FLOW PROCESSES: CONTINUUM-MECHANICAL MODELS HELP UNDERSTAND NATURAL DISASTERS
Since 2011, an expert team at the university hospital Berufsgenossenschaftliches Universitätsklinikum Bergmannsheil has been testing HAL, a robot suit that had been developed in Japan. HAL stands for “Hybrid Assistive Limb”. The ultimate aim of HAL is to help paraplegics to regain a certain mobility and activity level. The team carries out clinical trials at the Centre for Neurorobotic Movement Training in Bochum, which was founded specifically for this purpose.

Should an alcoholic receive a liver transplant, even though he had damaged the organ through his drinking habits? Is it fair that the insurance fees of health-conscious people are as high as those of obese people? Is it justifiable to refuse dialysis treatment to patients over the age of 60? Philosophy student Corinna Rubrech discusses what a fair and sustainable health-care system might look like in her PhD thesis.

In the Frankfurt Nordend on Monday, a few days later in the bank district, in Heidelberg on the weekend – a bank employee’s movement profile. It can be easily determined, because he drives an electric car; the charging stations betray him. In order to prevent this scenario becoming everyday reality, researchers at the Horst Görtz Institute for IT Security are developing a secure and privacy-enhancing process for electric car holders to charge their vehicles without becoming traceable.
FROM THE LONE-WOLF-MODEL TO THE RUB RESEARCH SCHOOL

Dear Reader,

As usual, this RUBIN edition provides an insight into the wide-ranging research projects conducted at our university. At the same time, we would like to use this edition as a platform to call your attention to the interlinked measures which are strategically relevant for the RUB’s research performance and which our university has implemented in the recent years with the aim of both supporting its PhD graduates and of promoting its PhD programmes, i.e. our campus-wide “RUB Research School”. On the following pages, three PhD students from the RUB Research School introduce their doctoral research subjects; for more information on our graduate school, see page 24.

When I took up my PhD research, which was almost 25 years ago, the “lone-wolf model” still prevailed at the German faculties – an approach describing the traditional individual doctoral research. Whilst granting the students maximum freedom in the research process, this approach, at the same time, resulted in student-tutor relationships with little commitment on the tutor’s part and much dependence on the student’s part. The immaterial and material support that the PhD student would receive was very much governed by coincidence. The lucky few, to whom I belonged, obtained their doctoral degree either within the framework of externally financed research projects or in one of the first research-training groups. In such endeavours, the doctoral students’ rights and responsibilities were structured more clearly. Due to deadlines determining how much time a student would spend on his or her research subject, the guidance process was more binding; the resources available to the individual were more clearly defined; and – first in the research-training groups – additional subject-specific programmes for research-focused training of the doctoral students were introduced.

A quarter of a century later, doctoral training programmes have become more differentiated – both across Germany and within the individual universities. The range spans from individual postgraduate PhD study models to comprehensive doctoral degree courses; some faculties stipulate binding tutoring agreements, others do not; some PhD students receive research-focused and soft-skill training, others are not given this opportunity.

By introducing its campus-wide RUB Research School, the Ruhr-Universität has been fundamentally reforming its PhD programme. The only graduate school of its kind in Germany, the RUB Research School, together with the faculties by which it is organisationally backed, develops high PhD standards that are consistent throughout all university departments. At the same time, it provides additional, highly diversified programmes that target all of the university’s 3,000 PhD students, thus complementing the research-focused courses provided by the faculties. Thematically, the programmes of the school range from science communication and data evaluation to such interdisciplinary formats as the Research Day and Science College. They enable each individual PhD student to structure his or her doctoral studies in accordance with the individual requirements, thus preparing him or her optimally for a career in and outside of academia.

Are you interested in our approach of combining maximum academic freedom with higher levels of commitment and predictability for the entire PhD period? If so, please read on, and feel free to visit the homepage of the Research School: research-school.rub.de.

We hope you enjoy this international edition of RUBIN 2014.

Yours,

Wilhelm Löwenstein, Vice Rector for Planning, Structure and Finance of the Ruhr-Universität Bochum
FROM THE SOUTH POLE INTO SPACE

RUB physicists at the “IceCube” lab in Antarctica, in collaboration with researchers from all across the world, are looking for the origins of cosmic radiation. In 2013, this endeavour was voted the “Breakthrough of the Year” project by the journal “Physics World”.

FROM THE TEST TUBE INTO THE LAMP

RUB chemists are researching ionic fluids, in order to develop powerful new phosphors for eco-friendly energy-saving lamps.
Deploying special computers that they develop in-house, RUB IT engineers have decoded quite a few ciphers. The team from the Horst Görtz Institute, for example, cracked the safety standards for satellite phones and the Amazon Cloud.
FROM WATER TO ICE

Ice comes in many different shapes and sizes. RUB geoscientists encounter them all when exploring caves in all four corners of the globe.
FROM POWDER TO COMPONENT
RUB material engineers strive to manufacture wear-resistant components within the space of milliseconds by storing energy that is then discharged in pulsed mode into a metal-powder mixture.
RUB researchers develop privacy-enhancing solutions for charging electric cars

I KNOW WHERE YOU CHARGED LAST SUMMER

In the Frankfurt Nordend on Monday, a few days later in the bank district, in Heidelberg on the weekend: a bank employee’s movement profile. It can be easily determined, because he drives an electric car; the charging stations betray him. In order to prevent this scenario becoming everyday reality, researchers at the Horst Görtz Institute for IT Security (fig. 2) are developing a secure and privacy-enhancing process for electric car holders to charge their vehicles without becoming traceable.

In 2001, the German newspaper “Die ZEIT” published the movement profile of Malte Spitz, a Green Party politician, that had been extracted from his mobile phone data, thus drawing the public’s attention to this technology’s major drawback. Each mobile phone user leaves a data trail behind and can therefore be traced. The same thing might be in store for electric car users. And yet it all seems so simple: hold your RFID card over the charging station’s reader or connect the plug (fig. 3). Charging an electric car is straightforward and, according to the Federal Government’s plans, will become routine for at least one million people from 2020 on. However, each charging is accompanied by a plethora of complex processes that happen in the background; the system saves information on when and where charging took place and by which customer – a privacy hazard. Electric cars are charged more often than conventional cars are fuelled up, because the expensive car battery should not be completely discharged. Electric car dealers therefore often advise their clients to recharge whenever possible.

Experience has shown that problems that are not identified until late, such as data trails of mobile phone users, are often rooted deeply within a technology’s actual design. In new technological areas such as electromobility, it is therefore vital to ensure that data security is incorporated into the design from the outset. In the course of the project “SecMobil”, supported by the German Federal Ministry of Economics and Technology, we are researching secure electromobility solutions. An important aspect is a privacy-enhancing charging infrastructure. Just like roaming in mobile communication, customers will be able to charge their cars at the stations of different providers who clear the costs via a clearing house.

The simplest solution would be if customers were anonymous. They could pay for the energy for their electric cars in cash, would not leave a data trail and nothing would have to be cleared, as the money would end up directly at the provider who supplied the electricity. However, cash logistics results in costs for the charging station providers. If the charging stations are spread across a large area in the public space, a central pick-up point for a cash
transport service does not exist. Rather, the transport service would have to call at each station individually. These costs can be avoided if customers simply identified themselves at the charging station with their RFID card and received an invoice at the end of each month. Each utility company does already have the infrastructure necessary for issuing invoices. Therefore, customers are known by name and address. If the customer cannot remain anonymous, is it possible for the charging station to be so? Our aim is to transfer and store the accounting data authentically, without the provider being able to track where the charging took place. The tools we use for this purpose are cryptographic methods, i.e. efficient encryption methods and modern digital signatures.

At the same time, we must also consider the legal aspects. If, for example, a user wants to appeal against his or her invoice in court, certain location-related data, such as the metre numbers, are necessary to resolve the issue. Using these data, one can determine if the energy metre at a charging station had been correctly calibrated and, consequently, if it had measured the customer's energy consumption correctly. If we want to apply our system in practice, we have to reconcile data protection and data security with legal regulations. To this end, we are collaborating with project partners from the Institute for Mining and Energy Law as well as with colleagues from the Faculty of Law who deal with IT law.

An important legal aspect is the following: the charging station provider must be
Fig. 4: Secure, privacy-enhancing and convenient to use: the RUB researchers’ system enables customers to use charging stations of different electricity suppliers. The data for the invoice are transmitted via the Tor network (info 1) to the clearing house. A digital signature confirms the validity of the data. As this is a group signature, the customer cannot be directly linked to one particular charging station.

The security protocol Transport Layer Security (TLS) is utilised, for example, to protect online banking transactions. If a HTTP connection is TLS-protected, the web browser usually displays a small lock symbol in the address bar. The TLS version deployed here (TLS-DHE) ensures high security standards. In practice, weaker TLS versions are still being used, but TLS-DHE is becoming increasingly prevalent.

Tilman Frosch
Fig. 1: This landslide in the Californian coastal town La Conchita in January 2005 led to ten casualties and destroyed 13 houses. Naturally occurring mass flows such as this are caused by a combination of various processes. The team at the Chair of Continuum Mechanics focuses on investigating the flow processes of water-saturated soils.
Continuum-mechanical models help understand natural disasters

When the soil slips away

An estimated 600 people worldwide die every year due to landslides, debris flows and rock avalanches; material damages amount to twelve million US Dollars. Such disasters occur when a previously solid mass of grain components, such as sand, gravel or rock, begins to slide or flow – like sand in an hourglass. Such events may be triggered by strong rainfall or earthquakes. If, in addition, the gaps between the grains are filled with water, the process becomes even more complex. Researchers at the Chair of Continuum Mechanics (fig. 2) are studying the underlying physical processes with the aid of mathematical models and computer simulations.

Due to the complex character of the events, it is almost impossible to gather data on geophysical mass flows that occur in nature. At the Chair of Continuum Mechanics, we therefore investigate those flow processes theoretically. We study mixtures of grains and fluids under clearly defined and controlled conditions, for example by considering the flow of a gravel-water mixture from a three-metre tall container (fig. 3). Our work is conducted in close collaboration with a team of geotechnical engineers from the TU Darmstadt who are studying this very flow process in experiments.

The first step in the experiment carried out by our Darmstadt colleagues is to open a hatch at the bottom of the filled container. The gravel-water mixture sets in motion with full force and streams out within a period of ten seconds. The processes inside the container are monitored with state-of-the-art measurement equipment.

In the field of continuum mechanics, we use mathematical models to describe processes like those happening in the test rig. In the first place, these models help us gain a better understanding of the physical laws that govern natural processes; secondly, they can be used to predict how a system will behave once the conditions change, for example if we alter the size of the hatch or the grain size of the gravel. We are developing such a model together with mathematicians from the TU Bucharest, Romania. The objective of this project is to mimic the flow process that was observed in the Darmstadt laboratory as precisely as possible and, eventually, to understand the motion of mass flows. We simulate the velocity of the fluid and granulate flow as they leave the container, the percentage they make up within the mixture and the pressure at different points inside the container. The results should correspond with the values determined in the experiments. The model development is based on mixture theory (info).

From the mathematical point of view, it does initially not matter what type of fluid and what type of grains are used, i.e. if we are dealing with gravel, sand or glass beads. We therefore use the general term granular-fluid mixture. We derive general equations for the respective mixture that are based on elementary physical principles. They are known as conservation equations, because they express that, for example, the mass inside a closed system such as
an air-tight room can neither increase nor decrease. In the next step, in order to be able to solve the equations at all, we require information pertaining to the actual behaviour exhibited by the deployed materials in experiments. For example, we can visualise the material behaviour of water in the following thought experiment (fig. 4): We fill the space between two infinite parallel glass plates with water. We hold the bottom plate in place, whilst sliding the top plate in one direction. The distance between the plates remains constant. Because of the friction inside the water layer, the top plate moves at a constant velocity, and the water layer is accordingly deformed. If we apply more force to push the top plate, the velocity increases. The force used for pushing the plate and the velocities inside the water layer stand in linear correlation to each other. Such behaviour of fluids is referred to as Newtonian rheology. The viscosity of a Newtonian fluid determines how strongly it resists being deformed: the more viscous it is, the higher the resistance against which the glass plate has to be moved. In mathematical terms, such material behaviour is described by a so-called constitutive relation, which is incorporated into our mathematical model.

Now, we have to consider the material behaviour of the grains. For this purpose, the water in our thought experiment is replaced by granulate, i.e. sand, gravel or glass beads. If the top plate is only lightly pushed, the grain cluster behaves like a solid body – the glass plate does not move at all. The “viscosity” is virtually infinitely large. Once a specific force is applied, however, the granulate starts flowing and the top plate is set in motion. Rather than behaving like a solid body, the material now behaves like a fluid, comparable with the sand in an hourglass that is just being flipped. Once we increase the force pushing the glass plate, the velocities inside the granulate layer change – however, unlike in a Newtonian fluid, the correlation is non-linear. In our model, this complex material behaviour, too, is described by a constitutive relation.

Furthermore, we have to include answers to the following questions into our constitutive equations: In its capacity as a “lubri...
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Fig. 5: The water content determines the material properties of a granulate composition made up of grains of sand: moist sand behaves like a solid body. Dry sand can attain the properties of a solid body or of a fluid. If the pores between the grains are fully water-saturated, the mixture becomes flowable.

cant” in the pore space, how does the fluid influence the flow behaviour of the granulate (fig. 5)? In what way does grain size matter? The larger the grains, the weaker the internal cohesion of the grain cluster – it is impossible to build a sandcastle with moist gravel. How are the shapes of the individual grains relevant? Angular gravel grains do not flow as well as perfectly round glass beads.

It is hardly possible to determine figures such as the minimal force required for moving the glass plate in our thought experiment and the viscosity of a water-saturated granulate in the laboratory. Therefore, the process is as follows: we make plausible assumptions, determine solutions on the basis of our system of equations and compare them with the results of the experiment. If our solutions deviate from the figures gathered in the experiment, we modify the equations that describe material behaviour accordingly. Consequently, our research aims at establishing those constitutive laws: we wish to modify them in such a manner that they will reflect the real flow behaviour of granular-fluid mixtures, in order to thus gain an understanding of the mixture’s material behaviour.

Before this can be attempted, a further obstacle has to be overcome: the equations are so complicated that they cannot be solved with the help of pen and paper; rather, we require a numerical method, i.e. a powerful arithmetic technique for calculating solutions approximately at the computer. Because a software in which our equation system may be implemented does not exist, we have to develop one first – a time-consuming endeavour. Deploying our model and the relevant software, we have already simulated simple processes such as sedimentation, i.e. the descent of granulate under gravity (fig. 6). Here, we examined only one space dimension, as the grains move in only one direction: downwards. In qualitative terms, the simulation results resemble the results of experimental sedimentation tests. This indicates that the principles of our model and the numerical method are essentially sound. For example, they predict sharp boundaries, such as the boundary between fully sedimented granulate and clear water. Most numerical methods have a problem with such abrupt junctions. Following the first positive tests, the programme is now ready to be translated into another programming language so that it may be deployed on high-performance computers with many processors to facilitate simulations in two or even three dimensions. Thus, we will get another step closer to establishing the correct constitutive relations and, consequently, to identifying the laws that govern debris flows.

Timo Reisner

Fig. 6: Simulation of granulate sedimentation. On the left, the granulate is distributed evenly; in the centre, it has partially sedimented. On top, a clear-water layer is created. On the right, the granulate is fully sedimented.
The health-care industry: between duty of care and financial straits

HEALTH WITHOUT BORDERS?

Should an alcoholic receive a liver transplant, even though he had damaged the organ through his drinking habits? Is it fair that the insurance fees of health-conscious people are as high as those of obese people? Is it justifiable to refuse dialysis treatment to patients over the age of 60? Philosophy student Corinna Rubrech (fig. 2) discusses what a fair and sustainable health-care system might look like in her PhD thesis.

The health-care industry in the Western industrial nations suffers increasingly from financial problems (fig. 1): technology marches steadily on, facilitating new, costly treatment methods. At the same time, as the population ages more and more (fig. 3), this generates a continuous demand for patient care solutions and treatments to combat chronic diseases. Consequently, scientists and politicians alike press for fundamental reforms to ensure that the health-care system remains financeable in future. This poses the question how the new system would have to be structured in order to ensure that the health-care industry remains fair – in addition to meeting all economic requirements?

One particularly controversial question pertains to the relation between the market and the state with regard to health-care issues. Should every individual in the free market be responsible for his or her insurance or is society responsible for ensuring that each citizen is provided appropriate health care? The advocates of the market solution and the proponents of the state-run system have for many years been in conflict, as currently exemplified in the USA. The advocates of a market-based care system emphasise the efficiency of their solution and point out that each citizen should be given the freedom to decide for or against a care system. Such a line of reasoning, however, appears short-sighted, as it ignores the fact that every individual has the right to receive basic health care. The state has the duty to fulfil this requirement – if necessary by deploying market mechanisms.

If the state is the central authority responsible for distributing limited means – how is it to determine who requires those means most acutely, i.e. which patients take priority over the others? Also, which health-care services are to be preferred over other treatment methods? In order to answer these questions, designated criteria are necessary that ensure that the distribu-
The evaluation of the cost-benefit factor of healthcare services poses a huge challenge for health-care policy.
I am familiarising myself with relevant literature by reading books and papers pertinent to that subject, as well as by scrutinising and comparing the individual suggestions.

It appears obvious to take social criteria under consideration in order to establish priorities. Two such criteria are routinely produced in the debate pertaining to health-care policy. One initial suggestion is to exclude those individuals who have “gambled away” their health due to a high-risk lifestyle from the health-care system or to at least grant them lower priority. This criterion raises several controversial questions. Should an extreme athlete who enjoys parachuting obtain additional insurance covering the risks that he takes voluntarily? The philosophical theories that propagate a strong sense of personal responsibility emphasise that an individual should be accountable for the consequences of the diseases he or she brought upon himself or herself (fig. 4). However, this raises the question who decides if, for example, a patient suffers from cancer because he had been a heavy smoker for many years or because of a genetic predisposition due to which he had always been likely to get larynx cancer. On top of these practical concerns, such a distribution system appears highly problematic, as it stigmatises patients and poses the risk that people might be left alone with their suffering. In
contrast to this, it may be plausible to have patients who take high risks consciously and voluntarily, for example by practising high-risk sport or through frequent visits to the solarium, pay compensation to the community in advance, i.e. before they are affected by a disease or an injury.

Another criterion that is subject to controversial debate is age. Rationing according to age (info) is already in place in some countries, albeit covertly. In the UK, for example, patients over the age of 60 are exempt from dialysis treatment. Health-care politicians are debating if old people, whose lives are for the most part spent, should have the same claims on health-care services as young people (fig. 5). Certain philosophical theories, which I look into in my thesis, present plausible arguments in favour of old-age rationing. If confronted with the choice of providing highly expensive life-prolonging treatment to everybody, regardless of their age, or only to individuals under a certain age limit, it may make sense to prioritise younger people. They would thus be given the chance of living to an old age. Such distribution seems particularly appropriate if resources are in short supply, for example, if there are only a few beds in the intensive care unit or if only a few donor organs are available for transplantation. With the exception of those instances of absolute shortage, a distribution system should be deployed that considers possible benefits for the patients regardless of their respective age. How such benefits may be defined is yet another problem that I will be addressing in my thesis.

By looking into the rationale behind different distribution processes and criteria, I am attempting to put forward ideas of how a sustainable health-care system may be structured – and where it has its limits.

Corinna Rubrech

Fig. 5: Who should take priority in health care – old or young people?

info

DIFFERENTIATION OF RATIONALISATION, RATIONING AND PRIORITISATION

Rationalisation: Rationalisation measures should boost the efficiency and productivity of health-care services. Certain processes and practices that, at the same cost, would be inefficient or less efficient than alternative measures or not more efficient than cheaper means are no longer carried out. Rationalisation measures are deployed to cut costs without withholding health-care services from the patients.

Rationing: A society’s health-care funds are limited. A resources shortage may become an issue, following which not every patient can be guaranteed appropriate health care. Rationing means that necessary or beneficial treatment is withheld from patients.

Prioritisation: In case of permanent resource shortage, it is necessary to establish according to which criteria health-care services are distributed, in order for such services to be available at all. A rating system must be put in place to determine which treatment methods are available to which patient groups and which services the system may do without. Essentially, prioritisation describes which patient groups, treatment measures or indicators are prioritised.
In the years to come, the evaluation of RS PLUS will hopefully show us the needs of doctoral researchers for developing their own international network and the herewith-connected necessity of financial support from universities. Of course we hope that the number of international collaborations with RUB will sustainably increase by the mobility of doctoral researchers.

— Dr Christiane Wüllner, Managing Director RUB Research School

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»The Research School provided the perfect interdisciplinary and international framework to develop my doctoral studies. It offers great support, organises excellent educational events, and promotes communication and networking between its members and the external world – key elements in generating the ideal environment for successful research.«

VICENTE F. REYES-PUERTA, ALUMNUS

»From our first experiences we can tell that operating without predefined funding lines really enhances the creativity of our doctoral researchers. Dropping the narrow-mindedness of ‘just’ applying for a conference visit or a research stay, the applicants develop very creative projects which no programme line could have anticipated.«

DR THOMAS WEITNER, RESEARCH SCHOOL PLUS COORDINATION & CONSULTING

RESEARCH SCHOOL CONTRIBUTIONS TO THIS MAGAZINE
Please see pages 12, 16 and 20 for articles of Research School PhD students about their current work.
Fig. 1: “For Peace! For Life! For Happiness!”: official poster of the World Festival of Youth and Students in Moscow in 1954. At the festival, teenagers from the West “infected” the Soviet youth with their music.
DFG project looks into Russian-language pop music between 1953 and 1985

STEPCHILD OF THE SOVIET CULTURE

Pop music commonly refers to a light, unsophisticated music genre. The songs are inoffensive, simple, with trivial lyrics. The revolutionary potential of pop music has been demonstrated by Dr Ingo Grabowsky, Slavic studies scholar at the RUB, in his project “Ėstrada! Popular music and society in the Soviet Union between 1953 bis 1985” that was sponsored by the German Research Foundation (DFG) between 2010 and 2013.

Which role did pop music play for the Soviet people? This question constituted the starting point of the project, in the course of which Ingo Grabowsky interviewed numerous witnesses to history and studied various sources in Russian archives. He postulated the thesis that pop music was the driving force behind the westernisation process of the Soviet society. “People used popular music to create spaces of illusion beyond the Soviet Union and to dream themselves away from the bleakness that surrounded them,” explains the Slavic studies scholar. “Pop music provided the means to bear up within that ideology-driven world.” This thesis stands in direct opposition to the commonly held assumption that pop music was a means of stabilising the system.

Ingo Grabowsky’s investigation period commenced in 1953, following Stalin’s death. Several years previously, in 1948, there had been a government-run campaign against the influence of Western music, classical music as well as light music, known as ėstrada. Artists who did not adhere to the regulations were deported to penal camps. Around 1953, musicians would therefore not stray away from established formula; afraid of censorship, they created harmless lyrics and composed solely marches and waltzes. “That period is referred to as the ‘deathly dullness,’” says Ingo Grabowsky.

Following Stalin’s death, many things changed: artists would again play jazz and call it by that name, too – it had been forbidden to do so under Stalin (fig. 2). An important event was the World Festival of Youth and Students that took place in Moscow in 1957, attracting 34,000 young people from all over the world – including teenagers from the West (fig. 1). They brought along “their” music and “their” fashion: jazz, rock’n’roll (fig. 3), skiffle, combined with jeans and leather jackets. Six months previously, the concert given by the French chansonnier Yves Montand had made a huge impact, too. Unlike the formalised performances of Russian artists,
Montand’s gig did not consist of him standing stiffly behind the micro; rather, he was permanently in motion, gesticulating with his arms, dancing, smiling, and interacting with his audience. “These new influences led to considerable breakthroughs in the virtually completely isolated country,” says Grabowsky. Soviet artists began to model themselves on Western musicians.

One of them was the Polish singer Edita Piekha (fig. 4). She was the first artist to sing Russian as well as foreign songs in her own natural voice. She had a slight accent that Russians considered western, wore dresses that ended above the knee and would tell stories to accompany her songs during her stage performances. Piekha’s behaviour was more liberated than a Soviet person at that time could dream of. “That was a true revolution,” says Ingo Grabowsky.

This development obviously did not meet with the approval of the Soviet government. Art councils were established in order to put a stop to it. They were essentially censorship committees that were incorporated into all institutions, for example concert artists’ agencies or the record company Melodija. Those art councils were responsible for, among other things, approving a stage show before it premiered. They robbed many artists of their livelihood by prohibiting further performances. This eventually drove many musicians into emigration, including the successful singer Larissa Mondrus who fled to Munich in 1973.

In 1963, the Twist came to the Soviet Union from the West – another major event that was fought by the state. However, bands always found new ways to play Twist songs. A singer in Edita Piekha’s band, for example, would sometimes put on a cave-man costume on stage when performing the song “Let’s twist again”. The art council interpreted this performance as a parody of western stone-age music, and it was therefore permitted. “Parody was common practice at that time,” says Ingo Grabowsky. The Twist became a mass movement that could not be stopped. Accordingly, Soviet communists began to compose Twist music themselves.

Starting in 1966, the Beatles began to spill into the Soviet Union. “The Beatlemania was even more frenzied in the East than it was in the West,” explains Ingo Grabowsky. The Soviets founded their own beat bands and played Beatles songs, the lyrics of which had been translated into Russian. Grabowsky: “A further step towards westernisation.” The beat band “The Singing Guitars” from Leningrad performed in front of 100,000 people in the Kirov Stadium in St. Petersburg, but they had only the stadium’s low-quality loudspeaker system at their disposal. The band’s music was barely audible, but the audience did not mind. “It
was the liberal western mood that people found appealing,” explains IngoGrabowsky.

Unlike radio and television that broadcast what they considered ideologically sound, the state-run concert artists’ organisations had to fulfil an economic objective since the early 1970s – i.e. they had to make money. They did so by employing artists who followed western patterns. Thus, musicians and bands were, for the first time, able to make the kind of music they truly wanted. The stages offered much more freedom than radio and television, which were pretty bleak. Major stars performed in Palaces of Culture and Sports, which could host up to 12,000 people. They would play five gigs per day, one after the other. In addition, variety shows were organised, for example in culture clubs of factories, where cabaret artists, actors and circus artists would perform alongside pop singers. On such nights, ideological numbers were also played, but the audience accepted them in exchange for an entertainment show that was influenced by western themes.

During that period, there were fewer bands in the Soviet Union than in the West. “Thus, academics maintain a good general overview over the most prominent names; the same would not have been possible in the West because of the large number of different music acts,” says Grabowsky. Unlike the field of classical music, which enjoyed a good reputation and offered well-paid jobs, estrada always remained a stepchild of the Soviet culture. The musicians lived in tiny communal flats just like everybody else. “Those artists who were fit enough to benefit from the fall of the Iron Curtain were the lucky ones,” explains Ingo Grabowsky. He has met musicians who have become millionaires, because they were booked to perform in front of oligarchs after the collapse of communism.

In the course of his project, Ingo Grabowsky travelled many times to Russia, in order to interview witnesses (fig. 5). He found the relevant people through a friend who worked as a radio presenter in Moscow and who had the necessary contacts to get him phone numbers. The Slavic studies scholar talked to more than 25 witnesses, including artists, composers, librettists, radio and television staff, employees of the record company, and fans. Whilst the interviews constituted his most important source, Ingo Grabowsky also visited Russian archives to view art council protocols. “When it comes to state and party institutions, written sources are very scarce,” as he relates. “Plenty of material was quickly weeded out from the archive, because pop songs were not considered important.” In addition, he also investigated the art works and television programmes from that period.

Chronicles and biographical studies on individual pop artists do exist. As for the rest, one would search for academic papers on this subject in vain. With his project, Ingo Grabowsky has closed this gap by publishing an academic article in the journal “Osteuropa”. An essay in an anthology as well as a comprehensive monograph where he illustrates the history of Soviet pop music using key data are to be released in the near future. Moreover, in collaboration with RUB students, he produced a two-hour radio feature that was broadcast by the Dortmund campus radio Eldorado in October 2013.
Japanese HAL system helps paralysed patients regain mobility

WITH A LITTLE HELP FROM THE ROBOT

The young woman slowly puts one foot in front of the other, her gaze focused on what is in front of her, her hands gripping the treadmill handrails. From the waist down, white plastic extremities – not unlike those of a robot – are attached to her thin legs with Velcro, whilst her feet are clad in clunky white shoes (fig. 1). A low engine sound accompanies each step that the woman takes on the treadmill. The sound is made by HAL, the robot suit. Without it, the young woman could not possibly walk – she is a paraplegic.

Since 2011, an expert team headed by Prof Dr Thomas Schildhauer (fig. 2), Medical Director at the university hospital Berufsgenossenschaftliches Universitätsklinikum Bergmannsheil, has been testing HAL, a robot suit that had been developed in Japan (info). HAL stands for “Hybrid Assistive Limb”. The ultimate aim of HAL is to help paraplegics to regain a certain mobility and activity level. The team carries out clinical trials at the Centre for Neurorobotic Movement Training (Zentrum für Neurorobotales Bewegungstraining, ZNB) in Bochum, which was founded specifically for this purpose.

In order for the robot suit to work, it requires a wearer who wishes to make a voluntary movement. The usual process is as follows: via the spinal cord and the surrounding nerves, the brain sends a signal to a muscle, for example to one in the arm or the leg (fig. 3). However, the signals inside a paralysed patient’s muscle are very weak, which is why he is no longer able to walk. This is where HAL comes into play: the robot suit picks up those weak signals through sensors that are attached to the patient’s skin and it sets its motors in the pelvic and knee-joint regions in motion. Thus, HAL takes over locomotion on the patient’s behalf by connecting directly to the patient’s nervous system. “This is how we wish to activate and foster the residual function of the muscles and, ultimately, to help the patients attain better activity levels,” explains Professor Schildhauer.

To what extent the HAL therapy will enable a paralysed patient to walk unaided, depends on the type of injury. “After all, the robot does not repair the injured nerve structures in the spine; it merely ensures that the weakened signals reach the leg,” says Schildhauer. “Our aim is to optimise this loop. The residual functions that the patient possesses are to be strengthened.” However, that does not mean that the patient will be able to walk normally after the therapy is completed.

Each training session begins with physiotherapy exercises meant to improve the patient’s agility. Subsequently, the therapist wires up the patient (fig. 4) and puts him into the robot suit (fig. 5). At first, the treadmill session takes only five to ten minutes; later, it can take up to an hour. Its dura-
Fig. 1: The HAL robot suit is made of different synthetic materials as well as carbon and weighs roughly 14 kilogrammes. When in motion, it also supports its own weight – for the benefit of the patient.
Professor Schildhauer’s team uses the clinical trials at the ZNB to determine, among other things, how much training is required and how long the training effects will or will not last. They have implemented a three-month training cycle, with five training sessions per week. A control group in Japan undergoes only eight training sessions, which likewise result in an improvement of the functions. When comparing the trials in Japan with those in Bochum, it is evident that much better results are achieved with the intense training programme over a period of three months.

“Our patients attain activity levels which improve their ability to navigate around their everyday life and their surroundings. Thus, they continue to train their movement routine every day,” explains Professor Schildhauer. A patient who had been permanently confined to a wheelchair, for example, will be able to walk short distances with the aid of a walking frame after a three-month training period. Moreover, the patients appear to maintain their activity levels if they continue to train on a weekly or biweekly basis following the three-month HAL therapy phase.

Because only 14 patients in all age groups have completed their training at the ZNB to date, the expert team will have to conduct further trials to verify their results. “We have arrived at conclusions that are surprising in many ways,” says Professor Schildhauer. “However, these are individual results – we do not want to stir up too much hope too soon.” One thing is clear: following training sessions with the robot suit, the muscle activity and consequently the agility has improved in all patients.

Because of the results it has achieved, the ZNB has received comprehensive financial support, e.g. from the State of North Rhine-Westphalia and the Japanese Ministry of Economy, Trade and Industry. These funds are now used to expand the centre: this includes the purchase of new robots as well as the foray into new research areas. To date, the centre has been studying robots aiding both lower extremities; future studies will focus on applications for one single leg or one single arm. These specific robot suits are meant to be used by patients who, for example, had a stroke or suffer from multiple sclerosis. In the first quarter 2014, the ZNB will conduct a trial with stroke pa-
Patients in collaboration with the neurological clinic Bergmannsheil, headed by Prof Dr Martin Tegenthoff. In Germany, Bergmannsheil is the only hospital where the robot suit is in use. In Japan, similar suits are being utilised in some 200 geriatric rehab centres. Those suits, however, are much more basic and do not offer as many motor setting options. In addition to Bochum and Tsukuba, Japan, the Karolinska Institute in Sweden likewise conducts research into the robot suit, deploying it in stroke therapy. The three organisations have agreed which of them focuses on what kind of research and are thus able to solve specific questions in a target-ed manner.

The long-term objective is to launch HAL in the German market so that it can be used as a therapy instrument to help as many people as possible. In the next months, this treatment method for paraplegic patients is to become available in other centres across Germany, e.g. in the A&E hospital Unfallkrankenhaus Berlin and the Berufsgenossenschaftliche Unfallklinik in Frankfurt/Main. Insurance companies will not incorporate the therapy into their clearing system until well-founded data are available, which will only be the case once further trials have been conducted. Occupational health insurance associations do already consider the robot suit a therapy instrument; negotiations with other insurance companies are currently ongoing. “If the therapy method is demonstrably effective, insurance companies will have to include it in their treatment catalogue sooner or later,” concludes Schildhauer.

GERMAN-JAPANESE COLLABORATION
The HAL robot suit was developed by Prof Dr Yoshiyuki Sankai in a research group at the Tsukuba University, Japan, more than 20 years ago. In 2004, the company Cyberdyne Inc. emerged from the group, whose European headquarters were set up in the BioMedizinPark in Bochum in 2011. Its German shareholder is the Berufsgenossenschaft Rohstoffe und Chemische Industrie (BG RCI), which looks after some 1.3 million insurance holders and operates several occupational health insurance hospitals. The Bochum team communicates regularly with the research group in Tsukuba, aiming at optimising the robot suit so that it can be used in clinical applications. However, the HAL system is deployed not only in clinical rehabilitation: in the Fukushima region that is contaminated by radioactive fallout, the robot suit is worn by clean-up workers, as remotely controlled machines cannot be operated on the uneven debris-covered ground. HAL supports the workers’ motor abilities to such a degree that they can carry loads with a weight of up to 300 kilogrammes.
Fig. 1: In search of new antibiotics: protein analyses provide first insights into the mechanisms of action of potential drugs.
RUB researchers in search of new antibiotics

**BACTERIA UNDER FIRE**

A complicated surgery has been successfully completed, yet the patient remains in critical condition. He contracted an infection in the hospital that does not respond to antibiotic treatment. Due to an excessive application of drugs, bacterial strains have developed antibiotic resistance. If no new antibiotics are discovered in the near future, this scenario could become reality. In order to prevent this, Junior Professor Dr Julia Bandow (fig. 2), together with the junior research group Microbial Antibiotic Research, is in search of new antibiotic agents.

In nature, antibiotic agents are produced for example by fungi and bacteria. In addition, certain antibiotics are now also manufactured synthetically. Humans use them to prevent or to cure infections by destroying harmful bacteria. However, bacteria are highly adaptable and quickly develop defense mechanisms against drugs (info 1). “It is possible that, in ten years’ time, none of the currently approved antibiotics will be effective, because bacteria will have become resistant against them,” says Julia Bandow.

Despite these bleak prognoses, pharmaceutical companies have reduced their efforts in antibiotic research to a large extent, one of the reasons being that the profits are relatively small due to comparably short treatment times.

Consequently, other research institutes are called upon to do their bit. Julia Bandow dedicated herself to antibiotic research as a PhD student and is continuing this quest today. Together with five partners, she launched the project “Innovative Antibiotics from NRW” (InA, info 2) in 2009. Bandow’s team looks for yet undiscovered naturally occurring antibacterial agents that have not yet been exploited in pharmaceutical products. Due to the elusive character of such agents, the researchers at the same time attempt to manufacture antibiotics in the lab. An advantage of synthetic drugs may be that bacteria develop a resistance against them more slowly, because they have not been exposed to these agents before.

Certain synthetic substances that are studied by the researchers with regard to their antibiotic properties have been sup-

Fig. 2: Junior Professor Dr Julia Bandow (on the right) is testing substances with regard to their antibiotic properties. The bacterium *Streptomyces rimosus* (large brown colonies on the top right in the Petri dish) produces an antibiotic and excretes it into the surrounding culture medium (on the left). Other bacteria (small colonies) cannot grow in the presence of the antibiotic.
zymes important for the synthesis of the cell membrane. Bacteria attempt to counteract this blockade by producing more of the membrane-producing proteins. When, following antibiotic treatment, researchers observe an increase in production of proteins belonging to a particular biosynthetic pathway, these changes typically indicate that the tested antibiotic interferes with that particular process.

The InA Consortium has tested over 2,500 substances. The microbiologists found that 60 show promising antibiotic activity, 25 of which were not toxic to human cells. Julia Bandow’s team is now investigating the mechanisms of action of these potential antibiotics. One of the most promising substances contains three residues that are made up of a hydrocarbon fraction and a metal atom. These so-called organometallic residues are connected via a peptide nucleic acid (PNA) backbone; the PNA backbone is a molecule similar to DNA with peptide bonds (fig. 4). As it does not occur in this form in nature, bacteria find it difficult to degrade it; the researchers hope this might delay the development of resistance.

The organometallic PNA molecule attacks bacteria via several routes at the same time (fig. 5). “The PNA targets the bacterial membrane. Thus, it interferes with the diffusion barrier separating the cell’s interior from its exterior,” says Bandow. The cell’s energy supply breaks down. In addition, the PNA inhibits the synthesis of the cell wall, i.e. the layer of the bacterium that encloses the cell and its membrane. “Thus, the stability of the cell is compromised,” says the biologist.

**Development of Resistance**

Bacteria reproduce very quickly and are very good at adapting to their environment. Through mutations, they coincidentally develop mechanisms that disrupt or inhibit the efficiency of antibiotics. For example, they may identify the drugs as toxic substances and pump them out of the cell. In accordance with the principle of evolutionary selection, in the presence of the antibiotic those mutated cells have the best chances of survival and may be the only ones to reproduce. In the course of this process, the bacteria gradually build up resistance against multiple antibiotics. Alexander Fleming who discovered penicillin already warned as early as at the beginning of the 20th century that antibiotic drugs will lose their effectiveness if misused or overused.

Fig. 3: Proteome analysis: the microbiologists study the cellular protein composition and synthesis rates with 2D gels. First, they treat bacteria with an antibiotic and then they feed the bacteria radioactive precursors of proteins; these precursors are incorporated into all proteins newly synthesised by the bacteria. Subsequently, the researchers isolate the proteins and separate them, among other factors, according to size. Each dot in the autoradiograph above represents one particular protein species; the larger the dot, the more of a particular protein is newly synthesised. Green: proteins that bacteria generate without antibiotic treatment. Yellow: proteins that bacteria generate with and without antibiotic treatment. Red: proteins that bacteria generate only after antibiotic treatment; pictured here: proteome profile of *Bacillus subtilis* after treatment with cerulenin, an antibiotic that inhibits fatty acid synthesis. The proteins generated at higher rates after treatment (red, labelled) are crucial for the synthesis of the fatty acids of the cell membrane.
In order to boost the antibiotic’s efficacy, the researchers inserted a ferrous organometallic residue into the PNA molecule. The iron complex results in the generation of reactive oxygen species that damage the bacterial DNA and proteins; a condition referred to as oxidative stress. Even without this additional component, the PNA may destroy bacteria. However, the iron-containing complex enhances the antibiotic by adding an additional mechanism of action. As a result, it becomes even more difficult for bacteria to become resistant. “It is less likely that a cell can defend itself against several lines of attack than if you shoot with just one bullet,” explains Bandow.

Bandow’s project partners are currently looking for follow-up funding. If the InA project research activities are to continue on the promising path, a long search might eventually result in the discovery of a new antibiotic.

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RUB engineers compile first ecobalance for an offshore wind park

GREEN POWER FROM THE HIGH SEAS

Compared with coal-fired power plants, wind power stations are significantly more eco-friendly once they are up and running. That much is beyond dispute. However, the manufacture and the installation of a wind park require a high energy input. Is it nevertheless worth it to invest into regenerative energies? And if so, how long has a wind park to generate power before the plant amortises from the ecological point of view? RUB engineers were the first ones worldwide to settle these questions for an offshore wind park – with an ecobalance for “alpha ventus”.

Located in the North Sea, 45 kilometres off the coast of Borkum, “alpha ventus” was the first offshore wind park in Germany. Twelve plants supplied by two different manufacturers transform wind power into electric power. Before the park was commissioned in 2010, the team of Prof Dr Ing Hermann-Josef Wagner from the Chair of Energy Systems and Energy Economics (fig. 1) compiled its ecobalance. Today, the engineers can reassess the accuracy of their initial calculations.

“For the ecobalance, we looked into the entire process from start to finish,” explains Hermann-Josef Wagner. “In case of ‘alpha ventus’ this entails the following questions: how much energy is required to manufacture the materials for the park, to produce the necessary components, to transport them to their destination, to install them, to service and to dismantle them again one day, and how many pollutants are generated in the process?” The engineers compared the results with how much energy resp. pollutants are saved if generating power with “alpha ventus” rather than with coal-fired power plants or by the German fuel mix. At present, the fuel mix is made up from nuclear energy (16 per cent) and regenerative energy (23 per cent); the rest is generated by coal-fired and gas-fired power plants. Financial aspects do not figure in the calculation. “The thing with the best ecobalance may well be an economic disaster,” says Wagner.

For the purpose of the analysis, the engineers have to take every detail under consideration; keeping track is vitally important. The “alpha ventus” ecobalance is subdivided into six comprehensive segments: the wind power stations, their foundations, the wiring installations in the wind park, the offshore substation, the submarine cables, and finally the onshore substation (fig. 2). The RUB scientists then broke down all those components into their respective parts. Professor Wagner provides an example: “If a wind power station is equipped with an electric generator, we have to know how much iron, copper and other materials that generator contains, how those materials had been processed, how much energy is required to manufacture the materials necessary for coiling a generator, and how many pollutants were emitted in the process.” The energy-input and pollutant-emission data for standard components are available in large databanks; the data pertaining to special components have to be
leading from the wind turbine to the offshore platform. It shows the components of the single Multibrid M5000 wind turbine, including foundations and the cable that is adapted to the voltage requirements of the high-voltage lines on land. On the bottom right, the diagram illustrates the cumulative energy demand of the park’s three lifecycle phases: manufacture, operation and dismantling (fig. 3). Whilst dismantling consumes by far the smallest amount of energy, operation figures significantly, using up 20 per cent of the entire energy input – mainly due to maintenance-related ship and helicopter deployment. The manufacturing phase, namely material production and installation, accounts for at least three-quarter of the cumulative energy demand. Wagner’s team then broke down this data into smaller and smaller components. In the manufacturing phase, some 80 per cent of the energy input are necessary for the manufacture and installation of the wind turbines and the associated cable systems. Close to 20 per cent are allotted to the offshore substation with its switchgear and the cable leading to the shore. There, the wind power is fed into the high-voltage network via a second substation.

Breaking down the balance even further, the engineers considered individual components of the offshore park (fig. 3). Thus, they found out that a much higher energy input is required for the manufacture of the wind power plant foundations than for the manufacture of the wind power station itself (fig. 4). “It turns out that the steel volumes used in ‘alpha ventus’ are the true heavyweights that leave their mark in the ecobalance,” sums up Professor Wagner. Steel makes up some 87 per cent of the energy input used for the manufacture of one cable, the researchers factor in how much energy was necessary to manufacture those wafers from high-purity silicon. Consequently, the volumes of pollutants associated with the production of solar cells are very high.

**info**

**WIND POWER VS. SOLAR ENERGY**

The energetic amortisation time is the period of time a plant has to be up and running in order to compensate for its cumulative energy demand, i.e. the energy that was invested in its manufacture and maintenance. Once a wind power plant has been commissioned, it produces more energy than it uses. According to the calculations of Wagner’s team, the offshore park “alpha ventus” amortises within the period of less than one year. The amortisation time of solar plants, on the other hand, was determined as three years according to an analysis which was made several years ago. Thanks to improvements in the production process it has however been reduced since then. The higher amortisation time for solar energy is due to the specific technology demands of photovoltaic installations. Basic components of solar cells are thin silicon wafers. An enormous energy input is required to manufacture those wafers from high-purity silicon. Consequently, the volumes of pollutants associated with the production of solar cells are very high.
the ones described above for the cumulative energy demand. In addition, they collected emission data pertaining to four other types of pollutants: such with eutrophication potential that generate an excess supply of nutrients in the soil and in water; acid-forming emissions that cause acid rain; photo-oxidants such as ozone that cause smog; and substances with human-toxicity properties that damage human health. They then compared the data pertaining to “alpha ventus” with those pertaining to the German fuel mix (fig. 5). There, a surprise awaited them. “Alpha ventus” was superior to the fuel mix with regard to all indicators but one: “Human toxicity was higher per kilowatt-hour of wind power than per kilowatt-hour fuel mix,” tells us Wagner. “We initially assumed we had miscalculated.” But the figures were correct, and the explanation turned out to be obvious. The pollutants are mainly generated during the process of steel production, and wind power stations have more steel per generated electricity volume than a compact coal-fired plant. One single wind power plant in the sea weighs 300 tons, some 260 tons of which are steel. “We’ve got to accept that, in some respects, wind power does not necessarily offer more benefits than fuel mix,” believes Hermann-Josef Wagner. “With regard to all other indicators, however, wind power is excellent.” Moreover, the volume of human-toxic substances may be higher than in the fuel mix, but the absolute figures are still very small.

From the energy-efficiency point of view, ‘alpha ventus’ has long amortised. The RUB engineers’ ecobalance had predicted that it would take only one year until it is worth generating power with the offshore park instead of the German fuel mix – amortising much more quickly than a solar plant (info). “Even though our calculations were on the pessimistic side,” adds Wagner. After two years in operation, “alpha ventus” has generated more power than the ecobalance had assumed; 2011 and 2012, the output grew by 13 per cent and 14 per cent respectively. However, even though the wind supply remains on a constantly high level, it is estimated that this growth trend will not continue in 2013, due to maintenance work that will slow down operations. Still: any kilowatt hour of energy generated by „alpha ventus“ is good for the environment.

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**Fig. 4:** A turbine in the offshore wind park “alpha ventus” requires a strong foundation (on the right).

**Fig. 5:** Environmentally relevant emissions for the wind park “alpha ventus” in comparison with the German fuel mix. The wind park is superior to the fuel mix with regard to all figures, except those pertaining to human-toxicity substances.
THERAPY WITH NO ACTIVE TRAINING
Fig. 1: Hubert Dinse investigates learning through passive stimulation at the Institute for Neuroinformatics. His aim is to understand basic learning mechanisms and to understand how passive stimulation may be applied as a therapy for stroke and brain injured patients.
BRAIN STIMULATION AT YOUR FINGERTIPS

Stimulation glove for stroke patients improves sense of touch and motor skills

Hubert R. Dinse and Martin Tegenthoff

Learning an instrument, dancing ballet or reading braille – the golden rule for acquiring skills such as these is: practise, practise, practise. However, there are some things that the brain learns without any training at all. RUB researchers have demonstrated in several studies that perception and motor skills can be improved through repeated passive stimulation. Patients suffering from brain damage benefit from this approach. In collaboration with partners from the industry, the Bochum-based team is developing a stimulation glove which alleviates stroke impairments.

The principle underlying our learning processes is based on changes in communication between nerve cells, so-called neurons. On the cellular level, the learning process is determined by the signal transmission at the synapses (the contact points between two neurons) which can become more or less efficient. Such modification of synaptic efficiency is referred to as neuroplasticity. The molecular principles of synaptic plasticity have been studied in depth in individual cells, mainly those of rodents. The long-term changes of synaptic transmissions that occur in the course of the learning process are studied in a number of models, for example through long-term potentiation (LTP) and long-term depression (LTD). High-frequency electrical nerve cell stimulation, for example, triggers LTP; that means the communication between the stimulated cells is improved. Low-frequency stimulation, on the other hand, results in LTD; the communication efficiency between the cells declines. Consequently, LTD and LTP are two exemplary mechanisms that control the information flow within the brain network by controlling learning processes. The question is in what way does synaptic plasticity influence learning processes that are relevant for humans? Do LTP and LTD play a role at all in everyday life? In the Collaborative Research Centre 874 (info 1), we attempt to provide answers to these questions.

Generally speaking, we distinguish between two types of learning: procedural and declarative. Declarative learning enables us to learn facts and memorise events; procedural learning enables us to acquire motor skills and improve perception. The best way to acquire such skills is training over a long period of time; learning to play an instrument, for example, takes many years. Our perception, too, can be improved through continuous training. Doctors, for example, find it easier to recognise structures in X-ray images with increasing experience. Blind people and musicians have a particularly good sense of touch, because they use their fingers a lot. Non-invasive imaging procedures have shown that heightened perception goes hand in hand with specific macroscopic changes to the brain organisation: in musicians and in blind people, the brain regions responsible for fingers and hands exhibit an enhanced and spatially more extensive activity; that means that the sense of touch, among others, recruits

info 1

SFB 874: SENSORY PROCESSES IN THE BRAIN
The interdisciplinary Collaborative Research Centre SFB 874 “Integration and Representation of Sensory Processes” was launched at the Ruhr-Universität Bochum on July 1, 2010. The SFB members investigate in what way perception leads to plasticity, how different sensations are integrated and subsequently represented in the brain and how the processing of sensory information leads to memory building.
nerve cells for its purposes, thereby making information processing more efficient. However, scientists have not as yet been able to determine which cellular and molecular processes are responsible for this.

In order to study in what way synaptic plasticity influences learning processes in humans, our work group has for many years chosen a different approach, namely one based on the following hypothesis: LTP and LTD-related processes constitute the foundation of learning, and learning can be induced on a cellular level through specific electrical stimulation protocols (fig. 2). Consequently, it should be possible to induce plastic processes in humans directly through sensory stimulation. In other words: an individual should be able to improve their sense of touch without any active contribution on their part. It should be sufficient to stimulate the skin surface repeatedly, either tactually by touching it repeatedly, or electrically through weak electrical impulses that cause a tingling sensation. However, this approach will only be successful if the same timing is applied that induces synaptic plasticity on the cellular level.

What seems improbable at first glance does indeed work: if we tactually stimulate the index finger of a young participant for the duration of 30 minutes with a LTP-like stimulation protocol, the sense of touch in the stimulated finger improves by some 15 per cent, but not in the index finger of the other hand. If, conversely, a LTD-related protocol is applied for the same length of time, the sense of touch in the stimulated finger declines (fig. 2). That means it is possible to control through the choice of the stimulation protocol if a person’s tactile perception weakens or strengthens. After a single stimulation session, all changes revert to the baseline after some 24 hours. If, however, the stimulation is repeated, for example five days a week over the period of several weeks, the induced effect is just as strong, and it remains constant for weeks.

The quality of the sense of touch is measured using the discrimination threshold, also called “differential threshold”. We determine whether a participant is able to tell the spatial difference between two discrete tactile stimuli in close proximity to each other (fig. 7). In the experiment described above, we altered the discrimination threshold by 15 per cent – is this a high or a low value? To compare: we know that blind people have a much better sense of touch than sighted people; in this case, the difference in the discrimination threshold amounts to up to 20 per cent. Consequently, passive stimulation causes a considerable change to the tactile perception.

What happens in the brain during and after behavioural changes? Is it possible to
measure the neuronal signatures of the induced perception alterations? We examined this question using magnetic resonance imaging and high-density EEG measurements which require the participants to wear caps with up to 256 electrodes in order to record brain activity. In both studies, the sense of touch improved through repeated stimulation of the fingers, and the brain regions that process tactile information in and around the fingers were enlarged (fig. 3). The following interpretation suggests itself: the maps that are created in the brain (cortical maps) were enlarged, because the brain recruits additional resources in order to process signals from the hand more efficiently. Therefore, we assume that the modification of brain maps is causally related to the altered discrimination ability. Indeed, the changes to brain maps remained minimal in those participants in whom the discrimination ability only minimally improved. Conversely, the most significant improvements to the sense of touch happened in participants whose brain maps underwent the most significant changes. These findings indicate, on the one hand, that repetitive stimulation results in selective reorganisation in somatosensory areas of the cortex that are responsible for the sense of touch (fig. 4). Moreover, it is evident that the brain maps of individuals who do not benefit much from the repetitive stimulation change minimally. The fact that the learning outcome differs from individual to individual is a typical observation – everybody learns differently. What is interesting is that the differences apparently derive from the actual differences in the individual reorganisation in the brain.

Passive stimulation leads to a targeted modification of synaptic transmission in neural networks (info 2). In light of these findings, we have postulated the hypothesis that all neuronal processes related to tactile, haptic and sensorimotor information processing may be modified. This list is based on the assumption of a hierarchy of increasing behavioural complexity: tactile processing, for example, comes into play if something touches my finger. Haptic processes happen when I move my fingers actively in order to explore something, for example to feel for a key in the pocket. The sensorimotor performance describes the complex interactions between senso-
Fig. 5: Older people have a higher (worse) discrimination threshold than younger people; i.e. the distance between two stimuli (e.g. the two tips of a pair of compasses) has to be greater to perceive the two stimuli as separate. However, the representation of the hand area takes up more space in their brain than in the brain of a young person (on the right) because the activation is more diffuse. Through repetitive stimulation, the discrimination threshold of older people improves much more significantly than that of younger people (on the left).

Passive stimulation and synaptic plasticity

When passive stimulation changes both perception and behaviour, this is caused by a modulation of the synaptic transmission, i.e. by neuroplastic processes. It is assumed that synaptic transmission is controlled by only a few basic mechanisms. It is generally believed that the N-methyl-D-aspartate (NMDA) receptor plays a vital role in the regulation of synaptic plasticity. The efficiency of repetitive stimulation, too, is determined by such plasticity-conveying mechanisms, namely the activation of NMDA receptors. In order to demonstrate this, we administered memantine, a substance that selectively blocks NMDA receptors, to a group of participants. With the following result: the stimulation-induced learning was blocked completely, both on the perception level and on the cortical level. These findings were an additional link in the chain of evidence that learning through repetitive stimulation and the cortical changes related thereto are conveyed through basic synaptic plasticity mechanisms.
the effects of the therapy as comprehensively as possible. In addition, we examined not only the sensibility of the tactile sense and motor functions, but also the proprioception, i.e. the perception of one’s own body, for example the position of the body and the joints. Using standardised test batteries, we also recorded situations relevant for everyday life: picking up small items, mimicking a feeding motion or stacking objects; all these are actions that may constitute hurdles for stroke patients in their everyday life.

The particular advantage of repetitive stimulation lies in its passive nature: it does not require a person to participate actively or attend to the stimulation. It is therefore possible to apply the stimulation during other activities such as going for a walk, watching television or reading. This increases the likelihood of the procedure being accepted and the drop-out rate remaining low. We have started to treat individual patients over long periods of time (longer than one year), some of whom had suffered an infarct longer than ten years ago. All seven patients applied repetitive stimulation regularly at home, 45 to 60 minutes per day, five days a week. The stimulation was carried out by means of computer-aided commercial equipment which also controlled time and duration of the stimulation sessions. To date, we have treated patients over a period of more than two years. In almost all cases, we clearly observed a positive effect with regard to the tactile, haptic and sensorimotor performance (fig. 6). The patients, for example, reported that, following the passive stimulation, they were able to recognise the surface structure of objects and to better manipulate objects, for example removing the cap from a pen. Interestingly enough, in individual cases it may take several months until the stimulation shows positive results, which then continue to intensify and manifest in the course of the following months.

We also examined the field of sub-acute treatment. The treatment commences two to three weeks after a stroke and runs over a period of two to three weeks, depending on the rehabilitation centre. In a randomised placebo-controlled study with 50 patients, we analysed in how far repetitive stimulation treatment in combination with standard therapy compares to mere stand-
ard therapy. The latter includes, for example, occupational therapy, training of everyday activities and curative pedagogy. We discovered that the effects of passive stimulation on patients in the sub-acute phase as well as in chronic patients were very beneficial, especially in terms of sensory information and proprioception improvement. Repetitive stimulation cannot work wonders, however; the impairments do not regress fully, but they can be significantly alleviated.

In order to facilitate the stimulation application, the study has pioneered the use of a special glove that we developed together with partners from the industry. Electrical contacts that are located at the finger tips and worked into the glove in form of a conductible material transmit short electric impulses to stimulate the nerves leading from the fingers to the brain. The users themselves can control the intensity of the stimulation; they should be able to feel it distinctly. Some users describe the feeling as “finger massage”. The patented product has been available in the market since the end of September 2013.

These data suggest that repetitive stimulation is an instrument suitable for additional or perhaps even exclusive brain injury treatment, the application of which is still in an early stage. Additional studies will be necessary to gain a better understanding of this remarkable phenomenon: electrical stimulation of the skin of the fingers activates the somatosensory cortex in an unspecific manner. Nevertheless, it does not result in a disorganised state in the relevant brain networks; on the contrary, it facilitates a new, highly organised state the relevance of which is reflected in an improved perception and an improved behaviour. At present, it is not clear which of the properties enable the cortical networks to emerge into new, stable and structured states and lead to better efficiency. This is the field on which our research will be focusing in future.

PD Dr Hubert R. Dinse, Institute for Neuroinformatics, and Prof Dr Martin Tegenthoff, Neurological Clinic, Berufsgenossenschaftliches Universitätsklinikum Bergmannsheil

**info 3**

**STROKE AND ITS CONSEQUENCES**

In Germany, almost 270,000 people suffer from stroke every year. Due to the changing age patterns in our society, the number of patients is going to increase in the next decades. Even though many patients may regain their motor abilities to some degree, the extent to which a patient recovers depends on the individual. The consequences often include invalidity and very high socio-economic costs. The most severe impairment in 80 per cent of the patients suffering from acute stroke is hemiplegic paralysis. Effects of stroke frequently include impairments of voluntary motor functions, for example gripping, and of the somatosensory system, for example numbness, with the arms and legs both being affected to the same degree.
CLIMATE CHANGE IN FOCUS
Fig. 1: Prof Dr Andreas Pflitsch and his team research lava, ice and caves around the world.
RUB researchers explore climate dynamics in caves

Andreas Pflichtsch, Christiane Meyer and David Holmgren

Gale-force currents, ice bodies that move like glaciers, as well as unique temperature and humidity conditions that lead to the creation of singular life forms – there is a lot going on in caves. Much more than people have generally thought. It had long been assumed that caves possess a constant climate; however, that was only due to imprecise measurement technology. In caves, meteorological processes do exist. RUB climatologists study those hidden dynamics.

In the last years, our work group “Cave and Subway Climatology” has developed high-precision measurement processes capable of detecting even the weakest air currents in underground railway tunnels. We are now deploying this technology in cave research.

In Bochum, we launched cave climate research in the late 1990s, following a Polish colleague’s invitation to join him on an expedition to a cave in the Sudetes Mountains. Until that point, we had mainly studied ventilation processes in an urban environment. In the Polish cave, our task was to record air currents that had hitherto not been possible to measure directly, by deploying an ultrasonic method previously utilised in the field of urban climatology. The first measurements led to numerous new findings, and the work group from Bochum got gripped by the cave fever. By the light of the lamps, the dark underworld turned out to be fascinating, full of unfamiliar shapes and different colours – as well as unexpectedly dynamic. The research area was soon expanded to include caves in the Czech Republic and in Slovakia. Previously explored by the Bochum-based geologist Prof Dr Detlev Richter, the cave Dechenhöhle in Iserlohn, too, became a research subject. Our cave research follows three objectives: we wish to study the effects of climate change; to protect valuable climate archives by analysing them; and to promote cave protection.

Fig. 2a: Correlation between the behaviour of the air pressure and the wind direction as well as the wind velocity (represented as the x component of the current) around the opening of the Jewel Cave in South Dakota, USA. If the external pressure rises, air pours into the cave; if the external pressure falls, the air pours outside. The graph shows the hourly mean.

Fig. 2b: Impact of Hurricane Irene in August 2011 on the behaviour of the air temperature in a talus cave in New Hampshire, USA. The information pertaining to the passing hurricane (v: wind velocity in km/h, Wd: wind direction) were recorded at Mt. Washington stations nearby. The air in the cave was significantly warmed by the hurricane’s southeast winds (orange).
In the European caves, we mainly focused on analysing air current systems and ventilation. For this purpose, we had to measure very faint air movements of several centimetres per second. In the past, this had been determined indirectly by analysing changes in concentration of the radioactive gas radon. Our measurements with ultrasound anemometers (info 1) were much more precise. These measurements showed, for example, in what way the cave climate changes when a group of tourists walks through the cave. Their body heat and exhaled air warm the air by up to two Kelvin, especially under the ceiling. In addition, the group’s body heat and movement cause turbulent air movements, thus modifying the natural current system. At the same time, cave protection plays an important role, as we aim at preserving the cave fauna and flora as well as speleothems such as dripstones.

Just like in Germany, cave climate research in the USA was non-existent in the early 21st century. The last relevant studies in the then second and third-longest known cave systems on earth, Wind Cave and Jewel Cave in South Dakota, dated from the 1960s. Here, the husband and wife team Connn had effectively recorded the air flow with basic measuring systems made of wood. On the basis of these data, they calculated the size of the cave systems that amounts to several hundred kilometres, even before they were found.

In 2001, we launched a measuring programme in the Wind Cave, in 2002 in the Jewel Cave (fig. 2a). We installed ultrasound anemometers and sensors in several locations throughout the cave to record air temperature and humidity. The recordings are still ongoing. Our ultrasound measurements have confirmed the analysis of the Conns, who had proved the barometric character of the Wind Cave and the Jewel Cave. The particular property of barometric caves is that their entire current structure is determined by variations in the air pressure in the external atmosphere and compensation currents between the external atmosphere and the cave air – unlike in convective caves. In the latter, the current structure is determined by temperature differences between the cave air and the external atmosphere resp. the atmosphere inside the cave. A barometric current regime requires a large cave system with one or several small surface open-

**info 1**

**ULTRASOUND ANEMOMETER**

An ultrasound anemometer can be used to detect the three-dimensional wind vector; this unit describes the movement of an air current within a specific space. The device records the horizontal and vertical air movement as well as the air temperature. The measurement process is based on the wave structure of sound. Ultrasound impulses are exchanged between two sensors, with each sensor fulfilling the function of a sender and a receiver at the same time. Air movement makes sound waves move faster in the one direction and slower in the other. The difference between the two gives the wind velocity for one direction. Using three sensor pairs arranged in a specific position, the three-dimensional wind vector may be established. As the sonic speed of air is determined by its density, which, in turn, is determined by the temperature, air temperature can be calculated with the help of the average runtimes of all sensor pairs. This method can be used to verify faint air currents of only a few centimetres per second as well as the faintest fluctuations in wind direction and velocity.
Different forms: exogenous ice, for example snow that gathers by the entrance, and endogenous ice, such as water that trickles into the cave and freezes there. Some several hundred to thousand years old, the ice masses in the ice caverns (info 2) are very interesting for scientists. More often than not, cave ice is clearly structured and stacked in layers. Often magnificent in appearance, those layers contain, just like the growth rings of a tree, crucial information regarding historical climate conditions. Frozen biomass remains, air bubbles or minerals crystallised from the ice tell us something about the palaeoclimate, and also about the way the cave and the surrounding fauna and flora have evolved.

Our work group has recorded ice caves and their climatology in different climate zones. Because of particular cave morphologies and because of the processes determined by those morphologies (info 3), ice caves may be found in regions that are not snow-covered throughout the year and in which the summer temperatures lie considerably above the freezing point.

One example is the Schellenberg Ice Cave near Berchtesgaden (fig. 3) – the only ice cave in Germany that is also a show cave. It is located some 1570 metres above sea level, the outside temperature may reach 30 degrees Celsius in the summer. And yet, the cave possesses a large ice mass with a circumference of 10 to 30 metres. This is because of the specific cave structure: the surface opening is situated in one of the highest spots in the cave. The ice-conducting part drops downwards like a sack, constituting an ideal reservoir for the cold winter air so that the air temperature in the lower part of the cave rises above the freezing point only briefly. Unlike the many ice caves in Austria, the Schellenberg Cave does not possess any manmade entrances or sluice systems. It is therefore of scientific interest, because its structural conditions that lead to the creation of ice have never been modified. Any changes to the ice mass are consequently caused by climatic changes. By analysing a leaf that we extracted from the ice mass in July 2013, we have concluded that the oldest ice layers are at least 1000 years old.

Temperatures and ice levels in the Schellenberg Cave were documented by Eberhard Fugger and later by Fritz Eigert as far
nal conditions should have promoted ice building. Unfortunately, the available data are not comprehensive enough to explain if the ice melting in the Schellenberg Cave followed the alpine trend of glacier melting and why small-scale variations of ice melting occurred in the cave.

Our measurements in the period between October 2007 and June 2013 suggest that the ice retreated in some parts of the cave, whilst ice masses grew in other parts as early as 1876; those data, however, are incomplete. In order to catch up on the climate research results in this location at least in essentials, we have digitalised and analysed all original protocols and added our own measurement data collected since 2007. The analysis of the old data showed that the ice volume had increased at the end of the 19th century. Further increase was halted only due to a torrential downpour of rain. We assume that the cave climate was influenced by the “Little Ice Age” that occurred between the mid-14th and the late 19th century.

At the time Fritz Eigert conducted his research, between 1958 and 1978, the warming of the 20th century had apparently already commenced. Even though the data did not indicate that that period included particularly humid or particularly dry years, the ice mass was reduced by up to 30 centimetres per annum on average. The data gathered at different measurement points varied strongly. Still, we have determined that in the top part of the cave larger variations in the ice mass occurred, whereas the ice mass in the bottom part of the cave remained at a constant level. Noticeably, there was a strong ice melting period between 1958 and 1978, 3600 cubic metres in the so-called Angermayer Hall of the Schellenberg Cave alone – even though the external conditions should have promoted ice building.
er areas. It will take a few years more until clear trends will emerge, based on the data derived from 32 measuring points we set up to record the ice levels. It is obvious that the cave had warmed up significantly between 1876 and 2008, resulting in long-term thawing – analogous to many glaciers on the surface of the earth. Moreover, our data show that extreme years and extreme events with heavy rainfall or particularly high or particularly low winter temperatures lead to variations in the ice volume and temperature in the cave. Following the cold winters Germany experienced in the last few years, the decline in ice volume appears to have temporarily halted; in some places in the Schellenberg Cave, there was even an increase in ice masses. Since climate change is likely to lead to extreme events in future, cave climate might likewise vary much more strongly. Consequently, ice caves provide an interesting field of research if we want to monitor the impact that climate change has on our environment. Because the caverns inside a mountain and those underground are connected with the external atmosphere only very slightly or not at all, any signals from the outside are muffled and their influence inside the cave is not felt until hours or even years later.

Unlike in the Schellenberg Cave, we did not find a trend of thawing in the caves studied in New Hampshire in the Northeast of the US after the first three years of researching them. Here, in so-called pseudo caves, in caverns underneath massive boulders, ice deposits exist at an altitude of only 600 metres above sea level. With a diameter of one to two metres, these are small ice bodies and they last for many years in small caves that had formed between boulders amidst large rock waste on mountain slopes. In New Hampshire, we monitor continuously the temperature inside and outside the caves and measure the ice levels every year early in the winter. So far, the ice volume has been varying strongly. Warm rainfall and storms in particular disturb the cave climate; for example in 2011, the air inside the cave was considerably warmer following Hurricane Irene (fig. 2b). By contrast, the ice is only little affected during warm, low-wind and dry periods.

These findings indicate how important it is to keep track of ice in caves in different places on earth, because each location is additionally influenced by regional weather patterns that may deviate significantly from the global atmospheric conditions that affect the place as well. Therefore, we have been characterising caves and their ice levels in many locations around the world, for example in Wyoming, Alaska and Hawaii (fig. 4). Ice caves just above sea level are rare and may only ever occur in polar or subpolar regions, for example in southern central Alaska. There, an ice-filled car tunnel with
two almost completely closed-up entrances and two small openings at a high altitude constitutes the ideal research lab (fig. 5), because, unlike a natural cave, the tunnel structure can be precisely measured. We have only recently discovered that space with a length of almost 200 metres and a height of 6.3 metres. The first recording showed almost 550 separate ice forms in different stages of development. Here, ice structures that are still growing stand side by side with aged ice masses with crystal-lised cryogenic material – creating a visually and scientifically magic landscape. In future, this will be the place where we are going to monitor freezing, thawing and sublimation processes, with sublimation describing the transition from the solid directly to the gas phase and vice versa. Moreover, we analyse the generation of ice crystals and the formation of bubble structures (fig. 6). We are hoping, for example, to be able to verify under which conditions the old ice masses developed.

In addition, we explore the ice caves of Mauna Loa in Hawaii, the furthest ones from any continent. They constitute a climate archive for that region the information of which we need to read and archive before the ice thaws. Hawaiian lava caves – without any ice – hold surprises, too. Bacteria that form bio mats on the cave walls and exist only under specific climate conditions in caves may become relevant in the development of new drugs.

In order to strengthen the research capacities in Hawaii, we are currently launching a research and teaching centre for cave climatology of lava caves in collaboration with the Cave Conservancy of Hawaii. For this purpose, we have already purchased property above a lava cave, the Akeakamai Cave, and have begun setting up a monitoring system. The premises provide basic accommodation. Three student groups from the RUB visited the Hawaiian caves in 2013. Now, we are planning to secure funds that will permit us to continuously enhance the centre in the next years, in order to eventually establish an internationally recognised research and teaching centre.

A highly diverse field, cave climate research provides crucial information for applied climate issues, despite being hidden from the public eye. The underground ice contains information pertaining to global climate processes – just as air currents in caves provide important information pertaining to underground train networks; underground railway tunnels are not dissimilar to natural caves in climate terms. The information gathered there might thus save lives in case of a terrorist attack.

Prof Dr Andreas Pflitsch, Christiane Meyer, David Holmgren, work group Cave and Subway Climatology, Geographical Institute, Faculty of Geosciences

Fig. 6: Small cave components that might contain a lot of information: air bubbles with a diameter of some five centimetres are locked in inside the ice.
RUHR-UNIVERSITÄT BOCHUM

Publisher
Rectorate of the Ruhr-Universität Bochum in cooperation with the Corporate Communications Department/Science Communications of the Ruhr-Universität Bochum (Dezernat 8 für Hochschulkommunikation, Abteilung Wissenschaftskommunikation)

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Imprint
Rubin | International Edition 2014

Mailing address
Corporate Communications, Science Communications (Dezernat 8 für Hochschulkommunikation, Abteilung Wissenschaftskommunikation)

Rectorate of the Ruhr-Universität Bochum in cooperation with the Corporate Communications Department/Science Communications of the Ruhr-Universität Bochum (Dezernat 8 für Hochschulkommunikation, Abteilung Wissenschaftskommunikation)