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DFG

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Contributions to a better understanding of the miracle of neuronal plasticity: Neurobiologist Martin Korte examines basic cellular mechanisms in memory processes.

Election in Rostock

Illustration: DFG/Ausserhofer

First Female President for the DFG

At the beginning of July, Katja Becker became the first woman to be elected to the top position in Germany's largest research funding organisation and central self-governing body of the research community. The Giessen-based biochemist will succeed Peter Strohschneider on 1 January 2020.

The DFG has elected its first female president. On 3 July 2019, biochemist and medical scientist Prof. Dr. Katja Becker from Justus Liebig University Giessen was elected by the DFG's General Assembly in Rostock as the first woman to head Germany's largest research funding organisation and the central self-governing body of the German research community.

Becker has served as DFG Vice President since 2014 and will take office on 1 January 2020 for an initial term of four years. She succeeds German medievalist Prof. Dr. Peter Strohschneider, who has served as President of the DFG since 2013 and will leave office at the end of his second term.

The 2019 General Assembly of the DFG elected Katja Becker from a pool of three candidates, which also included engineering scientist and process engineer Prof. Dr.-Ing. Wolfgang Marquardt from Forschungszentrum Jülich and theoretical computer scientist Prof. Dr. Dorothea Wagner from the Karlsruhe Institute of Technology (KIT). All three candidates were nominated to the member organisations of the DFG in April by the selection committee.

The future DFG President is 54 years old and has extensive experience in research, academic self-governance and policy advice. Katja Becker was born on 7 March 1965 in Heidelberg. In 1984 she began studying medicine at Heidelberg University, where she earned her doctorate in 1991 and completed her habilitation in biochemistry in 1996. In parallel to her research work, which included stays at Heidelberg University's Biochemistry Center and the University of Sydney, Becker continued her clinical and physician's training, working in Basel (Switzerland), Oxford (UK) and Nigeria and at the Heidelberg University Children's Hospital, and passing her specialist examinations in 1998. After working as an associate professor in Heidelberg and as the leader of an independent junior research group at the Research Center for Infectious Diseases at the University of Würzburg, in 2000 Becker was appointed Professor of Biochemistry and Molecular Biology in Giessen, a position she still holds today.

Left: On the morning after her election in Rostock – Katja Becker, photographed by David Ausserhofer at Wissenschafts-Forum in Berlin

Between 2009 and 2012, Becker served as Vice President of Research and Early Career Support at Giessen University, having previously been spokesperson for the university's Interdisciplinary Research Centre in 2004/2005. She completed a research sabbatical at Scripps Research in La Jolla, California. Her research interests include cellular thiol metabolism, the structure and function of redox-active proteins and rational drug development for tumours and infectious diseases, particularly tropical malaria.

She has received multiple awards for her work, including the Carus Medal from the German National Academy of Sciences Leopoldina and the Rudolf Leuckart Medal from the German Society for Parasitology.

Katja Becker has been closely associated with the DFG as a funded researcher, for example as the current spokesperson for the DFG Priority Programme "Dynamics of Thiol-Based Redox Switches in Cellular Physiology". Furthermore, she is spokesperson of the Hessian LOEWE Centre DRUID dedicated to developing novel drugs, vaccines, and diagnostics against poverty-associated and neglected tropical infectious diseases. Since 2014, Katja Becker has also been involved in the statutory bodies of the DFG at a senior level, as Vice President and as chair of the Permanent Senate Commission on Genetic Research. Among other activities, she played a key role in formulating a state-

Illustration: DFG/Ausserhofer

"I'm coming directly from research": With these words, and a brief outline of her career as a biochemist and medical scientist, future DFG President Katja Becker introduced herself to the media and the general public at the annual press conference on 4 July in Berlin. She described her election in Rostock on the previous day as the first woman to head the DFG as "a signal and a source of encouragement to all women who do outstanding research every day". Becker declined to comment on possible focal areas of her presidency, as she will not take office until January. However, she noted that the freedom of research and its defence will certainly be important concerns. "I've always regarded it as a privilege to work in Germany, where the freedom of research is so highly valued. So it's all the more worrying to see how this freedom is coming under attack in a growing number of countries." Prior to this, DFG President Peter Strohschneider had given a positive résumé of the annual meeting in Rostock and the current science policy situation: "Over the last few days and weeks, decisions have been made that point the way forward for the DFG and German research." Strohschneider was particularly satisfied "and also appreciative" with regard to the decision by the federal and state governments to continue the nationwide science initiatives, especially the Pact for Research and Innovation (PFI): "A budget increase of 3 percent per year for another ten years for the DFG and the other organisations involved in the initiative is probably unparalleled anywhere in the world." For the coming year, Strohschneider announced a national campaign entitled "DFG2020 – Because Research Matters", with which the DFG aims to raise public awareness of the principle of free research and its value to an informed, open society (see also the back cover of this issue).

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ment entitled "The Opportunities and Limits of Genome Editing", published by the DFG, the German National Academy of Sciences Leopoldina and acatech – National Academy of Science and Engineering, and in discussions spearheaded by the DFG, Leopoldina and the German Ethics Council on a new definition of genetic engineering. Under Becker's leadership, the Senate Commission prepared a document appraising the current situation in synthetic biology and engaged with the recent statement by the Ethics Council on interventions in the human germline.

On the DFG's Executive Committee, Becker has been involved in discussions on modern research infrastructures in the life sciences, the harmonisation of the Animal Welfare Act and the expansion of research cooperation with India. She has also served as chair of the jury for the Eugen and Ilse Seibold Prize, which honours outstanding examples of German-Japanese cooperation in research.

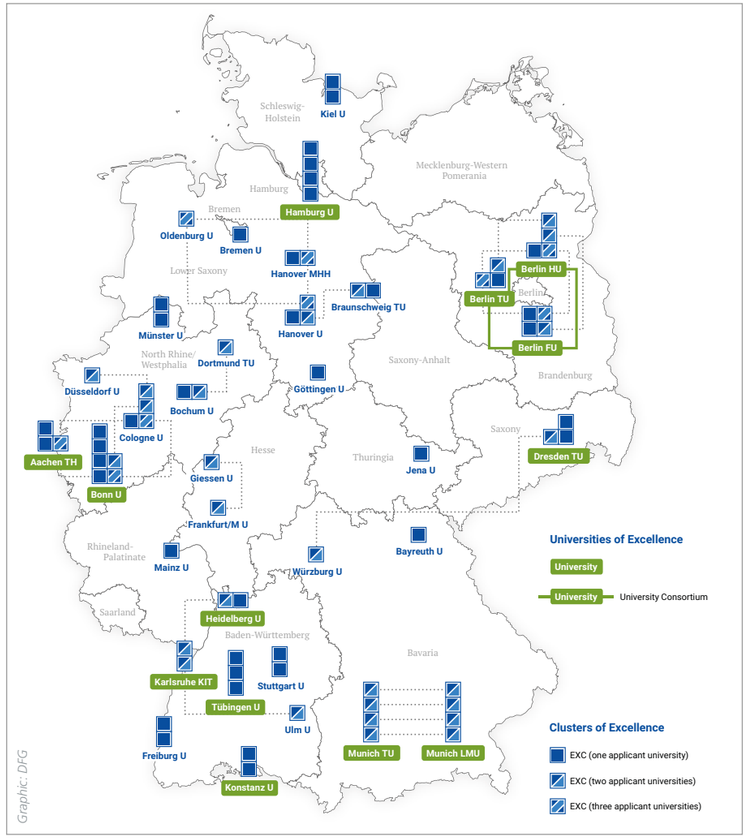
Becker is actively involved in the research system as a member of several learned societies and academies, among them the Leopoldina, the German Society for Tropical Medicine and Global Health, and the International Society for Free Radical Research.

Her special interest in professional dialogue between researchers and policymakers is also demonstrated by her involvement in the statements issued by the Leopoldina on Neglected Tropical Diseases for the G7 summit in 2015 and Improving Global Health for the G20 summit in 2017.

www.dfg.de/en/service/press/press_releases/2019/press_release_no_24

Excellence Twice Over

Excellence Strategy: Following their success in the Clusters of Excellence competition, ten universities and one consortium have also been selected for the Universities of Excellence funding line.



Graphic: DFG

This is the long-awaited and much-anticipated outcome of the first round of the Excellence Strategy. On 19 July 2019, after three and a half days of meetings in Bonn, firstly of the Committee of Experts for the Excellence Strategy and then of the Excellence Commission, eleven out of 19 applicant universities and university consortia were selected for permanent funding by both academics and politicians and with considerable unanimity.

The selected institutions (in alphabetical order by location) are:

- RWTH Aachen University
- Berlin University Alliance
- University of Bonn
- Technische Universität Dresden
- Universität Hamburg
- Heidelberg University
- Karlsruhe Institute of Technology (KIT)
- University of Konstanz
- Ludwig-Maximilians-Universität München
- Technical University of Munich
- University of Tübingen

"I would like to congratulate and pay my greatest respect to the selected universities and the Berlin University Alliance," WR-chairwoman Professor Dr. Martina Brockmeier commented. "The selected universities have very impressively demonstrated how universities of the future could look like. In order to compete with the top institutions on the international level, a university requires a very strong foundation in excellent research as well as a clear sense of its institutional profile and sound plans for its institutional development. The selected universities have all demonstrated very convincingly that they are in an excellent position with respect to all of these aspects".

DFG President Professor Dr. Peter Strohschneider summarised, stating: "Today's decisions on Universities of Excellence were based on the decisions to fund 57 Clusters of Excellence. The Clusters were selected last September and have been funded since 1 January. With the completion of this first round of competition, the Excellence Strategy builds on the three funding rounds in the Excellence Initiative (2006, 2007 and 2012). Both competitions together reflect the remarkable cooperation between research and politics in promoting top-level research at German universities at an internationally competitive level."

To be eligible for the title of University of Excellence, institutions had to be successful in the DFG-administered, research-driven Clusters of Excellence funding line, having at least two (in the case of individual universities) or three (for consortia) Clusters of Excellence. A total of 17 universities and two consortia from eight federal states met these criteria.

Illustration: BMBF / Rickel

Satisfied faces in Bonn: Federal Science Minister Anja Karliczek and Bremen's Senator for Science Eva Quante-Brandt (2nd and 3rd from left) announced the results at a press conference immediately after the meeting of the Excellence Commission. Martina Brockmeier, Chair of the German Council of Sciences and Humanities (left) and DFG President Peter Strohschneider explained the process and the procedures involved.

The first step in the Universities of Excellence competition, administered by the German Council of Science and Humanities, was the on-site visits to the universities and consortia, which took place between the end of January and the beginning of May 2019 and involved 190 reviewers, over 90 percent of whom came from abroad. During these visits the universities were considered as whole institutions – not only with respect to research performance, but also other areas such as teaching, transfer and research infrastructure, and finally their plans for future development. The compiled review results provided the basis for the consultations of the Committee of Experts, consisting of 39 international researchers, whose appraisals then formed the starting point for the decisions of the Excellence Commission.

With effect from 1 November 2019, the selected universities and consortium will receive an annual €148 million in funding. The funding will be offered on an essentially permanent basis. However, in seven years' time the universities will again have to successfully propose at least two Clusters of Excellence, or, as consortia, at least three. They will also be subject to evaluation, with funding being continued in the event of a positive result. Subject to a successful outcome in the competitive process, four new funding cases will be added in the second round of applications, with funding due to begin in 2026.

www.dfg.de/excellence_strategy

Moving Moments at Yad Vashem

DFG delegation presents first two volumes of large-scale English version of Holocaust edition

Illustrations: DFG/Bienert

It was an impressive demonstration of international research cooperation – and a moving moment at a highly symbolic site. At the beginning of June, at the Yad Vashem memorial near Jerusalem, a DFG delegation formally handed over the first two volumes of the largest collection of Holocaust documents so far produced in English to representatives of Israeli academia, politics and society (the picture above shows DFG Vice President Julika Griem and Yad Vashem director Avner Shalev).

The launch of the English-language version marks a new phase of the edition, the German version of which has been funded by the DFG as a long-term project since 2004, and of which 12 out of 16 planned volumes have so far been published. The presentation was embedded in an academic symposium, after which the DFG delegation was given a guided tour of the Holocaust memorial (pictured to the left). **fine**

Eugen and Ilse Seibold Prize …

… goes to Kōichirō Agata and Harald Baum

Two committed and successful cultural mediators between Germany and Japan, political and administrative scientist Prof. Dr. Kōichirō Agata from Tokyo and legal scholar Prof. Dr. Harald Baum from Hamburg, have been selected to receive the Eugen and Ilse Seibold Prize by the DFG. In addition to being renowned as outstanding researchers in their respective countries and subject areas, both are also highly regarded in each other's country and have made a significant contribution to German-Japanese understanding through their considerable personal dedication, especially in the area of student exchanges. The prize, worth €10,000, is awarded biennially.

Illustration: U Bonn/Lannert

Illustration: www.mpipriv.de

www.dfg.de/en/service/press/press_releases/2019/press_release_no_18

Bernd Rendel Prize 2019 …

… goes to Dini Adyasari and Michael Grund

Dini Adyasari, a doctoral researcher at the Leibniz Centre for Tropical Marine Research in Bremen, and Michael Grund, a doctoral researcher in geophysics at the Karlsruhe Institute of Technology, are to be awarded the Bernd Rendel Prize for promising and original research in the earth sciences at an early stage of their careers. They will each receive €2,000 from the Bernd Rendel Foundation, administered by Stifterverband. The prize money is to be used for scientific purposes, for example to enable recipients to participate in international conferences and meetings. The award will be presented during the annual meeting of the German Geological Society in Münster at the end of September.

www.dfg.de/en/service/press/press_releases/2019/press_release_no_20

Remembering Wolfgang Frühwald

DFG and Humboldt Foundation pay tribute to former president in Bonn

The gift of genuine openness towards others – this was a quality mentioned many times when the DFG and the Alexander von Humboldt Foundation (AvH) came together at the end of June at the Godesburg in Bonn to remember their former president Wolfgang Frühwald, who died in January at the age of 83.

More than 120 friends and colleagues attended a special event hosted by the two organisations, which Frühwald led between 1992 and 2007.

In their addresses, the current presidents of the AvH and the DFG, Hans-Christian Pape and Peter Strohschneider, recalled their personal encounters with Wolfgang Frühwald: one as a newly appointed Humboldt professor, the other as a first-year student of German literature in his second week at university. With regard to his presidency, Pape emphasised Frühwald's "philosophy of solidarity", which made him an ambassador for German research and for Germany all over the world. Strohschneider recalled the former president's "high ethical standards and rigorous appeals for the accountability of research", both of which, he noted, could still serve as useful standards today.

Germanist Ernst Osterkamp sketched Frühwald's scholarly work and influences, which ranged from Clemens von Brentano to Ernst Toller and Johann Wolfgang von Goethe, after which former federal research minister Annette Schavan (on right in picture below with Frühwald's widow Viktoria) paid tribute in very personal words to Frühwald as a man who, in his modesty, always remained loyal and whose influence on his offices and on the public was greater than the other way round. **fine**

Illustrations: DFG/Unkel

Vera Schlindwein

Destination: The Ultraslow Gakkel Ridge

Plate tectonics, volcanic activity and ocean floor spreading in the Arctic: Following several complex research expeditions and earthquake measurements, the Emmy Noether group MOVE has obtained some surprising findings about the formation and structure of the ocean lithosphere. A look at the results so far

The research vessel has to brave stormy seas, for example here in the "Furious Fifties" near the Southwest Indian Ridge.

Illustration: AWI/Florian Schmid

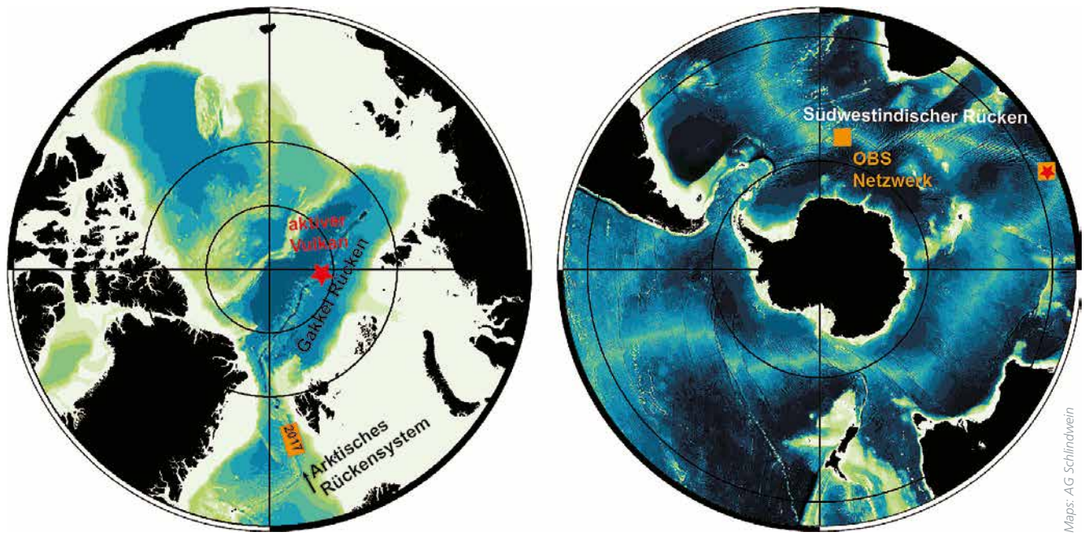
In the icy grip of the long winter, the Arctic slows everything down. Progress is difficult and inevitably slow. Like earlier generations of polar researchers, the scientists of today need patience and endurance. Even deep under the Arctic sea ice, things move slowly – in fact, they're "ultraslow". While the world's oceans grow by more than 20 millimetres a year at the seams of the mid-ocean ridges, along the Arctic ridge system and its cousin, the Southwest Indian Ridge (SWIR) midway between Africa and the Antarctic, new ocean floor forms at a rate of less than 15 millimetres a year.

For a long time, ultraslow mid-ocean ridges were largely ignored in plate tectonics research. On top of that, the Arctic ridge system is difficult to access because it is covered by sea ice, while the sea in the "Furious Fifties" around the SWIR is too rough for ambitious research projects. Scientists also believed that conclusions could be drawn about ultraslow ridges based on the much better studied processes of ocean floor formation at slow ridges. But in 1999, a powerful earthquake swarm in the Arctic Ocean forced geophysicists to sit up and take notice. The quakes continued for nine months, sometimes registering at magnitude 5, near a large volcano on the Gakkel Ridge.

Normally, the numerous volcanic eruptions that occur at mid-ocean ridges go completely unnoticed: around volcanic ridges the young ocean lithosphere is too warm for major earthquakes, which can be registered on land over 1,000 kilometres away. Volcanic eruptions were also considered to be rare at ultraslow ridges. When the lithospheric plates move apart at mid-ocean ridges, the decrease in pressure causes the Earth's mantle to melt. Material from the mantle then wells up as magma and continuously fills the gap between the plates. This creates a crust around 6 to 8 kilometres thick across all the oceans. At ultraslow ridges this process is reduced to a sputter, and little magma is produced. But how does this eruption fit into our understanding of a region which is reckoned to have a spreading rate of just 9 to 10 millimetres per year?

In 2001, an interdisciplinary expedition set out on board the icebreakers USGC *Healy* and RV *Polarstern*, with the objective of systematically mapping the Gakkel Ridge, collecting rock samples from the seabed, measuring the thickness of the crust, searching for hot springs on the ocean floor – and measuring earthquakes in situ. The expedition was certainly groundbreaking, resulting in four articles published in *Nature*, but it also lent further support to the idea that ultraslow ridges are not simply slow versions of "slow ridges", but a category of their own. Their main characteristic seems to be that the

Maps of the ultraslow-spreading ridges in the Arctic (left) and the Southwest Indian Ocean (right).



Maps: AG Schlindwein

Illustration: AWI/Vera Schlindwein

Hard at work in the icy cold: Setting up a seismometer on an ice floe in the Arctic sea ice.

thickness of the Earth's crust varies considerably along the length of the ridge. While some sections of the ridge have a thin crust and many volcanic structures, others have little magma and the sea floor may be up to 5,000 metres deep, with mantle rock being found on the ocean floor itself. These amagmatic areas, which are often as much as 100 kilometres long and without notable volcanism, are punctuated by gigantic volcanic centres with a thick crust. This was the kind of volcano that appeared to have erupted in 1999, causing a series of earthquakes.

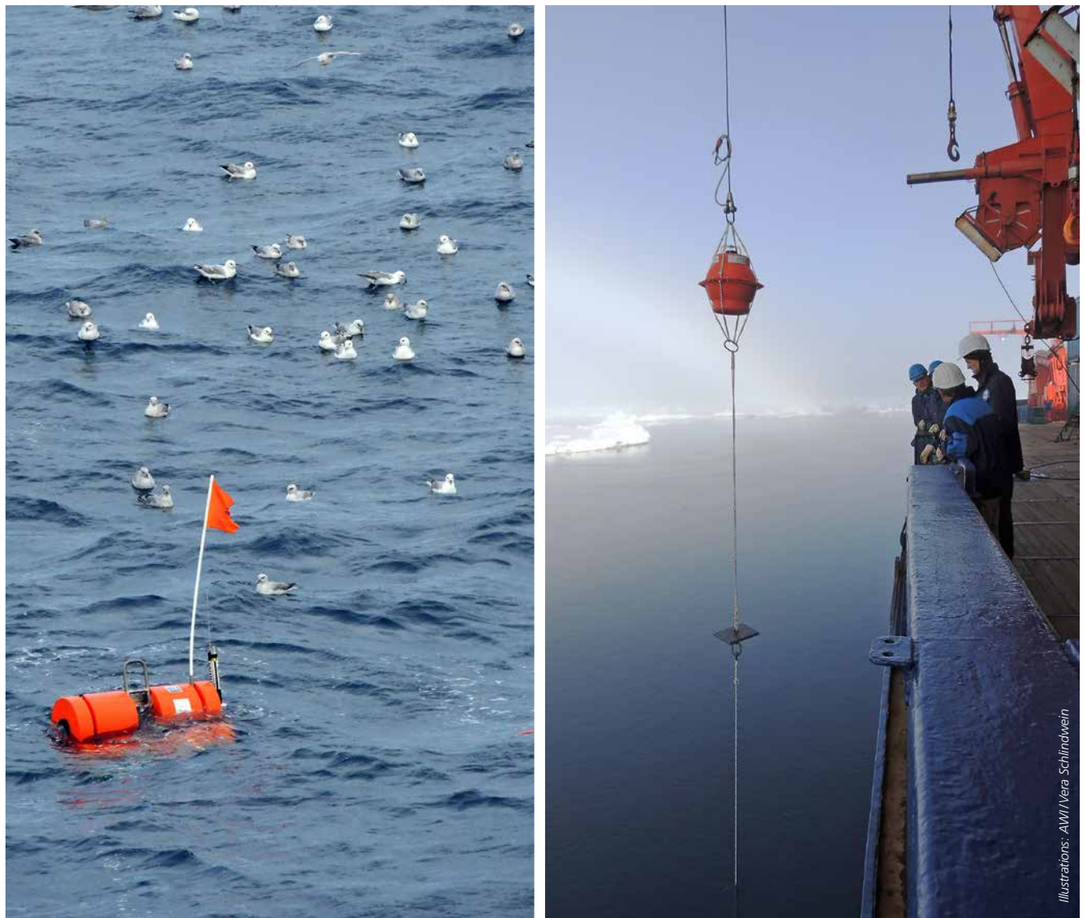
It was in early 2003 that the researcher who would later become the project leader had her first experience of ultraslow ridges. No one was quite certain what to do with the seismological data recorded during the cruise. The measuring technique used, of placing seismometers on drifting ice floes to record earthquakes, seemed too unusual. But she had previously worked with unusual seismological data and was fascinated. The technique worked, and a number of minor earthquakes were detected between the cracking of the ice floes. This indicated that small gas explosions were occurring near the volcano under the enormous pressure of the four-kilometre water column. This surprising discovery was all the motivation the researchers needed to take a closer look at the seismic activity of this ultraslow ridge.

The idea for the Emmy Noether project was born. The aim was to systematically investigate the seismicity of ultraslow ridges, comparing magmatic and amagmatic ridge sections. The team would also look at different scales, from the smallest earthquakes that give clues about local spreading processes, to major earthquakes that supply large-scale information about ocean floor formation along an entire ridge. The independent junior research group "Mid-Ocean Volcanoes and Earthquakes (MOVE)" started work in September 2006. For family reasons, the project was

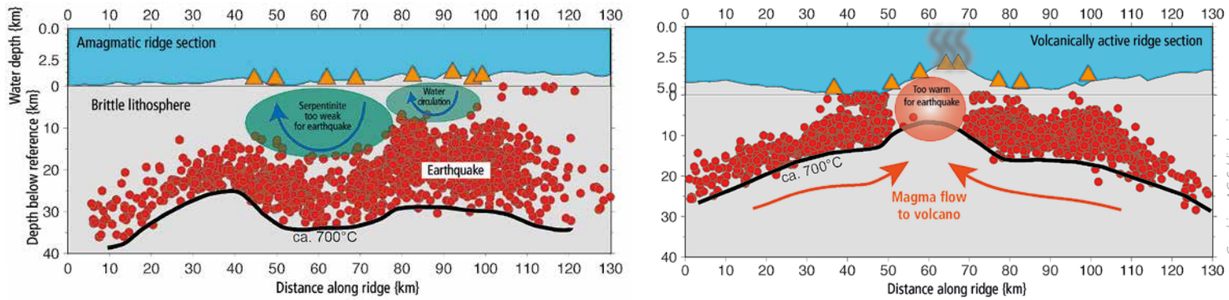
designed from the outset to take eight years on a part-time basis. This also had the advantage that the necessary amount of patience and persistence could be applied to the laborious process of acquiring the seismological data; in hindsight, this would not have been possible on a time scale of just five years.

Because the data for major earthquakes is publicly available in catalogues, the team was able to start analysing it. To use seismometers in situ to record micro-earthquakes, which provide information about active spreading processes and the structure and temperature of the lithosphere, the researchers needed ship time on board RV *Polarstern*. Starting with "piggyback" experiments on RV *Polarstern* and IB *Oden*, seismological data was gathered from instruments set up on drifting ice floes. It was essential to take traditional measurements using ocean bottom seismometers (OBS), but it was impossible to do this in the ice-covered Arctic Ocean since the OBS resurface with their precious data somewhere in a radius of one kilometre around the deployment position – often beneath an ice floe. So to use this technique, the team had to travel to geologically similar areas of the SWIR. Since a research vessel, which is expensive to operate, cannot wait around idly for fair weather to recover an OBS, in 2013 an interdisciplinary team of 35 researchers set off on board RV *Polarstern* to spend a month working together in these stormy seas. At the same time, scientists on two other cruises were able to gather data on volcanic activity at more temperate latitudes of the SWIR.

Left: Gulls are always curious about ocean bottom seismometers, which makes it easier to locate them. Right: Scientists perform a test run with a sea ice seismometer.



Illustrations: AWI/Vera Schlindwein



Graphics: AG Schlindwein

Pictures that tell a story: Painstakingly acquired earthquake data from the Southwest Indian Ridge provides information about spreading processes.

Seven years after MOVE got underway, the result was a comprehensive set of seismic data collected with enormous effort (no less than seven cruises). The data confirmed the conjecture that seismic activity at ultraslow ridges provides surprising insights into the formation and structure of the young ocean lithosphere.

After locating more than 5,000 earthquakes, the team discovered the deepest earthquakes of all at mid-ocean ridges, at a depth of 35 kilometres. This demonstrated that in amagmatic regions, the young ocean lithosphere is much colder than previously thought. Beneath the volcanoes the lithosphere thins considerably, allowing magma to flow along its base from cold amagmatic areas to the volcanoes. Petrologists (scientists who study rocks) had proposed such a topography to explain the uneven distribution of magma along ultraslow ridges. These results provided the first geophysical evidence for this hypothesis.

Especially exciting was another realisation: that in areas where mantle rock can be found on the sea floor, no earthquakes were detected up to a depth of 15 kilometres. When rock from the Earth's mantle comes into contact with water, it forms a very soft rock known as serpentinite which does not fracture during an earthquake but behaves more like soft soap. This means that water can penetrate to previously unsuspected depths of 15 kilometres and that an exchange of material may be taking place between the lithosphere and the ocean in much larger dimensions than previously thought. The researchers were also able to study a volcano on the SWIR which had repeatedly triggered major earthquakes over a period of ten years. Sure enough, beneath it they found a magma chamber. The OBS provided live coverage of a "magma intrusion" and its seismic tremor – a rare instance of an in-situ measurement of subsea volcanism.

Although the independent junior research group MOVE made slow progress, it produced an enormous amount of knowledge and generated a host of new questions. Because polar research proceeds at a slow pace, a follow-up project is already underway. Since 2017, the team has had access to seismological recordings from 27 OBS spread over 160 kilometres of ridge south of Spitzbergen. This is the most comprehensive set of micro-earthquake data yet obtained for mid-ocean ridges.

The prototype of an OBS suitable for deployment on sea ice is also due to start trials, to help a major interdisciplinary expedition investigate the exchange of material between lithosphere and ocean at the hydrothermal source AURORA on the ice-covered Gakkel Ridge – but for that, we'll have to wait until 2022.

Geophysicist
PD Dr. rer. nat. Vera Schlindwein
was the leader of the Emmy Noether independent junior research group "Mid-Ocean Volcanoes and Earthquakes (MOVE)" at the Alfred Wegener Institute in Bremerhaven.

Contact: Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung, Am Handelshafen 12, 27570 Bremerhaven, Germany

www.awi.de/nc/en/about-us/organisation/staff/vera-schlindwein.html

Rembert Unterstell

Learning, Remembering and Forgetting

Neurobiologist Martin Korte studies the basic cellular mechanisms involved in memory processes, combining ambitious research with varied science communication. An interview at the Zoological Institute at TU Braunschweig

His office door at Braunschweig's Biocentre is wide open. He quickly moves some notes from his previous meeting from the conference table to his desk, beside which sits his cycling helmet, and then Martin Korte is ready. He has the athletic look of someone who enjoys sport – blue T-shirt, running jacket and outdoor shoes. When he talks, it's fast – very fast – and with focus. When the visitor poses a longer question, he inclines his head slightly to one side and closes his eyes to deliver a well-worded answer: precise and on target.

As a neurobiologist, Professor Martin Korte (55), director of the Zoological Institute at TU Braunschweig, studies the molecular processes in the brain that form the basis of learning, recall and loss of recall. In other words the cellular mechanisms and biochemical processes that make learning and memory possible. In addition to highly focused research into the brain and cognition, he is interested in the "learning processes that shape us as humans" – and making these accessible to a wide range of audiences outside the lab. Korte has built an international reputation as a learning researcher.

"I saw myself as a teacher from an early stage," says Korte, who had a curiosity about the big questions of nature from a young age. Today, he combines research and teaching in neurobiology with a range of activities in science communication, including policy advice. "I'm a driven person," he says, adding with a twinkle, "I cycle 20 kilometres a day to the institute on my race bike – but I can't do it slowly."

Korte began his biology studies in 1985 in Münster and Tübingen. For his diploma dissertation, the Studienstiftung scholar worked in the lab of the renowned National Institutes of Health (NIH) in Bethesda, Maryland. With this experience under his belt, he began his doctoral research at the MPI for Brain Research in Frankfurt directed by Wolf Singer, which he completed at the MPI of Neurobiology in Martinsried, under the supervision of Tobias Bonhoeffer. In his dissertation ("Retrograde Signal Systems in Long-term Potentiation on Synapses", 1995) he was the first to demonstrate that nerve growth factors play an important role in learning processes at the level of synapses. After working as a postdoctoral researcher, he completed his habilitation in 2001 at LMU Munich and was appointed professor at TU Braunschweig in 2004.

Neural networks: Sensory stimuli and highly complex information processing trigger continuous changes in the brain.

Graphic: Shutterstock

Illustration: Unterstell

Agile and creative at his standing desk: Brain researcher Martin Korte in his office.

A former recipient of a DFG Heisenberg fellowship, he is interested in the functioning of the healthy and diseased brain, which he mostly studies using mouse models. Most recently, in a DFG project he investigated neural malfunctions in connection with fragile X syndrome, which he describes as "the most common neurological developmental disorder in children, associated with autistic symptoms". During his research he discovered a new cause for the disease: insufficient maturing of certain synapses which are evidently unavailable for learning processes in later life. Could this lead to new treatments in the long term?

In 2000, lateral and forward thinker Korte was appointed as a founding member of Die Junge Akademie, an academy for young scholars from German-speaking countries. Today, he is a member of the board of the Berlin-Brandenburg Academy of Sciences and Humanities and spokesperson for the Gene Technology Report working group. Here and in public, he calls for "an approach to gene technologies that harnesses opportunities while taking account of the risks". It's soberly formulated, but the urgency of the issue is clearly perceptible.

His policy work is linked to science communication efforts. As well as being a sought-after interviewee for newspapers, radio and TV, he writes his own column (*Hirn auf!* Brain Up) in the daily regional paper *Braunschweiger Zeitung* and has produced videos and podcasts for a lay audience. His three books, which came out first in hardback and then in paperback, are also doing extremely well: *Jung im Kopf* (Young in Mind), *Wie Kinder heute lernen* (How Children Learn Today) and *Wir sind Gedächtnis* (We Are Memory). "But my favourite thing is talking to audiences," he says. "That direct dialogue is simply inspiring."

Every year he gives between 60 and 70 talks to school children, parents, students, teachers and judges. With two colleagues in Braunschweig, he developed a modular teaching concept for students teaching in schools, which was awarded the Ars Legendi Prize in the biology category in 2015.

Learning, remembering and forgetting – Korte expects that future research at the cellular level will be shaped not only by neuron-neuron interactions, but also by "other molecular players", such as glial cells, which are often dismissed as simply supports or what cements the nerves together. He also believes that data-supported network modelling and simulation will acquire a whole new importance. "This would be hugely beneficial to our understanding of learning and memory processes," says Korte, "because when it comes to predicting the functioning of complex networks, neuroscientists are really just at the beginning."

Dr. Rembert Unterstell
is Publishing Executive Editor of *german research*.

Michaela Fenske

The Urban Beekeeper

Beekeeping is growing in popularity in urban areas with more and more city dwellers in Europe and North America keeping bees in their spare time. In Berlin, for example, we can observe new ways of thinking and behaving that straddle ecological concerns, human-animal interaction and a new perception of the self and the environment.

Since the spring, and in the sunshine, the bees have been flying. Honey bees have always been of great interest to mankind: ever since ancient times, people have vividly expressed their admiration for both honey bees and their wild cousins. In poetry and philosophical works, bees are celebrated for their hard work, cleanliness and amazing degree of social organisation. In more recent times, scientists in various disciplines have discovered that bees possess other qualities: they are vitally important to ecosystems, they pollinate plants and trees, and are therefore essential to the production of food for humans.

However, the reason why honey bees are currently a subject of such interest to politicians, scientists and the general public is something quite different: since the turn of the millennium, honey bees have been dying in huge numbers all over the world. There has been alarmist media coverage of the issue, with the decline in bee populations being seen as representative or symbolic of the crisis phenomena of the 21st century: accelerated species loss, climate change, threats to food security for a growing world population, and the problems associated with industrialised agriculture.

Left: Beekeepers working with a swarm against the background of an urban backyard. Right: The level of interest and demand for information are tremendous – an open-air course for hobby beekeepers at the Prinzessinnengärten, an urban gardening project in Berlin's Kreuzberg neighbourhood.

Illustrations: Fenske

In response, more and more people are turning to beekeeping in the global North. In Germany alone the number of beekeepers has risen by 30 percent, mostly in cities. In New York, Paris, London, Amsterdam, Copenhagen and Berlin, middle-class citizens – and increasingly their political representatives – are taking a stand for honey bees. Whenever politicians or beekeepers express a view on the decline in bee numbers, they can be sure of gaining media attention.

A research project at the Institute of European Ethnology at the Humboldt University of Berlin investigated urban beekeeping using the example of the German capital. The study illuminates critical, as well as positive, aspects of beekeeping. The new urban dweller's hobby has attracted criticism from many quarters, the main message being that urban beekeeping will not change any of the basic problems of our times. There are accusations of taking symbolic action while biodiversity continues to decline and failing to implement the urgently needed structural change in our economies and societies. Some people see beekeeping as a craze that ultimately does more harm than good. Not all new beekeepers take a responsible attitude to caring for their bees, they say, and the density of bees in European cities is no longer ecologically advisable.

However, a closer look at the motivations and practices of beekeepers also reveals that beekeeping offers unique potential. With the bee serving as a key species, linking culture and nature like few other species can, those with an interest in bees are in a position to re-establish some of the relationships between humans and the world they live in that have been disturbed by the modern age's emphasis on growth. Following Sociologist Hartmut Rosa one may perceive beekeeping as a practise enabling people to rediscover their connections with the world and experience a resonance with it.

Beekeeping creates a variety of new connections between beekeepers and their social and ecological environment. This special potential becomes clear in the context of "multispecies ethnography", a branch of ethnological research concerned with interaction of humans and non-human organisms. A closer look at the interactions between humans and bees shows how people learn to view themselves as part of the web of life. This begins with a change in perception of the environment which comes about through the keeping of bees.

The bees' cycle gives urban dwellers an awareness of the changes in the seasons and the weather. What's the weather like today and what is the forecast for the next few days? Might it be too dry during the main growing season, such that the flowers will not produce nectar? Is it cold enough in the winter to make the bees stop their brood care? What impact is global climate change having on my environment? Anthropologist Sara Schroer has described this phenomenon, which she observed in falconry, as "weathering". Beekeeping also focuses attention on the constantly changing urban landscape, the growth or non-flourishing of the vegetation on which the bees depend.

In conversation, nearly all beekeepers in Berlin point to the large number of flowering trees in the city, normally in conjunction with two comments: praise for the foresight and horticultural knowledge of the earlier city planners who planted the trees, and annoyance with some urban planners of today. In some areas lime trees are now rarely planted in order to avoid the sticky deposits on windscreens that annoy the owners of parked cars so much. The basic insights of beekeepers also include what grows where and, above all, how little is blossoming and flourishing in some parts of their city. As a result, they are actively advocating the greening of their neighbourhoods, or better still the planting of flowering plants. Finally, bees give people a different perspective on the space they inhabit – changes in perception that also extend to an individual's own body. Beekeeping is experienced with the body and all the senses. In visually oriented western society, senses other than sight are suddenly called into play: smell, touch and hearing acquire new importance. For example, one beekeeper explains how much he likes the smell of the beehives: "Yeah, I just love it, walking past the hives and smelling that bee smell. That's (…) the unique thing about bees: you get a bit of honey, a bit of flowery scent, a bit of everything. It's absolutely amazing." Another one speaks enthusiastically about the "wonderful smell, (…) that gorgeous smell from the hives. It's an odour I've never smelled before, and it's something I find absolutely amazing about beehives (…)". In conversation and in interviews, sounds – such as the humming and buzzing of the bees – are also mentioned as important sensory impressions.

Observing and listening to beekeepers, you also notice that in interacting with the animals they engage intellectually, cognitively and emotionally. They become acquainted with a broader spectrum of perception of their environment and find that they require diverse forms of knowledge from bodily to theoretical knowledge. The concept developed by the philosopher Henri Bergson of intuition as a specific "access from within", helps us to better understand this complex process of relating between beekeepers and bees. If we adopt Bergson's perspective, then in modern western societies intuition has been suppressed in favour of the sharpening of intelligence and intellect.

Above: A rooftop beekeeping site in Berlin against a night-time backdrop. Right: Demonstrators, including beekeepers, protest against industrial agriculture under the slogan "We've had enough".

Illustrations: Fenske

Illustration: Fenske

A hive of activity and loud humming: life on a honeycomb.

Urban beekeeping opens up new possibilities for the development of intuition. A man who has been a successful beekeeper for several years explains: "There's something about beekeeping that appeals to me a lot. It's a kind of whole-body experience. (…) I'm not just sitting at a desk, I'm outside. I'm carrying parts around, I need to use a balance of strength and fine motor skills, because you're carrying heavy things but also delicate frames and you need to be careful that you haven't got a bee between your fingers. You need to look, you can hear, smell, you need to ask yourself, what am I actually perceiving here, now what will I do with it? It's a combination of intuition and knowledge, that I somehow need to combine with the power of observation, and I still find this whole combination simply fascinating (…)."

Learning to live with bees can be a painful experience. This can be literally true when alarmed bees attack a beekeeper. Yet by contrast, beekeepers, especially less experienced ones, report having nightmares at the idea that a mistake on their part could cause serious harm to the bees. To avoid both, beekeepers talk about how they learn not only techniques and practices but also attitudes and perspectives. Some, for example, learn a calmer way of moving to avoid disturbing the animals. Others learn to hope that the feared winter losses will be low. And others talk about gaining an insight into their own limitations, which are revealed when the bees unexpectedly swarm (leave the hive), or die.

Ethical questions play a crucial role in the care of bees. At beekeeping events, people discuss whether bees have the right to die, for example if a colony cannot make it through the winter on its own. To what extent should beekeepers intervene in such situations? How much honey can be harvested without harming the wellbeing of the animals in the hive? People in cities are learning through bees that everything on planet Earth is connected. Living with bees enables people to not only acknowledge the death of the bees but also recognise their own vulnerability. The fact that new beekeepers tend to move solely within their own social milieu and that the new processes of learning and seeking are currently taking place mostly among the middle class remains a challenge.

Research is illuminating the potential of urban beekeeping from the perspective of European ethnology, a field concerned primarily with the day-to-day practices of human life. Enhanced by the perspectives of multispecies ethnography, it becomes clear that human practices are both integral and effective in the web of life, and in what way. This opens up new options for action – not only for beekeepers, be they professional or amateur, but also for all those seeking solutions to the today's ecological crisis phenomena.

Prof. Dr. Michaela Fenske
has held, since the winter semester 2017/18, the Chair of European Ethnology at the Julius Maximilian University of Würzburg.
Contact: Lehrstuhl für Europäische Ethnologie/Volkskunde, Am Hubland, 97074 Würzburg, Germany
www.euroethno.hu-berlin.de/de/institut/personen/fenske
gepris.dfg.de/gepris/projekt/253668468?language=en

J. Schmidt, M. Wendisch, J. Curtius, M. Scheinert and B.-M. Sinnhuber

Above the Clouds

Taking to the skies to study the atmosphere, climate and planet: Funded by a consortium of major German research institutes, HALO has quickly become the most advanced research aircraft in Europe. With an array of modern and variable equipment, it can be used for demanding measurement campaigns from aerosol particles to air pollutants and clouds.

HALO (High Altitude and Long Range Research Aircraft) has been flying in the service of atmospheric, climate and geoscience research since 2010. Resembling a unicorn horn, the red and white nose mast measures variables such as wind speed and air pressure. The research aircraft is packed full of instrumentation.

Illustration: DLR/FX

The idea of using aircraft for scientific research is nearly as old as aviation itself. In 1784, a year after the first manned balloon ascent in the famous Montgolfière, the American physician and aviation pioneer John Jeffries fitted a balloon with measuring instruments such as a thermometer, barometer, electrometer and hygrometer. On his flights, Jeffries ascended to impressive altitudes of up to 2,800 metres. He was subsequently outdone, for example by physicist Victor Franz Hess (1883–1964), who made balloon ascents as high as 5,300 metres. His measuring equipment enabled him to discover cosmic radiation, for which he was awarded the Nobel Prize in 1936.

Today, scientists have access not only to a much wider range of measuring instruments but also to a larger fleet of specially equipped research aircraft. Depending on the research task and the questions they want to answer, scientists may use balloons, airships, helicopters, drones, and of course aeroplanes. The most state-of-the-art platform currently available in Germany is the High Altitude and Long Range Research Aircraft (HALO). With a payload of three tonnes, a range of up to 10,000 kilometres and a maximum altitude of 15 kilometres, HALO is exceptionally well suited to demanding atmospheric and geophysical research.

It would be no exaggeration to say that HALO has evolved into what is currently the most cutting-edge, high-performance research aircraft in Europe. Originally a business jet of the Gulfstream G 550 type, HALO required extensive technical adaptations to make it suitable for scientific use. In 2006, HALO touched down for the first time at its home base at Oberpfaffenhofen airport near Munich. The aircraft then underwent a conversion phase lasting nearly two years. Technicians added several attachment points for external instrument pods to the fuselage and wings, which made it necessary to reinforce the aircraft's mechanical structure. More than 20 openings were made in the fuselage – a unique challenge, because HALO's cabin needs to remain pressure-tight against the surrounding air. There was also plenty of paperwork to be done before the aircraft, along with its modifications, could be approved by Germany's national aviation authority. In 2010, HALO was finally ready for its first test measurement campaign. Several flights were carried out over Germany to put HALO and various scientific instruments through their paces. Having successfully passed these tests, aircraft and equipment could go into regular scientific operation. HALO has now been in regular use since 2012.

Since then the aircraft has completed 15 scientific measurement campaigns, providing valuable data for atmospheric, climate and geoscience research. HALO has flown over the Amazon basin, the northern and tropical Atlantic and the Arabian peninsula, not to mention south-east Asia, northern, central and southern Europe and the Arctic. HALO conducted its first measurements during the Geophysical Investigation of the Mediterranean using HALO (GEOHALO) campaign. On four research flights that took off from Oberpfaffenhofen, researchers measured variations in the Earth's gravitational and magnetic fields over Italy and the adjacent Mediterranean. This region has a higher earthquake risk, which creates an additional incentive for geoscience research. Further campaigns with HALO followed. An essential aspect of the Polar Stratosphere in a Changing Climate (POLSTRACC) campaign, carried out with HALO in 2015/16, was the investigation of the altitude range between 10 and 15 kilometres above the Arctic. The presence and distribution of short-lived greenhouse gases such as ozone and water vapour in this area are especially relevant to the Earth's atmospheric radiation budget and thus the global climate. The POLSTRACC flights produced a very surprising insight: even at these altitudes above the Arctic, there is significant ozone depletion caused by anthropogenic chlorine compounds, with up to 50 percent of Arctic ozone being depleted over the course of the winter. Although Arctic ozone depletion had been observed above 15 kilometres in previous winters, scientists were startled by the extent of the depletion at these altitudes, which are crucial to the global climate. Current climate models do not take full account of these influencing factors. The detailed measurements collected by HALO during the POLSTRACC campaign will help researchers to understand and describe the underlying processes more accurately in their models.

HALO can deploy a wide range of different measuring instruments. For example, it can use remote sensing devices to study the properties and effects of clouds, aerosol particles and trace gases

Over the course of two years, HALO, originally a Gulfstream G 550 business jet, was converted and equipped for measurement campaigns. This included making various openings in the roof (centre top).

Illustration: Sinnhuber

Illustrations: DLR-FX

Illustration: DLR-FX

PMS (Particle Measurement System) probes can be mounted below HALO's wings. These systems allow high-precision in-situ measurements of aerosol particles, cloud droplets and ice crystals.

from a distance of a few metres to many kilometres away. For the two Next Generation Remote Sensing for Validation Studies (NARVAL) campaigns over the Caribbean in 2013/14 and 2016, researchers used a combination of laser measuring devices, radar systems and other instruments. With this extensive equipment it was possible to validate measurements taken by satellites that use comparable but simpler instrumentation. Other measurement campaigns frequently use in-situ instruments, which either directly sample particles in ambient air or collect small amounts of the ambient air to measure cloud droplets, ice crystals, aerosol particles and trace gases with high precision.

In the summer of 2017, HALO was used for the Effect of Megacities on the Transport and Transformation of Pollutants on the Regional and Global Scale (EMeRGe) campaign. This involved analysing emissions of air pollutants from major European population centres such as London, the Benelux region and the Ruhr area. To detect the relevant air masses, HALO spent part of the time flying at just 500 metres above the ground – highly unusual for a high-altitude research aircraft, but once again HALO proved its capabilities. Because the emissions from major urban areas contain a whole cocktail of chemical substances, a wide range of measuring instruments were necessary to accurately record the mix.

As well as documenting air pollutants and how they are transported, EMeRGe investigated some of the chemical conversion processes of these emissions. Solar radiation causes chemical reactions between air pollutants, creating new compounds whose effects on human health and the global climate differ significantly from those of the originally emitted substances. To understand these conversion processes, it is necessary to record effects not just locally but regionally and globally. This is where HALO's long range comes in very useful.

These examples of HALO campaigns and their aims demonstrate that the potential of this airborne platform can only be fully exploited through cooperation between research institutions. One individual institute could not completely equip HALO with instrumentation or make use of all the various flight scenarios that HALO makes possible.

The DFG's contribution to the scientific use of HALO is organised in coordination with Priority Programme (PP) 1294 "Atmospheric and Earth System Research with HALO" (see box for more information). This Priority Programme is an important component of the cooperation in German atmospheric, climate, and geoscience research, which has been intensified in recent years, providing novel forms of support for coordinated activities.

The impressive successes of the HALO campaigns – with over 200 peer-reviewed articles having appeared in scientific journals to date – is sustaining a lively interest in further research deployments. The aircraft is already fully booked with scientific measurement campaigns through to mid-2022. Among other missions, it will be studying cirrus clouds in northern Europe and the Arctic which impact on the climate, as part of the Cirrus in High Latitudes (CIRRUS-HL) campaign. The Carbon Dioxide and Methane Mission for HALO (COMET) campaign will take more precise measurements of emissions of the greenhouse gases carbon dioxide and methane. And in the HALO-(AC)3 project, which is associated with CRC/TRR 172 "Arctic Amplification: Climate Relevant Atmospheric and Surface Processes and Feedback Mechanisms (AC)3" scientists will be investigating the drastic climate changes in the Arctic. HALO's activities have gained attention and recognition in a variety of disciplines and areas of research and the aircraft has become an indispensable platform for atmospheric science, climate science and geosciences.

Dr. Jörg Schmidt
is the user coordinator for the HALO consortium and is based at the University of Leipzig.

Prof. Dr. Manfred Wendisch
is the Director of the Institute for Meteorology at the University of Leipzig and coordinates PP 1294.

Prof. Dr. Joachim Curtius
is Professor of Experimental Atmospheric Research at the Institute for Atmospheric and Environmental Sciences, Goethe University Frankfurt, and coordinates PP 1294.

Dr. Mirko Scheinert
is a research assistant at TU Dresden and coordinates PP 1294.

Dr. Björn-Martin Sinnhuber
is a research assistant at the Karlsruhe Institute of Technology.

Contact: Universität Leipzig, Institut für Meteorologie, Stephanstr. 3, 04103 Leipzig, Germany

www.halo-spp.de

The DFG and HALO

The High Altitude and Long Range Research Aircraft (HALO) is a research platform for atmospheric and Earth system research, operated by a consortium consisting of the DFG, the Max Planck Society, the German Aerospace Center, Forschungszentrum Jülich, the Karlsruhe Institute of Technology, the German Research Centre for Geosciences and the Leibniz Institute for Tropospheric Research. The DFG has been funding the Infrastructure Priority Programme "Atmospheric and Earth System Research with HALO" since 2007. This programme is being coordinated at the University of Leipzig, Goethe University Frankfurt and TU Dresden. PP 1294 is currently in its third three-year funding period (2016–2019).

HALO-supported research is intended to help answer questions in climate and environmental science at the intersection of Earth system processes and human activity as part of an interdisciplinary collaboration, through integrated and system-oriented approaches. It also enables scientists to develop high-technology sensors and new instruments and deploy them in atmospheric and geoscience research. **RU**

www.halo-spp.de

Ekkard Brinksmeier, Stefanie Reese and Jens Sölter

Illustration: Leibniz-IWT Bremen

The Right Signature for Every Process

The hardness, residual stress and other properties of a component's surface layers are crucial to its functionality and durability. To achieve specific improvements to the component's "skin", engineers need a more detailed understanding of the physical and chemical processes at work during manufacturing processes and how these can be exploited to modify the material properties.

The engineered products that we use on a daily basis, be it a toaster, a bicycle or a lawnmower, are designed to do their job as reliably as possible. This is what the consumer expects in all areas of life: he or she is critical and usually has a broad range of products to choose from.

For the manufacturer and the factory, the decisive factors are low costs, minimal weight and other factors such as energy consumption. However, the first consideration for any product or component is the material it is made of. For parts that are subject to high loads, such as gears, roller bearings or engine and turbine parts, this means special steels. In the aerospace industry, the preferred materials are lightweight metals such as aluminium and titanium alloys, and, increasingly, fibre-reinforced plastics.

Left: Grinding a component. This process can generate a lot of heat. Scientists and engineers are looking for ways to prevent thermal damage to the component.

No matter what manufacturing technique is used, the aim is to transform the material into a specified form with defined dimensions and surface roughness. In addition to these geometric properties, the manufacturing process is required to "adjust" the material properties of the product to optimise it for its future function and substantially improve them compared with the original condition – but without altering the composition of the material.

But how can manufacturing processes improve the material? One well-known example is heat treatment, used for example to harden steel. When the material is heated and then quickly cooled, the molecular lattice structure of the steel is stressed, giving the material its hardness and wear resistance. The same effect can also be achieved without heating, by utilising external forces that achieve a permanent "plastic" deformation of the material. This happens when we bend a wire into the desired shape, for example.

Plastic deformation of the surface layer or "skin" of the material is especially important. It creates permanent forces inside the material which are referred to as residual stress. Just as building muscle strengthens the spine, plastic deformation of the surface layer can generate greater internal strength as long as the resulting residual stress is mathematically negative and therefore compressive.

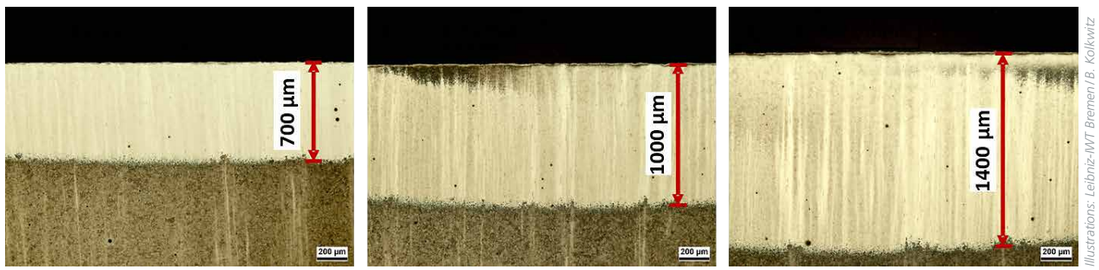
But to return to the original question, how can the surface layer of a material be strengthened during processing to give the finished component improved functional properties for its intended use? It is, indeed, possible to permanently enhance these properties during manufacturing. But achieving the exact desired effect requires an understanding of how a manufacturing process works in terms of the physical and chemical processes that it initiates inside the material. For the majority of industrial manufacturing processes, we do not currently have the required level of knowledge.

This was the starting point for the transregional Collaborative Research Centre "Process Signatures". The team of researchers has developed a new way of looking at manufacturing processes: depending on the production technique used, the mechanisms inside the material may be mechanically, thermally or chemically activated. For example, let's take the case of hardening steel again. The high temperatures reached during the heating phase and the dramatic temperature changes resulting from rapid cooling cause thermal stress, resulting in a modification of the material. This would be described as a process with a thermal effect.

Turning, milling, drilling and grinding, on the other hand, all involve material being removed as chips. Their effects are thermomechanical – in other words, the modification is achieved by a combination of thermal and mechanical internal material loads. In electrochemical machining, chemical effects are also involved. The ultimate aim is to apply the effects or internal material loads in a controlled manner. If this is achieved successfully, the material's resistance to wear and corrosion and the strength of a component can be significantly increased.

It may sound simple, but it's actually very complex. The fact is that it is very difficult to achieve

The effects of grinding: When the component skin is heated, this can harden the workpiece material near the ground surface (at the top of the image). The hardened areas, which appear white in the images, are made visible by special preparation of the component. As the heat input is increased (shown from left to right), the thickness of the hardened layer increases.



Illustrations: Leibniz-IWT Bremen/B. Kolkwitz

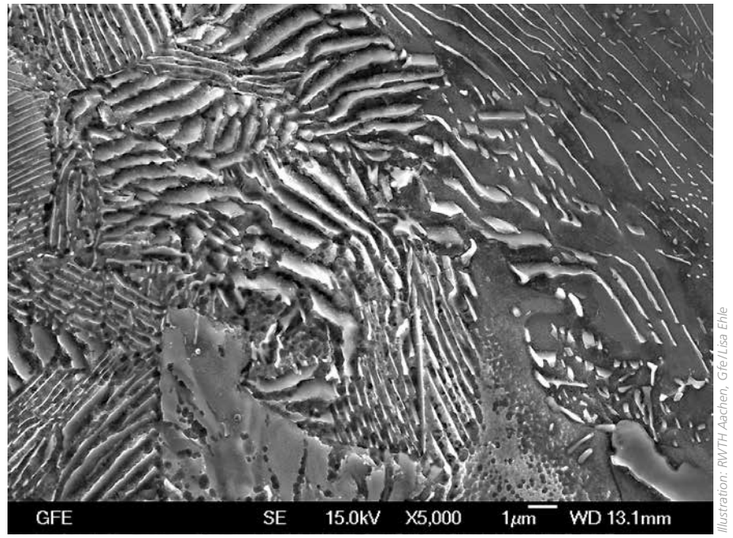


Illustration: RWTH Aachen, GFE/Lisa Ehle

the desired internal loads during the process. The mechanical and thermal effects that influence the condition of the material's surface layer depend on both the machine settings and the material being machined. It is the material properties, such as thermal conductivity, that influence the processes leading to a material modification.

In industry, the desired properties are usually achieved by "approaching" them incrementally, the machine settings being gradually adjusted until the required properties are obtained. The reason for this time-consuming method is that the various relationships involved, from the settings on a machine to the resulting material properties of the component, are not well documented or understood.

Until the transregional research group – involving researchers from the University of Bremen, RWTH Aachen University and Oklahoma State University (USA) – was established, there had been no systematic investigation of the relationship between the internal material loads during machining and the resulting material modifications – a relationship referred to as a "Process Signature". Through their work in the Collaborative Research Centre, the researchers are aiming to address this knowledge gap. For a representative range of manufacturing processes involving different types of internal material loads, Process Signatures are being developed. These signatures are the scientific key to achieving specific material properties in the surface zones of components during the production process.

Changes in the material can be detected relatively accurately using appropriate measurement techniques: residual stress, for example, can be measured using X-rays. However, to identify Process Signatures it is also necessary to understand the internal material loads that occur during the process. Determining these experimentally with established measuring techniques is much more difficult, and sometimes it is simply impossible to

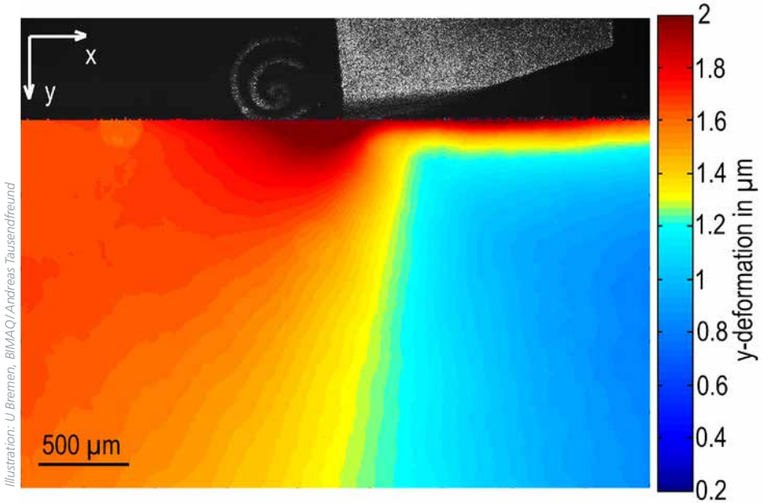
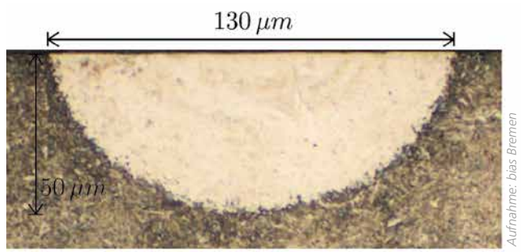
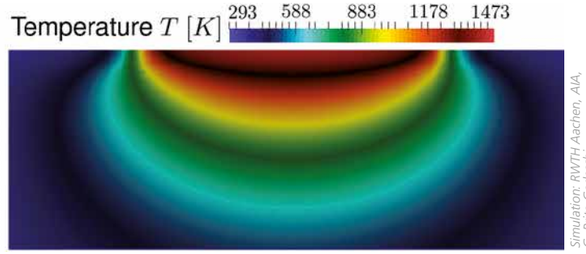


Illustration: U Bremen, BIMAQ/Andreas Tausendfreund

Above: Electrochemical machining (ECM) removes areas of material at the surface through chemical reactions, resulting in a fissured structure. Right: In milling, material is removed by cutting edges (just seen at the top of the image). The deformation of the material is recorded during the process using a new measurement technique called speckle photography. The degree of deformation is represented by the colour code.



Aufnahme: bias Bremen



Simulation: RWTH Aachen, AIA, G. Brito-Gadeschi

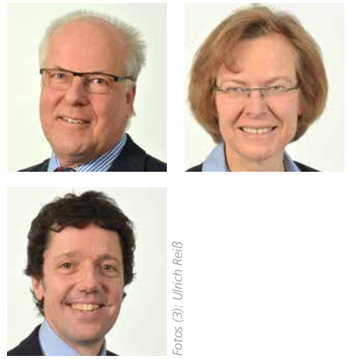
Material is removed from the surface layer of the component using laser pulses. High temperatures can modify the molecular lattice structure (white area in the left image). Right: Simulations are used to obtain information about temperature profiles inside the material.

measure the relevant variables with the required temporal and spatial resolution. So the CRC follows a two-pronged strategy, developing new, high-resolution in-process measurement techniques and at the same time designing new tools for computer-assisted simulations of manufacturing processes. The objective is to observe what happens inside the material during the process in a "virtual" manner, or by means of measurements.

High-precision measurement techniques provide crucial data, for example on the geometry and deformation of the molecular lattice structure of the material. But this alone is not enough to understand the physical and chemical processes taking place. It is important to understand the relationship between the mechanisms occurring on a small scale in the material and the larger-scale effects that result. The small scale is the microstructural level, what is happening inside the material. The large scale includes the manufacturing process which is intended to give the material the desired properties. Modern simulation techniques enable the researchers to link the two scales. For example, it is possible to represent and investigate on a computer how the process of grinding affects the molecular lattice structure of the material and what material properties are likely to result from a specific adjustment to the process. Clearly, a simulation tool such as this has the potential to significantly improve manufacturing processes.

As well as being used "offline" to support the optimisation of a manufacturing process, simulations could potentially also be used "online" to provide valuable data during a process. The second scenario, also referred to as "real-time simulation", is still in the future, but research is already being carried out in this area. The long-term goal is to be able to use in-process measurements and real-time simulations to design manufacturing processes that give the finished component the exact functional properties required.

The challenge of describing manufacturing processes in a new way using Process Signatures has been keeping the project team busy for four years. Since 2018, the researchers have been building on this work by developing and refining Process Signatures with the aim of improving the adjustment of material properties in the surface layers of components in industrial manufacturing. In the long term, this could contribute to the production of more resilient and more durable components. In addition to the economic benefits, Process Signatures also offer an opportunity to reduce resource consumption. This could contribute to more sustainable manufacturing long after the project is finished.



Fotos (3): Ulrich Reiß

Prof. Dr.-Ing. habil. Prof. h.c. Dr.-Ing. E.h. Ekkard Brinksmeier
is the deputy managing director of the Leibniz Institute for Materials Engineering IWT Bremen and the spokesperson for SFB/TRR 136.

Prof. Dr.-Ing. habil. Stefanie Reese
is the director of the Institute of Applied Mechanics at RWTH Aachen University and deputy spokesperson for SFB/TRR 136.

Dr.-Ing. Jens Sölter
is a research assistant in the department of Manufacturing Processes at the University of Bremen and the managing director of SFB/TRR 136.

Contact: SFB/TRR 136, Universität Bremen, Badgasteiner Str. 1, 28359 Bremen, Germany

www.prozesssignaturen.de/en

Kerstin Kaufmann

Beautiful Monstrosities

Double flowers are the result of a battle between genes that activate or inhibit the development of different kinds of structures and organs. Molecular biologists are particularly interested in mutants because they provide clues about the mechanisms of flower development and their evolutionary origin. This area of research reveals more about the highly complex "regulatory code" of flowers.

Johann Wolfgang von Goethe's "perfoliate rose". Watercolour commissioned for Metamorphosis of Plants, probably painted around 1790 by a pupil of the Weimar drawing school.

Illustration: from Goethe, Die Schriften zur Naturwissenschaft (LA), I,9 (Hrsg. D. Kuhn), 1954, Tafel XVI 2

From the Little Prince and his rose to the talking tiger lily that Alice meets in Wonderland, or Mr. Ribblestone's moon flower in the more recent children's book *Die Mondblume*, flowers inspire the human imagination. They are integral to human cultural history: even in Ancient Egypt, the love of flowers and ornamental gardens is reflected in poetry and religious rituals. But flowers are also the basis of sexual reproduction and fruit development in plants, making them crucial to food production and crop breeding.

In Ancient Greece, the works of Theophrastus (ca. 374/369–288/285 BC), a pupil of Aristotle, marked the beginning of scientific interest in the secrets of flowers and the sheer diversity of their forms. Theophrastus even described a "hundred-leaved rose", because in antiquity the love of plants prompted the propagation of special flowers, including "double-flowered" roses with extra petals.

In the 17th and 18th centuries, these unusual forms piqued the interest of botanists who were trying to bring order to this morphological diversity. In 1768, embryologist Caspar Friedrich Wolff postulated that leaves and all the organs of a flower – sepals, petals, stamens and carpels – have a shared developmental origin. The idea that leaves and floral organs were related was brought to greater attention by Johann Wolfgang von Goethe in his *Metamorphosis of Plants*, a work inspired by his journey through Italy (1786–1788). As a particular example of his theory, Goethe cited the "perfoliate rose", where a new flower grows out of a double one. In the 20th century, the "secret relationships" or "homologies" between different floral organs were also recognised as evidence of their common evolutionary origin.

While some mutant flowers are popular with gardeners, others are only of interest to researchers. Descriptions of mutated flowers or "monstrosities" became popular in the 19th century, but it wasn't until the advent of modern techniques in genetics and molecular biology that their secrets began to be unravelled. Once again researchers focused on double flowers, this time in the model plants thale cress *(Arabidopsis thaliana)* and the common snapdragon *(Antirrhinum majus)*.

In double flowers, the male and female reproductive organs (stamens and carpels) are replaced by petals and sepals. Similar, if less visually attractive, mutants exhibit changes in the stamens and carpels. In homeotic mutants, where certain types of floral organs are replaced by others, normally only a few developmental control genes are faulty. The "monsters" that in some cases have been delighting gardeners for thousands of years only have mutations in one or a few of the 30,000 or so genes in the plant genome.

The basic regulatory function of these special genes is relatively conserved between different plant species, although the appearance, number and size of the floral organs vary from one species to another. This means that when related homeotic genes are deactivated in different species, similar changes occur in the organ identities of the flower. Research using model plants has identified an important model for the specification of floral organs, known as the ABC model. In principle it can be applied to all flowering plants – whether grasses, poplars or sunflowers. Some evolutionary changes in the flower structure, for example the development of petal-like organs instead of sepals in tulips, can be explained by simple adjustments in the model. The ABC model became widely known thanks to an article in *Nature* in 1991 by Enrico Coen and Elliot Meyerowitz, two pioneers in plant developmental genetics. According to this model, three classes of regulatory genes interact on a combinatorial basis to form the four different types of organs in a flower. If one of these genes loses its function through mutation, the still intact gene classes take over the specification of the corresponding organs, which are then replaced by a different type of organ according to their function. For example, B and C function genes together specify stamens and C function genes alone control carpels. When B function genes mutate, then instead of stamens an extra ring of carpels can form in the flower, and sepals form instead of petals. This model can describe fundamental mechanisms of flower development, but can it substantiate Goethe's theory according to which all types of floral organs are equivalent to a leaf?

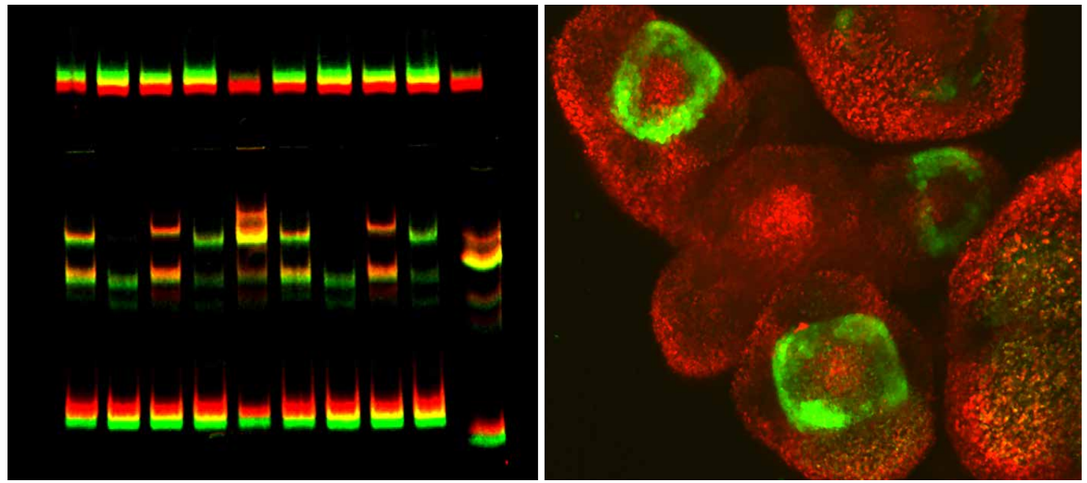
If several homeotic gene classes are deactivated at the same time, then leaf-like organs do indeed form. At the beginning of the new millennium a new class of homeotic genes was discovered, mutations of which resulted in the formation of leaves rather than floral organs. Although these "monsters" are not reproductively successful, they are treasure trove for researchers. It was thanks to them that the long-postulated "secret relationships" between plant organs were firmly identified. They also gave us our first glimpse into the molecular mechanisms that underlie the ap-

Arabidopsis thaliana inflorescence: *The topmost part of an inflorescence with four-petalled flowers can be seen here.*

Illustration: Wiki Commons/Alberto Salguero

Illustration: Wiki Commons/Claudia Vorra

Experimental plants in the greenhouse: Thale cress (Arabidopsis thaliana) *is a popular model organism.*



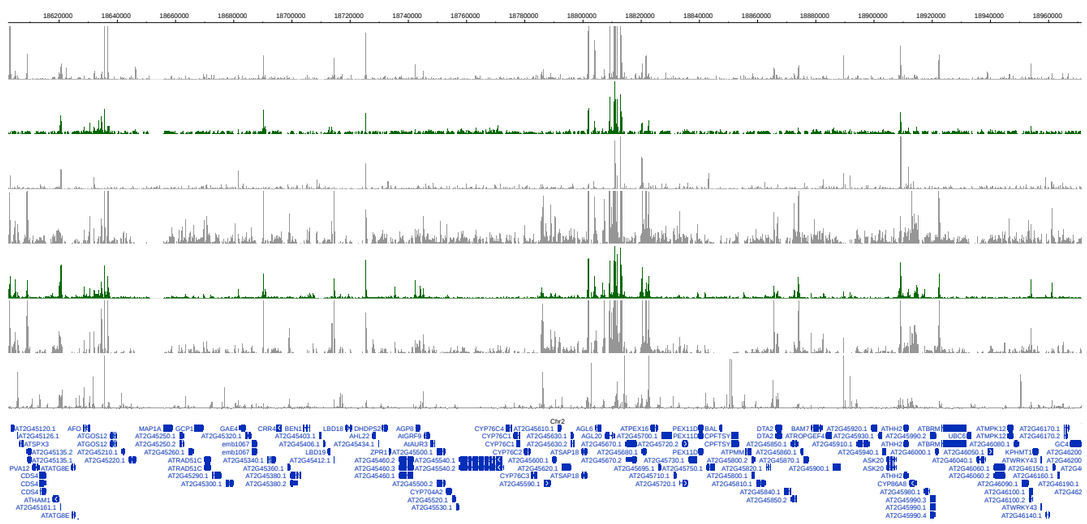
Illustrations: AG Kaufmann

Left: DNA binding studies of floral homeotic transcription factors – an EMSA experiment. Right: Expression of a floral homeotic protein as GFP fusion (green) in young meristematic tissue.

pearance and function of the various organs. In 2001, these molecular mechanisms were summarised in a model postulated by plant geneticist and evolutionary biologist Guenter Theissen at the Max Planck Institute for Plant Breeding Research in Cologne (now a professor at FSU Jena). Thus, floral organs can indeed be regarded as "modified" leaves, bringing Goethe's *Metamorphosis of Plants* into the focus of attention for Theissen and his colleagues.

So how do plants make different kinds of organs from non-differentiated stem cells, regardless of when and where in the plant these organs develop? Or, to put it another way, how are developmental processes controlled by ho-

The processes of life on a tiny scale: Section of a genomic map with binding profiles of homeotic transcription factors.



Graphic: AG Kaufmann

Flowering Arabidopsis *mutant with "cauliflower" phenotype.*

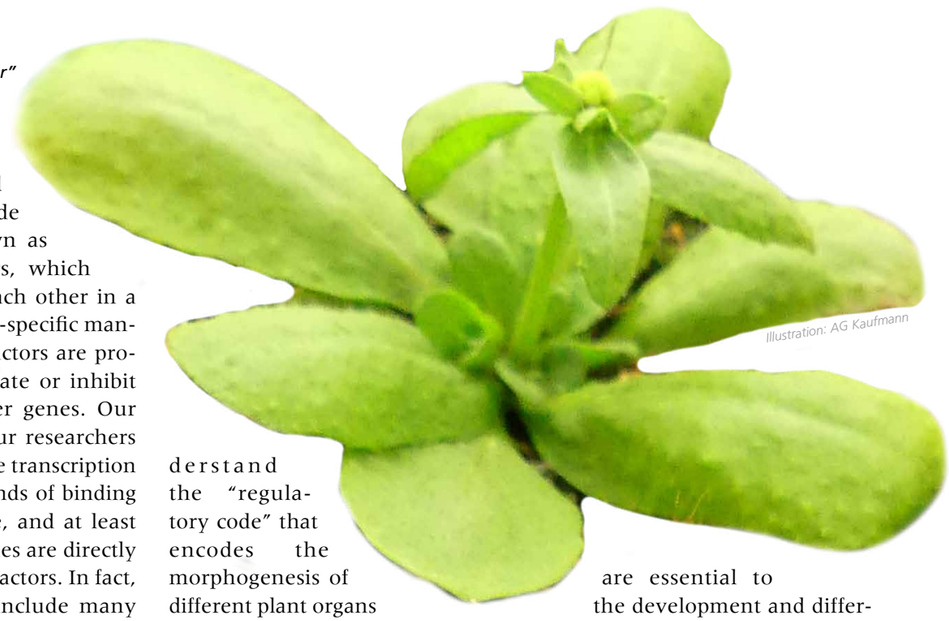


Illustration: AG Kaufmann

meotic genes at the molecular level? All homeotic genes code for what are known as transcription factors, which can interact with each other in a combinatorial organ-specific manner. Transcription factors are proteins that can activate or inhibit the activity of other genes. Our work and that of our researchers has shown that these transcription factors have thousands of binding sites in the genome, and at least several hundred genes are directly controlled by these factors. In fact, their target genes include many representatives that play a role in determining leaf organ morphology, for example genes that control organ polarity, trichome development and organ growth (and thus organ size). The activity of these genes is modified such that floral organs form instead of leaves.

Other target genes are only active during flower development, for example those required for the production of pollen. However, the analysis of the target gene networks of homeotic transcription factors is still in its early stages. We are only just beginning to understand how the function of individual homeotic gene classes comes about, in other words how the development of a stamen differs from that of a petal at molecular level, and how exactly the master transcription factors select their binding sites in the genome. However, with the aid of new technologies and interdisciplinary approaches, it will one day be possible to understand the "regulatory code" that encodes the morphogenesis of different plant organs in the genome.

But why do we want to know any of this? Is seeking to understand the beauty of the "monsters" in our gardens and their wild cousins all just a matter of intellectual curiosity? In fact, this is far from useless knowledge. Flowers are crucial to plant reproduction and therefore the production of seeds and fruits, an important food source for humans. For example, cauliflower is simply the result of a mutation in developmental control genes that delays differentiation of the meristem (the tissue containing undifferentiated cells, the part that we eat as a vegetable) into separate floral organs.

There are also fascinating parallels in the developmental processes of plants and animals. In the animal kingdom we also find homeotic mutants, for example fruit flies with legs instead of antennae. Although homeotic genes evolved independently in plants and animals, in both systems they are essential to the development and differentiation of organs.

Ultimately, there is one major question that fascinates researchers and gardeners alike: how do complex multicellular organisms develop from individual fertilised egg cells and how were they able to arise during the course of evolution? This question will keep researchers in various disciplines busy for a long time to come.

Prof. Dr. Kerstin Kaufmann
heads the Department for Plant Cell and Molecular Biology at HU Berlin.

Contact: Humboldt-Universität zu Berlin, Institut für Biologie, Lehrstuhl für Pflanzliche Zell- und Molekularbiologie, Philippstraße 11–13, 10115 Berlin, Germany

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