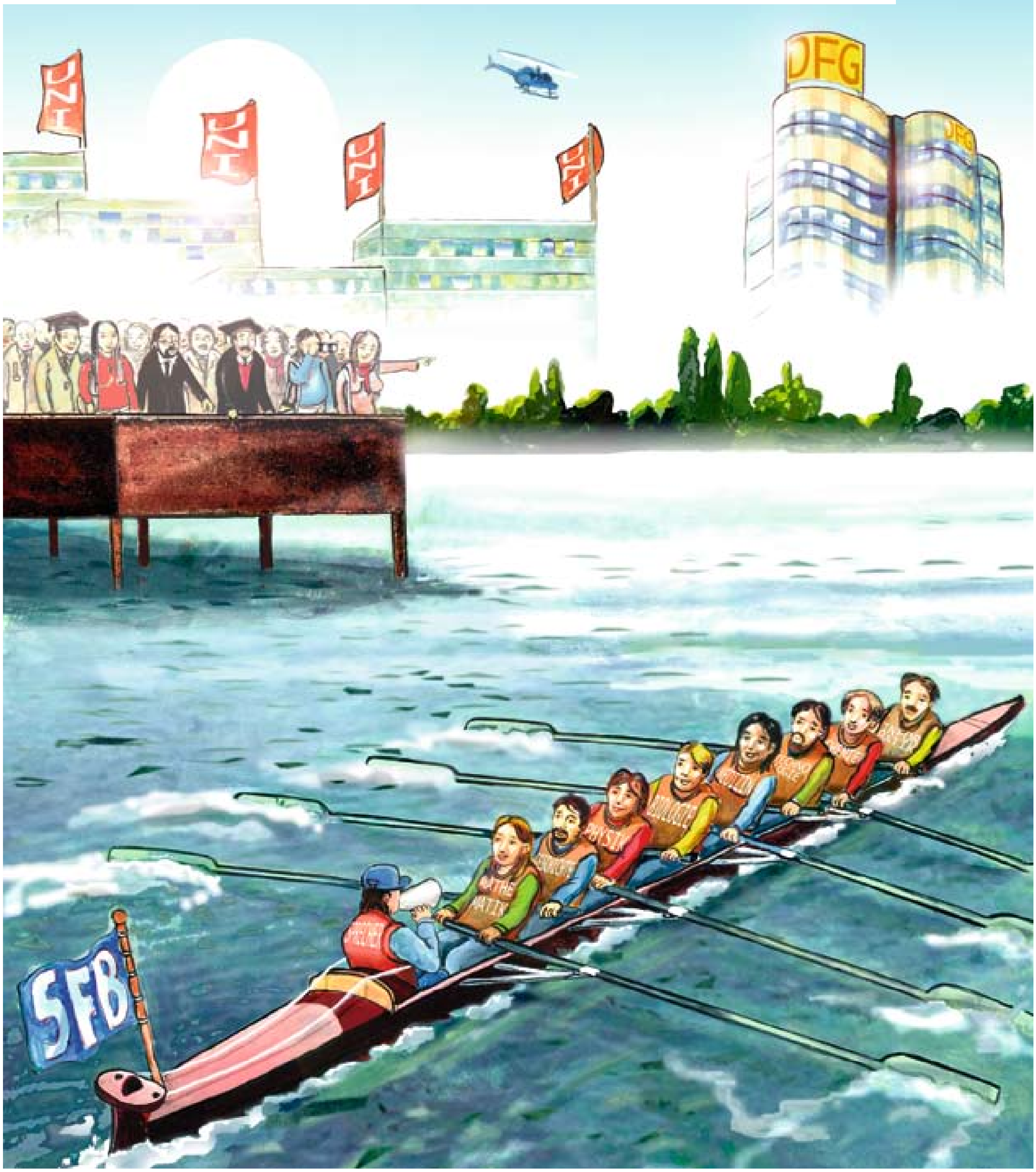
Collaborative Research Centres

of the Deutsche Forschungsgemeinschaft



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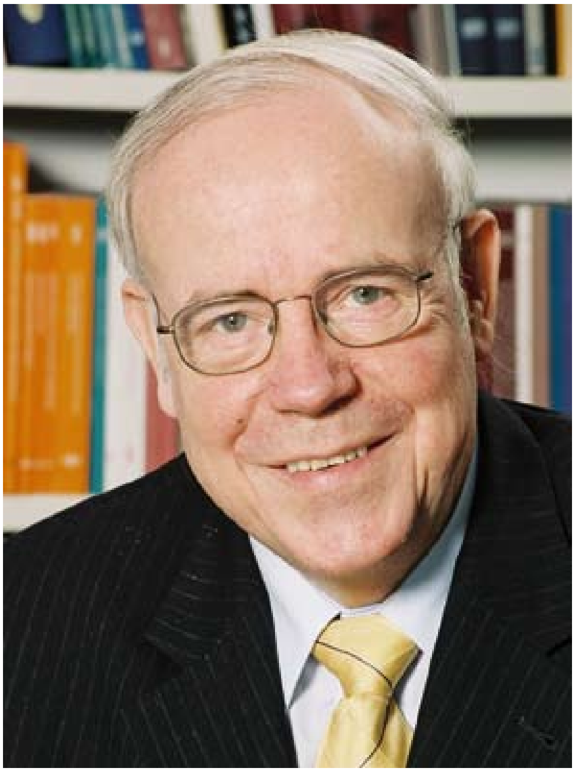

An Ideal Setting for Research

By Ernst-Ludwig Winnacker

A flash of inspiration during a solitary walk in the woods is as much a part of research as tireless laboratory investigation and teamwork over many years. The most fascinating research topics can often be found where different disciplines intersect; dialogue between experts creates novelty. Collaboration within a network can be stimulating and fertile when based on a well-conceived, interesting and exciting concept. To promote this cooperative approach in German academia, the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation), in addition to funding individual projects, offers programmes for coordinated network-based research. **Collaborative Research Centres** (Sonderforschungsbereiche, SFBs) enable scientists and academics to form **interdisciplinary** communities that engage in **long-term research**, for up to twelve years, on a jointly selected topic. The key objective is to promote excellent research on an **ambitious** topic by focusing resources at the host university. A Collaborative Research Centre shapes a university's profile and builds cooperative structures that last. It is an excellent setting for young researchers. The integration of research institutions outside the university fosters networking in research and enriches the SFB. As prominent beacons of science, Collaborative Research Centres substantially enhance the competitive quality and reputation of German research in the international arena.

Since this funding instrument was introduced in 1968, its topics, structure and scope have continuously evolved. Today the DFG supports a total of 276 SFBs with more than 400 million euros per year. Now as then, the core of the programme consists of **location-based Collaborative Research Centres**, in which scientists at a particular university collaborate with research institutions based in the same region. Close cooperation is accomplished most easily in geographic proximity. Seminal ideas are often born when doctoral researchers from various disciplines chat over afternoon tea. Some topics, however, defy geographic restriction. Thanks to modern means of communication (and the researchers' wanderlust), productive collaboration is possible even across larger distances. This is where the **Transregional Collaborative Research Centre programme** comes in, which was introduced in 1999. It allows researchers from up to three locations to join forces, complement each others' expertise, and establish new core research areas at their respective universities.

The inception of a Collaborative Research Centre is preceded by a strict selection process. Fewer than half of all proposals succeed. A group of internationally renowned experts visits the location for two days to review the proposal. Then a committee made up primarily of researchers compares it against numerous competing proposals to decide whether the DFG should fund it. What are the selection **criteria**? The topic chosen by the research network should be interesting and current, and each individual project has to relate to it. The network as a whole, as well as each individual project, must be scientifically convincing. Funding goes to those who have done relevant groundwork and can present interesting new ideas and good proposals for implementation. All the disciplines represented in a research network should pursue a joint approach and present specific strategies for collaboration. To assume the role of coordinator, there should be a persuasive researcher personality who can lead the community in a knowledgeable, integrative and decisive manner. After four years, the network is once again visited by the DFG: a group of reviewers examines the results and either approves or denies continued funding. Particularly outstanding projects may be funded for up to twelve years.

And what happens then? A Collaborative Research Centre shapes a **university's profile**: it can strengthen a previously existing core research area, or it may establish a new focus. Either way, personnel policies at the departments involved are geared to the joint project, and valuable research equipment is purchased for shared use. This helps make the most of scarce resources and achieve top-level research results, even while building cooperative structures that outlast the funding period. Another special strength of Collaborative Research Centres is the promotion of **young researchers**. Junior scientists and academics find excellent conditions for research here, the freedom to realise their ideas, a climate of dialogue and cooperation, as well as the support, advice and example of more experienced colleagues. By being assigned to lead projects, young researchers are allowed and required to take on responsibility. Independent junior research groups within Collaborative Research Centres are prime examples of how the DFG promotes early independence.

Gender equality in science and academia is a major concern of DFG research funding. The percentage of women in research is especially low in Germany and dwindles significantly from the graduate to the doctoral to the professorial level. To promote female researchers in particular, the DFG has made gender equality a key feature of its SFB programme. Each proposal is reviewed very closely for participation of women. Universities and project leaders must demonstrate their commitment to gender equality and are supported by the DFG for taking appropriate actions. Researchers should have the opportunity to successfully combine career and family, and this entails the availability of child care that can accommodate researchers' unconventional schedules.

> *"Basic research is the core of the SFB programme, but looking at practical applications is also important."*

Basic research forms the core of the SFB programme. But looking at practical applications of research findings is also important and worthwhile. Most frequently in the engineering sciences, but also in the life and natural sciences, SFB researchers safeguard their intellectual property with patents. In cooperation with industry, results are developed further, and particularly promising ideas may even become the basis of small start-ups. The DFG specifically supports such developments. In the **Transfer Project** component of the programme, the DFG systematically promotes the transition to applications. Together with one or more industry partners, findings are turned into practical solutions even during the Collaborative Research Centre's funding period. Industry partners contribute their own financial share. Issues regarding intellectual property rights and academic freedom of publication are settled by contract. The interplay of Collaborative Research Centre and Transfer Project is most successful when insights gained in practice are fed back to the SFB, helping to advance research even further. The most important transfer, however, is the "brain transfer": scientists who train in Collaborative Research Centres bring outstanding knowledge and skills to their future jobs.

International cooperation is another key feature of Collaborative Research Centres. Teams consist of researchers from multiple countries. Each SFB has an international visiting researcher programme. It is a given that findings are presented and discussed at international conferences. Contacts are intensified during visits abroad lasting several weeks or months. This gives especially young researchers a chance to be inspired not only by other investigative methods, but also by other personalities and cultures. Research partners working on their own projects in other countries may be included in a network if they contribute expertise that is not available at the SFB location.

New research methods and findings are shared among experts as a matter of course. It is equally important, but perhaps more difficult, for researchers to present their activities to the general public. The DFG supports such endeavours as well and provides SFBs with funding for **public relations**. Target groups might be students, parents and teachers, or representatives from business and government. Examples of such initiatives include lab open house weeks and "Children's University", films and exhibitions, and trade show participation.

For a list of Collaborative Research Centres funded by the DFG, visit our website (www.dfg.de/en), where I'm sure you'll see a research topic that interests you.

Prof. Dr. Ernst-Ludwig Winnacker was the President of the DFG from 1998 to 2006.

The Final Play-Off

Hamburg is in the grip of soccer fever. This afternoon the group game Italy versus the Czech Republic will be held at Volkspark Stadium. But on Bundesstraße, at the Centre for Marine and Atmospheric Sciences, people aren't paying much attention to the FIFA World Cup today. The scientists of SFB 512 "Cyclones and the North Atlantic Climate System" are fighting to make it into their own final round: SFB coordinator Burghard Brümmer and four of his colleagues are about to present their research findings and plans for the future in order to apply for a fourth funding period.

SFB 512 has been in existence since 1998. As is still practice today, the researchers from Hamburg, prior to submitting their initial proposal, had met with peers in their field and DFG representatives for an informal consultation to introduce their concept. "We came back from this consultation feeling confident that our field of research is potential SFB material," Brümmer remembers. Proposal submission was followed by an official review in Hamburg, which led to a recommendation. The Grants Committee endorsed the recommendation and SFB 512 began its work.

Since then, the researchers in Hamburg have successfully passed three reviews. But this doesn't mean that routine is creeping in. Applying for the final funding period is by no means less work than the previous proposals – after all, each individual project, each postgraduate position, each new piece of equipment must be convincingly justified. Failing that, planned projects may not be approved, which occurred in the previous review.

The team is working hard to keep this from happening again. They have shared many in-depth discussions in which they zeroed in on the issues that really matter – the results they want to achieve in their joint research, a realistic schedule, necessary modifications to their current structure, gaps that need to be closed, and last but not least, whether each project truly supports the big picture. "This is exactly where the added value of an SFB comes in," says Dieter Etling, one of the reviewers, who teaches theoretical meteorology at the University of Hannover. Equally important, according to Etling, is the question of whether the scientists involved can point to a publication track record that promises high quality for the proposed projects. Burghard Brümmer is well aware of this: "If your proposal talks the talk but you don't walk the walk, then you're not credible." It took just under a year to draft the report and renewal proposal – a volume of over 400 pages, which was then presented to the DFG and its reviewers. "If you can describe your project plausibly and intelligibly, you're already ahead of the game," says Etling.

> *"Each individual project must support the big picture."*

On this Thursday morning, the SFB's research assistants are also gathering in room 22. For many of the younger ones, it is the first time they experience an event like this, and their faces look serious; after all, their very careers are at stake here. Burghard Brümmer and his associates show grace under pressure, cordially shaking hands with their scientific peers who are here to review the proposal.

The fact that reviewers and reviewees know each other does not make this an easy home game for Brümmer's team. The DFG's officers for scientific affairs handpick the expert reviewers, taking into consideration not only their proven expertise but also making sure, as much as possible, that no bias of any kind will taint the experts' judgement; in this case, none of them may be affiliated with the University of Hamburg. Care is also taken to avoid that a negative evaluation can be used to harm a scientific competitor or, conversely, that potentially weak projects are overlooked out of sheer sympathy for the research area. The more disciplines are represented in a research team, the more diverse the review team. In the end, however, reviewers should not just add up their individual opinions, but rather come to a joint conclusion regarding the merits of the overriding research objective. Reviewers are joined by two DFG representatives – one with and one without special expertise in the subject matter at hand – whose job is to ensure fairness and transparency, and to report about the review process to the Grants Committee, which ultimately approves or denies funding.

Burghard Brümmer begins his presentation: "The North Atlantic is right at the front door of Europe and has an immediate influence on our climate." Hot summers or stormy winters – Europe's mild but variable weather is directly related to the North Atlantic climate system. Following this presentation, the project leaders talk about the ways in which they examine complex interactions within and between the ocean, the atmosphere, the sea ice, and the land surface. They are what cause the weather to change – from day to day, from year to year, from decade to decade.

Exactly how all these processes are interconnected – also in a global context – is still not clear. Using model calculations and field experiments, the scientists in Hamburg want to get a better understanding.

The SFB's eleven project segments pursue one common objective: to predict these processes and their probable effects as soon as a pattern has been identified. Forecasts for the El Niño phenomenon in the Pacific Ocean, which are already quite successful today, serve as a model.

To persuade the reviewers, Brümmer brings up additional arguments: new scenarios from the United Nations' Intergovernmental Panel on Climate Change (IPCC) are to be included in the planned model calculations, as are new satellite data. In addition, Hamburg-based sea ice research is expected to make a significant contribution to the International Polar Year 2007.

The reviewers do not seem to doubt the relevance of the research topic itself. Whenever they follow up with critical questions, they focus on organisational, methodical, or scientific details. For instance, they want to know what hypotheses the proposed field studies are based on, and whether the final funding period of three years will suffice to analyse the resulting data. They also probe the exact meaning of certain predictions, for example that calculations of small-scale aerosol effects can be applied to large-scale dimensions. And again and again, they keep asking whether it can be assured that the data collected by the SFB will remain available to researchers beyond its duration. Is this a good sign?

The project leaders join the lively discussion. And in the group talks that follow, even the doctoral researchers face tough questions. They have been involved in the preparations from the beginning and helped design the posters that explain each project through images and texts. It is apparent that each individual here contributes to the whole.

After the reviewers gather for their first closed meeting in the afternoon, the game goes into its second half the following morning. University president Jürgen Lüthje talks about the significance of SFB 512 for his institution, where climate and marine research has become a core research area with international visibility. This SFB has helped the University of Hamburg to focus its expertise: "Three years ago we were able to combine the University's Centre for Marine and Climate Research and the Max Planck Institute for Meteorology into the Centre for Marine and Atmospheric Sciences," says Lüthje, adding that the Hamburg-based German Climate Computing Centre is also part of the SFB, as are the GKSS Research Center in Geesthacht and the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven. A beacon for the promotion of young researchers is the Max Planck International Research School, where the SFB's junior scientists are active.

After the SFB researchers field a second round of questions and the reviewers hold a second closed meeting, the moment of truth arrives at about 1 pm. When the review team's spokesperson announces to coordinator Burghard Brümmer that the experts have agreed on a positive recommendation, a wave of relief can be felt sweeping over the room. Only minor cuts are being proposed regarding consumables and some postgraduate positions.

The main reason given for the recommendation is that the SFB's research programme looks beyond the three-year funding period. "These colleagues have eliminated weak spots, convincingly made the case for three new projects, and plausibly laid out how they plan to harvest and develop the fruits of their research," says Dieter Etling later, reflecting on his impressions.

Meanwhile, Burghard Brümmer can't wait to tell his associates the good news. Although the ultimate decision lies with the Grants Committee, the reviewers' recommendation is a good enough reason for them to celebrate – even without the World Cup
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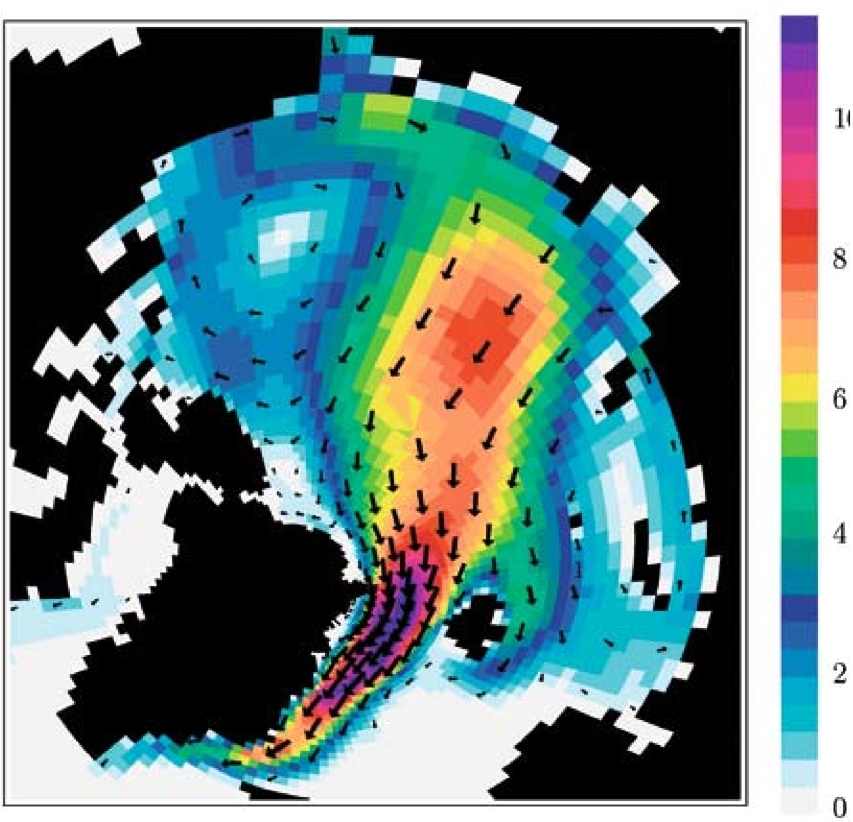
Marion Kälke



SFB 512

Sea ice transport from the Arctic Ocean, especially via Fram Strait between Greenland and Spitsbergen, is largely responsible for the North Atlantic freshwater balance.

Commotion at the Bottom of the Ocean

As the German research vessel *Meteor* ploughs the waves off Costa Rica and Nicaragua, there is incessant bubbling, rumbling and crackling far below the water surface. As a consequence, frequent tremors shake the ocean floor as well as the land. In 1972 an earthquake left 250,000 people homeless and 6,000 dead in Managua. In 1992 an earthquake triggered a tsunami, with waves over 10 metres high breaking over the coast. A belt of volcanoes stretches across Nicaragua, including three highly explosive volcanoes near Managua that have been active within the last few thousand years. Again and again, the researchers of SFB 574 "Volatiles and Fluids in Subduction Zones: Climate Feedback and Trigger Mechanisms for Natural Disasters", based at the University of Kiel's Leibniz Institute of Marine Sciences (IFM-GEOMAR), put out to sea to get to the bottom of the processes occurring at the ocean floor. Such a cruise is described in the richly illustrated book *Expedition Tiefsee* (Deep Sea Expedition) published by the SFB.

The research region is the Central American subduction zone. The surface of the Earth consists of plates that drift on our planet's viscous mantle like floats. At the west coast of Central America, the oceanic Cocos Plate collides with the Caribbean Plate and, due to its higher density, sinks beneath it; in other words, it subducts. It is easy to imagine the drama that happens at this juncture: enormous masses of rock are compressed, squeezed, transformed and broken; enormous amounts of seismic energy are released in earthquakes, which can cause slumping/sliding of the continental margin and tsunamis; and explosive volcanic eruptions threaten many of the major cities of Central America.

"A key to these processes is water," explains Klaus Wallmann, expert for marine biogeochemistry. He is not referring to the ocean but to the at least equally vast amount of water that has penetrated the ocean floor. It is chemically bound in mantle rock and in sediment that has settled on the bottom of the sea. As the oceanic plate moves beneath the continental shelf, it transports this water. Caught between the proverbial rock and hard place, the subducting Cocos Plate is continuously wrung out and drained. The fluids that escape – liquids enriched with volatile gases such as methane and carbon dioxide – trigger a variety of complex processes on the seafloor.

One of the SFB's specialties are so-called mud mounds which form on the continental slope due to disturbances in the sediment layers. The pressure of the Caribbean Plate on the submerging oceanic plate, combined with a temperature of about 150 degrees centigrade, alters the structure of the water-rich clay minerals, squeezing out their water. This water seeps upward through the crust of the continental slope and liquefies the overlying sediment, causing it to rise rapidly: gas-laden mud shoots to the surface and throws up bulging mounds.

At the boundary between the plates, the water that escapes the clay minerals serves as a lubricant, preventing severe tremors from occurring by movement of the down going plate. But further down along the edge of the plate, where the clay minerals have already been drained, that lubricant is lacking. This allows stress to build, which may result in earthquakes. "Our theory is that there's a direct connection between earthquakes and the dehydration of clay minerals," says Timothy Reston, a Briton who specialises in marine geodynamics. All the fluid release occurs between the quake epicentres and the deep sea trench, where the oceanic and continental plates intersect. The hypothesis that earthquakes immediately follow dewatering has been around for a while. "But by determining where the water is released in relation to the earthquakes, we found the first solid piece of evidence that backs it up."

While mud volcanoes are the main source of deep water, inactive deep-sea volcanoes also contribute their share. "The seamounts off the coast of Central America formed an ancient Galapagos Archipelago about 15 million years ago, which was located where the Galapagos Islands are presently located," says SFB coordinator Kaj Hoernle, an American scientist who studies volcanism. "Movement of the Cocos Plate carried them to the Costa Rican margin. Along the way they were eroded and subsided beneath sea level." As they underthrust the continental edge in the course of


SFB 574

A volcano exhales water vapour and other gases through fumaroles (gas vents). SFB researcher Kristin Garofalo samples these emissions to better understand their composition.

Subduction zone off Costa Rica: Clearly visible are several seamounts and – on the other side of the deep sea trench – scars that were left by such underground volcanoes when the Cocos Plate submerged.

subduction, they compress and oversteepen the continental slope, causing faulting, fracturing and slumping, which in turn lead to earthquakes and tsunamis. It is also along these structures that fluids and gases escape into the sea.

The most important gas is methane. It forms within sediments as microorganisms decompose organic material, but also in depths of several kilometres at high temperatures. Methane is a powerful greenhouse gas which, per molecule, contributes about 25 times more to climate change than carbon dioxide. In the ocean's natural cycle, bacteria and archaea work as a filter that keeps this methane from entering the atmosphere. They use the gas that is dissolved in the fluids for their metabolism and in turn provide nutrients for mussels and tube worms. And yet another mechanism keeps the methane in check. At the bottom of the ocean, where temperatures are low and pressure is high, water freezes and encloses the gas molecules in tiny ice cages. These gas hydrates are primarily found along continental slopes and in regions with permanent ice. However, when fluids migrate to the surface, they heat up the surroundings and thaw the gas hydrates. Methane released in this manner is also a vital resource for microorganisms.

In particularly sensitive areas, destabilised gas hydrates can trigger slumps and thereby tsunamis. "It doesn't happen the way Frank Schätzing describes it in his novel *The Swarm*," says Wallmann, probably for the hundredth time, and laughs. Still, that thriller made the Kiel-based researchers famous and actually explained many things quite well. "The worms that cause the disaster in the book are Schätzing's invention though." Adds geologist Warner Brückmann, "Humans, on the other hand, might indeed attack the gas hydrates in the long run by causing climate changes." For instance, if the water temperature at the bottom of the ocean rises by three degrees, about 80 percent of the gas hydrates would melt. Not only would this trigger natural disasters, but the escaping methane would also further increase global temperatures.

For 15 years now, the researchers from Kiel have been surveying, mapping, sampling, analysing and modelling the coast of Central America. "But it's mostly thanks to the establishment of this SFB in 2001 that we've been able to integrate our efforts so successfully as a team," explains Wallmann. When talking to these scientists from a variety of disciplines, it becomes quite clear that they are all in the same boat. The SFB is unique internationally in that it is the only programme that studies the entire subduction system (marine and terrestrial) within a single, large-scale project, bringing together researchers from multiple disciplines at a single university, according to Hoernle. The SFB has also inspired other international research activities, including two new ocean drilling proposals to drill into the earthquake generating (seismogenic) zone of the Central American subduction system and into mounds formed by fluid venting.

Of course, holistic research needs to consider the entire geographic zone, including the volcanic belt on shore. The latter is the focus of Armin Freundt's research. By looking at a volcano's type, age and size, he determines its past behaviour in order to draw conclusions regarding possible future eruptions and their severity. As is the case with earthquakes and tsunamis, only early warnings can save lives when it comes to eruptions.

Volcanoes develop from magma – rock molten in the Earth's mantle and crust, which erupts as lava or as an explosive mix of lava and gases. Mantle rock melts under extreme pressure and at temperatures of over 1,200 degrees; the temperature of the mantle wedge above the subducting plate is below its melting point. This is where water comes in: "Water lowers the melting point. It's as if you put salt on ice," explains Freundt. Once again, the cause can be found in the dewatering of minerals, in this case hydrous olivine known as serpentine. Fluid is released at depths of over 100 kilometres as the oceanic plate submerges into the mantle and heats up in the process. Whatever brews at the bottom will be hurled out at the top. Along with magma, the volcanoes spit out not only water but also the greenhouse gas carbon dioxide, as well as sulphur dioxide, which has a cooling effect on the atmosphere because it helps form clouds that reflect sunrays back into outer space. The explosiveness of magma depends on the amount and type of volatiles (gases) it contains.

There is still a lot left to do: "We don't know why quakes off Nicaragua trigger tsunamis and those off Costa Rica don't," says seismology expert Ernst Flüh. The team also has expanded its research region to include the Chilean coast. Different from Central America, where the Cocos Plate eats into the Caribbean Plate from underneath, one finds in Chile an accretionary wedge, formed from sediment that the subducting plate has pushed along and accumulated. "The transition from one variant to another, which we find off Chile within a small area, allows us to better study the system as a whole," explains Flüh.

Marion Kälke

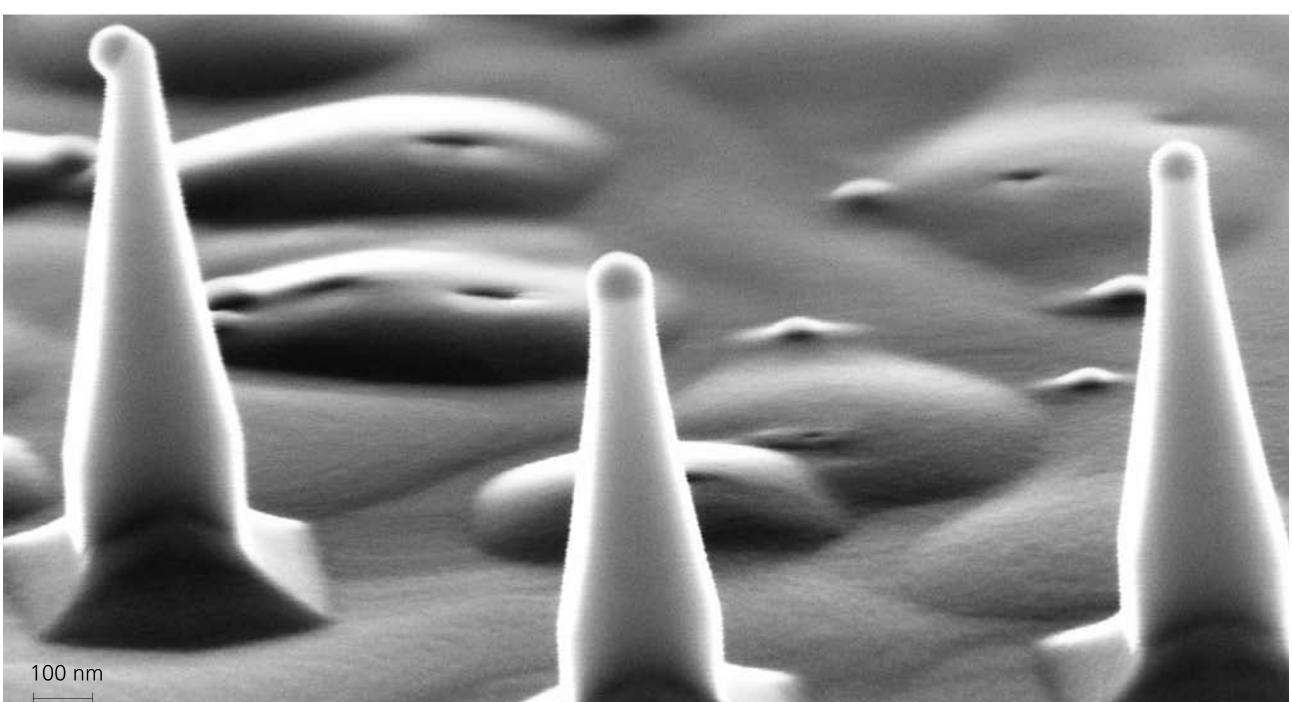
Plenty of Room at the Bottom

Wherever we look today, nanotechnology and nanoscience are beginning to penetrate our everyday lives. Almost daily, new findings lead to novel product ideas, as creative scientists and engineers in companies and research institutions advance the necessary technologies. "In this environment, through strategic and skilful hiring policy, the Universität Duisburg-Essen has developed into an important nanotechnology player," says physicist Axel Lorke, who six years ago moved from Munich to Duisburg, where he enjoys "fantastic working conditions" and now represents the SFB 445 as its coordinator. Under the common theme of "Nanoparticles from the Gas Phase: Formation, Structure, Properties", an unusually diverse crowd, comprising physicists and chemists, as well as electrical and mechanical engineers, work together hand in hand.

"'From the Gas Phase' – these words already indicate the interdisciplinary approach of our joint research," Lorke remarks. The SFB owes its foundation to the foresight of mechanical engineers, who realised that the extremely tiny dust particles that occur in combustion processes as unwanted side products have something in common with the structures that their colleagues in the natural sciences were investigating for their more or less exotic properties – namely their nanometre scale. And once these researchers realised that they had lots to talk about, not just as colleagues but also as scientists, they quickly agreed to join forces and look for new insights in this unexplored territory of traditional research. Further partners and allies were found, the SFB was proposed, reviewed, funded, and finally established in Duisburg in 1999.

"We reverse the usual research and development chain."

The objective of SFB 445 and its 16 projects is to investigate, through experiments, computer simulations and model calculations, the formation of nanoparticles in the gas phase; to characterise them in terms of their morphology as well as their physical and chemical behaviour; and to elucidate how



SFB 445

Underneath the catalytic nanoparticles of gold – the little beads at the tips of the whiskers as seen through a scanning electron microscope – nanowires consisting of compound semiconductor material grow on a silicon substrate.

a particle's structure relates to its properties. "In some ways our SFB reverses the usual development chain, which normally starts in the basic sciences and then makes the transition to engineering," says Axel Lorke. "In our case it starts out with the particles. Only after the engineers have produced the nanomaterials – which happens in project area A of our SFB – can the

"Material combinations normally considered impossible become reality."

physicists and chemists in project area B characterise and analyse them for their new and often surprising properties." Examples include light-emitting particles that consist of silicon, the very material which the entire modern computer industry is based on, but which has so far been unsuitable for optoelectronic applications; or magnetic particles, which self-organise into chains or ordered layers, as if moved by an invisible hand. In the end though, everything falls into place again in the SFB 445, as the engineers in project area C turn the newly found properties into novel applications.

Nanoparticles are characterised by their reduced size in all three dimensions. This is why scientists often refer to their "quasi-non-dimensionality" and their enormous surface-to-volume ratio. This means that, unlike with "normal" solids, interfacial effects dominate and quantum phenomena occur, which can be used technologically in electrical, magnetic, or optical components with entirely new or customised properties. An example for this kind of customisation within SFB 445 is the development of ultrasensitive gas sensors, based on tin oxide nanoparticles.

In 2004, Franz-Josef Tegude joined the research team to make use of the nanoparticles produced in the SFB and realise innovative concepts for microelectronic components. "For example, we try to emulate typical transistor functions using nanoparticles," he says and pulls out an electron microscope image that shows three thin spikes on a more or less flat surface. Looking closely, one notices a small round cap on each tip. "These are nanoparticles made of gold," explains Tegude. "What's so great about it is that these gold dots act as catalysts and make sure that, in our usual process of metal-organic vapour-phase epitaxy, solid material grows right beneath them – and only there – in the presence of gaseous semiconductor source materials, even at a relatively low working temperature." The microscopic image shows clearly how elongated structures, tipped with nano-gold, stretch vertically upward toward the substrate surface. "They're called whiskers", says Tegude, "and they grow into wires of up to several hundred nanometres length while measuring only ten nanometres in diameter. They obviously form in a self-organising process, which we gradually learn to understand within the SFB."

These super-thin wires consist of indium arsenide (InAs) or indium antimonide (InSb) and grow on a silicon base – a combination of materials normally considered impossible by experts, because their crystals have different lattice constants (distances between atom positions), which has fatal consequences: if the materials are deposited onto a large area, mechanical tensions arise, which sooner or later cause the growing film to tear. "It's one reason why compound semiconductors haven't been able to play much of a role in microelectronics," comments Tegude. "But since our whiskers only grow locally, we get around this problem, and along the way we happen to conquer the third dimension for the development of components."

"Nanowires are a prime example of our multifaceted work", says Lorke, as he describes the enthusiastic atmosphere at the SFB. Of course, it is not easy to find a common language between all the subject areas involved; different mindsets and terminologies need to be understood among the different disciplines. For this purpose, SFB researchers gather for informal as well as for scheduled meetings, such as the weekly discussions at theorist Dietrich Wolf's office. One of the challenges here is to comprehend the electrical resistance of a thin layer of nanoparticles. The issue only appears to be easy – after all, textbook formulas developed for macroscopic physics fail at the nanoscale, where current is no longer a continuous flow. Rather it is carried by individual electrons, which on the one hand behave like bouncy ping-pong balls, and on the other like enigmatic quantum objects. A stimulating topic for experimental and theoretical discussions, in which, quite naturally, undergraduates participate just as much as the SFB's postdocs and doctoral researchers.

"We try to show our young researchers the importance of thinking outside the boundaries of their

"Textbook formulas from macroscopic physics do not apply at the nanoscale."

own subjects," the colleagues agree – and those aren't just empty words. A case in point: the SFB has established a cooperation with the University of Minnesota's IGERT programme (Integrative Graduate Education and Research Traineeship) and thus enables its young scientists to travel to Minneapolis to share results and know-how with their colleagues and to learn about the research environment in the United States.

The SFB's annual retreat also plays an important role, as the entire SFB crew goes away to a secluded cabin in the mountains for one week. Here, professors and research assistants report on their projects, but also students talk about their graduate work within the SFB. "That's when we're away from it all and fully focused to pick each other's brains – without picking on each other," says Lorke. "It's a great exercise in communication, especially for the younger people. And it's not unheard of that ideas for new interdisciplinary projects come up when we talk over a beer in the evening."

Dieter Beste

Nature's Repair Shop

A skinned knee isn't all that bad – the wound will heal within a few days. A damaged liver will regain part of its function within a few weeks. Donating blood is not a problem, because the loss will quickly be replenished. Still, our body's own ability to repair damage is limited. No one can make a lost arm grow back. The axolotl, however, can. If this Mexican salamander has, for example, its tail cut off, it will restore it completely – backbone, nerves, muscles, blood vessels and all.

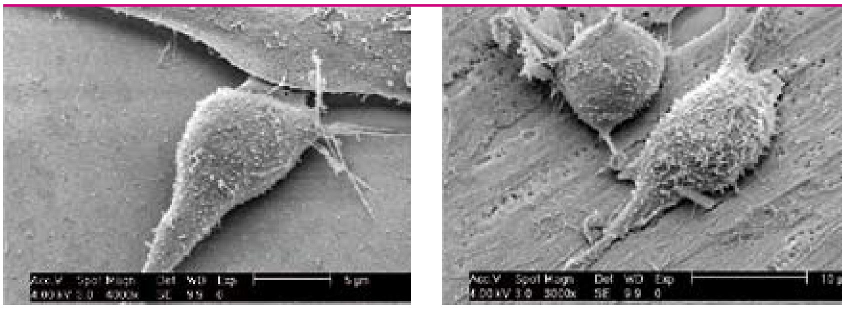
"The axolotl is the king of regeneration, and there's a lot we can learn from it," says Gerhard Ehninger, coordinator of SFB 655 "Cells into Tissues: Stem Cell and Progenitor Commitment and Interaction During Tissue Formation" at the Technical University of Dresden. The sources of tissue formation are stem cells, two variations of which are interesting to biomedical researchers. All-rounders are the "pluripotent" embryonic stem cells that have not yet decided what they're going to be. They develop on approximately day four after the ovum has been fertilised in the inner cell mass of the blastocyst and are then able to differentiate into any cell type the organism needs. But the adult body still has a reservoir of stem cells, for example in the skin, the intestines, the bone marrow and the brain. These adult stem cells are specific to a certain type of tissue. However, their ability to develop into mature cells is more or less limited, depending on the organ, and when they do, the number of stem cells decreases because they cannot regenerate indefinitely.

"Cultivating limbs or complex organs is science fiction," says Ehninger. But the SFB's researchers do hope to be able to jump-start nature's repair shop in the future. "How can we train stem cells in or outside of the body to help them correct injuries better or replace missing tissues?" To begin answering this question, one needs to understand what causes a stem cell to become a certain body cell and to behave in a useful and friendly manner within the target tissue. Because a remarkable group of internationally renowned researchers has taken up residence in Dresden – not least thanks to the state of Saxony's biotechnology initiative – it was an obvious choice to combine this rich expertise into an SFB. In 2005, experts in molecular and cellular biology, bioengineering and medicine joined forces to uncover the mystery of tissue formation. They focus on the haematopoietic system – stem cells in the bone marrow and blood – and the nervous system, down to the pancreatic islet cells that produce insulin.

While the day care centre at Dresden's university clinic looks after her child, Elly Tanaka can devote her full attention to the axolotl. The American scientist, who works for the SFB's partner institution, the Max Planck Institute of Molecular Cell Biology and Genetics, wants to know how this salamander manages to completely regenerate its spinal cord. Why can't mammals do this? After all, they too have neural stem cells. SFB project leaders Wieland Huttner from Germany und Denis Corbeil from Canada were able to isolate neural stem cells in mice after they had discovered on the cell surface a marker called prominin. Just like embryonic stem cells, according to Huttner's hypothesis, they seem to be able to divide asymmetrically: on the one hand they can multiply, and on the other hand they can specialise into nerve cells – albeit only in test tubes. Rather than prompting stem cells to differentiate, the brain prefers a less effective route: it compensates for an injury by creating new connections between undamaged neurons. Examining the axolotl for clues, Elly Tanaka has already discovered that neighbouring cells are in part responsible for whether or not a neural stem cell differentiates. In the spi-

Max Planck Institute of Molecular Cell Biology and Genetics

Axolotl as model: this salamander is the king of regeneration.



Martin Bornhäuser

This electron-microscope image shows blood stem cells that have grown for seven days on mesenchymal stem cells, which function as "developmental aids".

nal cords of mammals, however, this kind of interaction between cells appears to be blocked by certain signal molecules. Now she wants to implant neural stem cells from mice in injured axolotl tails to find out whether it is possible to "infect" mammalian cells with the salamander's self-healing strategies.

The strange thing, according to Ehninger, is that while the cell biology of neural stem cells is quite well known at this point, these insights have so far resisted medical utilisation. When it comes to haematopoietic cells, however, the opposite is true: knowledge about their cell biology is quite limited, and yet leukaemia patients, for example, whose own degenerative bone marrow needs to be destroyed by chemotherapy, have been successfully treated with blood stem cell transplants. Dresden has one of Europe's largest centres for these procedures. To be able to even detect the sparse number of stem cells in the bone marrow or blood, Ehninger also uses the marker molecule prominin, which can be found on the membranes of blood stem cells as well as on those of neural stem cells. Because they can be purified much better today than in the past, the risk of the recipient's body showing a defensive reaction is also lower.

Little is known so far about how implanted blood stem cells settle into their niche in the bone marrow, or how they multiply, differentiate and survive there. To date, says Ehninger, there has been no successful attempt to reproduce blood stem cells outside the body. More precise knowledge would be a boon to transplantation medicine. A clue might be held by so-called mesenchymal stem cells, also located in the bone marrow. They apparently stimulate the self-renewal of blood stem cells and support them in making red and white blood cells as well as platelets. These two cell types, according to Corbeil's theory, are able to communicate thanks to certain surface proteins, including prominin, and corresponding receptors. The researchers try to get to the bottom of this collusion between mesenchymal and prominin blood stem cells by recreating their natural bone marrow niche. Together with materials scientists from the Leibniz Institute of Polymer Research, Martin Bornhäuser cultivates the cells on a plastic matrix whose surface is covered with natural body proteins.

Ehninger's goals for this project are highly ambitious. After transplantations, it turned out that the descendants of especially pure blood stem cell lines showed up in other tissues as well. The fact that they did not – as was often feared – simply fuse with body cells might be a sign that prominin blood stem cells are able to differentiate into other tissue types as well, and are thus "multipotent". Ehninger wants to cultivate them and implant them into mice to see whether they actually form not only blood cells but also muscle, kidney, or nerve cells.

"To be able to assess the possibilities of adult stem cells you also have to study embryonic stem cells," says Ehninger, "because they're the blueprint for the entire tissue formation." Australian Francis Stewart works with those in mice. "They have two notable qualities," he says. "For one thing, they divide indefinitely and very quickly. For another, mice are unique among mammals in that under stress they can stop embryonic development at the blastocyst stage." To be able to study the differentiation of these cells as well as the function of certain genes, he develops, on this basis, methods that will help him to cultivate them and preserve their pluripotency. Undifferentiated stem cells, unlike more mature ones, have no epigenetic markers yet. The epigenome is a kind of master plan outside of the DNA: "Epigenetic markers in cell development are kind of like locks, in that they perpetually seal decisions about the direction in which a cell lineage specialises," says Stewart. Investigating them would not just provide insights into the steps involved in stem cell differentiation – picking these locks would also enable scientists to reprogramme adult cells and "reboot" their descendants.

Nobody knows yet whether murine embryonic stem cells are similar to human ones. For a project outside of the SFB, Stewart now has been granted permission to research human embryonic stem cells as well. German law currently restricts the use of surplus blastocysts from in vitro fertilisations to those generated in other countries before 1 January 2002. Stewart thinks that ethical qualms may eventually be dispelled: "If embryonic stem cells can do everything, they can also become egg cells." No new embryos would be needed at that point. But until then, Ehninger believes, it would be important for the quality of research to be able to work with younger cells – just old enough to be sure they were not produced specifically for this purpose.

"The competition between adult and embryonic stem cells is open," says Ehninger. "But our ultimate goal for the 12-year maximum funding period is to advance, at least in one of our fields, a new therapy to the point where we actually can heal patients."

Marion Kälke

Learning and Forgetting

New communication technologies, aided by the internet, promote a process in which businesses increasingly become placeless. While industrial manufacturing just a few years ago still entailed many workers concentrated in one location, the boundaries of production plants are now becoming blurry. The parts of an automobile, for instance, may now arrive from all corners of the world and be assembled by an invisible guiding hand at locations that can change any day. And thanks to laptop computers and PDAs, today's information elite can set up office anywhere, anytime.

"This has consequences that go far beyond what meets the eye," says Otthein Herzog, coordinator of SFB 637 "Autonomous Cooperating Logistic Processes: A Paradigm Shift and its Limitations" at the University of Bremen. "Internal and external logistic processes across companies are becoming increasingly complex, and the markets accelerate this process even further by changing from sellers' markets, which are essentially maintained by centralised supply chains, to buyers' markets, in which a wide variety of individual demands try to coax ever new streams of products."

> *"Let that container from China decide how to get to Bremen."*

Logistics is therefore due for a paradigm shift, as summarised by Herzog's slogan "From conventional to autonomous control". Logistics companies traditionally use hierarchically organised information and communication structures. But as markets become ever more dynamic and logistic networks more complex, centralised planning will no longer be enough to make sure that the right product gets to the right place at the right time. Distribution processes will need to be automatic, with increasingly autonomous and decentralised controls. "That container from China on the ship to Bremen will have the intelligence to know what its cargo is, how perishable the goods are, what its current location is, and by way of which transfer stations it will best reach its destination."

Since the beginning of 2004, researchers from disciplines as different as economics, production engineering, electrical engineering, computer science, and mathematics have been working hand in hand within SFB 637. They want to find out to what extent logistics systems can be left to the devices of autonomously controlled processes. As of yet, unanswered questions abound: It sounds so simple, but what exactly are autonomous logistic processes, and how are they different from externally controlled processes? How does autonomous control change order processing? How can these new processes be modelled, and which methods can be used? How can autonomously controlled processes be measured and evaluated?

"Logistics as a research focus at the University of Bremen relates to a traditional core competency of Bremen-based business," says

SFB637

Two demonstrators give lab visitors a sense of the work SFB 637 does for autonomous processes in automotive logistics.

Herzog, adding that a research network for logistics had been in place for quite a while at the university. The idea to establish an SFB was the brainchild of engineer Bernd Scholz-Reiter from Cottbus, who in 2000 became professor of production engineering in Bremen. He saw at this university a wide-ranging scientific potential to explore issues of autonomous control in logistics collaboratively from a variety of perspectives. "One of our initial tasks was, of course, to clarify the terminology," he says and introduces the SFB's working definition: autonomous control describes processes of decentralised decision making in heterarchical (horizontal rather than vertical) structures. It presumes interacting elements in non-deterministic systems that are capable and enabled to make independent decisions, and it aims to achieve "increased robustness and positive emergence of the total system due to distributed and flexible coping with dynamics and complexity". Positive emergence? "It's a term from systems theory," explains Scholz-Reiter. "Complex, autonomously controlled systems may develop properties that can't be understood as the sum of the individual components. Emergence is a typical feature of biological systems."

In addition to modern information and communication technologies, new developments in computing were another source of inspiration for the researchers in Bremen: Soon it will be possible to tag all kinds of goods not just with passive barcodes but with radio frequency identification chips that communicate actively. The initials RFID spur the imagination not only of researchers but also of professionals in the logistics industry. Together with wireless communication networks, satellite-based positioning systems, modern sensor technology, and continuously expanding computing power and data capacity in tiny spaces, RFIDs make the vision of autonomously deciding intelligent logistic objects, putting together their own itineraries almost like travellers, "a distinct possibility", comments Michael Freitag.

Freitag, also an engineer, is the managing director of SFB 637. He organises fortnightly talks, which always include guest speakers from other universities as well as businesses. To promote internal and external communication, he publishes an eight-page newsletter twice a year that gives interested readers, especially among the business community and the general public, a chance to learn about the SFB's work. At the 2006 Hannover Fair, the SFB exhibited a "smart" container, prepared by the scientists as a demonstration platform to provide, at a reduced scale of 1:16, a glimpse into the future: The scenario involved shipping fresh fish from Bremerhaven to Frankfurt, with an electronic waybill that could be accessed anytime, anywhere by software agents with a knowledge base. "Throughout this scenario there are all kinds of internal and external disruptions such as congested highways and communication breakdowns and cooling outages," explains Freitag, "all of which our container can recognise and thereby trigger decision processes in and between software agents."

"Many technologies for autonomous control are already, or will soon be, available."

From the beginning, the SFB has been guided by the idea that the results of basic research should be implemented in the real business world even while the SFB is still in progress. Right in its first year, it sponsored an industry colloquium with about 80 logistics professionals from businesses small and large. "These conversations helped us ask sharper questions," say Otthein Herzog und Bernd Scholz-Reiter in unison. In a total of 13 projects, the scientists in Bremen examine the foundations of modelling autonomous logistic processes, develop methods and tools, identify potential areas of application – and even within this first funding period, they are preparing to increasingly focus on developing applications beginning in 2008.

But they are not quite ready yet. The first two years have proven the old adage about the devil in the details: "Many of the useful technologies we need for autonomous control have already been developed or will be available in the near future," says Scholz-Reiter. "But the bottleneck we have to get past with our research is the overall organisation." Economists do have organisational theory models, but those need to be adapted to the task of autonomous control. Different technologies have to be integrated to cooperate fruitfully, and "developing the algorithms for all of that is going to be a tough piece of work for us, because we're looking at systems that behave in a non-linear, dynamic way, and there are no analytic methods to describe these yet."

"At the level of simulations we can already show how autonomous control works," says Herzog. "But the paradigm shift we mention in the title of our SFB hasn't been explored yet by a long shot." If logistic objects are to make autonomous decisions, they need, among other things, a knowledge base – just like humans do. These types of issues are being investigated by the knowledge management project. And how potentially scattered knowledge can be made available to technical objects in a way that makes sure they use the right information – that is the kind of question asked by researchers in the risk management project. Two years into their endeavour, they know about the importance not only of creating a knowledge base for interacting software agents, so-called multi-agent systems, but also of something human beings know all too well: forgetting. "Learning and forgetting knowledge – that's an unsolved mystery," says Herzog. An RFID chip on a logistic object has to be capable of forgetting, simply because its storage capacity is limited – "and even a container that had to select a route several times before, in similar situations, should only be able to remember the right paths." *Dieter Beste*

Dangerous Shapeshifters

"Basically, malaria can be contained using simple tools," says Olaf Müller, who heads the working group for malaria combat in SFB 544 "Control of Tropical Infectious Diseases" at the University of Heidelberg. "And these tools are bed nets that have been treated with insecticides." The key is pyrethroid, an insecticide with no adverse effects on humans. Mosquitoes of the *Anopheles* genus cannot stand its odour and hence buzz off. And if they still happen to come into contact with the chemical, they die. "When all households put up these nets, it drastically reduces the number of mosquitoes," explains Müller. Field studies in the 1990s, in which Müller participated, proved how effective bed nets are in protecting small children and pregnant women.

Still, many scientists stopped short of recommending treated nets. A long-standing hypothesis had it that children who were never bitten by mosquitoes will not be able to develop immunity. It was feared that they might end up with even worse cases of malaria later in their lives. Many children, such as in Africa, whose blood is injected with different variants of the parasite through hundreds of mosquito bites, gradually form a defence which, while not protecting them against the disease entirely, will at least prevent the worst.

But this immunity is no reason to relax. Tropical fever claims one to two million human lives each year. The fact that 20 percent of children in Burkina Faso die before they reach the age of five, and one-quarter of them from malaria, prompted Olaf Müller to conduct a study in that country's Nouna region. It proved that mosquito nets do not simply postpone child mortality and that children who sleep under nets actually enjoy more robust health than those who do not. The World Health Organization (WHO) includes malaria prevention in its programme as one of the most important strategies. Now Müller wants to make sure that enough nets are hung in each village. "That exactly is the weak spot." In a new study he wants to find out which measure works best to increase acceptance of these nets among the population.

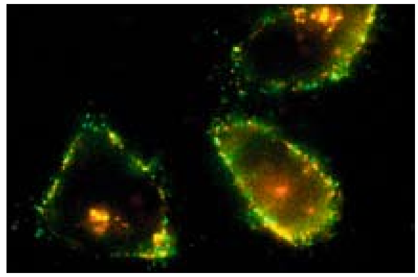
For many years, the Nouna Health Research Centre, which belongs to the Burkina Faso Ministry of Health, has been a partner of SFB 544, whose work clearly does not stop at the lab door. Scientists from Heidelberg and Nouna conduct epidemiological and demographic studies, perform drug and vaccine trials, and do research on healthcare system development, including efforts to provide people with health insurance. The University of Heidelberg is the only German institution that cooperates this closely and across disciplines with an African research station. "It's important that our work helps those who need it most," says SFB coordinator Hans-Georg Kräusslich. One-third of all deaths worldwide are due to infectious diseases, and sub-Saharan Africa holds the sad record in this category.

While most of the SFB's projects focus on malaria, some others look at the AIDS virus HIV and at trypanosomatids, which cause conditions such as sleeping sickness. The biggest and most


SFB 544

Fighting malaria: In a patient study in Burkina Faso, physicians test the combination drug BlueCQ.

Outguessing the AIDS virus requires understanding the interaction between the pathogen and the infected cell: HIV particles that attach to the cells are marked with a fluorescent protein.



Marko Lampe, Department of Virology, University of Heidelberg

crucial part of the SFB's work is done by scientists in Heidelberg: biomedical research, therapy and drug development, clinical trials. "The fact that we have to bridge all these areas means that people talk more," says Kräusslich. The SFB employs an unusually high percentage of young researchers; six of them are already project leaders. An independent junior research group, with dedicated DFG funding to promote the integration of young scientists, is also part of the network. Junior research groups in SFBs, similar to those under the DFG's Emmy Noether Programme, receive especially generous financial support.

As different as the parasite *Plasmodium falciparum*, which causes lethal malaria tropica, and the AIDS virus may be, they share a frightening ability to constantly change and thus become resistant to drugs. This is the reason why the researchers can never rest on their laurels. Kräusslich has been studying HIV for 18 years now. Among the topics he studied during this time are the virus's sophisticated resistance mechanisms. All the drugs that are currently available inhibit or block the virus's ability to replicate in the infected patient's body. But again and again, and with breathtaking speed, it keeps altering its structure in mutations and thus eludes its attackers.

This is why HIV patients today are treated with a combination of drugs – if one doesn't work, others may still have a chance to keep the pathogen from reproducing. However, if the point of attack remains the same, there is a risk of cross resistance: if the virus is already resistant to five different inhibitors, a sixth one may not be able to get to it either. "For this reason, and also because of the side effects, there's a need not just for new agents but for new classes of agents," says Kräusslich. New mechanisms must continually be identified to allow intervention at various stages of viral development.

Kräusslich's own project looks at the viral particles that are released during the last stage as the virus leaves the infected cell. A possible target for antiviral drugs could be the assembly process. "You can think of it like a Lego structure," explains the virologist. "If we can manage to insert a piece somewhere that doesn't fit, there won't be a house – or, in our case, a virus." Such a piece – a short protein fragment – has already been generated by the researchers. "We've been able to do it in vitro but not yet in the complete virus," says Kräusslich. "Pharmacological development is still a ways off. For now we want to prove that assembly inhibition is feasible to begin with."

Sometimes it helps to take an unusual path. Biochemist Heiner Schirmer, who researches malaria medicines at the SFB, had the idea of bringing back an ancient, long-forgotten substance to outsmart the *Plasmodium* parasite's resistance – methylene blue. It was first used in the late 19th century by Paul Ehrlich to successfully treat malaria patients. Schirmer wanted to combine it with the staple drug chloroquine, whose efficacy against *Plasmodia* is waning. Methylene blue is doubly effective because it inhibits glutathione reductase, an enzyme that protects the parasite both against being attacked by our immune system and against chloroquine. For a patient study on the combination drug BlueCQ, Schirmer received the Dream Action Award from the Dutch chemicals group DSM in 2002.

"Schirmer had no experience with clinical trials," remembers Olaf Müller, "so he approached me within the SFB." They put together a multidisciplinary team that began testing BlueCQ on patients in Burkina Faso. Ultimately the scientists had to face a setback – the synergy between the two substances was not sufficient. Today, however, they have once again cause to be hopeful: laboratory tests have shown that methylene blue harmonises well with artemisinins, a new group of drugs extracted from a Chinese wormwood plant. A total of 180 patients, who currently participate in a pilot study, hope that this cocktail can cure them.

"The best weapon, of course, would be a vaccine," says Müller. Taking the first step, SFB project leader Hermann Bujard has been able to identify a protein in the *Plasmodium* parasite that is considered a vaccine candidate and, according to Müller, "reason to be cautiously optimistic". HIV vaccinations, however, are currently not on the horizon. The sad part, says Kräusslich, is that there is actually an easy way for people to protect themselves – "avoid getting infected". That is why education remains the most important task. But the fight must continue on all fronts. One of them brings basic researcher Kräusslich closer to the daily lives of the people who are affected in Burkina Faso. This project aims to keep HIV-positive mothers from transmitting the virus to their children, at birth and then through breast milk. To be able to effectively treat mother and child, he checks the patient's immune response and the resistance of her virus. "This project in particular was initiated at the request of our colleagues in Nouna, because up to that point there were no counselling or treatment programmes for HIV in the entire region," says Kräusslich. "It never would've happened without the SFB."

Marion Kälke

Control of Quantum Correlations in Tailored Matter

When experimental physicists meet theoretical physicists, when nanophysicists want to talk to quantum opticians, or solid state physicists to quantum information scientists, a blackboard and chalk may be needed to cope with a Babylonian jumble of terms – only the formula written on the wall will bring clarity. "For example, in semiconductor physics we refer to the quality of a resonator as quality factor," says Reinhold Kleiner, "but opticians call it finesse." This Friday, the colloquium of SFB/TRR 21 (TRR stands for Transregional) was held in Tübingen, and Reinhold Kleiner, one of the project leaders and a solid state physicist at the University of Tübingen, once again hosted a panel of about two dozen scientists.

They meet every other week at rotating locations because the Transregional SFB also includes physicists from the universities of Ulm and Stuttgart, as well as from the Max Planck Institute for Solid State Research in Stuttgart. In mid-2005 these researchers teamed up and set out to control quantum matter. They also hoped they could discover new states of matter, which they suspected to exist somewhere in the limbo between mesoscopic systems – the domain of solid state physics – and quantum gases – the research field of quantum physicists. The latter topic received a major boost in 1995, when the so-called Bose-Einstein condensation of ultracold atomic gases near absolute zero was realised for the first time. This achievement earned American scientists Eric Cornell and Carl Wieman and US-based German researcher Wolfgang Ketterle the 2001 Nobel Prize in Physics.

"In 1997 we were first in Europe to produce Bose-Einstein condensates," says Wolfgang Peter Schleich, quantum physicist at the University of Ulm. By "we" he means the DFG-funded research group that was formed in the mid-1990s and ultimately led to the proposal of SFB/TRR 21.

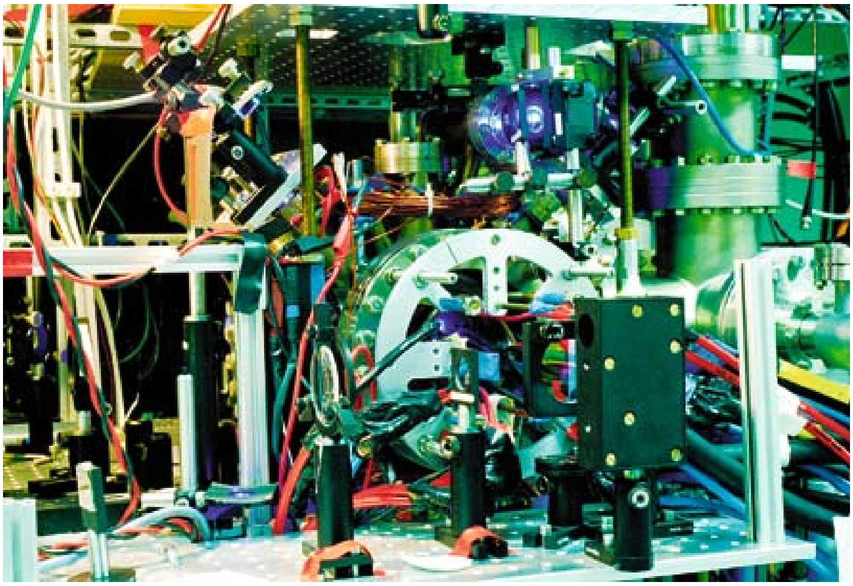
"We're building a bridge between atomic and solid state physics."

The transregional variation of an SFB is often favoured by applicants when the expertise needed for the chosen research area is not available at one single university and therefore requires cooperation with others. At the same time, the standard against which potential Transregionals are measured in terms of partner choice and scientific quality is especially high. Reviewers apply stringent criteria: the work packages that the various universities contribute need to complement each other perfectly, and only the best of the best in science may be included in the network. In addition, each university has to make the topic of the SFB/TRR a core research area.

From the very beginning, a driving force behind the inception of SFB/TRR 21 was Tilman Pfau, who in 2000 left the University of Constance to head the 5th Institute of Physics at the University of Stuttgart. Pfau is the coordinator of SFB/TRR 21. "In our former quantum gas research group we were only focusing on one aspect of the current Collaborative Research Centre though," he says, "and that was the physics of cold atoms."

Tilman Pfau's research in SFB/TRR 21 is still centred on Bose-Einstein condensates. In a world-wide first, his working group at the University of Stuttgart succeeded last year in condensing chromium gas at a temperature of 700 nanokelvins from more than 50,000 chromium atoms, and subsequently even from twice that number. Although Albert Einstein had predicted the phase transition from "regular" matter to a Bose-Einstein condensate as early as 1925, the experimental confirmation was not to happen until many decades later. Only laser cooling – recognised with the 1997 Nobel Prize – made it possible to cool atoms in the gas phase down to about 10 to 100 microkelvins. Since they are already quite motionless at this level, moving only a few centimetres per second in the gas cloud, atoms can be collected individually by physicists using magnetic or optical traps, and chilled even further to just a few 100 nanokelvins with a technique called evaporative cooling.

And then, close to absolute zero, it happens: atoms lose their independence and behave as one single quantum-mechanical object. Their classic manifestation as individual, distinguishable particles suddenly flips into a new state of matter with collective, quantum-mechanical wave behaviour – in a Bose-Einstein condensate, atoms become indistinguishable. Characteristic is the coherence of the wave behaviour, meaning the uniform wavelength throughout the entire extension of the condensate, along with the formation of entirely new properties of matter. Physicists have suspected for a while that this fundamental difference to "regular" matter might be the basis for macroscopic quantum phenomena such as superconductivity or superfluidity. "Our Bose-Einstein condensates of chromium atoms, for example, showed ferro-



Tilman Pfau

Experimental setup at the 5th Institute of Physics, University of Stuttgart: It allows Tilman Pfau and his team to transform 100,000 chromium atoms into a Bose-Einstein condensate. The top right part of the picture shows the laser beam being reflected into the vacuum chamber for cooling.

magnetic properties," reports Pfau. He suspects that chromium condensates may at some point be used in nanotechnology as a source of atom lasers to deposit individual atoms on surfaces, with high resolution.

Ultracold atoms, quantum gases, Bose-Einstein condensates – this is just one of 14 projects in SFB/TRR 21. "In a sense we're approaching from two sides the middle of a bridge that we're building between atomic physicists and solid state physicists," says Tilman Pfau. Because once the conversation got underway, it quickly became clear that "the physics of atoms and of mesoscopic systems with object dimensions of 10 to 100 nanometres, which are also ruled by quantum effects, are actually quite similar."

The common goal of the various physics disciplines in SFB/TRR 21 is to utilise the partially complementary control options in order to direct multi-particle quantum correlations and use the commonalities of mesoscopic systems and quantum gases to find new states of matter, generate new dynamic quantum states, understand scaling behaviour from few-body to many-body systems, manipulate and investigate the effects of decoherence, and control light-matter states.

In fact, several successful attempts have been made in recent years to control quantum gases as interactive quantum matter in very well-defined geometries and at ultracold temperatures. "With our supercomputer at the University of Stuttgart, we can also simulate the interaction between particles," says Alejandro Muramatsu from the University of Stuttgart, another SFB/TRR 21 project leader. But he also points to the limits of theoretical virtual analysis of quantum matter: "When it was installed a year ago, our computer was the fastest one in Germany and, in its capacity as a vector computer, the fastest supercomputer in Europe – and still it only manages to show the behaviour of 36 particles."

The SFB/TRR researchers are confident that the techniques and methods from solid state physics will enable them to assemble quantum matter like in a Lego system. "I can't wait to see how the experimental findings are going to compare to our calculations," says Wolfgang Peter Schleich. "What is it going to look like for 30 particles? Will the experiment and the calculation arrive at the same result for 35 particles? And then, of course, I dream about new experimental territory – 40 particles, 50 particles, 100 even."

The optimistic faith in being able to strike lucky and make new discoveries in the no man's land between micro- and mesocosm is due to the fact "that after our initial talks across the intra-scientific cultural boundary we quickly realised we were already holding the necessary tools in our hands," says Reinhold Kleiner. "It took us a bit of time to see that, but once we did, it certainly electrified us." "Each community really has its own history and developed over time a shared understanding of the underlying physics," explains Pfau. "So if together now we learn how the other side looks at these things, we all benefit – and that's an added value this Transregional Collaborative Research Centre is going to generate." "And it's not just about mutual understanding – our techniques are different too, each community has its own methods," adds Kleiner.

Tilman Pfau and his colleagues therefore concluded that they needed to go out of their way in SFB/TRR 21 to establish a new basis of understanding among physicists. This entails, for instance, that doctoral researchers are required to spend at least one week on one of the other community's projects – collaborating, learning about other mindsets and methods, and finally giving a talk about their experience. "We're hoping that the euphoric enthusiasm that has gripped the project leaders will also catch on at the level of our doctoral researchers," says Pfau.

. *Dieter Beste*

Archaeology of Remembrance

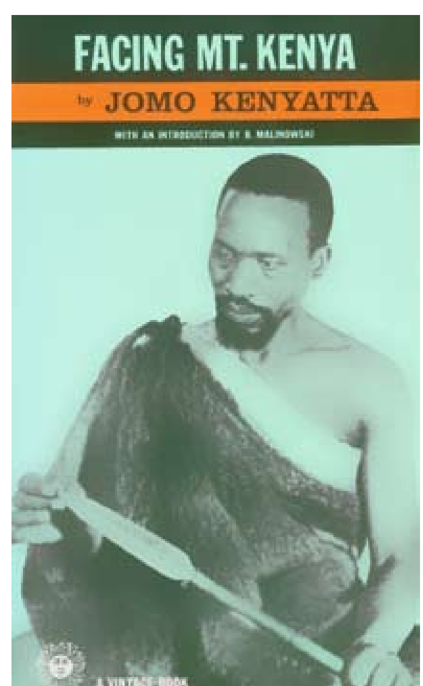
One of the most intriguing triggers of memory in literature is a piece of cake dunked in tea, a madeleine. An aunt used to give it to the narrator when he was a child. In Marcel Proust's novel *In Search of Lost Time* (1913), this experience is repeated many years later, and suddenly "all the flowers in our garden and [...] the good folk of the village and their little dwellings and the parish church [...] sprang into being [...] from my cup of tea."

People prefer not to rely on their mental memory alone, or on coincidences of the sort encountered by this novel's protagonist. Rather, they use mnemonics such as photo albums, travel souvenirs – which have become commercial mass products – or an heirloom pocket watch. This topic was explored in an exhibition about "The Souvenir", in the broadest sense of the word, which was put together by the SFB 434 "Memory Cultures" at the University of Gießen and presented in 2006 at the Museum of Applied Arts in Frankfurt. It documented individual and collective efforts to outwit forgetfulness, be they serious, trivial, tacky, nostalgic or bizarre. In the Middle Ages, pilgrims brought relics home as keepsakes. In the 18th and 19th centuries, hair locks were artfully woven, braided and framed to commemorate a deceased lover. Other mementos symbolise political upheaval: models, made circa 1880, of the Bastille, the storming of which had unleashed the French Revolution; or chunks of the Berlin Wall, which were sold in the streets after the reunification of Germany.

Historians, by definition, are professional rememberers, chroniclers of previous events. Art and literary history also look back to the past. "In the nineties we saw a shift in the humanities," reports historian Jürgen Reulecke, who heads the SFB. "On the one hand there was textbook history. But now there was suddenly an interest in people's experiences within their particular *Zeitheimat* [home in time]." After the SFB was founded in 1997, it developed into something like an engine of this trend.

The researchers investigate the question: "Who remembers what, and how?" – and their scope spans all the way from antiquity to the present. To be sure, memory is first of all something subjective and intimate that happens inside a person's head. But "it never occurs in a vacuum," says English literature scholar Birgit Neumann, who coordinates the SFB together with Reulecke. Memories are tied into social, religious, cultural, ethnic, generational and gender-specific contexts. "And transporting them effectively across generations requires the use of media." These include not only "things", as the exhibition in Frankfurt called them, but also spoken and written language, images and sounds, rituals, ceremonies, and performances. Over time, technological revolutions changed the media and, by extension, the character of the memories. This is the topic of the work groups, where young researchers feature prominently and which serve as a collaborative forum for the representatives of the 20 projects.

Memories are even a factor where one would not expect them to be. Sociologist Andreas Langenohl focuses on an industry that actually specialises in anticipating the future – financial trading. He asked analysts and fund managers about the significance of the past and of memory in their day-to-day work. Of course they use chart techniques, which serve to forecast price development on a mathematical basis, to forge their strategies. They also consider the history of individual companies and their stock performance, because they have to justify any recommendations and decisions to their investors. "But every trader is also aware of the earliest incidences of speculative bubble bursts – the Dutch Tulip Mania of 1636 and the South Sea crash of 1720 in London." Not to mention more recent events that impacted the stock markets: the first Iraq War, the boom of the 1990s, the collapse of the New Economy hype in 2000. Langenohl thinks it peculiar that professional inves-



Winfried Speitkamp

Staged tradition: former Kenyan president Kenyatta in Kikuyu garb.

Axel Schneider / Museum of Applied Arts, Frankfurt

In friendship albums, similar to today's autograph books, good friends immortalised themselves with dedications. The one in the picture, from 1792, belonged to one Johann Gottlieb Krantz.

tors, in keeping with the principles of stock market guru André Kostolany, expect prices to rise in the long term based on the real economy – while on the trading floor, they're all about quick reactions, buying and selling rapidly. Their decisions follow the assumption that the other investors are also guided by previous crises, rumours, or success stories.

"We purposely chose the plural of the word 'culture' for the name of our SFB," explains Reulecke, "because it implies the changeability, diversity, and conflicts of memory." Financial experts remember the Iraq War differently from the Iraqis, who in turn remember it differently from US soldiers. And population groups everywhere are at odds about what is worth remembering in the first place. Taboos are common, and so is repression. The crimes of the Nazi regime, for instance, did not fully enter public awareness until the youth rebellion of the 1960s, after Germany was rebuilt – this too is the topic of an SFB project. A case in point of how difficult this remains for Germans is the construction of the Holocaust memorial in Berlin, which, among other controversies, raised the question of whether there is a "hierarchy of Nazi victims", as the magazine *Der Spiegel* put it. "At first, of course, the victims were the Jews, the Sinti and Roma, the population of the occupied territories, and the persecuted," says Reulecke. Forgotten to this day, however, are those who experienced World War II as children and who – unlike expellees, for example – have no lobby. In 2005 the SFB cosponsored a conference about "The Generation of War Children", and one SFB project examines the traumatic experiences of these "children without fathers".

Especially the radical upheavals of the last hundred years have given rise to conflicted memories. In cooperation with the Hebrew University in Jerusalem, Reulecke investigates, in another project, the cultural shock that young German Jews underwent when they emigrated to Palestine. Back when they were involved in the Weimar Republic's youth movement, they would "naturally hike through the German forests in Wandervogel groups". The scholars try to find out which notions they took with them to the foreign world.

A different confrontation of two cultures occupies historian Winfried Speitkamp. He examines how people in colonial and post-colonial East Africa reflected on their life histories and how in their memories the values, norms and attitudes of their colonial masters merged with their own. The encounter also shaped their notion of tradition, because between the experience of childhood and its remembrance lies a long period filled with new impressions. Among them, says Speitkamp, is interestingly also the influence that the critique of Western civilisation had on Africans in the early 20th century – it led them to construct a mythicised image of their own roots. In the colonial era, tradition furthermore became an instrument for politicians in their fight for national independence. Former Kenyan president Jomo Kenyatta (circa 1892 to 1978), for example, wrote his master's thesis in London about the Kikuyu people. When it was published in 1938 as the book *Facing Mount Kenya*, the cover photo showed him sporting traditional dress. "In real life, of course, he wore a suit."

Speitkamp's sources are mostly autobiographies. Obadiah Kariuki, bishop of the Anglican Church in Kenya, recounts in his memoir (1985) how he rose from a goat herder to a respected church elder. He explores the values of Western and traditional religion and culture, ultimately defining his own position in today's Africa as a synthesis of both. "Many others like him have constructed narratives of their lives that gave them meaning and identity," says Speitkamp.

Before long, the SFB will be able to remember its own history. When the 12-year funding period ends in 2008, the scholars will have a cornucopia of results to show for it: a wide range of books, including a special series with 27 volumes to date; an interdisciplinary series of countless lectures by guest presenters for Gießen audiences with intellectual interests; as well as intense collaborations with Jerusalem, with Cornell University in Ithaca, New York, and with European institutions. "What's exciting," says Reulecke, "is that the topic still won't be exhausted when the SFB is over." He is convinced that the younger generation of researchers will continue to follow the traces of remembrance. *Marion Kälke*

The Mystery of Properties

Their number is legion: 2,288 steel grades are currently listed by the European Steel Registry alone, and that does not even include proprietary grades and steels according to non-European regulations. The number of grades reflects the spectrum of properties that this material may exhibit – differences in hardness, toughness, or malleability, to name a few. "Isn't it strange that all these different properties emerge from almost the same chemical composition?" asks Günter Gottstein, head of the Department of Physical Metallurgy and Metal Physics at RWTH Aachen University, and goes on to answer his own question: "It's not chemistry but physics that determines the properties of steel – the microstructure, the spatial distribution of elements, the crystal structure, but also defects in the crystal lattice."

Günter Gottstein is the coordinator of Transfer Project 63 "Industrially Relevant Modelling Tools", a 3-year undertaking at RWTH Aachen that began early in 2006, following the conclusion of SFB 370 "Integral Materials Modelling". It pursues joint projects with manufacturing businesses to exploit basic research findings for industrial applications and test their essential feasibility, but also to feed new or farther-reaching research issues back to the university. For 12 years, the SFB had focused on developing a "through-process simulation of materials".

Steel, for instance, is an alloy of iron and carbon, to which other elements such as nickel, chromium, manganese or titanium may be added in varying percentages. The tricky part: "Composition allows us only vaguely to predict the properties of a material," says Gottstein. "To do so with any precision we need to know its particular microstructure, which unfortunately comes in a wide variety at the atomic level. Not only that, it also continually changes along the process chain during material production." On the one hand, this multitude of microstructure states enables engineers to achieve a wide range of properties with one and the same material by setting process parameters accordingly. But on the other hand, this delicate dependence of microstructure on the material's individual production history is a veritable nightmare for developers who want, as Gottstein puts it, "to tailor materials".

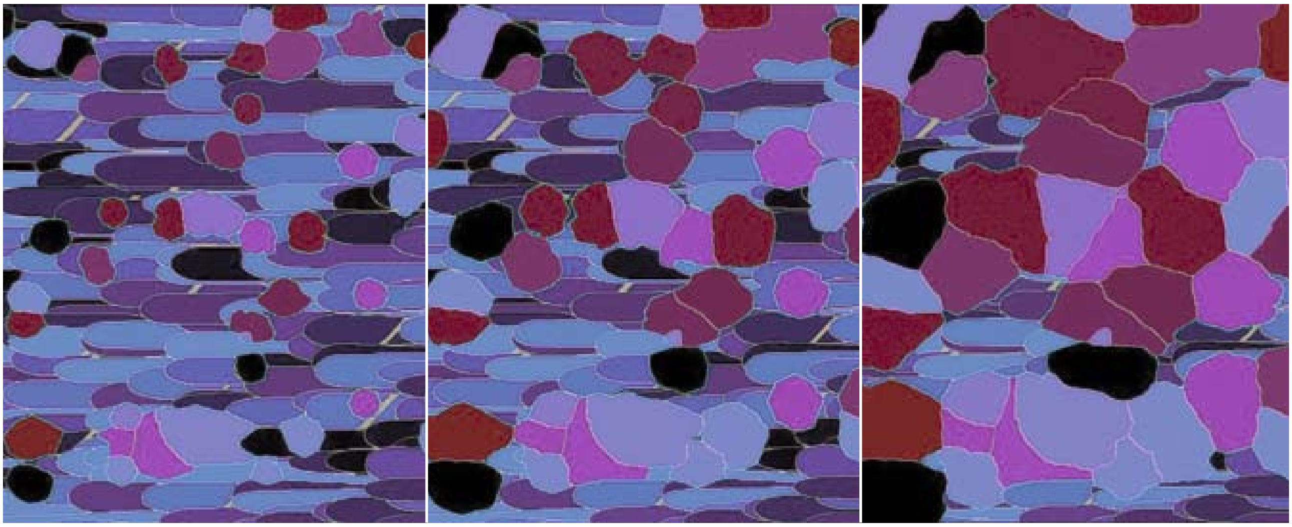
"The idea for our Collaborative Research Centre was born when it became clear that the performance of computers could be expected to continue its dynamic development going forward," remembers Gottstein. In the 1980s and 1990s, when the opportunity emerged to use numerical methods to perform complete calculations of scientific models and to create simulations at affordable costs, it was eagerly seized, not least by materials scientists. "Before that," says Gottstein, "we had to keep our models simple to capture them, say, in a differential equation." But unfortunately, in a complicated environment like materials science, these equations usually did not have a closed form solution; therefore "we often had to make do with upper and lower limits," he adds.

"We were able to calculate changes in the microstructure of materials along process chains."

When SFB 370 began its work on 1 January 1994, the researchers in Aachen, who had already collaborated on various projects within the RWTH Materials Science Forum, were optimistic that computers were going to help them arrive at results that to date had been considered impossible. The challenge was to shorten the customarily long development times in materials science – it can easily take 10 or even 15 years for a product to make it from the lab to the market. Because of the complicated, nonlinear dependencies, scientists have to formulate empirical relationships between process conditions and material properties – "and this requires an endless number of test series," adds Gottstein, "many attempts that may well fail, the development of pilot production facilities to evaluate process feasibility, and finally the effort to optimise a material's qualities for its specific application."

The industry's increasingly shorter product cycles and rising costs provided additional motivation for basic research scientists to look for remedies. The SFB had a clear strategy for tackling the issue of long development times: theoretically describe the physical laws underlying microstructure development along the process chain, and pass on critical microstructural state variables from process stage to process stage, until finally arriving at the end product's microstructure, which determines its properties.

During the SFB's initial three years, the focus was therefore on formulating physical models and choosing suitable simulation methods. "In the second phase, we then developed simulation codes and customised them for specific materials and product lines," reports Gottstein. The third SFB stage was dedicated to linking the microstructure models with each other and combining them with the process models. For example, in a certain time interval during the hot rolling of an aluminium sheet, the simulation modules for phase transformation, recrystallisation, crystal plasticity, and texture had to be interfaced interactively and integrated into finite



Screenshots: Mediakonzept

Image sequence of a recrystallisation process simulation. Online demonstration at: www.imm.rwth-aachen.de/hp/institut/fg/sim/welcome.htm

element programmes. In the last SFB period "we then defined specific materials and components whose properties we wanted to predict" reports Gottstein. A steel component was selected, namely a bracket made from carbon steel; in addition, an aluminium sheet, which was to be moulded with a deep drawing technique; a turbine blade made from a nickel-base superalloy, with a surface that had to be coated; and a pipe fitting made from the plastic polypropylene.

"We were able to describe property relations along process chains on the basis of microstructure and calculate, in models, changes in the microstructure," says Gottstein, summarising the SFB's accomplishments. What this means for the practice of material development is clarified with an example by engineer Sonja Stratemeier from the RWTH Department of Ferrous Metallurgy. She recounts her attempts to apply an SFB-developed programme for simulating the solidification of melt to the solidification processes in continuous casting. To predict the grain growth of solidifying steel crystals – primary austenite in this case – she uses a semi-empirical model: with a laboratory mould, she adjusts various cooling conditions as she calculates the parameters of solidification and microstructure. Her conclusion: "Through further development of the simulation programme and the grain growth model, it will be possible to adjust the microstructure in the continuous casting process directly."

Dieter G. Senk, chair of iron and steel metallurgy at the Department of Ferrous Metallurgy and chairman of the RWTH Materials Science Forum, in which 56 professors work together, helps to practically implement SFB research findings in Transfer Project 63: "We collaborate with a total of 16 companies, most of which were already involved in joint projects during the SFB period," says Senk. "Long development times are a big issue with material producers." It is usually large industrial companies that have recognised the economic potential of the Aachen-made modelling tools and therefore contribute their own personnel and laboratory resources to transfer projects, along with the financial investments this entails.

"The transfer of our SFB research on the coated turbine blade also involves smaller companies, but we've noticed that it's really not that easy for small businesses to free up personnel for this task," reports Senk. "On top of that, the modelling tools that we make available to our partners via the internet are not that easy to operate. At the moment, a lot of time still goes into the employees at our partner firms learning the ropes." "You also have to understand, first of all, what it is that these tools do," adds Gottstein. "And that's why we meet very frequently right now," says Senk. "Also, we want to get to know our industry partners better, because after all, we have to do the experimental work together, which of course means there can't be any miscommunication between us scientists and the developers in the industry."

"When we started working on the transfer project, we considered very carefully which practical industry issues we should tackle," says Günter Gottstein. Together with seven industrial businesses, the Aachen-based researchers worked on challenges such as predicting local mechanical properties in welds; and together with a major aluminium manufacturer, they set out to simulate the properties of certain alloys through a number of steps – hot rolling, cold rolling, and multi-stage annealing. "We want to test the capabilities of our modelling tools, and from that angle, of course, it's a lot more interesting not to predict properties you already know from experience, but to focus on critical points that can abruptly change a material's properties. That our tools are capable of doing this is what we're trying to show." *Dieter Beste*

Interview

A Collaborative Research Centre Pulls People Together

Ursula Gather is the coordinator of SFB 475 "Reduction of Complexity for Multivariate Data Structures" at the University of Dortmund. For nine years, statisticians have been collaborating here with computer scientists, mathematicians, medical scientists, economists and engineering scientists, mostly from the University of Dortmund, the Institute of Occupational Physiology and the Surgical Clinic, both in Dortmund, and the Institute for Economic Research in Essen. The SFB aims to develop and implement new statistical methods to analyse complex data and model difficult cause-and-effect relationships. For example: How can vital information be extracted from the numerous data streams that an intensive care bed's alarm system delivers online?

? *How did the various project groups end up together nine years ago?*

! The motivation was, of course, a scientific one. In the beginning, there was the realisation that the classical methods of data analysis and statistical modelling were no longer adequate for the complex issues we encounter in the applied sciences. But because many data analysis problems in the life, economic and engineering sciences are structurally similar, we wanted to bring them together under the umbrella of statistics and thus create a new type of statistic methodology and procedures. The specific projects came together in part also because there were excellent researchers available for these areas in the Dortmund region. We started out as a small core group already with experience cooperating with one another and then gradually expanded from there.

? *Was it challenging to get the communication going between all the participants from different subject cultures?*

! The SFB as a funding instrument requires evidence of interdisciplinary collaboration. A group of researchers sets out to pioneer breakthroughs, both in their own field and across disciplines, that would otherwise be virtually impossible. When everybody gets ready for a review, it pulls people together. You're only going to make it as a team.

But we've also created structures that force collaboration and communication. Each project has two leaders from different disciplines, and each methodologist also heads an application project. This way, nobody stands alone, and each area has several caretakers. In the beginning, we also promoted continuous exchange. For example, we held periodic retreats, and quite a few good ideas were born there at the dinner table. Our young researchers organised topical discussion circles. In addition, we have exciting related events going on in Dortmund, such as workshops, guest lectures, or colloquiums. This makes it fun for everybody to think outside the borders of their subject. It's how we avoid creating islands.

Our policies regarding resource allocation, scheduling, responsibilities and documentation were all openly and jointly agreed on so that we don't get much friction in our day-to-day work. The researchers understand that they strengthen both their own position and the project when they work hand in hand.

? *What was the effect of personnel changes, which are bound to happen when a project extends over many years?*

! Well, you have to change to survive. In each funding phase we adapted to new challenges by including new projects, for example on gene expression data, or by adjusting to the fact that the lines between certain areas were beginning to blur, by appointing young researchers as project leaders, integrating new colleagues with interesting specialities and by anticipating upcoming retirements. Whenever a colleague receives an offer from another institution, it's both regrettable and an honour, although our retention negotiations have usually been successful. And for young researchers, it means that the SFB is seen as a springboard to success, even internationally.

? *And what will happen after the SFB concludes in 2009?*

! Of course we'd like to build on our findings. There are already two transfer projects associated with our SFB, where we work with industry partners to create practical implementations of our results. We plan to continue along these lines. In addition, there are a number of basic statistical problems that persist. An ongoing challenge, for example, is the "curse of dimensionality", meaning that none of our traditional methods work for high-dimensional data structures. There's no one way to overcome this challenge; rather, we have to tackle it with specific new approaches depending on the given data structure. There's plenty of material here for exciting future projects.

Interviewers: Dieter Beste and Marion Kälke

Collaborative Research Centres: Essential for Basic Research and Transfer

Bernd Huber, rector of Ludwig-Maximilians University in Munich (photo left), and Burkhard Rauhut, rector of RWTH University in Aachen, discuss the timeliness of Collaborative Research Centres and talk about current challenges.

Huber: Collaborative Research Centres are the most important instrument for implementing and consolidating basic research at universities, thus being able to continually focus on new topics. In addition, SFBs are critical for strengthening excellence in academia. Given tight public finances, SFB funding is also ultimately the only way for a German university to successfully compete in international research. Furthermore, SFBs help promote young researchers and encourage networking across disciplines, which is important to tap any potentials that may be found where disciplines intersect.

Rauhut: I can only agree here. When it comes to basic research, SFBs are an indispensable instrument. This is particularly true for the technological disciplines, as we hardly obtain any support from industry for basic research. However, we do need basic research in order to feed into the proverbial pipeline something that may become a relevant innovation for industry 15 or 20 years down the road.

Huber: I think there is no argument, and it has been known for a while, that our shortcoming in Germany, and probably all of Europe, is that the conversion of research findings into economic activity and products takes too long. Then again, I believe we also have to be careful not to adopt a simplistic view – put money in the slot of the vending machine, meaning the SFB, and expect a market-ready commercial product to pop out at the bottom.

Rauhut: Naturally these chains are far more complicated than that. But then an SFB may run as long as twelve years. The way I see it society is entitled to expect a return on its investment in research, even though the focus may be on basic research. In my opinion, it was a logical step for the DFG to not only fund the basic research of SFBs, but also the real-world application of results in Transfer Units – working with business, for example, to implement newly developed technologies. Society's demand for a transfer of research findings is something that SFBs that deal with the humanities should consider as well.

Huber: But I do think we have to understand that researchers, first and foremost, want to do research and are not necessarily interested in thinking about the practical uses of what they do. I do agree that the transfer concept is important and correct. However, it should not cloud our view. At their core, SFBs should be about strengthening scientific excellence and working toward new scientific insights, initially without any specific purpose.

Rauhut: I think it is great that the promotion of collaborative research in SFBs continues to spur scientists' curiosity again and again. In that sense it's actually quite smart that an SFB ends after a maximum of twelve years. As researchers we do not only wish but also ought to continually tackle new topics all the time. So far, so good – the current government-sponsored Excellence Initiative does show how copiously the fountain of ideas flows. But for our universities this also means that DFG-funded SFBs tie up university resources to boot. And the more successful a university's researchers are in attracting SFB funds, the more of the university's own money has to be earmarked.

Huber: More SFBs are desirable. But to better empower universities, the DFG will have to increase SFB funding.

Rauhut: For this reason, we intend to ask the federal and state governments to make more money available for SFB funding, and this in the short term, not only four or five years from now. There is an agreement on this issue among the members of the German Rectors' Conference.

Huber: Many high-quality funding proposals for clusters of excellence and graduate schools, which were submitted within the Excellence Initiative of the Federal and State Governments and might have to be turned down, would actually make great starting points for SFBs.

Rauhut: To make a long story short: We need more money for good university research in Germany – not least to salvage all those great ideas that have been and are still being generated under the Excellence Initiative.

Moderator: Dieter Beste

Collaborative Research Centres
Facts and Figures

Collaborative Research Centres (Sonderforschungsbereiche, SFBs) are long-term university research centres in which scientists and academics work together within a cross-disciplinary research programme. In addition to promoting excellent research in networks, the development of core research areas in universities is an important structural objective of the programme.

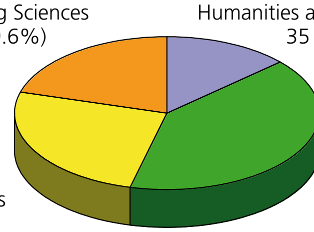
Under the SFB programme, funding is also provided for variations of traditional SFBs: Cultural Studies Research Centres (SFB/FKO) and Transregional Collaborative Research Centres (SFB/TRR); and for supplementary programmes: Transfer Projects (TFP) and Independent Junior Research Groups (SFB-NWG). All programmes support and encourage international cooperation.

SFBs total	270
Thereof variations:	
SFB/FKO	4
SFB/TRR	36
Supplementary programmes:	
TFP	15

Number of SFBs/variations/supplementary programmes currently funded

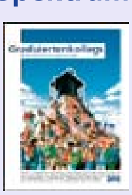
State	Number of SFBs	% of all SFBs	Number of universities with SFBs
Baden Württemberg	44	16.3	9
Bavaria	41	15.2	7
Berlin	27	10.0	3
Brandenburg	2	0.7	2
Bremen	6	2.2	1
Hamburg	6	2.2	1
Hesse	20	7.4	5
Lower Saxony	21	7.8	7
Mecklenburg-Western Pomerania	3	1.1	2
North Rhine-Westphalia	66	24.5	11
Rhineland-Palatinate	9	3.3	2
Saarland	2	0.7	1
Saxony	10	3.7	3
Saxony-Anhalt	3	1.1	1
Schleswig-Holstein	5	1.9	2
Thuringia	5	1.9	2

Since the inception of the programme in October 1968, a total of 728 SFBs have been funded. Currently, 270 SFBs receive a total of € 419.5 million in funding for personnel, consumables and equipment.

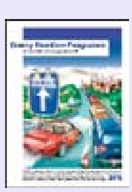


Distribution of currently funded SFBs by discipline

Previously published in Spektrum der Wissenschaft:



Research Training Groups of the Deutsche Forschungsgemeinschaft, Spektrum der Wissenschaft, July 2005



Promoting Excellent Researchers Today for the Science of Tomorrow: The Emmy Noether Programme, Spektrum der Wissenschaft, January 2006

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