests with the first subjects have so far not revealed any side effects,” reports Willbold.

However, patience is needed before any possible approval of the drug: on average, seven years elapse between the start of a Phase I trial and marketing approval, with only one-fifth of all active ingredients tested making it from Phase I to market entry. And it takes money, a lot of money: development costs can run into billions.

Not only suitable active substances are needed, however, but also better studies to test their effectiveness, as the researchers agree that one important reason for the failure of numerous previous studies is the selection of test persons. So far, patients with mild to severe signs of dementia have been recruited for such studies. “However, since the disease spreads decades before the first mental impairments in the brain, it is crucial to include those in the studies who are affected and do not yet show symptoms,” says Dieter Willbold.

Peptides have been used for medications for a long time. A well-known example is insulin. The disadvantage: peptides are quickly recognised and broken down by the body’s own enzymes. Therefore, such therapeutic agents usually have to be injected at regular intervals. PRI-002, on the other hand, belongs to an entirely new class of peptides.

The molecule is fully composed of the mirror images of the normal amino acid building blocks. Therefore, the body’s own enzymes cannot recognise it and break it down. Accordingly, PRI-002 can be taken in the form of a capsule, remaining stable and effective in the body for a long time. “We will apply our concept of developing and using mirror image peptides as possible active substances to other harmful aggregates, such as those made from modified tau protein in Alzheimer’s disease or molecules that play a decisive role in Parkinson’s disease,” reports Jülich researcher Dieter Willbold.
The basis for this is a reliable and, above all, early diagnosis of Alzheimer’s disease. Researchers around the world are working hard to achieve this. Only for a few years has it been possible to visualise amyloid beta plaques and tau fibrils in patients using imaging methods. And thanks to advanced technology, it is now also possible to detect specific biomarkers in the spinal fluid that reveal, even up to 15 years before the first signs of dementia, whether someone is highly likely to develop the disease.

“It would be ideal to have a low-priced blood test that shows even the slightest changes in brain metabolism before the majority of the nerve cells are irretrievably lost,” says Dr. Oliver Bannach, biophysicist and member of Dieter Willbold’s team. The Jülich scientists have also targeted the amyloid beta oligomers for such a diagnostic procedure. Oliver Bannach describes the status of the procedure: “We detect even the smallest amounts of oligomers in the spinal fluid of Alzheimer’s patients using fluorescent probes.” The researchers found a direct correlation between the increasing amount of amyloid oligomers and the progression of the disease.

“We were able to confirm this effect in our studies,” says Dr. Gérard Nisal Bischof from the Jülich Institute of Neuroscience and Medicine (INM-3). The researchers found, in the same disease stages, a significantly higher number of amyloid plaques and tau fibrils in the brains of patients with a higher level of education than in patients with a lower level of education.

“Still, our goal is a blood test,” says Bannach, who, to commercialise the test, founded attyloid GmbH in February 2018 together with colleagues from Forschungszentrum Jülich and Heinrich Heine University Düsseldorf. “Only specialists should take fluid from the spinal cord, blood can also be taken by the family doctor. This would allow patients to be diagnosed much faster,” he emphasises.

Despite all the progress made, however, the question remains as to why some people remain fully alert despite overwhelming biological evidence suggesting Alzheimer’s dementia. The Nun Study mentioned above – more precisely the personal biographies of the participants – provides a hint for solving the riddle. Despite numerous amyloid plaques and tau fibrils in the brain, nuns who had a rich vocabulary in their youth did not suffer from Alzheimer’s disease at all or fell ill much later than women with only a simple form of expression.

The level of education, but also the healthier lifestyle that is usually associated with it seem to be directly linked to the extent to which the brain can compensate for deficits caused by the progressive cell death. Apparently, the brain tries to shift tasks from areas that are already dead to others.

Bischof also stresses the correlation between physical and mental fitness. Researchers found that people with uncontrolled high blood pressure have more amyloid beta deposits in the brain than those with low blood pressure. This finding could be proven even for the inherited form of Alzheimer’s. “So, sport is extremely important, even if it’s just a walk. Because what is good for the heart is good for the head,” he emphasises.

He is therefore currently expanding the portfolio with his employees. The company is working on the detection of different tau aggregates and other molecules in blood samples in order to be able to distinguish between different neurodegenerative diseases earlier and, above all, better.

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“My mother hasn’t left home in several years. “She’s afraid of getting lost,” says the lady from the nursing service.

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“We want to leave. I can’t find the car key. Is this how it begins?”

BRIGITTE STAHL-BUSSE

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A force of nature with two faces

It can even be seen from space: the gigantic “Asian brown cloud”. In winter, the smog cloud in the lower atmosphere covers the South Asian region for months. The onset of the summer monsoon puts an end to the billowing spectre. The monsoon purifies the air, but also transports pollutants to high altitudes where they are distributed worldwide, as researchers have found out.

“It feels like having sandpaper in your throat,” says Dr. Fred Stroh from the Jülich Institute of Energy and Climate Research (IEK-7). Stroh has already taken part in several measurement campaigns in South Asia and inhaled the thick air – a composition of dust, sooty particles, sulphur dioxide and nitrogen oxides from factory chimneys, exhaust pipes and burning stubble fields. In broad daylight, the sun disappears behind a grey-brown veil, the smog gnaws at historical buildings, and airplanes cannot land because of low visibility. In November 2017, fine dust concentrations of over 1,000 micrograms per cubic meter of air were measured repeatedly in the megacity New Delhi. The World Health Organization WHO considers 25 micrograms per cubic meter over a period of 24 hours to be just barely acceptable. The pollutants are suspected of causing cancer and heart attacks – those who can move away do so.

Every year, the summer monsoon brings relief for the people living there, purifying the air locally and washing out the pollutants – the smog disappears. At the same time, the monsoon increases the self-cleaning properties of the atmosphere – by increasing the formation of the atmospheric “detergent”, the OH radicals. These transform the pollutants through chemical reactions into watersoluble compounds that can be washed out with the rain. “During our measurement flights at altitudes of up to 15 kilometres, we were able to prove that the OH radicals consumed by pollutants are effectively reproduced through the lightning activity, which is abundant during the monsoon storms,” says Dr. Andreas Hofzumahaus of the Jülich Institute of Energy and Climate Research (IEK-8). The reason is the nitrogen oxides in the thunderclouds. “Nitrogen oxides are not only generated by combustion processes, but also by lightning in the atmosphere, meaning it occurs particularly frequently in the monsoon thunderclouds.” They recycle the OH radicals, which can thus clean repeatedly.

But the monsoon has another face as well, as the researchers were able to prove for the first time: rapidly rising air transports a portion of unwashed pollutants, including sulphur-containing compounds to high altitudes of over 15 kilometres. There they are captured by powerful air vortices – the anticyclones. Some of them can reach the stratosphere at altitudes of up to 50 kilometres and be distributed globally in the process.

According to the researchers, the pollutants thus influence the global climate. Sulphate aerosols, for example, which reach the stratosphere or are formed there from sulphur-containing pollutants, have a cooling effect because they reflect sunlight and can serve as cloud germs in deeper layers of the atmosphere. “Aerosols are also

How summer monsoon develops

The air over large land masses such as India heats up very strongly in summer and rises rapidly. This takes moist ocean air in. Huge clouds then form over land, from which it can rain for months.

\[ T \text{ Low pressure area} \quad H \text{ High pressure area} \]

\[ \text{strong sunlight} \quad \text{air circulation} \quad \text{warm landmass} \quad \text{cold sea} \]
suspected of amplifying reactions of chlorine compounds in the atmosphere, which in turn destroy the protective ozone layer,” reports Hofzumahaus. “Therefore, effects of aerosols are considered one of the greatest uncertainties in predicting climate change.”

All these data and findings now need to be integrated into existing models. A central question is whether the cleaning and transport mechanisms will persist as air pollution increases. Or will one of the processes dominate?

To investigate the climatic effects of air pollution in higher atmospheric layers, the researchers flew even higher in another major measurement campaign called StratoClim in the summer of 2017. Fred Stroh reports: “With the help of the Russian high-altitude aircraft M55-Geophysika, we were able to examine the air composition at 20 kilometres above Nepal, India and Bangladesh in detail for the very first time.” The evaluation of these data is still ongoing, but the scientists are optimistic to learn more about the two faces of the monsoon with the material.

BRIGITTE STAHL-BUSSE

What happens to pollutants in the monsoon?

Lightning in the thunderclouds intensifies the self-cleaning capacity of the atmosphere: pollutants become more water-soluble. The thunderclouds can reach up to 14 kilometres high.

Ascending air transports pollutants to higher air layers. There they spread all over the world.

Rain washes out the pollutants.
The air in the ground level atmosphere becomes cleaner.

Halfway around the world

In the extensive “Oxidation Mechanism Observations” (OMO) measuring campaign, scientists explored exactly how the monsoon purifies the air. Equipped with state-of-the-art measurement technology, the German research aircraft HALO (photo) covered more than 100,000 flight kilometres in over 120 flying hours at altitudes of up to 15 kilometres between July and August 2015. The route went from Oberpfaffenhofen to Cyprus to the Maldives and back. The scientists evaluated the extensive data collection for three years. Around 60 researchers from the Max Planck Institute for Chemistry, Forschungszentrum Jülich, the German Aerospace Centre, the Karlsruhe Institute of Technology and the universities of Bremen, Heidelberg, Leipzig and Wuppertal were involved.

With StratoClim into the monsoon – a blog of the Jülich climate researcher Corinna Kloss: blogs.fz-juelich.de/climateresearch/category/stratoclim

BRIGITTE STAHL-BUSSE
A “TITAN” resides in Jülich’s Ernst Ruska-Centre, or more precisely, in room 2010, where a plaintive, clacking sound fills the laboratory whenever the machine sets to work. It comes from a vacuum pump that protects the nano samples from adversities like fine dust because “TITAN 60-300”, a special electron microscope, requires perfect conditions to examine materials right down to individual atoms. Even the smallest of contaminations would falsify the entire result.

What makes the TITAN special: it works with an unusual imaging method known as electron holography, which is used by only few research groups worldwide. This allows it to examine not only the atoms but also their magnetisation.

PRIMORDIAL ARCHIVE

This is where our story begins. We will hear about a meteorite that crashed to Earth decades ago, take a closer look at melted rock samples of the meteorite – and learn something about patience. So what’s the story about? It is about magnetism; more specifically, it is about evidence of how its forces possibly fared 4.6 billion years ago. The focus is on a few crumbs of rock, pieces of the meteorite “Bishunpur”, which fell to Earth in India 123 years ago. Fragments of it are now in the possession of the Natural History Museum in London.

Geophysicist Jay Shah is one of the scientists who, during his PhD at Imperial College London and the Natural History Museum in London, spent months studying the relics. “The rock samples are very different from what we find on Earth,” he says. “Tiny iron grains in the rock have a magnetisation that forms complex, uneven vortex structures.” What is really exciting is that these iron particles consisting of kamacite, an alloy of iron and nickel, were formed 4.6 billion years ago, probably under the influence of a magnetic field. It is therefore possible that the primordial dust of iron granules has stored information about the magnetic field in the early solar system. This would be interesting information for researchers around the world because the magnetic field at that time may have influenced the development of the early solar system.

PUT TO THE HEAT TEST

This is where the “TITAN”, with its electron holography, came into play. Shah and his colleagues from Great Britain, Norway and Jülich wanted to use it in order to prove that the magnetic structures of the samples had – for example due to temperature fluctuations – barely changed over the course of millions of years.

For this purpose, the researchers slowly heated the nano particles to up to 600 degrees – and exposed them to conditions as presumably prevailed in space in the past. The scientists wanted to see what this extreme treatment would do to the sample. The result was astonishing: the magnetic vortices remained stable.

For Shah, this was an extraordinary experiment: “For me, the test was a test of patience. The measurement itself took 13 hours and I only had one test because I had only received a single sample from the meteorite. The smallest mistake and the work would have been lost.”

Comparing the results of experiments with calculations subsequently proved that the magnetic information is actually stored much longer and
more stably than had previously been assumed. In the case of the Bishunpur meteorite samples, the researchers are even convinced that the magnetic structures have not changed significantly over the course of billions of years. “The fact that metal grains of this kind are able to store age-old magnetic fields encourages us to investigate this aspect in more rocks. Maybe this will gradually provide us with a complete archive of the magnetisation of our early solar system,” Shah hopes.

MEDICINE IS TO BENEFIT

His colleague Trevor P. Almeida from the University of Glasgow, who was also intensively involved in the project, sees another possible benefit of the discovery: “The more and the better we understand nanostructures – such as now in the investigation of the 120-year-old meteorite – the sooner we could use them in other fields as well.” An example for the near future is nanomedicines. These could be implanted into diseased cells and then heated from the outside by magnetism in order to activate them. The active substances are first directed magnetically and specifically at the cancer cells that need to be destroyed. “We can learn how to do this by studying the magnetic structures in the meteorites. We will certainly require electron microscopy again for the necessary research into the structure of suitable active substances,” according to Almeida. There seems to be more work in store for the “TITAN” and its colleagues.

MATTHIAS LAUERER

“For me, the test was a test of patience. The measurement itself took 13 hours and I only had one test.”

JAY SHAH
Plant health – measured from afar

Leaves and needles emit a red glow by means of which the condition of plants can be measured over large areas. The start-up JB Hyperspectral Devices manufactures measuring instruments for this purpose.

We are surrounded by a red glow day in, day out. The source: plants. They not only convert CO₂ into oxygen during photosynthesis, but also fluoresce while doing so – this is virtually a waste product. Granted: you cannot see much of it with the naked eye, but special measuring devices make it visible. “Through changes in this fluorescence, we can see that something is wrong with a plant – even before its leaves go limp or other symptoms,” says Dr. Andreas Burkart, who received his doctorate as a member of Prof. Uwe Rascher’s Jülich research group at the Institute of Bio- and Geosciences (IBG-2). With suitable measuring devices, the condition of plants can even be analysed remotely over a large area – for example from a tower next to a field or from an aircraft.

So far, however, the robustness of the measuring systems, among other things, has been lacking. Burkart eliminated this sensitivity: the system he developed braves wind and weather and also allows long-term measurements for the first time. The European Space Agency ESA was enthusiastic: throughout Europe, it plans to space out several such systems in forests, meadows and on agricultural land to collect reference data of various ecosystems for the planned satellite mission Fluorescence Explorer (FLEX). In order to be able to manufacture his system in large quantities, Burkart founded the start-up company JB Hyperspectral Devices together with his fellow student Dr. Tommaso Julitta in 2016. In 2022, the ESA plans to launch the FLEX satellite into space.

JANINE VAN ACKEREN

Exhibition
Visitors to Deutsches Museum in Bonn can see for themselves how leaves emit light: the exhibition “Das Leuchten der Pflanzen” is on display there until 23 September 2018.

The glow of plants explained in a film at: effzett.fz-juelich.de/en
“Precious, shiny metals are the focus of my research – but only in tiny quantities because I look at individual atoms. Expensive platinum, for example, which is used as a catalyst in fuel cells. With my colleagues, I look for inexpensive alternatives. We use high-resolution electron microscopy for this purpose. We could thus show that the arrangement of platinum and nickel in specially shaped nanoparticles is decisive for their performance. As a result, catalysts were designed that are ten times more efficient than pure platinum – and thus significantly cheaper.”
Forschungszentrum Jülich has a new gem: the JUWELS supercomputer. Its name could be an indication of how the experts at the Jülich Supercomputer Centre (JSC) classify it: as a jewel among high-performance computers. In fact, the name stands for Jülich Wizard for European Leadership Science, i.e. a computing genius. What accounts for this genius?
THE COMPUTING POWER
One thing first: it is not the current performance that makes the new computer unique. It is impressive all the same: In June, in the first test runs for the TOP500 list of the fastest supercomputers in the world, JUWELS achieved a speed of 6.2 quadrillion floating point operations per second, petaflops in short. This corresponds to the computing power of more than 30,000 modern PCs: if, starting from the sun, the supercomputer were to advance one millimetre for each arithmetic operation, it would reach Pluto, the outermost post of the solar system, in less than one second. JUWELS was thus the fastest German supercomputer on the list. It ranked 23rd worldwide, despite the current expansion stage consisting of only one module, which is not primarily geared to maximum computing power, but to flexibility and versatility. Next year, another module will multiply performance.

THE APPLICATIONS
"JUWELS is a milestone on the way to a new generation of highly flexible supercomputers that can handle an extended range of tasks," says JSC staff member Dr. Dorian Krause. The high-performance computers are no longer only used for computationally intensive simulations in almost all scientific disciplines. To an increasing degree, they are also to analyse large amounts of data – keyword: big data – or serve as platforms for machine learning. Even before the system was launched, many European researchers were pushing for calculating on the new supercomputer. With a total of 87 projects, it is fully booked for the first half year. “Among other things, JUWELS will be used in the near future for simulations in quantum physics or neuroscience and material sciences. Environmental researchers are also using the new supercomputer to develop high-resolution climate models, for instance,” says Dorian Krause. He stresses that the selection of projects is based solely on scientific excellence. The allocation is organised by the Gauss Centre for Supercomputing, the association of the three German high-performance computing centres through which the Federal Government and the State of North Rhine-Westphalia also finance JUWELS and its operation.

THE DEVELOPMENT
The cluster booster concept was first implemented by scientists from twelve European countries during the EU-funded projects DEEP and DEEP-ER, which ran until April 2017. Coordinated by a JSC team led by Estela Suarez, they built two prototypes and, with them, tested the performance of the design. The Munich-based company ParTec was the development partner. Its ParaStation software also manages JUWELS. Meanwhile in the DEEP-EST project, Suarez and her cooperation partners are already developing the cluster booster concept further by adding other specialised modules, particularly for applications that handle large amounts of data. The partners will build the prototype of a modular supercomputer with three modules.

“Modular supercomputing is the key to a promising, affordable and energy-efficient technology. With JUWELS, we and our European partners are pioneers in the development of this next generation of supercomputers.”

PROF. THOMAS LIPPERT,
DIRECTOR OF THE JULICH SUPERCOMPUTING CENTRE

THE CONSTRUCTION
JUWELS is distinguished by its adaptable and modular design, which goes back to an idea of JSC Director Prof. Thomas Lippert: the cluster booster concept. Here, two computer modules are cleverly combined with each other in order to improve the energy efficiency and performance of the supercomputer in everyday scientific life. Complex parts of the simulations, which are difficult to calculate simultaneously on a large number of processors, are executed on the so-called cluster module. Simpler program parts, which can be processed in parallel with greater efficiency, are outsourced to the booster, which will be added to JUWELS next year. This second module uses a large number of relatively slow but at the same time energy-efficient cores. “The basic idea of this concept is similar to house building: instead of exclusively employing highly specialised skilled workers, only the complicated, critical work such as the electrical installation is handed over to the experts. Simpler operations are then carried out by less qualified workers,” explains Dr. Estela Suarez of the JSC.

Another technical peculiarity: a new type of hot water cooling allows the majority of the waste heat of the cluster module to be cooled directly with the outside air without an additional energy-consuming cooler. This saves energy.

Time lapse video showing the construction of JUWELS in the online magazine: effzett.fz-juelich.de/en

FRANK FRICK
Spellbound by the channels

Everyone needs them, hardly anyone knows them: ion channels in cell membranes. The physician and biophysicist Christoph Fahlke has been researching them for decades – and is still fascinated.

He could have pursued many careers and would have been happy: “A pathologist, for example. Or an architect”, says Christoph Fahlke. Instead, he has become a “channel worker”, which is by no means meant to sound derogatory: “There are worse labels,” says the director of the Institute of Complex Systems (ICS-4) and laughs. Ion channels and ion transporters have fascinated the 54-year-old for decades: “These proteins are located in the cell membrane and serve as gates for the transport of different ions into or out of the cell. These processes are vital for our organism,” explains the professor of biophysics. Malfunctions can lead to diseases such as epilepsy or high blood pressure.

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**BETWEEN PHYSICS AND MEDICINE**

Many years ago, his curiosity about how cells function in the human body was the reason why the doctor of medicine decided against becoming a practising physician for a scientific career. “I wanted to study medicine after school, but found it rather boring at first,” recalls Fahlke. A friend took him to a
A physics lecture and the “technical spark” was immediately ignited. From a humanly point of view, he felt more comfortable among the physicians at that time: “The group was colourful, my fellows had various outlooks on life: Some wanted to become artists or general practitioners, others wanted to save the world or earn money,” says Fahlke – tall, slim, with thick dark hair and alert blue eyes – who can easily be pictured in a doctor’s white coat. “But my interests lie somewhere between medicine and physics. Today, I work in a field that wonderfully combines these two disciplines: neurophysiology. This field looks at how nerve cells communicate electrically and chemically with each other. “I have worked with physical measurement methods, calculate a lot and describe processes that are fundamental for humans.”

He received his doctorate in medicine from Ulm University in 1990, was awarded the prize for the best medical doctorate there in 1991, and received his licence to practise as a physician in 1992. At the same time, he was writing his diploma thesis in physics and working on chloride channels in a physiology laboratory, which are important for the functions of nerve cells and muscle cells, for the first time. He was unaware that the course of his life was to be set here: since then, electrophysiology as a subfield of neurophysiology has not only accompanied him: “It actually makes me happy. I keep telling my doctoral students that they should know as many techniques as possible, but they need one that is near and dear to them – that’s what electrophysiology is for me.” This includes the Nobel Prize-winning patch-clamp method, which allows small electrical currents flowing through ion channels in a cell membrane to be measured. Even individual ion channels can be observed this way as they open and close – like small gates. “There are few things so beautiful,” Fahlke raves.

THREE DISEASES IN FOCUS
Although many other techniques have long since found their way into Fahlke’s scientific everyday life, electrophysiology is still playing a central role: his group uses patch clamping to examine defective ion channels or ion transporters that are associated with three diseases. “We do research on neurological diseases in which the coordination of movement is disturbed for a short time, on epilepsy and on a certain form of hypertension,” explains the scientist. All three disease patterns are monogenetically determined diseases. This means that there is a direct connection between a deficient ion channel and an organ malfunction – much unlike complex diseases such as cancer, arteriosclerosis or Alzheimer’s disease. As recently as at the beginning of this year, his team was involved in an international publication presenting the disease mechanisms of a special form of hypertension. The Jülich researchers were able to show for the first time how a certain ion channel protein regulates blood pressure.

After working at RWTH Aachen University and Hannover Medical School, Fahlke has been living with his family in Jülich since 2012. This was exactly the right step for the former Heisenberg scholarship holder and Asia lover. “Forschungszentrum Jülich affords me many experimental approaches. I can have every protein function that comes to my mind measured at our institute or at a neighbouring institute, or I can measure it myself.” The variety of disciplines in Jülich and the cooperation with various universities in the region is also a great advantage of the location: “You find a contact person for every problem,” says the biophysicist. And this is where things come full circle: even though he once decided to become a medical doctor, Forschungszentrum Jülich offers him a platform to work with many other professions.

Everyone needs them, hardly anyone knows them: ion channels in cell membranes. The physician and biophysicist Christoph Fahlke has been researching them for decades – and is still fascinated.
Atomic nuclei consist of positive and neutral particles, protons and neutrons. A carbon atom, for example, has 6 protons and 6 neutrons, an iron atom 26 protons and 30 neutrons. But is it possible to build an atomic nucleus from 6 protons and 10 neutrons, for example? If so, how stable will it be? Does it exist infinitely or does it disintegrate within fractions of a second? Thanks to a new computer model that the Jülich physicist Prof. Ulf-G. Meißen has developed with an international team, this can now be calculated exactly.

Such calculations are extremely complex, however, as the components of the atomic nuclei cannot simply be put together like Lego bricks. Protons and neutrons cannot be stacked, but can move freely. As objects of the quantum world, they even overlay each other, following complicated mathematical laws. Unlike a Lego structure, an atomic nucleus is also lighter than the sum of its individual building blocks. The missing mass stands for the energy that is released during the formation of atomic nuclei: the binding energy. Only if this energy is positive can a nucleus develop. This is the case when the attracting force between the building blocks, the so-called nuclear power, is greater than the repulsive coulomb force between the protons with the same charge.

The various forces in the core can only be determined to a limited extent. Therefore, Meißen and his colleagues from the Nuclear Physics Institute/Institute for Advanced Simulation (IKP-3/IAS-4) employed a trick. They restricted the freedom of movement of neutrons and protons by arranging them firmly on a three-dimensional grid in their model. For these fixed positions, the binding energy can be calculated relatively easily. Then they changed the respective arrangement with a systematic random procedure – several million times.

**STEP BY STEP TOWARDS THE GOAL**

“This brought us ever closer to the energetically optimal core arrangement,” says Meißen. “On this basis, we can now determine whether a nucleus with the given number of neutrons and protons can exist.” In addition, the researchers also found less stable, so-called excited states. In these, the core components arrange as if the core consisted of several smaller atomic nuclei. Such states are particularly relevant if one wants to understand how, for example, elements such as carbon or nitrogen were formed inside stars after the big bang.

“Other calculation methods cannot map this. What is more, they do not make any statements about the accuracy of the calculation – while our method does,” says Meißen happily.
Inclusion in an emergency

When there is a fire, every minute counts. However, there are often major shortcomings in rescue plans for people with disabilities. The SiME project is developing new approaches.

Final whistle in the football stadium: Clusters of people pushing towards the exit, everyone wants to go home quickly – often an unpleasant situation, even for those who are quick on their feet. It is even worse when danger is looming and a stadium or concert hall has to be cleared. Such a crisis quickly turns into a nightmare for people who cannot walk or see well. “When we talk about inclusion, we often only talk about how people with disabilities can get to events, but not how they can leave these venues again safely – we are eliminating these shortcomings with the SiME project,” explains Dr. Stefan Holl from the Institute for Advanced Simulation (IAS-7).

The German abbreviation SiME stands for “safety for people with physical, mental or age-related disabilities”. In this three-year interdisciplinary research association, scientists work together with affected people to optimise escape and evacuation options for people who cannot leave a building without help or who do not recognise that there is a danger. The reason: “Previous evacuation plans have been developed primarily for people without disabilities. There is a lot of catching up to do,” explains Holl.

SCHEDULING MORE TIME
Against this background, the scientists carried out a large-scale experiment in a factory hall to record the movement behaviour of people with and without impairments: around 100 men and women pushed their way through a narrow corridor in 144 individual tests on two days. Cameras and sensors recorded the movements of each individual person. Holl and his colleagues use the data to calculate different evacuation scenarios.

They did so, for example, in another, smaller study in a residential care home of “Lebenshilfe Bergisches Land”, an institution for disabled people. The focus was on organisation-al aspects and activities that take place before a building is evacuated, such as putting bedridden people into an evacuation chair, the so-called Evac Chair. The researchers also timed how long a rescuer needed to get someone to safety via the stairs using the chair or an evacuation mattress. “In everyday life, hardly anyone has anything to do with such rescue equipment. So in the event of a crisis, there is a great deal of uncertainty, possibly combined with a life-threatening time delay,” explains Holl. Training concepts are needed, and evacuation plans must also be based on more realistic time assumptions.

Holl expects final results in spring 2019. The employees of Lebenshilfe have taken the first appropriate measures: They are getting their building inspected, and a new fire protection concept is being developed. “A sign that our work won’t just be buried in the files,” Holl sums up.
Korbinian Brodmann, who was born 150 years ago and died 100 years ago, has influenced generations of doctors with his map of the brain. The brain atlas of the Human Brain Project stands in this tradition, but at the same time for completely new scientific dimensions.

**Brodmann’s map**

There are 43 areas on Brodmann’s map – marked with numbers between 1 and 52. Confusingly, the numbers 12 to 16 and 48 to 51 are missing. Brodmann explained that the areas with the missing numbers were clearly recognisable in other mammals, but could not be identified in the human brain. He thus laid an important foundation for comparative anatomical investigations.

Prof. Katrin Amunts, scientific director of the Human Brain Project since 2016, has been working with state-of-the-art methods for over 20 years. The result was the JuBrain Atlas, which already covers more than 200 brain regions and reflects individual differences between the brains. The researchers analysed ten different brains for each area and, from this, calculated probabilities that show where the areas are located and how large they are. Here, algorithms determine the area boundaries in a uniform way, while different researchers would probably not always define the boundaries exactly the same. Both JuBrain and the Jülich reference brain Big Brain are incorporated into the atlas of the European Human Brain Project.
Korbinian Brodmann examined wafer-thin slices of brains. He viewed them under the microscope and sketched what he saw: cell tissue that is structured differently depending on the region of the brain being examined. In this way, the psychiatrist and anatomist created a map of the cerebral cortex that is left out of hardly any book on the human brain even today. He linked some areas on his map, which was published in 1909, with functions such as speaking, listening and seeing. For others, he could not make such an assignment. He was inspired by reports about the failure of functions due to brain damage or neurosurgical interventions.

“Today we know that Brodmann’s map is largely inaccurate. Brodmann had identified only three areas for the visual cortex, for instance. However, far more areas are involved in visual perception and processing.”

PROF. KATRIN AMUNTS, DIRECTOR AT THE JULICH INSTITUTE OF NEUROSCIENCE AND MEDICINE (INM-1)

JuBrain

JuBrain is a three-dimensional model of the brain that is also “multimodal”: it shows not only the cell architecture, but also the distribution of the messenger receptors, the functional tasks of the region and much more. All this data is freely available and is constantly being enhanced. The atlas also shows how fibre connections keep the areas in contact. This is important information for understanding how these areas work together on complex tasks.

“Brodmann’s work was an outstanding scientific achievement all the same – among other things, many doctors at the beginning of the 20th century believed that the brain had a uniform structure. Brodmann disproved this with his precise observations. Furthermore, despite all the differences between different mammals and humans, Brodmann recognised that there was a common evolutionary development of the cortex.”

PROF. KARL ZILLES, SENIOR PROFESSOR AT THE JULICH INSTITUTE OF NEUROSCIENCE AND MEDICINE (INM-1)
One of the places of interest in Trieste is the church of Sant’Antonio Nuovo. It is located at the end of the Canal Grande, the historic waterway leading from the harbour to the city centre.

Local geography

The EuroScience Open Forum has proclaimed Trieste the “European City of Science 2020”. Trieste will host the largest interdisciplinary meeting of scientists in Europe.

Coffee culture

The people of Trieste drink coffee from ten kilos of beans every year, which is more than twice as much as other Italians. And they have their own names: an espresso is called “caffè nero”, an espresso with a dash of milk is a “capo”.

Free territory

From 1947 to 1954, Trieste and its surroundings were a neutral state under the sovereignty of the United Nations. It was called “Free Territory of Trieste”. The area was claimed by Yugoslavia and Italy during this period.

Why there?

Dr. Vitaly Feyer is one of three Jülich researchers who work at the Italian synchrotron radiation facility Elettra.

Why do you work at Elettra?
The system generates intensive light, from the infrared range to X-rays. The special features of the light source make it possible to work with a very high spatial resolution. This is important for investigating the surfaces and interfaces of materials down to the nanometre scale. I use a special device for this: the NanoESCA microscope.

Who else uses the microscope?
30 per cent of the beam time is available to us Jülich researchers. The rest of the time, we support colleagues from all over the world in their experiments.

What is your own research about?
I am interested in processes that take place when organic molecules attach to metallic surfaces. These are important for the information technology of the future.

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About

1,300 scientists from more than 50 countries use Elettra every year – the Germans being the largest group after the Italians.

X-ray eyes and coffee culture

Forschungszentrum Jülich’s campus is 2.2 square kilometres in size. However, Jülich scientists are active even beyond the campus – at the particle accelerator Elettra in Trieste, for example.
THUMBS UP

YOUTUBE CHANNEL MAILAB

Smart science explanations

Whether maternity, dieting or alcohol – drawing from everyday topics and worries, Mai Thi Nguyen-Kim explains difficult scientific contexts to a young audience with wit and great competence. The chemist, who holds a PhD, received the Grimme Online Award 2018 in the Knowledge and Education category. Her YouTube channel “maiLab” is not only cool and funny, but also clever and informative. In short: it is an outstanding example of contemporary science journalism, according to the jury. And not only the experts were enthusiastic – the audience award also went to “maiLab”.

– YOUTUBE.COM/MAILAB –

RADICAL OCEAN FUTURES

Visions of the future of the seas

What does our future look like? Hardly any question is so difficult to answer. There are of course scientific studies that develop such scenarios. However, we often cannot really imagine the abstract depictions.

The “Radical Ocean Futures” project, which describes the future of the oceans in short stories, can help. The project uses so-called science fiction prototyping, the linking of scientific facts with creative speculations. At the heart of the project are four scientifically based “Radical Ocean Futures” – elaborately illustrated short stories about how oceans could develop.

– RADICALOCEANFUTURES.EARTH –

ONLINE GAME “HANDY CRASH”

Life cycle of a smartphone

They are our constant companions and we can hardly imagine what our everyday life used to look like without smartphone, tablet and co. But how are the devices produced? What raw materials are used, and what happens to all the electronic waste that is generated year after year? The online game “Handy Crash” pursues these questions and, between little games, explains what’s going on in the global mobile phone industry.

– HANDYCRASH.ORG –
RESEARCH IN A TWEET

Turbo batteries for mobile phones and co.! With a new electrode material, lithium batteries could charge faster and store even more energy in the future. #battery

Prof. Dina Fattakhova-Rohlfing developed the material in collaboration with colleagues from Jülich, Munich and Prague. The composite material contains nanoparticles of antimony-doped tin dioxide and graphene and is particularly conductive. According to the researchers, it is easy and inexpensive to produce. Lithium batteries are currently the standard in mobile phones, tablets and electric cars.

www.fz-juelich.de/turbocharge