german research

Magazine of the Deutsche Forschungsgemeinschaft

3/2009 ▶ In the Virtual Realm of the Myrmecologists ▶ It´s Never Too Early To Ask Questions ▶ Changing the World with Müsli ▶ Inspired by Nature ▶ Going Under the Knife with Mathematics

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Cooperating in the Patients' Interest

Oral and maxillofacial surgeons try to help people by performing operations. When preparing these operations, they are increasingly cooperating with mathematicians, who devise highly complex differential equations and three-dimensional visualisations to assist them in their work. **Page 24**

A Revolution on a Nanoscopic Scale

Novel metamaterials are inspiring physicists' imaginations and the use of "photonic atoms" is leading to novel optical applications, opening up a path to previously undreamt-of innovations. **Page 27**

Cover: Martin Pfeiffer

Fascinating Species Diversity

The nocturnal giant forest ant *Camponotus gigas* can grow to be as long as three centimetres in length. It lives in amongst fallen leaves on the forest floor of the South-east Asian rainforest – a habitat for hundreds of species of ants, many of them previously unknown. **Page 18**

Does life begin in the test tube? Can organisms be created in retorts? Could scientists be playing God? These and other questions are often raised whenever the new research field of synthetic biology is mentioned. We are also hearing reports that it is now impossible to imagine biomedical basic research without synthetic biology and that it will liberate tremendous economic forces. Very different perspectives, therefore, on a new discipline which is causing a commotion, both at home and in the international arena.

What is synthetic biology, and what are its aims? First and foremost, synthetic biology is a truly interdisciplinary branch of research based on the principles of engineering and molecular biology and incorporating topics and methods from medicine, chemistry, biotechnology and IT. It enables, for example, biological components, such as larger gene regions, to be specifically created in order to form cells with new properties. This allows the generation of completely new structures not found in naturally occurring organisms. Perhaps it does, after all, smack just a little of Frankenstein.

In any case, it is clear that a new scientific discipline like synthetic biology raises questions concerning the boundaries of science, its underlying ethical issues and the safety issues involved. Not only is this discussion both legitimate and predictable, it is also extremely useful and necessary.

Against this backdrop, the DFG has, together with the German Academy of Science and Engineering (acatech) and the German Academy of Sciences Leopoldina, recently issued a joint statement discussing the principles, opportunities and risks of synthetic biology. This document is well-timed. Even though synthetic biology is still a new field, it can never be too early to discuss the risks it poses and the opportunities it offers.

Firstly, the statement tackles the research fields involved in synthetic biology – and addresses the specifics of this new discipline. One of the capabilities on which synthetic biology is based is that of synthesising larger DNA fragments with several thousand components under lab conditions. These fragments can then be introduced into microorganisms in order to give them new properties or characteristics, enabling them, for example, to gain energy through new processes or to eliminate toxic substances. Organisms with new properties are, therefore, already being created – if not in retorts, then in the lab.

On the other hand, the genomes of microbes can be reduced so far that a "minimal genome" can be defined. This "minimal genome" serves as a "chassis" onto which new gene fragments can be mounted. Furthermore, the methods of synthetic biology are used to combine metabolic pathways in new ways, enabling new biomolecules to be produced – such as, for example, the preliminary stage of a malaria drug – which can then be processed further. Synthetic biology also facilitates the production of molecular machines or cellular constructs with new properties, known as "protocells", and allows the construction of regulatory circuits using natural genetic ranges or the addition of "orthogonal systems", which represent modified molecular machines. Synthetic biology is therefore, opening up a whole range of new avenues – and others will soon follow.

Jörg Hinrich Hacker

It's Never Too Early To Ask Questions

Synthetic biology is a new field, but the opportunities and risks need to enter public debate now

What effects do these new methods have? On the one hand, they enable important questions in basic research to be addressed – some of which it has not, until now, been possible to tackle, or only incompletely. It is now possible to ask how many and which genes an organism needs to survive – the question "How many genes are required to sustain life?" has suddenly become current. It allows scientists to test their hypotheses on modifying the universal genetic code – is it, in fact, possible to modify the building blocks of life? Genetic circuits can be used to study the control systems for life processes. These can, for example, be used to determine cell growth dependencies or to study differentiations in the occurrence of particular signal substances. All in all, molecular biological basic research will soon be unable to progress without the wide range of methods introduced by synthetic biology. And all this ultimately takes place in the lab, i.e. in a test tube.

Illustration: Himsel

Furthermore, it is already possible to say that synthetic biology is both economically relevant and will, in future, increase tremendously in economic significance. Working groups developing new medications, vaccines or gene therapy procedures are no longer able to proceed without the new methods. In addition, many forward-looking processes, including, for example, the production of fine and industrial chemicals, the development of new biofuels or the synthesis of new materials, will also benefit from this new field.

Naturally, the numerous opportunities offered by this new technology also pose questions about the risks involved. Are there specific problems relating to biosafety and biosecurity?

It is, first and foremost, important to bear in mind that many synthetic biology projects are based on the further development of genetic engineering processes and as such, are covered by the Gesetz zur Regelung der Gentechnik [the German Genetic Engineering Act]. No particular risks have yet been identified in this area. It would, however, appear sensible to verify the sequences of larger DNA fragments with regard to their potential abuse, for example for biological weapons. A central database could be created to do this. Otherwise, the products created through synthetic biology are, of course, subject to the legal requirements which currently regulate the production and proliferation of toxins and pathogens. In any case, performing ongoing security research in accordance with the precautionary principle is both sensible and appropriate.

Last but not least, there are the ethical implications. Are boundaries being breached? Are scientists really playing God? These questions are legitimate and it is important to keep them in focus.

Synthetic biology has, however, by no means yet reached the stage at which organic life could be created under lab conditions. The characteristics of organic life – independent reproduction, autonomous metabolism, evolution capabilities – have not yet been achieved; and they may never be. And yet, the potential risks must be weighed up and ethical issues must be raised – and this must be done in public. In this respect, a wide-ranging discussion of the opportunities offered and risks posed by synthetic biology is to be welcomed. And it would be good for science if, to paraphrase Brecht's Galileo Galilei, synthetic biology were to "emerge into the market place". If the statement prepared by the DFG, acatech and Leopoldina were to succeed in bringing this about, much will have been achieved.

Prof. Dr. Dr. h. c. mult. Jörg Hinrich Hacker served as Vice President of the DFG until July 2009. As such, the microbiologist from the University of Würzburg was significantly involved in the preparation of the "Stellungnahme zur Synthetischen Biologie" ("Statement on Synthetic Biology"), which was prepared by a joint working group comprising members of the DFG, acatech and Leopoldina under the direction of Dr. Bärbel Friedrich (Humboldt University of Berlin). Hacker has been President of the Robert Koch Institute in Berlin since March 2008.

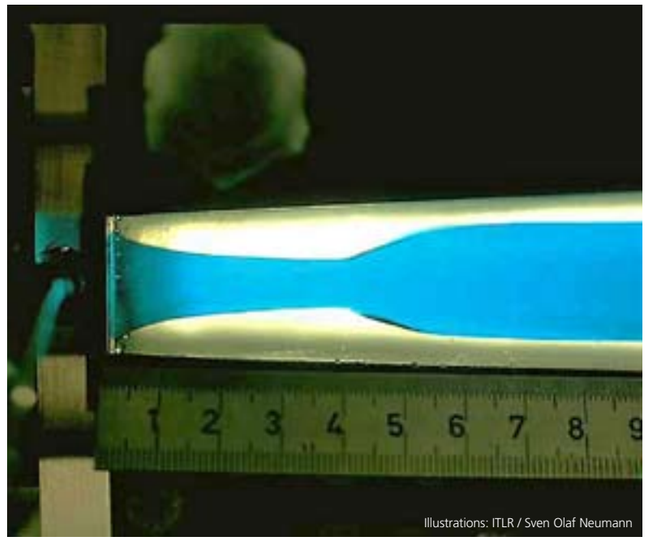
An engineer's dream:
the shape of a circumflowed object is optimised by the ice formation method, thus facilitating the design of new machine components

Inspired by Nature

By Bernhard Weigand, Sven Olaf Neumann, Helga Steinbrück and Sebastian Zehner

Illustration: Niggli

If you go for a stroll in winter after a rainy and frosty night, you will discover all sorts of picturesque coatings of ice on trees, masts, power lines and other objects. In mountainous regions, frozen streams and brooks are lined with unusually shaped ice sculptures. If you break a block of ice out of the surface of a frozen lake and turn it over, you are in for a surprise: the underside of the ice block is not smooth like the top surface, but has a distinctive structure with small bumps and depressions. These



Illustrations: ITLR / Sven Olaf Neumann

Left: A small brook with characteristic ice deposits along the edges. Right: Formation of ice (white) in a flow channel. Nature on the left, technology on the right – the similarity between the two structures is clearly apparent.

phenomena, which are surprising and remarkable at first sight, are also interesting for researchers and they lead to a basic question: how did these natural ice formations get their shape?

Engineers have known for a long time that the surface topology of a frozen body results from interactions between the flow of the surrounding medium, the object's geometry and the ice itself. This knowledge was already used 30 years ago by researchers in the USA who wanted to find out whether the obvious optimisation capabilities of nature could be exploited to create more efficient designs for technical applications. This approach was developed into a process that imitates nature and is aimed at finding the optimum shape for circumflowed objects: the ice formation method.

In this experimental method, a particular object, such as a cylinder or a turbine blade, is cooled to a temperature below the freezing point of water so that it becomes covered with a uniformly thick layer of ice. The iced object is then exposed to flowing water. The scientific explanation of the ice formation method is based on coupling between so-called momentum- and heat-exchange and their interaction with the wall consisting of a solidified phase (i.e. ice) whose contour is determined by a local thermal equilibrium.

> Optimisation capabilities of nature can be exploited to create more efficient designs for novel, creative technical applications

This means that the ice layer on the object melts away and remains thin in regions that are exposed to the current and a very intensive heat transfer – the front edge of a cylinder, for example. This melting sculpts the originally uniformly thick ice layer into a new shape, which is then resculpted by the current. When the shape of the ice layer has stopped changing, the resulting contour is precisely measured.

Although various boundary conditions, such as supercooling of walls and the flow rate, lead to different body contours, they all exhibit similarities in their "construction plan" (topology). Water flowing past a flat plate covered with a uniform layer of ice produces contours that grow continuously in the direction of flow. The absolute thickness of this layer differs depending on how fast the medium flows past the object. However, the shape of the ice layer remains similar. Analysis of the resulting shape reveals favourable body contours for the particular flow characteristics. These contours are especially efficient with respect to the lowest possible transformation rate of kinetic flow energy into friction losses because nature always tries to attain the state with

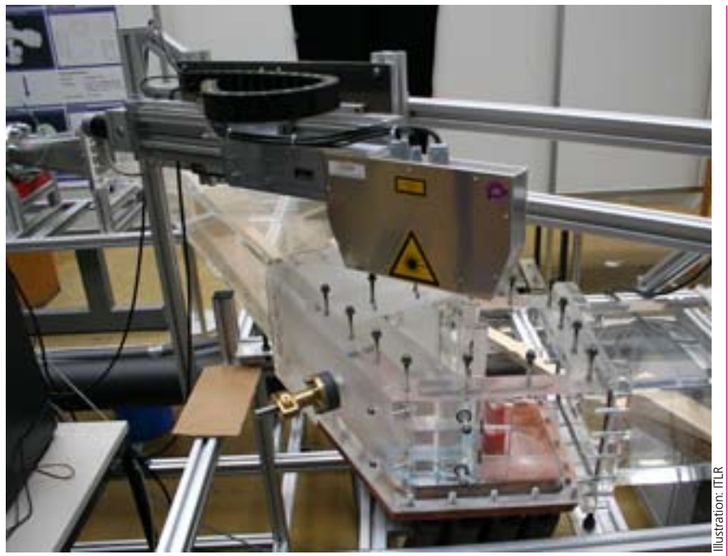


Illustration: ITLR

Left: Laboratory setup used for highly precise measurements of the ice layer thickness with a light-stripe sensor. Bottom: The laser stripe is clearly visible on the ice contour.

the lowest energy. The contour thus represents a good compromise between the maximum applicable flow resistance of the object and the minimum heat transfer at the object.

In practical applications, however, engineers are often interested in other optimisation criteria. Many components of modern jet engines or stationary gas turbines are not only subjected to extremely high temperatures, the maximum overpressure for flow through these components is limited by the machine. It is thus of primary importance to use the pressure difference or the heat transfer as the optimisation criterion in order to minimise them. In view of this, body contours obtained by the ice formation method are not always directly suitable. The ice formation method was occasionally used as an optimisation method in earlier times, but it then lost importance.

Instead of using the ice formation method to find "the" optimum body contour immediately and directly, the resulting body contour is used as the starting point in further numerical optimisation procedures. This approach provides particularly powerful advantages because shapes obtained with the ice formation method represent novel contours with a high development potential. Such body contours can hardly be obtained by conventional optimisation methods.

Thus, in a particular application, the body contours obtained experimentally with the ice formation method are first analysed, then automatically represented by functions and finally subjected to a classical numerical optimisation, for example with algorithms. Furthermore, target requirements, such as minimum pressure loss or low heat transfer, can be included as desired.

The ice formation method has already been used at the Institute of Aerospace Thermodynamics at the University of Stuttgart (Germany) to study a cooling channel with a 180° U-bend and for a turbine blade. The flow channel soon revealed that coupling of the experimental and numerical methods provided considerably more favourable flow regimes. Thus the pressure loss in the optimised geometry was 28 percent less than that of the original version. This is an impressive example of the method's advantages.

The results obtained so far show the difference with respect to the geometry of a U-bend in the cooling channel of a turbine blade optimised by standard methods. In the first step, experimental natural optimisation, an ice contour initially forms on the dividing wall (web) between two channels whose shape can be easily explained by the thermodynamic and flow mechanics properties of the flowing

Illustration: ITLR

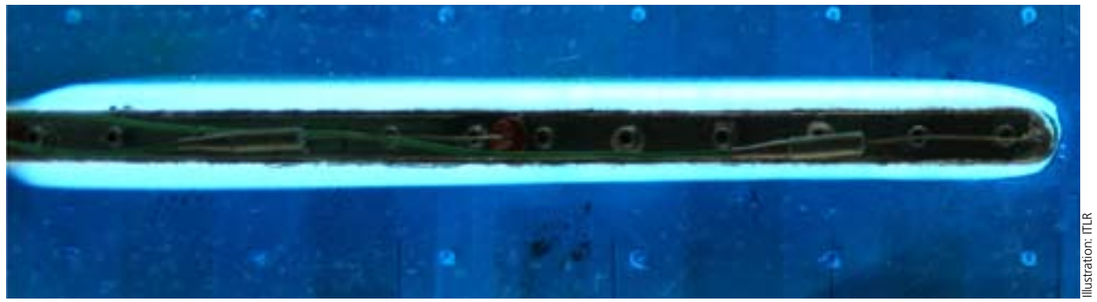


Illustration: ITLR

Above: Ice layer in a channel. Engineers can use the improved ice formation method to find an optimised contour.

medium. The numerical optimisation, aimed at minimising pressure loss in the U-bend between the first channel and the second, leads to a significant change in the geometry of the web at the channel outlet. However the shape of the intake hardly changes.

Although the resulting numerically optimised design is similar to that generally used in practice, it has an unconventional shape with many characteristic features. In short: the naturally optimised web contour from the experiments was a good basis for the subsequent numerical optimisation. The original contour of this naturally developed web geometry is still clearly visible after optimisation of the pressure loss.

To summarise: the ice formation method can be used to great advantage even for technically mature components in order to solve new and unknown design problems and for technical applications. This method provides a quick way of obtaining a first impression of the possible shape of a component and allows faster and cheaper implementation.

The results of investigations and applications show without a doubt that this more advanced method can be used for any machine component and is easily performed by simply icing a test model. It can therefore be expected that the ice formation method will be used successfully and profitably in the future for a wide range of different and complex optimisation studies.

Prof. Dr.-Ing. Bernhard Weigand, Dr.-Ing. Sven Olaf Neumann, Dipl.-Ing. Helga Steinbrück and **Dipl.-Ing. Sebastian Zehner** are researchers at the University of Stuttgart.

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▶ www.uni-stuttgart.de/itlr

Below: Cutaway view of a GP 7000 jet engine used in the Airbus A 380. Below right: A cooled low-pressure turbine blade made of a high-temperature resistant alloy.

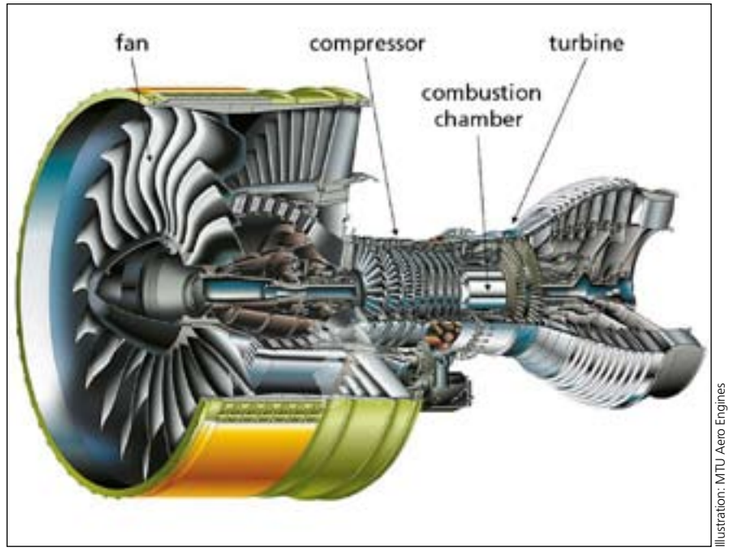

Illustration: MTU Aero Engines

Illustration: MTU Aero Engines

Portrait

Invisible Companions

Torsten Granzow creates Hightech Ceramics

By Hanno Schiffer

Torsten Granzow is a solid-state physicist. But he could have just as easily become a historian. The young researcher has always been fascinated by the Middle Ages, can quote historical passages from Faust and enjoys spending his free time among knights and jugglers at medieval festivals. "History, mathematics, languages – there were always many things that interested me and that I was able to pick up without difficulty," explained the 35-year-old as he recalled his school days.

But, after graduating from high school with perfect marks, the man of many talents decided to study physics – the only one in his class to do so. Today, Torsten Granzow is one of the leading German researchers in his area of specialisation: the characterisation of material fatigue in ferroelectrics. He has worked as a postdoctoral researcher at the Technical University of Darmstadt since 2004. He was awarded the Heinz Maier-Leibnitz Prize in 2008 for his work on ferroelectric ceramics, the DFG's most prestigious prize for young researchers.

For Granzow, who earned his doctorate summa cum laude in 2003, the prize served as true incentive: "It was not only a great honour, but also a push for motivation and performance." In addition, he is now better recognised as a researcher, he said. With the prize, he has come one step closer to his goal of becoming a "professor at a good university".

Work is piled high on his desk in the form of papers. The workday of the young, top-level researcher: Granzow researches ferroelectric ceramics for some ten hours per day, supervises doctoral researchers and exchanges ideas with professional colleagues located around the world. In addition, he is working on his habilitation thesis and other publications. Unimaginable for Granzow: a private life without planning. After work, he sweats for two hours in the fitness centre, and every weekend, the newly married scientist travels 250 kilometres to see his wife. "My schedule is quite full. I don't usually have very much free time," said the young researcher, shrugging his shoulders. "But when something is important, I am very disciplined. And now I am doing exactly what I want."

Illustration: Schiffer

When he began his studies in Cologne, Granzow had only a vague idea of what awaited him in the world of physics. But the science-fiction fan was fascinated by the variety of physical formulas. The deeper the young researcher immersed himself in his subject area, the more interested he became in applied physics – "where you can really see something and where you can do experiments and press buttons," he added mischievously. During this time, Granzow also discovered the diverse possibilities of ferroelectrics.

Ferroelectric ceramics consist of artificially produced crystals whose polarisation can be switched by external influences, such as an externally applied electrical field. Granzow is working to learn the conditions under which the performance of the ceramics change, such as high temperature, material defects or mechanical load.

The special ceramics – often a mixture of lead, zirconium and titanium – make possible higher-performance automotive valves, better pressure sensors and higher resolutions for medical diagnoses in order to find tumours just millimetres in size. Or they serve as the basis for new frequencies in mobile phones and car keys – invisible companions in daily life. "A person is often carrying four of five ferroelectric ceramics without even knowing it," said Granzow.

Ferroelectric piezomotors, for example, drive zoom lenses in typical digital cameras. Controlled by electrical impulses, the piezomaterial "pushes" a wheel in the motor via periodic material expansion. In this way, the piezomotors eliminate the need for large gearboxes in fine positioning systems. The tip of an electron microscope can be controlled with a pulse of 1,000 volts in order to move just 0.0004 millimetres.

Granzow frequently collaborates with industry. He finds the applicability of his work to be both a blessing and a curse: "In addition to all of the potential commercial applications, there must still be a certain amount of research freedom." Granzow says he finds this freedom only in university research – for example, as group leader in the DFG-funded Collaborative Research Centre "Electrical Fatigue".

In addition to scientific curiosity, Granzow is also motivated by the aesthetics of physics: "Truly beautiful optical effects occur with transparent ceramics when they are subjected to an electrical field." A hint of romance in the otherwise data-based world of physics.

Hanno Schiffer was an intern in the Press and Public Relations Office of the DFG.

Illustration: Eden-Archiv, Oranienburg

Changing the World with Müsli

The Lebensreform movement campaigned for a life more in tune with nature. Today the movement is only of historical interest, but it has had a lasting impact on health awareness

By Florentine Fritzen

Marie Ernst and Robert Boermel got to know each other while working at the Naturopathy Sanatorium, between Spessart and Vogelsberg, where the young woman massaged the patients and the young man introduced them to Kneipp's hydrotherapy. In their private life too they were well matched: Marie and Robert were both life reformers.

They shared a world view which was an object of ridicule for many people in the Wilhelmine Empire. Reformers like Robert and Marie campaigned for a more "natural" life. They recommended juice instead of alcohol, more fresh vegetables and less meat, plenty of activity, preferably in the forests and fields, loose garments rather than corset dresses, light and air rather than stuffy living rooms. People like Marie and Robert saw themselves as pioneers. They looked to the future, dreaming of a time when their ideas on healthy living would become common knowledge.

Until then, however, there was still a lot to be done. So after their wedding, the young couple opened a health store by the name of "Boermel-Ernst" on the Theaterplatz in Frankfurt am Main. From 1904 on, they sold products by Thalysia, a Leipzig based company which manufactured health food, reform clothes and body care products. The shop stocked everything that the customers needed for their way of life: fruit pastes, dried bananas, whole grain rice, vegetable oil, reform shoes, porous or "breathable" underwear.

"For your health": Health store advertisement for unfiltered apple juice, as "recommended by doctors".

The owners and customers of the health store did not see themselves as solitaries, but rather as part of a social movement, which by the turn of the century was already being referred to as the Lebensreform movement. The movement embraced various groups such as vegetarians, alternative practitioners, clothing reformers, teetotallers and naturists. The reformers also felt that they belonged to a greater whole, because they hoped to change the world for the better. They believed that if enough individuals turned their homes into "reform households", German society would also be transformed.

The health store in Frankfurt was one of the first in the German Empire. The turn of century also saw the emergence of the first manufacturing plants for health products. The Eden Cooperative in Oranienburg processed fruit into juice and puree, the Hensel factory in Cannstatt produced mineral salts, and the Steinmetz Company in Flensburg made bread and flour. The nascent health product industry grew quickly and united to form the Neuform Cooperative in the nineteen twenties. The reformers' ideas also started to spread. In the Weimar period, many German cities established "Light & Air Baths", created public parks

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Advertisement from "Reform-Rundschau", February 1940

Advertisement for "Pauly´s Wholemeal Baby Food" from 1940. The reformers believed that healthy eating should start early.

or engaged architects who were committed to the "New Building" style.

From today's vantage point, the reformers, who dreamed that their ideas would one day be interwoven with the fabric of German society, bringing about a radical alteration of that society, have been proved right on the one hand, but totally wrong on the other. More people than ever are tuned into the healthy lifestyle, and it has been a long time since health stores were the only location for health-conscious shopping. At the same time, the ideal of social reform has faded. Nowadays, when someone looks after their health, their only aim is to do themselves some good. There are not many people who can still relate to the Lebensreform movement, though it was the source of many theories and practices which are still relevant to the healthy way of life.

What really distinguished people like Marie and Robert as pioneers of health awareness was above all their pragmatism. The ideal of the healthy life existed already in antiquity, but the compromise of living a healthier life is a thoroughly modern idea. The notion of changing the world, or at least society, with muesli and gymnastics lived on for many decades, up to the end of the twentieth century in fact. At each stage, however, it has assumed a different guise, inasmuch as the Lebensreform movement has always been closely linked with German society. To the same extent that the reformers attempted to improve society, they were also invariably influenced by the fashions and thinking that characterised their own time.

The reform-minded contemporaries of Marie and Robert tended to be somewhat utopian. They often spoke of the year 2000, which they envisaged as a "golden age" that would be pretty much the opposite of Wilhelmine Germany, whose overcrowded hospitals and asylums they regarded as decadent, or even degenerate. The earthly paradise, on the other hand, would be populated by contented, healthy people with a penchant for circle dancing in the great outdoors, and the working day would be no more than three hours long.

In order for this culture of happiness to be inaugurated – so much was obvious – the people first had to change. The reformers had some very concrete, practical advice for their fellow men in this regard. Quite apart from their noble aims, reformers like Marie and Robert also made a tidy profit from the idea of Lebensreform. After all, the products they sold promised happiness.

In the interwar period, when muscles became fashionable and the first vitamin products appeared, there was also much talk of the vital body among reformers. They saw the body as a whole, which ought to be in harmony with the mind and the soul and also with its natural environment. The reformers spoke much about "inner" and "outer" nature. By this they meant, on the one hand, the nature incorporated by humans with their own bodies, and on the other, the natural environment. The two natures must become a harmonious unity – this was the great work pursued by the reform movement during the entire twentieth century.

During the nineteen twenties and thirties, however, the reformers were primarily interested in "inner nature", and in finding out what foods, what peeling agents or what exercises are most effective for strengthening the body. At this time the notion of the "national body" arose. Just as individuals should care for their own bodies, likewise the German people had to be steeled, so they could be forged into the healthiest nation of all. This notion was well suited to the ideology and purposes of the National Socialists. The health stores had a special mission to strengthen the German people, and the industry was co-opted into the Nazi's totalitarian programme. The reformers

Illustration: Eden-Archiv, Oranienburg

Illustration: Cover from "Reform-Rundschau", June 1940

At the feet of the master: Closing speech by the Swiss-born reformer Werner Zimmerman at the International Vegetarians Conference in 1932. Below: Distinctive appearance – front page of the customer magazine *Reform-Rundschau*.

adapted readily to the new regime, having been deluded into seeing the Third Reich as the "new age" which they had eagerly anticipated for decades.

On 5 April 1933, only a few weeks after Hitler took power, the Chairman of the Neuform Cooperative declared in the members' journal that, "Out of our 1200 member businesses, only four are in Jewish hands. Office holders, such as members of the Executive Board or the Supervisory Board or group representatives, are neither of Jewish extraction nor do they belong to subversive parties." What happened to the four Jewish health stores, the cooperative explains only in an oblique manner: an "immediate inspection" revealed that "the Executive Board had undertaken the kind of measures demanded by the present times".

Following the national socialist perversion of body culture into a body cult, and especially following the reduction of the body to race and blood, which resulted in the murder of millions of people, the Lebensreform movement switched its focus to "outer nature", which before long was referred to as the "environment". This is evident, among other things, from the images in the customer magazines issued by the health store. Whereas before the war, the magazines, which had been released monthly since 1925, were filled with pictures of well-formed, scantily-clad bodies, in the second half of the twentieth century, the Reformhaus-Rundschau magazine preferred to print photos of mountains, lakes and plants. After the war, belief in a bright future was also subdued. There was no more talk of a "new age". Instead, the foremost concern was now to protect the environment and prevent the ecological collapse, which was perceived as a tangible threat.

Health store products now stood more for naturalness and organic agriculture, than for strengthening the body. By now, most health businesses had a tradition going back over decades. Since the seventies more and more suppliers have crowded the market for health products: organic shops, drug stores and even grocery stores. There was also competition for the Lebensreform movement on the market for ideas and ideologies.

The ecological movement which emerged after 1968 had many beliefs in common with the reformers, and these ideas continued to disseminate into every corner of society. Newspapers and magazines started reporting about seal deaths and the destruction of the rainforest. Fitness trails were created in the woods. The book market was flooded with handbooks on healthy eating, relaxation techniques and stress prevention.

But the reformers and "alternative types" had very little to say, in any case little that was positive. In 1966, the Reform-Rundschau magazine complained about the "drop-out" culture among young people, and in 1968 they criticised the "youth in revolt". At this time, the protagonists of the Lebensreform movement and the health product industry were themselves predominantly older gentlemen, gradually approaching retirement age. They belonged to the second, well-established generation of the Lebensreform movement, the generation of the children of Marie Ernst and Robert Boermel.

Illustration from the "Reform-Rundschau", June 1941

Alternating foot bath and hydrotherapy to prevent vein infections: Illustration of a "preventative article" from the *Reform-Rundschau* in 1941. Bottom: Children visiting the fruit growing commune, Eden, in Oranienburg, which had early links to the Lebensreform movement.

Illustration: Eden-Archiv, Oranienburg

Many of these reform advocates died at the end of the twentieth century. Along with them died the ambition to bring about a change in society by means of the healthy lifestyle of as many people as possible. The Boermel-Ernst health store in Frankfurt still exists, run by the fourth generation of the family. Many other health stores had to close, due to the level of competition. Still, knowledge of the healthy way of life, once proclaimed by a few much-derided reformers, is now available to all.

Dr. Florentine Fritzen has completed a doctoral dissertation on the Lebensreform movement. The publication of her study "Gesünder leben: Die Lebensreformbewegung im 20. Jahrhundert (A Healthier Life: The Lebensreform Movement in the Twentieth Century)" (publisher: Franz Steiner Verlag) has been funded by the Deutsche Forschungsgemeinschaft. Following her Ph.D., the author joined the editorial team of the *Frankfurter Allgemeine* newspaper.

Contact: Frankfurter Allgemeine Zeitung, Hellerhofstraße 2– 4, 60327 Frankfurt am Main, Germany

Local border traffic in the village of Mödlareuth, which was known as "Little Berlin"

Illustration: dpa-Bildarchiv / DB Felix

Crossing the Language Barrier

The Iron Curtain not only bisected the inhabitants' homeland – in the Thuringian-Bavarian region, the political divide also caused a surprising shift in their dialects

By Rüdiger Harnisch

When, in 1989, the Iron Curtain fell and the people living on either side of the border met for the first time, they made differing observations, some of which pertained to the speech of their respective neighbours "from over there". When the older people spoke with their contemporaries from neighbouring towns and villages on the other side, they noticed similarities in their dialects. The language of the younger generation, on the other hand, sounded strange to their ears. When the younger inhabitants, in their turn, spoke to their contemporaries on the "other" side, they experienced a similar level of unfamiliarity. And yet the older people from the other side of the "border" sounded just like their parents and grandparents.

Before the division of Germany, homogenous dialect zones criss-crossed what would later become the boundary. Furthermore, the walling-off of the two parts of the country from each other had obviously been sufficient to alienate these formerly homogenous linguistic regions from one another. This situation raised many questions for linguists, the first and foremost being the issue of whether the fortified political border between the GDR and the Federal Republic of Germany had, indeed, become a language boundary. The investigative project began its research in the early 1990s, with the comparative evaluation of the compiled material against older language data taking place ten years later.

The socio-political side effect of this linguistic research is obvious: if the inhabitants of the border region recognised that, before the division, people did indeed "speak a common language", it would be easier to make "grow together what belonged together" once the metal fences had been torn down. But how could studies prove that these old dialectal similarities really existed and that, during the decades of separation, linguistic development diverged precisely at the demarcation line?

It would be possible for the linguistic situation immediately following the end of the GDR to be documented through dialectological field research. This must, however, begin immediately, in the linguistic "zero hour". This linguistic state of affairs would also serve as a benchmark for all developments occurring after the Reunification.

Against this backdrop, two dialectological institutions, whose scientific interests reached from different sides of the border to the boundary itself, joined forces in 1990: the "Thüringische Wörterbuch" (*"Thuringian Dictionary"*) in Jena and the "Sprachatlas von Nordostbayern" (*"Linguistic Atlas of North East Bavaria"*) in Bayreuth. The DFG provided the funding for the project, which was

entitled "Erhebung der Dialektsituation im thüringisch-bayerischen Grenzgebiet" ("*Survey of the Dialect Situation in the Thuringian-Bavarian Border Region*"). Between 1991 and 1994, linguistic material was collected in eleven pairs of towns and villages along the border, including the formerly divided village of Mödlareuth. The village rose to fame during a visit by then U.S. Vice President George Bush Sr. on 5 February 1983 to its western side. "Little Berlin" made a name for itself and became known all over the world.

Linguistic informants for the project were selected from four different age groups and included people who had either been born in the places studied or who had lived there since their earliest childhood. First, however, there were "preliminary questions" to be answered: which linguistic idiosyncrasies seemed likely to provide information pertaining to the research question? What linguistic data would it, therefore, be sensible to collect? Bureaucratic phraseology (including official terms like "Fahrerlaubnis" in the GDR and "Führerschein" in the Federal Republic of Germany [both terms for "driving license"]) was of no interest, as differences in such areas were to be expected. Instead, the researchers were looking for traits which permeated the entire language system: pronunciation, grammatical forms and everyday words.

These traits were determined primarily using a questionnaire tailored to the dialectal characteristics of the individual pairs of villages in both East and West. In order to verify the requested data, moreover, a free narration task was included, in which the informants were asked to describe their experiences of the border opening. These narratives, incidentally, include many moving stories containing historiographically valuable material, which is particularly useful in documenting the oral history of this period of change.

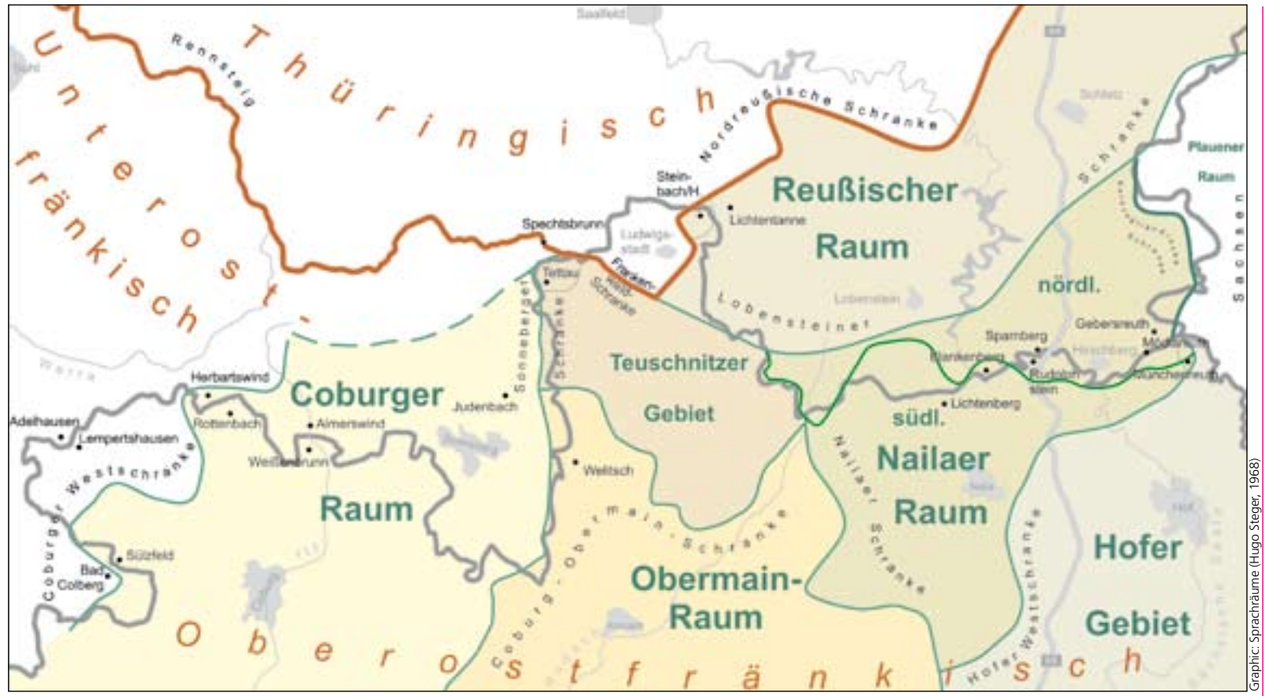
The German-German border – a piece of which has been preserved as a memorial in Mödlareuth – audibly modified dialects on both sides of the boundary.

Illustration: picture-alliance / Bildagentur Huber

While the completion of the field work meant that the current linguistic reality had been documented, comparative data from the time before the demarcation was required in order to ascertain whether or not the Iron Curtain had actually created a new dialect boundary. In this, we were lucky enough to be able to access original material from a language geography dissertation from 1938. In addition, material which had been collected as part of the "Linguistic Atlas of North East Bavaria" project was also used for comparison. Due to the fact that the pre-war investigation and the Linguistic Atlas project documented the speech of the oldest generations of speakers, while the post-Wende project included all the generations, the birth dates of the informants and the periods during which their linguistic development was influenced range from the time of the post-1870 German Empire until the 1970s.

The material collected at the beginning of the 1990s had to wait some time for its evaluation, however, as the institutions which had collected it were fully occupied with their core tasks (the Dictionary and the Linguistic Atlas) over the next few years. It was not until the end of 2005 that a follow-up project at the University of Passau, again funded by the DFG, enabled the data to be further examined and compared with the linguistic material from the pre-war era. This evaluation repeatedly confirmed the initial hypothesis – that the fortified border had formed a linguistic barrier between the GDR and the Federal Republic of Germany in this border region.

Although linguistic geography research over the past two decades has demonstrated that political borders between states with the same or closely related "Dachsprachen" ("umbrella languages"), i.e. political borders such as those between Germany and Austria or between Germany and the Netherlands, for example, can create similar linguistic borders in previously homogeneous cross-border dialect landscapes, these processes have taken centuries and occurred in relatively open border regions. In the case of the German-German border, however, the process happened relatively quickly. The short period of prohibited contact was obviously compensated for by the hermetic nature of this hitherto unprecedented type of boundary.



Graphic: Sprachräume (Hugo Steger, 1968)

Dialect areas in the Thuringian-Bavarian border region: after the political "Wende", linguistic material was collected in eleven locations east and west of the former German-German demarcation line, which is marked in grey on the map.

By way of example, three linguistic phenomena are listed below. Each of them demonstrates the gradual alignment of the dialect boundary with the former state border. The term "gradual" is used here to indicate the fact that this process became more clearly delineated with each generation. The three examples are all related to pronunciation criteria, due to the fact that pronunciation is evident in every spoken utterance and thus provides the strongest impression of a linguistic landscape.

The first characteristic is what's known as "centralisation", in which all the vowels are formed somewhat closer to the centre of the oral cavity. This vowel colouring is a fundamental distinguishing feature of what is commonly described as "Sächseln" (speaking the Saxon dialect). In towns and villages on the Bavarian side, which also formerly demonstrated this trait, it has been abandoned by the younger generations. In the West, it was a rarity which contrasted with the Franconian dialects of the hinterland. Those in the Old Länder also considered it "typical of the GDR" and, therefore, disreputable. In contrast, on the Thuringian side, where it was supported not only by the neighbouring Saxon and Thuringian dialects, but also by the Central German vernacular and the regional High German, it was not considered a stigmatised dialectal trait and was retained.

A second phonetic trait is the pronunciation of the "r" sound. Before the division, its delineation meandered across what would later become the political border, sometimes taking in areas of Thuringia in the Franconian linguistic region, and sometimes areas of Bavarian Franconia in the Thuringian linguistic region. Over the generations, the Thuringian-sounding rear [R] from the former western settlements retreated just as much towards the former state border as the Franconian-sounding frontal [r] from the former Eastern settlements.

As our third example, we can take the characteristic use of vowel diphthongs, which occur in words like veis 'Wiese' (meadow), geisn 'gießen' (to pour) and noudl 'Nudel' (noodle), fous 'Fuß' (foot) on both sides of what would later become the inner-German border. While this trait has been abandoned by the younger generation in the East, a third of this generation in the West still adheres to the old vowel pronunciation.

It is apparent from these examples that there are two possible ways in which a new language boundary can have been formed: either the inhabitants on both sides realigned themselves with their respective dialectal hinterlands, or varying degrees of "dialect erosion" in favour of supra-regional vernacular or standard language took place on each side of the political divide.

Along the former inner-German border both transpired, with some of the older traits being preserved in the West (such as, for example, the pronunciation of the vowels in veis (meadow), fous (foot), and others (such as vowel centralisation) in the East. In all cases, however, the old cross-border homogeneity was lost. The conclusion: new, internal linguistic frontiers developed along the "Iron Curtain".

It remains to be seen whether the trends towards linguistic divergence along the former demarcation line will intensify, or whether the linguistic differences which developed here over a 40-year period will even out once more to form cross-border dialectal "solidarities" like those which previously existed. The field for cross-border dialectology is wide open.

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▶ www.phil.uni-passau.de/germanistik/sprachwis1/sprig.htm

In the Virtual Realm of the Myrmecologists

The amazing diversity of ant fauna in Southeast Asia is showcased in a new scientific internet portal. High-resolution automontage photographs show even the smallest of anatomical details – a valuable aid for ant researchers all over the world

By Martin Pfeiffer

Illustration: Katzmann

At the start of the 21st century, the width and diversity of the fauna and flora are endangered in many regions of the planet. This is especially true for tropical ecosystems where more than seven million hectares of rain forest are lost each year due to deforestation. The disappearance of tropical forests is accompanied by large-scale extinction of the native species. Furthermore, many of these species are still unnamed and have not yet been scientifically characterised.

Insects make up the majority of the unknown species, whose number is estimated to be as many as five million. Their exact identification and description – biologists call this "taxonomic classification" – is both difficult and time-consuming. Identification and documentation of the huge number of tropical species is hampered by the limited availability of taxonomic reference materials, which are generally stored in science museums around the world where they are archived and managed by specialists. Owing to the fact only a few examples are collected each time of the rarer insect species, which make up the majority of the tropical collections, the small number of reference specimens has greatly limited the circle of experts.

Until recently, this also applied to tropical ants, which are found in all rain forest habitats. They perform key functions in the ever-changing tropical ecosystems, have been well-studied by taxonomists, are easy to collect and are relatively easy to classify down to the genus. This means that they are predestined for comparative studies on biodiversity.

Up to now, ant fauna was identified by sending the prepared insects to taxonomic specialists or by borrowing specimens from science museums as reference materials. Nowadays, an increasing number of insect researchers – or entomologists – are able to compare their ant specimens with high-quality images downloaded from the internet.

Taxonomic image databases, such as the DFG-sponsored portal www.antbase.net provide high-resolution photographs of characteristic species. The pinned animals are shown in sharp, crystal-clear images with high magnification. These "automontage" photographs are calculated by a computer from up to 80 individual images and have an "infinite" depth of focus. All details of the object are in sharp focus and none of the contours are blurred. Such results have only been possible to date with an electron microscope after the objects have been subjected to an elaborate gold-coating process. With automontage photography, which uses optical microscopy, the pinned insects retain their original state and even the colours of the specimens remain authentic.

Illustration: Pfeiffer

Illustrations: Deufel (left), Mezger (right)

Illustrations (both): Katzmann

Mammoth undertaking: weaver ants building a nest held together with sticky threads of larval secretions. Fascinating diversity (bottom, from left to right): an as-yet unclassified *Myrmoteras* species, a hungry *Camponotus gigas* worker, the impressive head of *Myrmoteras bakeri* and a long-legged *Pheidole aglae*.

Technological advances in the digitisation of image data greatly facilitate taxonomic classification of the collected material," sums up Dirk Mezger, doctoral researcher at the Institute of Experimental Ecology at the University of Ulm. He is currently studying the food web on the floor of Malaysian rain forests and is comparing the ant fauna in the different types of forests in Borneo. Although the entomologist will still have to use taxonomic keys for time-consuming identification of specimens, he can avoid using reference specimens in most cases.

In addition to a stereomicroscope for identifying his specimens, he also works with photographs of ants on his computer screen. "Classifying insects with automontage images has major advantages over a direct comparison with reference objects," explains Dirk Mezger, "this avoids having to swap between specimens and refocusing the stereomicroscope on morphological details. Because I can see all the key features on the computer

screen at the same time, I can simply compare the specimen and its identification characteristics."

This is particularly important for tropical insects, for which the number of unidentified species largely exceeds those already classified. Automontage photographs help to avoid incorrect classifications. In earlier times, only taxonomic specialists had direct access to reference materials so that they could carry out identification quickly and accurately. Nowadays, a much wider group of experts, including the doctoral researcher in Ulm, are able to classify many of the specimens with sufficient accuracy using the online images.

The internet database providing the photographs is also compiled by the institute in Ulm. Hans Peter Katzmann, the project manager of the portal, is responsible for the ant photographs and for compiling the web pages, which have been produced since 2003 at the University of Ulm by the group of Professor Elisabeth Kalko. This project has been sponsored by the DFG since 2006. More than 500 ant species from 94 genera have already been digitalised, two-thirds of which were processed with the new technology.

The foundation of the picturebase is the zoological collection of the University of Würzburg, one of the largest ant collections in Europe. For more than 15 years, tropical ecologists working in the group of Professor K. Eduard Linsenmair have been carrying out intensive research on the diversity of tropical organisms and have been searching for ants, particularly in the Bornean rain forests. This collection will now be continued and substantially expanded by the researchers in Ulm. The lively contacts and busy loan service between leading taxonomists all over the world means that the materials are continuously examined and classified. Newly classified species are often made available online within a short time. The resonance from the experts is huge: on a monthly average, more than 38,000 pages are viewed and about 1,800 MB data are downloaded.

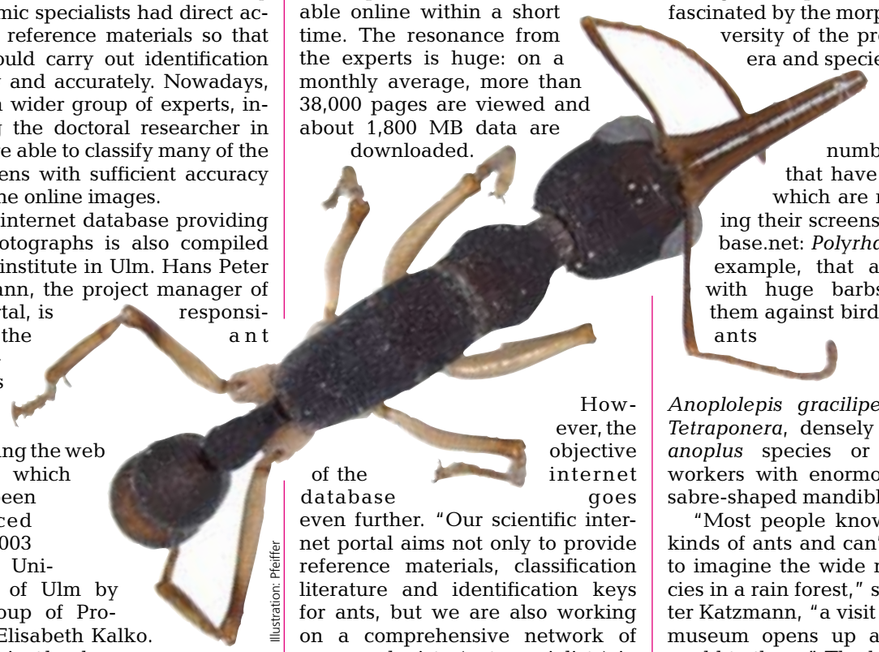

Illustration: Pfeiffer

Distinctive contours and pincer-like jaws: *Harpegnathos venator*. These ants are specialised hunters – their mandibles and large eyes enable them to hunt ground fauna.

However, the objective of the internet database goes even further. "Our scientific internet portal aims not only to provide reference materials, classification literature and identification keys for ants, but we are also working on a comprehensive network of myrmecologists (ant specialists) in Asia," emphasises Katzmann. He has recently added home pages of 30 scientists to the portal. "Particularly in Asia, many of the smaller institutes still do not have an English version of their website. These scientists can upload their data to our portal thus making it available to a wider audience. This also provides them with an opportunity to come into contact with other experts." The internet portal also provides a range of such services to support "ANeT", an international network for ant research in Asia. A comprehensive research database is gradually being expanded to promote the exchange of information between scientists.

In addition to networking scientists and supporting their research, documentation of the diversity of tropical species is one of the core objectives of the internet portal. Interested non-specialists surfing through the picturebase will be fascinated by the morphological diversity of the presented genera and species. And many are surprised by the huge number of species that have evolved and which are now populating their screens at www.antbase.net: *Polyrhachis* ants, for example, that are equipped with huge barbs to protect them against birds, blind army ants of the genus *Aenictus*, long-legged *Anoplolepis gracilipes*, wasp-like *Tetraponera*, densely haired *Meranoplus* species or *Myrmoteras* workers with enormous eyes and sabre-shaped mandibles.

"Most people know only a few kinds of ants and can't even begin to imagine the wide range of species in a rain forest," says Hans Peter Katzmann, "a visit to our virtual museum opens up a whole new world to them." The belief that humankind protects only what it knows is one of the many factors motivating the database specialists. As a consequence, this information platform also provides texts on ant ecology, a virtual exhibition of scientific posters as well as a collection of ant videos. And, to maximise the number of people getting to know about ants, the pages with the explanatory texts are available in three languages – English, German and Malaysian.

> The internet portal ANeT networks scientists and research and extensively documents the diversity of tropical species

A large number of the species presented on the web originate from Malaysia, a tropical country with a particularly diverse fauna. An ant diversity hotspot was discovered in a small area at the foot of Mount Kinabalu, the highest mountain in Southeast Asia: 640 ant species were found within a few square kilometres, whereas only 114 species are found in the whole of Germany. Many of the species from this hotspot have already been documented in the internet database.

Because the creation of each automontage photograph is a lengthy process (more than three hours in some cases), it will still take some time until all the species found in the Kinabalu National Park have been photographed with the new technology. Unfortunately, the algorithm used by the program is still not working absolutely correctly so that the combined images have to be reworked in many places. The perfect final product requires a lot of experienced manual work and photographic skills. Nevertheless, the database team plans to show the majority of the more than 1000 ant species of Borneo by the end of the project.

Thanks to the cooperation between researchers from other Asian countries, species from Thailand, India, Iran and the Philippines will also be presented. Most of the ant fauna of Mongolia is already included in the database. Even "German ants" will be added to the database – in the interests of research and the documentation of the worldwide diversity of species.

Right: In the Malaysian rain forest – Dirk Mezger with locals who are helping to search for ants. Middle: Each ant has to be described down to the last detail. Bottom: The final result – the immense diversity of species documented at the portal.

Illustration: Pfeiffer

Illustration: Pfeiffer

Screenshot: antbase.net

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▶ www.antbase.net

Going Under the Knife with Mathematics

Disfigurations that occur in a person's face can be partially corrected by oral and maxillofacial surgery. When planning an operation, highly complex differential equations and three-dimensional visualisations can be of great assistance

By Peter Deuflhard

It is a proven fact that a "beautiful" face has social benefits. It can be beneficial in many situations, virtually acting as a key that unlocks many doors. As psychological experiments have demonstrated beyond any doubt, good looking children (of both sexes) are already at an advantage at school when it comes to getting good marks. The same holds true in working life, where HR managers subconsciously favour beautiful and attractive applicants, and where wage negotiations often "run more smoothly".

So it is all the worse if a person's face is disfigured or maimed, either from birth or due to an accident. Oral and maxillofacial surgery (also known as OMFS) attempts to lessen this burden with operations that can often involve massive interventions, such as sawing jaw bones, sometimes removing several centimetres of bone, or – if necessary – extending or relocating them. The aim of such operations is to achieve a functional and aesthetically pleasing restoration of the entire face. These operations are highly complex and, in view of the key importance of the face, are very complex and can have serious consequences. Mathematics is not only important in planning such operations, but is now more or less indispensable.

Researchers at the Zuse Institute Berlin (ZIB) have been working on practical medical and associated theoretical mathematical problems since the early 1990s. Initially they concentrated on hyperthermia, working in close cooperation with the Virchow Clinics (now the Charité Campus Virchow Clinics) – a process used in treating cancer based on artificial local heating .

This work gave rise to a need to deal with mathematical methods in such a way that the doctors could use them in the hospital without needing to understand the underlying methodology. This led to the first "virtual lab", HyperPlan, which was used as a planning system for hyperthermia treatment. Since then, this approach has proven itself in numerous other projects in medicine and medical engineering as well as biology. This eventually led to the powerful software platform Amira, which is now marketed and used by a spin-off company worldwide.

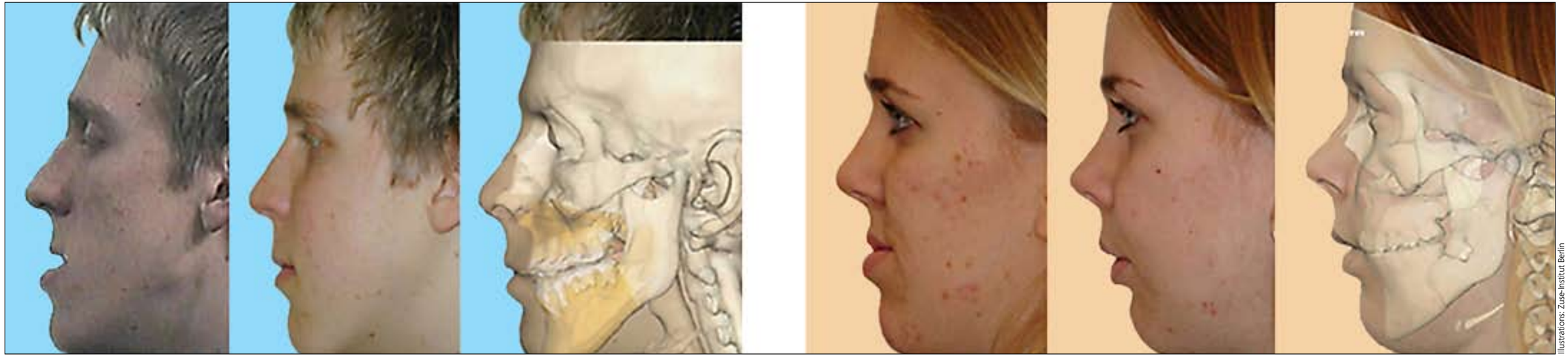
> The "virtual patient" is calculated in detail on the basis of image data of the real patient for use in planning the operation

In the course of the cooperation between mathematicians and medics a basic pattern emerged and established itself. The process always begins with the calculation of the "virtual patient", which is done on the basis of graphics data of the real patient. Then the therapy or operation needs to be planned mathematically in the "virtual lab". Finally, the results of this planning need to be transferred into the real-life patient's situation.

All three of these stages have one thing in common: efficient 3D visualisation. This is necessary to create a virtual lab that is also useful in hospital. The first stage of the process therefore requires a 3D image of the patient to be generated in the computer, based on the medical image data obtained by processes such as computer tomography, magnetic resonance imaging or ultrasound. This is accompanied, in practice, by a number of complex mathematical problems that needed to be tackled and solved in the early years of the project.

The end result is a finite element mesh consisting of approximately 50,000 tetrahedra, which gives a sufficiently accurate representation of the individual patient. The second stage of the process involves generating patient-specific mathematical models, generally using systems of partial differential equations, which describe the physical processes occurring in the body and the function of the medical devices mathematically. OMFS uses differential equations from biomechanical engineering, which are used to mathematically model the soft tissue of the face (for experts, Lamé-Navier equations of linear elastomechanics and their extension by geometric nonlinearity and nonlinear material laws, Ogden-type materials, for instance).

Solving these differential equations fast and reliably is essential for the method to be able to be used subsequently in the hospital. Here, state-of-the-art multi-grid methods are used, where the extremely high-dimensional finite element mesh generated using the medical images must first be thinned out to allow it to be used as a starting mesh. Here, as is so often the case, experience shows that problems from medicine can also pose genuine mathematical challenges to scientists, too. Once this stage has been completed, the virtual lab is



Help is at hand for people with disfigured mouths, jaws or faces: A male patient (left) and a female patient before and after a complex operation. The predicted outcome of the operation, planned in detail using mathematics, is shown as the third image in the sequence.

Illustrations: Zuse-Institut Berlin

Right: An on-screen consultation between a patient and the surgeon. Visualising the possible outcomes of the operation (bottom) can be very helpful in making tough decisions in advance. Middle: The surgeons and the mathematicians can plan the operation in detail by holding a teleconference on the basis of 3D visualisations.

All illustrations: Zuse-Institut Berlin

complete and ready to be used for planning the therapy or operation. The solutions generated there are transferred back into real life in the third stage of the process. In OMFS, this means that the sequence of incisions for surgery is planned in precise detail by the doctors and the mathematicians. This is usually done by means of a teleconference between the hospital and the ZIB using the 3D visualisation. In the virtual lab it is possible to reliably predict what the patient will look like after the operation – even before the surgeon makes the first incision. In particular, this makes it possible to visualise, discuss and, last but not least, plan various options for the operation flexibly and cheaply.

A very useful side-effect of this improved planning is the opportunity it provides to inform the patient of the risks and potential hazards involved. This allows the patient to be more actively involved in the decision-making process. Simultaneously, it also makes detailed documentation and quality assurance much simpler.

The new method has already been used by ZIB for over 30 operations, in close cooperation with hospitals in Germany, Sweden and Austria. Now, the procedure has already matured to an extent that it might indeed be fair to claim that "if at all you need to go under the knife, then only with the support by modern mathematics".

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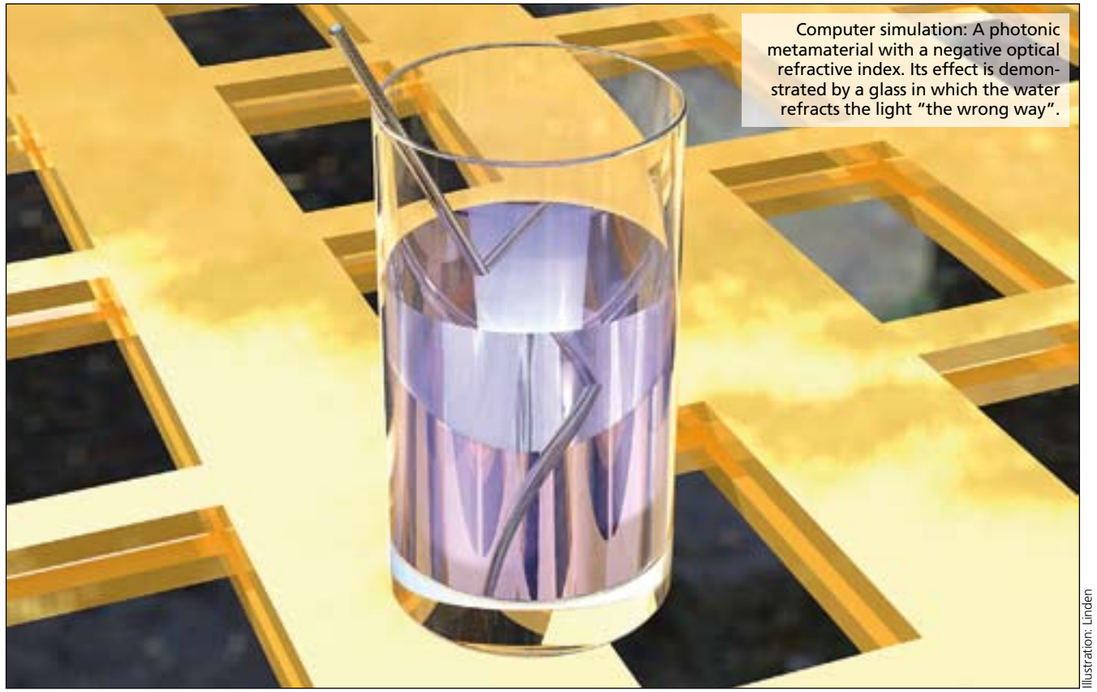


Computer simulation: A photonic metamaterial with a negative optical refractive index. Its effect is demonstrated by a glass in which the water refracts the light "the wrong way".

Illustration: Linden

Optics Starts Walking on Two Legs

Nanoscopically small and artificially made: Metamaterials open up previously undreamed of possibilities for researchers. Tailored "photonic atoms" help them achieving new optical properties and inspire them to develop innovative applications

By Martin Wegener and Stefan Linden

What laws govern how light propagates, and how is it possible to influence the way it propagates? The quest to discover the "laws of optics" has inspired people ever since antiquity and has been of enormous technological interest in a wide variety of areas – ranging from modern day telecommunications to molecular spectroscopy – ever since the discovery of the laser. Scientific and technological progress in all of these fields always depends on one thing: The availability of novel optical materials.

Or, to put it another way: Natural materials and crystals are the limiting factors, because they determine the bounds of how light can be manipulated. The Scottish physicist James Clerk Maxwell postulated that light may be described as an electromagnetic wave as early as 1865. According to this theory, light essentially possesses an electrical and a magnetic "leg". It is impossible to directly manipulate the magnetic component of a wave of light using any known natural material. Materials such as glass, silicon or gold only influence the light's electrical "leg", meaning that, so far, half of optics has effectively been missing. A fact that is obviously dissatisfactory for physicists.

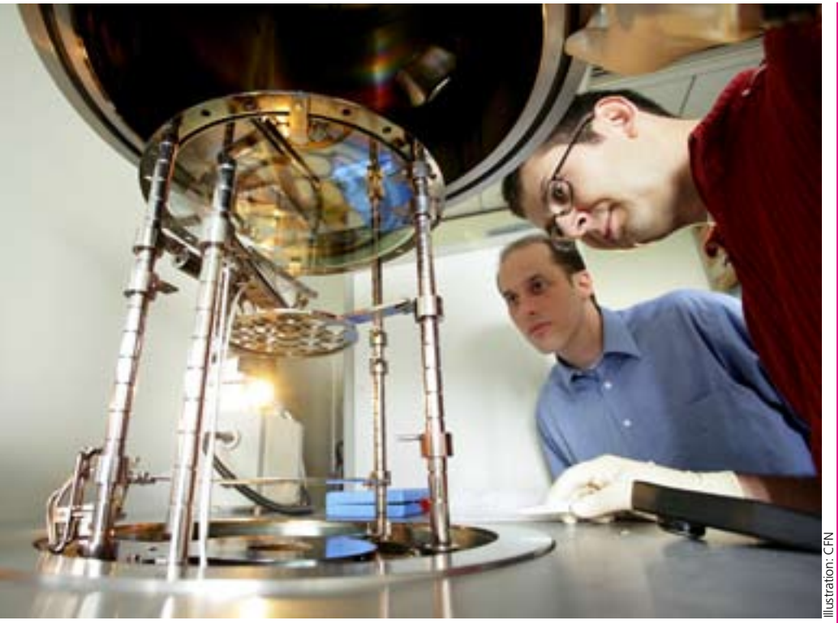


Illustration: CFN

Expectant faces: Using a vapour deposition system, researchers are able to develop and manufacture novel photonic metamaterials.

In 1999 the English physicist Sir John Pendry and his research group raised the idea of a new class of tailored artificial materials. These so-called metamaterials are artificial crystals that are made up of tightly packed components that are significantly smaller than the wavelength of the electromagnetic wave.

Their decisive potential all depends on metallic components made up of minute resonant circuits or electromagnets, into which the wave of light induces a circulating and oscillating electrical current. This, in turn, generates a resonating localised magnetic field, which acts back on the magnetic component of the electromagnetic wave. Since visible light has a wavelength of between 400 and 800 nanometres, the spacing between the components (periods) needs to be about 100 nanometres; the smallest feature sizes are even lower than 10 nanometres (1 nanometre being 0.000 000 001 meters). That also means that here, once again, the possibilities of state-of-the-art nanoscience are called upon.

Just ten years ago many scientists were still very sceptical, especially as an ever increasing number of optical properties were being predicted theoretically that, at first sight, seemed downright bizarre. For instance, materials with a negative refractive index were predicted. That means, in other words, that the light's phase velocity is negative and the electromagnetic wave in the material "goes backwards".

This aspect was already discussed in a theoretical publication by the Russian physicist Victor Veselago written in 1968, but was dismissed as a theoretical obscurity and then forgotten for a long time. Also, in the year 2000 the physicist John Pendry predicted that it would be possible to make the "perfect lens" using materials with a negative refractive index, which could be used to achieve an optical resolution at certain wavelengths that was far below the wavelength of the light – in principle as far below the wavelength as required, even. This is possible because the time it takes the light to travel through the metamaterial is actually negative because of the fact that it is "going backwards". Combined with the positive amount of time taken for the light to travel through air, it can be concluded that a maximum of the light wave oscillation is capable of travelling from an object to an image of the object in "no time". However, this claim was also not readily accepted.

It was therefore necessary to perform experiments to verify these theories. In 2001, the American electrical engineer David Smith and his group became the first to demonstrate in the microwave range that a metamaterial really is capable of displaying negative refraction, and so refracting light the wrong way due to the negative refractive index. At wavelengths of about three centimetres fabrication was shifted into the millimetre range, and thus became much simpler. In 2003 a group working for Boeing was able to reproduce this decisive experiment.

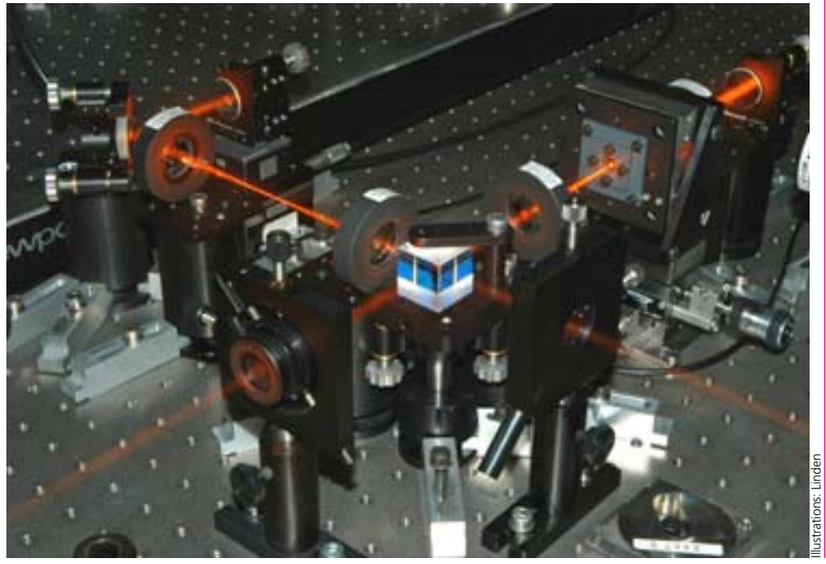
There was a resounding echo! The journal "Science" soon named metamaterials one of the "top ten scientific breakthroughs in 2003". It remained unclear, however, how applicable these results would be to the optical part of the electromagnetic spectrum. In mid-2004 Costas Soukoulis, a theoretical physicist from Greece who has been a pioneer in the field of photonic crystals, spent a few months as a visiting researcher at the DFG Research Center for Functional Nanostructures (CFN) in Karlsruhe. While there, he soon entered a lively debate about whether it wouldn't be possible for the researchers to make the grid of electromagnets in the crystals a factor of ten thousand or even a hundred thousand times smaller, in order to get down to the optical part of the spectrum.

Just a few weeks later a researcher from Karlsruhe, Stefan Linden, made the first such metamaterials, characterised them optically, and compared his results directly with the theories proposed by Costas Soukoulis' group. In November 2004 the results of the Karlsruhe study on the first magnetic metamaterial at optical frequencies were published in the journal "Science". This news sparked a worldwide race to create the first metamaterial with a negative refractive index in the visible part of the spectrum.

However, at that time the disadvantages of the electromagnets that had been produced also became apparent. It seemed that it was not only necessary to further miniaturise them, but also to come up with an entirely new design for the "photonic atoms" used in the metamaterials. Due to the close interaction of theory and experimentation this also proved possible, so that the research group from Karlsruhe was soon able to demonstrate a negative refractive index at the wavelengths used for telecommunications. In an experiment to measure the speed of the light, the researchers measured the amount of time it took the light to travel from the front of the sample to the back. Because of the fact that the light was effectively travelling backwards, a maximum of the light wave arrived at the back before it had entered the front of the sample.

This finding may appear astonishing, but it does not contradict the fundamental laws of physics. The experiments carried out so far have, however, meant that some lecturers now have to be even more careful about their choice of words when explaining things in lectures on optics than was the case just five years ago.

The glass of water containing a rod on the left shows the natural refraction of light. "Water" with a negative refractive index (right) would cause the rod to be refracted the "wrong" way. Bottom: The experimental setup used to demonstrate the negative refractive index in the red part of the spectrum.



Illustrations: Linden

What can we expect in future? There is still quite a lot of research needed before it will be possible to use optical metamaterials for commercial applications. For example, the losses need to be reduced and the dimensions, or the volume of the metamaterials needs to be increased and cheaper manufacturing methods need to be developed. It may be possible to chemically synthesise metamaterials from ring-shaped molecules that are just a few nanometres in size and that could act as electromagnets.

Another thing not to lose sight of is that the actual and immense charm of the concept of metamaterials lies in the fact that it is possible to make photonic atoms belonging to this artificial class of materials that are "tailor-made". This means that it may be possible to obtain optical properties that are simply impossible in natural materials and crystals. A magnetic response and a negative refractive index are just the first two examples of such properties. On the other hand, it is becoming increasingly clear that the hurdles standing in the way of new developments do not lie in the metamaterials themselves. The only real limits for future developments are the limits of human creativity.

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"Directing Attention to the Essentials"

Between information and entertainment: Bernhard Fink presents his video diary "Love à la Darwin" on DFG Science TV – benefitting not only science communication but his research as well

german research: Your video diary on DFG Science TV runs under the catchy title "Love à la Darwin". What is it about?

Fink: We are exploring the question: what makes a person attractive to the opposite sex? For a long time, it was thought that a partner was chosen randomly and that physical attraction was strictly a matter of taste. Now, 150 years after Darwin's fundamental findings on evolution, it is becoming increasingly apparent that the perception and assessment of human beauty, as well as the choice of a partner, are deeply embedded in human nature. We are using experimental methods to try to better understand this – such as studying the signal effects of facial and body features and the movement patterns of people.

Six episodes of "Love à la Darwin" are already available online for viewing in the second series on the video portal. Are you satisfied with the results?

Bernhard Fink: We learned quickly – we had to. In April, we participated in the DFG training course on camera use and technique. That was helpful in getting us started. Then in June, we produced the trailer. A student test pair is the focal point of all episodes. In this way, we feel that we move on the same level as the viewer. In any case, the films stir emotions within the viewer; laughter comes at the right times. That's important to us, because the videos are intended to be delivered in an entertaining format.

As a researcher, can you benefit from this as well?

Fink: Yes, absolutely. Even though it took us considerably more time than we had anticipated, being able to succinctly present the scientific material is beneficial to the scientific work in the team. That's what is most important. And, in this way, DFG Science TV enriches all of our projects by directing attention to the essentials.

You are media-savvy and have been presenting your behaviour-related topics on TV, radio and in newspapers for years. Against this backdrop, what makes DFG Science TV special for you?

Fink: That the researchers do the actual filming, develop the episodes and translate their results for a broad audience. The videos tell exciting stories and are easy to understand; my impression is that they can be understood by viewers from 14 to 90 years of age. The film-based presentation is well received – I can see that from the reactions of my peers and laypeople alike. Viewers forgive our weaknesses in filming, yet also compliment us on the objectivity that is often lacking in even professionally produced programmes. So, images alone aren't everything. It's a matter of finding the right mix, and Science TV has succeeded in that.

Illustration: Unterstell

The behavioural biologist **Dr. Bernhard Fink**, 36, directs the Emmy Noether independent junior research group "Evolutionary Psychology of Human Physical Appearance and Body Movement" at the University of Göttingen. Fink's both unusual and attractive research field – partner selection from an evolutionary perspective – is among ten projects from all scientific disciplines that were selected by the DFG in a competition for the second series of DFG Science TV and have been presented since June 2009.
german research spoke with Bernhard Fink about his video diary, the new DFG Science TV series and modern methods in scientific communication.

▶ www.dfg-science-tv.de

The second series of DFG Science TV is even more consistently targeted at the 14–19-year-old demographic. Does this give the portal a new quality?

Fink: It makes it more modern. I think it's a good idea to make increased use of Web 2.0 features and to integrate with social networks like Facebook, MySpace and YouTube. In this way, it's possible to catch the young Internet surfers where they're already active. This may be beneficial in interesting young people in research early on, and maybe even in generating outright enthusiasm.

What types of minds are needed for modern, multimedia science communication?

Fink: Knowledge stemming from research needs people who can promote it. On the one hand, these are science journalists, who competently take up topics from the world of research and present it in a media-appropriate manner. On the other hand, we also need specialists who are capable of preparing and presenting their topics for the media. I consider the latter to be a new generation of researchers who are rhetorically knowledgeable with respect to science – a fact of life, given modern communication possibilities. Without a doubt, there is a great amount of catching up to be done in this area. The DFG and Science TV are making an important and welcome contribution to this.

The interview was conducted by **Dr. Rembert Unterstell**.

"Research Needs Managerial Assistance"

DFG Secretary General Dorothee Dzwonnek on the relationship between science and management

How much management does science require – and how much management can science tolerate? This was the trenchantly formulated topic of the fourth "Tage des Wissenschaftsmanagements" ("Scientific Management Days") held at the Villa Vigoni on Lake Como. This year's event united 30 scientists and scientific managers from all disciplines in intensive discussions. DFG Secretary General Dorothee Dzwonnek, co-organiser and moderator, summarised the situation in an interview with Marco Finetti.

forschung: Ms Dzwonnek, if your meeting's central questions had been posed a few years ago, the answer would have been clear: science does not require much management and it has a very low tolerance for it.

Dorothee Dzwonnek: Yes, but no-one would say that now. All scientific disciplines have now come to the realisation that science is becoming more and more complex and therefore requires a high level of support from management professionals. We were all agreed on this, including hospital directors, University Chancellors and Speakers of the Cluster of Excellence.

But even that sounds more like acceptance of the inevitable than enthusiasm?!

Dzwonnek: No, that would be interpreting it incorrectly. The term "requires" is a very positive one, because it's a means to a positive end.

What form does that end take?

Dzwonnek: The goal must be to give science more freedom and to organise its increasing complexity to enable it to develop its potential and productivity. Professional assistance is more important than ever in achieving this goal.

And on the other side: How much management can science tolerate?

Dzwonnek: We discussed this question from two different angles. On the one hand, we were in agreement that the bureaucratic parameters have, to a certain extent, become so complex that they are hindering the free development of science. We must take measures to counteract this, regardless of the importance of good management.

Where is this the case?

Dzwonnek: This applies, for example, to many taxation aspects or to state aid legislation, but in particular to the emerging European Research Area. With the Starting Grants from the European Research Council, all successful applicants first had to negotiate an individual contract with the ERC. In many cases, these negotiations took longer than evaluating their applications. This is an example of the type of excessive management which science cannot tolerate. On the other hand – and this was the second, somewhat delicate issue under discussion – science sometimes tends to overestimate its own capabilities to a certain degree. This is not healthy.

Illustration: Himsel

How do you mean?

Dzwonnek: There are those who feel that they could, perhaps, perform the requisite management duties themselves. By doing so, however, they are only giving themselves unnecessary tasks which are not theirs to carry out and which only take them away from what they should be doing. This then results in the all-too-familiar complaints, namely that no-one can get any scientific work done because of all their management duties.

And you want to protect scientists from this, by giving them managers?!

Dzwonnek: We want and need to become more professional in all disciplines and at all levels. And this professionalism involves science not only recognising and using its own strengths, but also knowing when and where it would be better to accept professional help.

What form should this professional help take?

Dzwonnek: Managers must truly be the oft-cited "wanders between worlds". They must understand the administrative side of things, as well as science and its culture. Reconciling both and placing themselves at the service of science is a fine art …

… Something which can be learned?

… that could certainly be approached in a more organised way than before. We need a professional training curriculum, to which practical phases and further training can be added in order to tailor it to the specific needs of the various different disciplines and facilities. The DFG has already made a start in this direction through our "Forum Hochschul- und Wissenschaftsmanagement" ("University and Scientific Management Forum") at the Centre for Science and Research Management in Speyer. We want to continue to expand on this.

The Deutsche Forschungsgemeinschaft

The Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) is the central self-governing organisation responsible for promoting research in Germany. According to its statutes, the DFG serves all branches of science and the humanities. The DFG supports and coordinates research projects in all scientific disciplines, in particular in the areas of basic and applied research. Particular attention is paid to promoting young researchers. Researchers who work at a university or research institution in Germany are eligible to apply for DFG funding. Proposals will be peer reviewed. The final assessment will be carried out by review boards, the members of which are elected by researchers in Germany in their individual subject areas every four years.

The DFG distinguishes between the following programmes for research funding: In the *Individual Grants Programme,* any researcher can apply for financial assistance for an individual research project. *Priority Programmes* allow researchers from various research institutions and laboratories to cooperate within the framework of a set topic or project for a defined period of time, each working at his/her respective research institution. A *Research Unit* is a longer-term collaboration between several researchers who generally work together on a research topic at a single location. In *Central Research Facilities* there is a particular concentration of personnel and equipment that is required to provide scientific and technical services.

Collaborative Research Centres are long-term university research centres in which scientists and academics pursue ambitious joint interdisciplinary research undertakings. They are generally established for a period of twelve years. In addition to the classic Collaborative Research Centres, which are concentrated at one location and open to all subject areas, the DFG also offers several programme variations. T*ransregional Collaborative Research Centres* allow various locations to cooperate on one topical focus. *Cultural Studies Research Centres* are designed to support the transition in the humanities to an integrated cultural studies paradigm. *Transfer Units* serve to transfer the findings of basic research produced by Collaborative Research Centres into the realm of practical application by promoting cooperation between research institutes and users.

DFG Research Centres are an important strategic funding instrument. They concentrate scientific research competence in particularly innovative fields and create temporary, internationally visible research priorities at research universities.

Illustration: Querbach

Research Training Groups are university training programmes established for a specific time period to support young researchers by actively involving them in research work. This focusses on a coherent, topically defined, research and study programme. Research Training Groups are designed to promote the early independence of doctoral students and intensify international exchange. They are open to international participants. In *International Research Training Groups,* a jointly structured doctoral programme is offered by German and foreign universities. Other funding opportunities for qualified young researchers are offered by the *Heisenberg Programme* and the *Emmy Noether Programme.* In so called *Reinhart Koselleck Projects,* the DFG supports especially innovative research undertakings by outstanding scientists and academics.

The *Excellence Initiative* aims to promote top-level research and improve the quality of German universities and research institutions in the long term. Funding is provided for graduate schools, clusters of excellence and institutional strategies.

The DFG also funds and initiates measures to promote scientific libraries, equips computer centres with computing hardware, provides instrumentation for research purposes and conducts peer reviews on proposals for scientific instrumentation. On an international level, the DFG has assumed the role of Scientific Representative to international organisations, coordinates and funds the German contribution towards large-scale international research programmes, and supports international scientific relations.

Another important role of the DFG is to provide policy advice to parliaments and public authorities on scientific issues. A large number of expert commissions and committees provide the scientific background for the passing of new legislation, primarily in the areas of environmental protection and health care.

The legal status of the DFG is that of an association under private law. Its member organisations include research universities, major non-university research institutions, such as the Max Planck Society, the Fraunhofer Society and the Leibniz Association, the Academies of Sciences and Humanities and a number of scientific associations. In order to meet its responsibilities, the DFG receives funding from the German federal government and the federal states, as well as an annual contribution from the Donors' Association for the Promotion of Sciences and Humanities in Germany.

Impressum

german research is published by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation); Publisher: WILEY-VCH Verlag GmbH & Co. KGaA, P.O. Box 101161, D-69541 Weinheim; Annual subscription price: € 61.00 (Europe), US $ 66.00 (all other countries) including postage and handling charges. Prices are exclusive of VAT and subject to change. Address of editorial staff: DFG, Press and Public Relations Office, Kennedyallee 40, 53175 Bonn; postmaster@dfg.de; www.dfg.de

Editor-in-chief: Marco Finetti (responsible for content); Publishing Executive Editor: Dr. Rembert Unterstell; Copy Editors: Stephanie Henseler, Angela Kügler-Seifert; Translation: SciTech Communications GmbH, Heidelberg; Printed by: Bonner Universitäts-Buchdruckerei (BUB); printed on chlorine-free bleached paper with 50 % recycling fibres.

ISSN 0172-1518

www.dfg.de

Illustration: Ausserhofer

Optimistic and looking into the future: A view of the DFG's New Year's reception in Berlin. In mid-January, leading figures from the world of science, politics, business and society once again met in the Leibniz Room at the Berlin-Brandenburg Academy of Sciences and Humanities to look ahead at the major challenges facing research and funding policy in the coming months.