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2-3/2004 ▶ Interview with the Sociable Honeybee ▶ When the Skylark Abandons the Meadow ▶ Zhuangzi and the Cultivation of Life ▶ A Listening Post to the Universe ▶ On Truth and Reconciliation

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Messages from the Wadden Sea

The Wadden Sea and other mud flats in coastal regions around the world, in a variety of climates, are a result of the tides. Taking the southern North Sea as an example of this habitat, scientists study how ecological processes operate in the threatened "Wadden Sea habitat". This, it is hoped, will lead to a new understanding of the processes taking place in tidal mud flats. **Page 8**

A Royal Tomb in Syria

In one of the largest palace complexes in the ancient Orient, in the palace of Qatna, archaeologists have discovered the first royal tomb in Syria not to have been raided by grave robbers. The subterranean burial chambers and the treasures they contained provide new insights into the world of the living and of the dead in the ancient royal city of Qatna. This began a new chapter in the uncovering of ancient Syrian culture. **Page 16**

With the Help of Robots

To treat serious injuries to the skull it is necessary to implant high precision titanium plates. Doctors have now teamed up with engineers to tackle this problem. The results so far have shown that not only computer-aided processes can help with the prefabrication of individual skull implants, but also robots are able to provide valuable assistance. **Page 34**

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Communication in the Kingdom of the Bees

Honey bees are social creatures. The flow of information within a bee colony is therefore of central importance. Biologists are studying the basics (page 36).
 Cover: Fiola Bode/beegroup

Impressum

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The German Chancellor has declared 2004 the "Year of Innovation". In addition, elite universities, top-level research and the prerequisites that are necessary for topnotch research are currently the topic of discussion in more than just the talk shows and feature pages. In the course of the debate, the question is often asked: What framework conditions are needed for top-level research and innovative science in Germany? There is a consensus in this country regarding the financial aspect. In the end, we still have much to do to reach the goal of investing three percent of the gross

damental life processes to be better analysed, private sector, and last but not least practical medicine because new, safer drugs like human insulin could be developed. Medically relevant genetic research (also known as "red genetic engineering") is all in all a story of success.

At the beginning of the new era of genetic engineering, there were also debates about the risks such as for example the emergence of new pathogens. Researchers therefore agreed on a "moratorium" to allow lawmakers to come up with regulations that divided genetically modi-

plants. Nearly 70 million hectares containing genetically modified crops have now been recorded worldwide, corresponding to an area that is roughly double the size of Germany. The methods of green genetic engineering are used to cultivate new varieties of plants that are resistant to certain pathogens or insecticides or to form new ingredients such as vitamins or proteins. The use of transgenic plants therefore produces crops more economically and using fewer pesticides. In the United States, transgenic varieties of such crops as maize, cotton or soybeans already make up more

Prof. Dr.
Jörg Hinrich Hacker

A "Year of Innovation" for Genetic Engineering as well?

domestic product in research, as is already the case in other countries. In short, science in Germany is under-financed. If we want innovation, this is where we have to start.

But what about the principal, immaterial requirements for research? Is Germany even a research-friendly country? Let us look at the example of genetic engineering. Almost 30 years ago, researchers discovered that they can isolate genetic material from organisms (bacteria, plants, animals) and purposely alter it in the laboratory. Many have benefited from this innovation, which soon received several Nobel prizes: science, because this allowed fun-

dified organisms into different risk categories to which specific working conditions apply. These regulations have paid off. Red genetic engineering has proven itself to be not only extremely efficient but also a very safe technology. This technology is finding more and more acceptance throughout the world, including Germany, so that the laws have been gradually liberalised over time, which has led to relatively stable framework conditions.

Alongside red genetic engineering, "green genetic engineering" has also been developed, which centres on research using genetically engineered or "transgenic"

than 50 percent of the harvest. While large amounts of genetically modified plants are being cultivated in many non-European countries, citizens of many European countries continue to have serious reservations about the so-called "gene food".

What are the current topics of research in green genetic engineering? Many extremely interesting and relevant scientific questions can be answered with the help of genetically modified plants. For example, scientists are researching the origins of various diseases in plants. A large number of crops continue to be destroyed by pests, such

as vine pest, which attacks and weakens the fine roots of grapevines or blight, which is a pathogen of grain. Knowledge about the mechanisms of these plant diseases will contribute to the development of new and more resistant varieties, but we can also study how plants develop – for example, how different tissues emerge from one germ bud. Scientists can also analyse metabolic pathways in plants. That is why it is not astonishing that over 30 percent of all “releases” of transgenic plants in Germany are carried out by research institutes such as the Max Planck Society, the univer-

which has since run out. Germany has recently implemented a general EU guideline in German law, which passed the German parliament in November 2004. In light of the importance of green genetic engineering for science, the expectations for this new law were high, especially with regard to the establishment of reliable regulatory conditions. However, it is doubtful whether this goal can be achieved with the new Genetic Engineering Law. In the view of the DFG, this depends on two central points. The first point is that one of the main concerns of the new Genetic Engineering Law is to

hope that lawmakers and administrators will come up with a regulation within the framework of the legislative procedure that takes the concerns of sciences into account as much as those of agriculture.

The second point is also important: the registration and approval procedures will be more expensive and more bureaucratic. Instead of creating more streamlined structures, the Central Commission for Biological Safety (Zentrale Kommission für Biologische Sicherheit), which has proven to be quite effective in the past, will have to be restructured and virtually doubled in size. In addition, the application procedure and the accompanying record-keeping will be more expensive than before. In other words, instead of streamlining and reducing bureaucracy we will have more commissions and more unproductive paperwork! Science also expects that the administrative process will create improvements here as well.

In other words, we have to ask ourselves: is Germany a country that wants innovations in the area of genetic engineering, or will the risks alone become the centre of attention? Will green genetic engineering be placed under common suspicion or can scientists count on a leap of faith? Does the constitutionally protected freedom in the pursuit of research also apply to green genetic engineering? Whether 2004 will be remembered as the “Year of Innovation” also depends on the answers to these questions.



sities or the Leibniz Association. Many of these projects are also funded by the DFG.

As before with “red” genetic engineering, there are also debates about the risks of “green” genetic engineering: from the possibility of supposedly “harmful” genes being transferred to neighbouring plants to the idea that genetically modified plants could have adverse effects on human health. Many of these scenarios are based on conjecture and have not been proven based on the experiences gained from large cultivations abroad. Nevertheless, there was an EU moratorium for certain areas of green genetic engineering,

avert the “penetration” of genetically modified organisms in conventional crops. It does not matter whether the regulatory authorities have classified the transgenic plants as harmless. Only the fact that there may be transference of genes from genetically engineered plants is considered. The user is held liable if a specific threshold value of transgenic plants is exceeded. This applies to commercial growers as well as scientists. One thing is clear: with the new gene law, the actual “innovation” in the area of green genetic engineering will be the fact that this work will take place outside Germany in the future. One can only

A handwritten signature in blue ink that reads 'Jörg Hacker'.

Prof. Dr. Dr. h.c. Jörg H. Hacker

Jörg Hinrich Hacker, Professor for Molecular Infection Biology at the University of Würzburg, is the Vice President of the DFG. The Executive Committee of the DFG is composed of the President and eight Vice Presidents, as well as the President of the Donor’s Association for the Promotion of Science and Humanities in Germany (Stifterverband für die Deutsche Wissenschaft).



We still have in our minds a view of gravity that is largely influenced by the work done by the English physicist Isaac Newton three hundred years ago. He described it as a force of attraction, acting between all masses. However, the observation of masses in free-fall leads to the conclusion that this is a motion free of the influence of forces, which, at any given point in space, is always independent of the size and composition of the masses involved. From this, Albert Einstein deduced that gravitation is an effect that depends on the geometry of space. The development of this idea led, in 1915, to the general theory of relativity.

From the Einsteinian point of view, physical space is neither a rigid scaffold nor the arena for processes occurring in nature; it is, itself, a participant in events. Space is distorted by the presence of mass-

A Listening Post to the Universe

es. The resulting curvature of space has a direct influence on the motion of other masses and thus gives the appearance of a diversionary force. When masses move at high speed, the resulting changes in the curvature of space are propagated in all directions with the speed of light, giving rise to gravitational waves. However, it was already acknowledged by Einstein that only very large masses with very high accelerations would generate gravitational waves of a measurable ampli-

tude. The only possible sources are therefore objects or events such as systems of black holes and neutron stars or supernovae.

The effect of these waves is expressed as a distortion of space, as stretching and compression of its geometrical structure. This leads to differing changes in the lengths of mutually perpendicular objects, which can be detected if the said objects are parts of a measuring system. Such a device for detecting relative changes in length is the



Demonstrating the existence of gravitational waves has recently become possible. A newly developed, highly sensitive detector generates new information used to research black holes and the origins of the universe

Michelson interferometer. This is used to compare the transit time of light over two perpendicular paths. The problem for the experimental physicist is that the changes in length to be expected are extremely small. For example, a supernova explosion in a neighbouring galaxy would change the length of a kilometre-long arm by one thousandth of the diameter of a proton – and this for just a few milliseconds.

For 40 years, attempts have been made to confirm the existence of

gravitational waves but only now do we have sufficiently sensitive laser measuring technology. The GEO 600 gravitational wave detector is a joint project of German and British research groups. This is a Michelson interferometer with 600-metre arms that has been set up on grounds belonging to the University of Hannover in Ruthe, to the south of the city. Responsible for the project are scientists from Hannover, Golm, Glasgow, Garching and Cardiff. It is expected that gravitational waves

will be detected with frequencies in the audible range – making GEO600 literally a listening post in space.

There are many effects that make the observation of gravitational waves very difficult. They cause changes in the light-path difference between the two arms and thus simulate a signal. These are, for example, acoustic disturbances (variations in air pressure); for this reason, all optical structures are housed in large vacuum tanks. The arms themselves are enclosed in evacuat-

Demonstrating the existence of gravitational waves requires highly sensitive laser measuring technology that was only developed in recent years. In the main building of the new GEO600 gravitational wave detector, all optical components are housed in evacuated stainless steel tanks.



A bird's eye view of GEO600: Running from the main building are two 600-metre arms, each with its own terminal building. The arms themselves (right) are enclosed in stainless steel tubes that are suspended in trenches.



ed stainless steel tubes of 60 centimetres in diameter. The vacuum required here is similar to near-earth space.

Evident sources of interference are also seismic tremors of all kinds, thermal motion of the optical components, as well as technical variations in the light intensity that introduce noise. To reach the required sensitivity, these interference sources must be adequately suppressed or displaced to a frequency range outside the measurement window. A particular challenge was the development of a suitable laser for GEO 600. Laser for gravitational wave detectors must be not only particularly powerful but also extremely stable in frequency, amplitude and beam geometry. In addition, they must be capable of continuous operation for months at a time. In recent years, a laser was developed jointly with the Laser Centre, Hannover, that is based on a special laser system and has a continuous output

power of 17 watts. However, since the optimum optical power for GEO600 is in the kilowatt range, a means had to be found of increasing the circulating optical power in the detector. The interferometer works with a so-called null method. Feedback loops keep the output dark. Only when a gravitational wave arrives does light get through to the output. This means that, after passing down the arms, the laser light is returned to the input. An additional mirror returns this light to the arms and superimposes it on the incident light ("power recycling"). In this way, GEO600 can work with an effective power of ten kilowatts. In a similar way, the signal is amplified by "signal recycling".

Since 1995, there has been a worldwide upsurge in the building of large laser interferometers for detecting gravitational waves. In the American LIGO project, detectors with four-kilometre arms were constructed in two locations, one in the northwest of the USA (Washington) and the other in the southeast (Louisiana). Near Pisa, the Franco-Italian VIRGO project, with three-kilometre arms, has just been completed.

In spite of its shorter arm length, GEO600 has about the same sensitivity as the larger detectors, as it differs from them in having incorporated the advanced techniques developed in recent years from its inception. Signal recycling, the suspension of the optical components from quartz glass fibres and the possibility of tuning the detector to a desired frequency are still unique to GEO600.

The various projects depend on cooperation. Only by working together with a remote detector can local disturbances be reliably eliminated. However, to obtain information on the source direction and the waveform of the signals requires a worldwide network of at least

four detectors. The various stations have therefore agreed to exchange data and evaluate them jointly. The collaboration between GEO600 and LIGO is particularly close. From the end of December 2001 until mid-January 2002, there were parallel trial runs of both detectors in which the system stability and programs for data recording and evaluation were successfully tested. First results are now being published.

A challenging piece of research work was the development of a high-power laser for GEO600

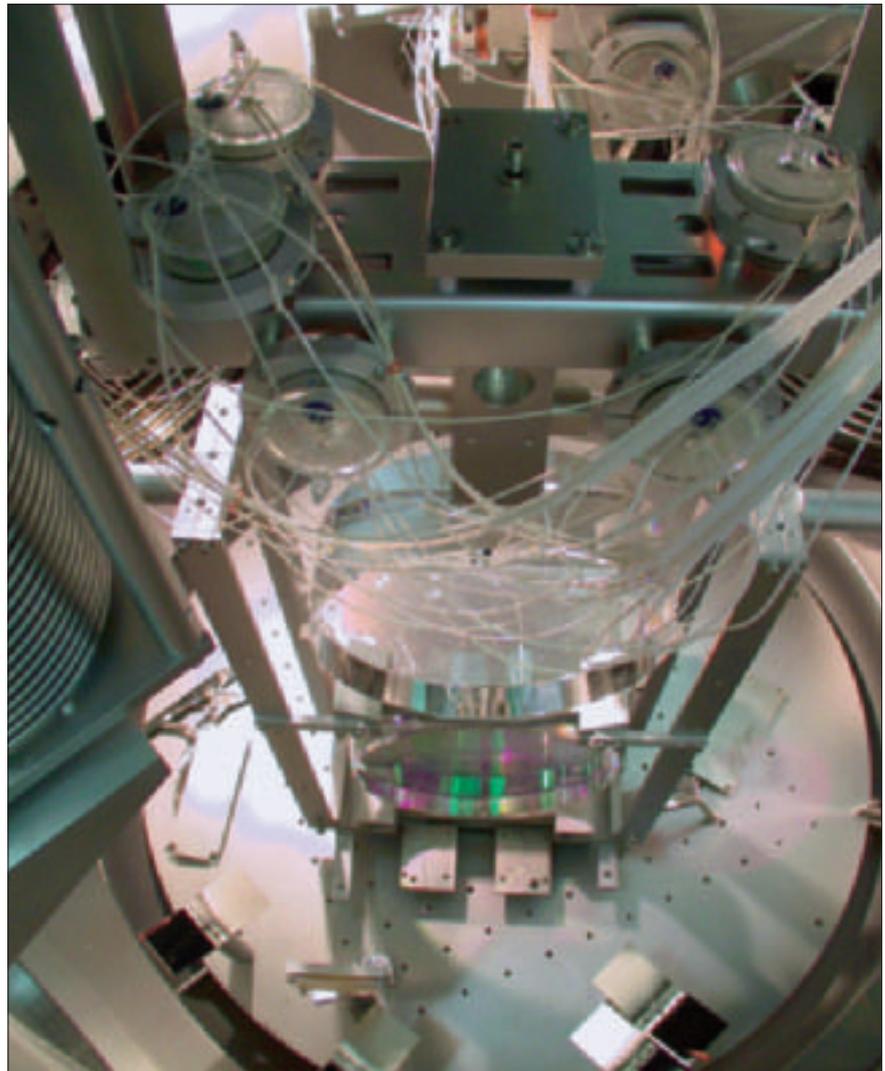
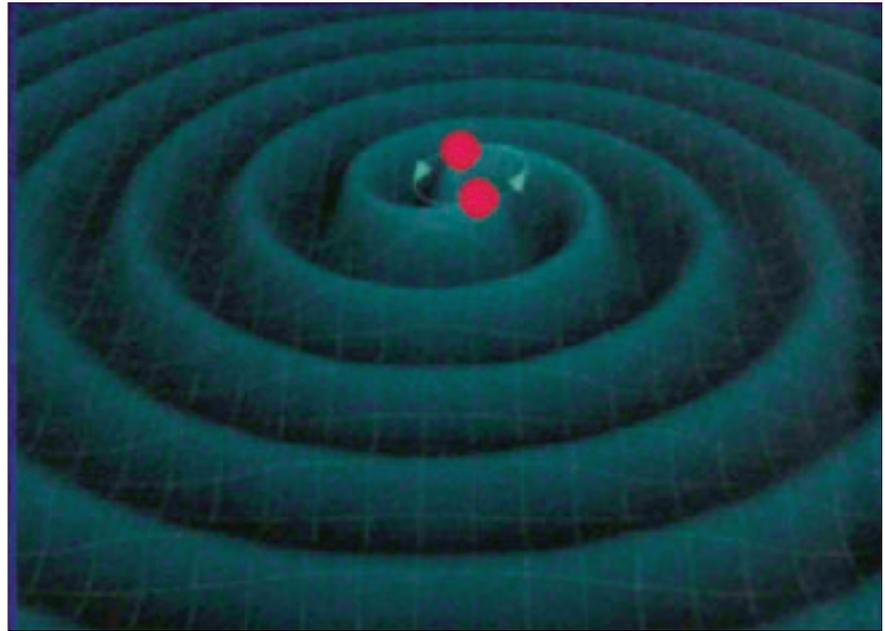
Two neutron stars orbiting one another generate gravitational waves that travel to the earth with the speed of light. Below: to prevent GEO600 responding to earth tremors, mirrors and beam splitters are hung in multiple pendulums.

However, as neither of the detectors has yet reached the planned sensitivity, only estimates are currently possible. The detectors are being continually improved. At the end of 2003 and beginning of 2004, data were again recorded jointly from GEO600 and LIGO. From 2004, the detectors should go into regular measuring operation.

The observation of gravitational waves will open a new field in astronomy. The structure of the waves is a precise image of the astrophysical phenomenon that generated them. We will thus obtain information about the universe that is of a quite different kind to that from classical astronomy, using light, radio waves or X-rays. Most sources of gravitational waves do not emit any electromagnetic radiation and vice versa. These two branches of astronomy will thus provide complementary information about space. Furthermore, the major part of the universe is made up of dark matter that can only be detected by any gravitational waves that it might generate.

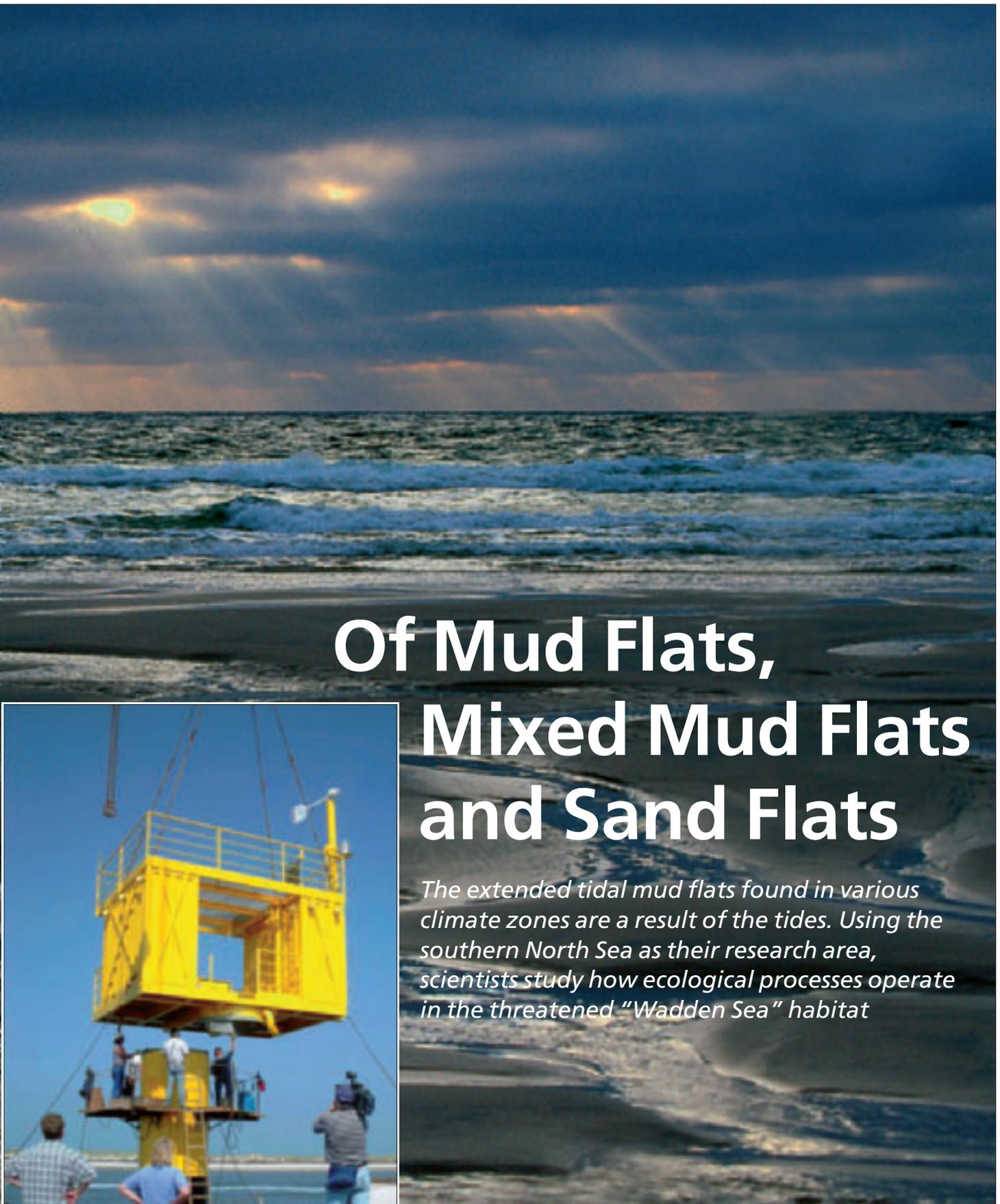
Gravitational waves hardly interact with matter. While this makes it difficult to demonstrate their existence, this also makes them ideal information carriers. The entire universe is transparent to gravitational waves. Researchers therefore expect to observe gravitational waves from the areas of the universe that are obscured by clouds, as well as waves generated by its creation. The gravitational waves generated by the big bang should still be observable as background radiation. Recording these signals provides information about the universe shortly after its origin – it is as if we were listening in to the first cry of our world.

*Dr. Peter Aufmuth
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The tidal flats only appear inhospitable at first glance. A new time-series station supports the study of this habitat. Measuring instruments that directly transmit data to the shore are housed in a work container.



Of Mud Flats, Mixed Mud Flats and Sand Flats

The extended tidal mud flats found in various climate zones are a result of the tides. Using the southern North Sea as their research area, scientists study how ecological processes operate in the threatened "Wadden Sea" habitat



Why does East Frisia have tides? It's simple: when the East Frisians came to the sea, the water took fright and ran away. Now it comes back twice a day to see if they are still there." This rather old joke hinges upon the most prominent characteristic of the mud flats: the tides. The rapid change in environmental conditions, which also results in fluctuations of direct insolation and salt concentration, may at first sight seem inhospitable, but in fact, biological activity is particularly high in the mud flat ecosystem.

Mud flats are an important component of coastlines affected by the tides in various climate zones and with different current conditions. They are among the most productive natural ecosystems on the planet and play an important role in the global biochemical and geochemical balance. Tidal flats not only provide a habitat for many species of birds, but are also the nursery for a wide variety of marine organisms. Because sediments are deposited near the coast during high tide, tidal flats also provide important protection against marine erosion. For centuries, a major part of human activity all over the world has been concentrated in coastal regions. It is assumed that in the year 2025 about 75 percent of the world's population (as opposed to 50 percent today) will be living in coastal regions. The demand for exploitation of this space will therefore increase. This applies to industrially useful materials from marine organisms, marine biotechnology as well as to the production of renewable energy in coastal wind power systems. This is accompanied by the risk that the exploitation of resources will irreparably destroy this ecosystem. Knowledge of the ecological processes and the health status of the flats, which can be derived from this knowledge is therefore of great importance to the coastal population.

The particular characteristics of the tidal flat ecosystem, which are seen as being particularly worthwhile protecting, have led to parts of this ecosystem being declared a National Park, which has restrictions
10 regulating exploitation through

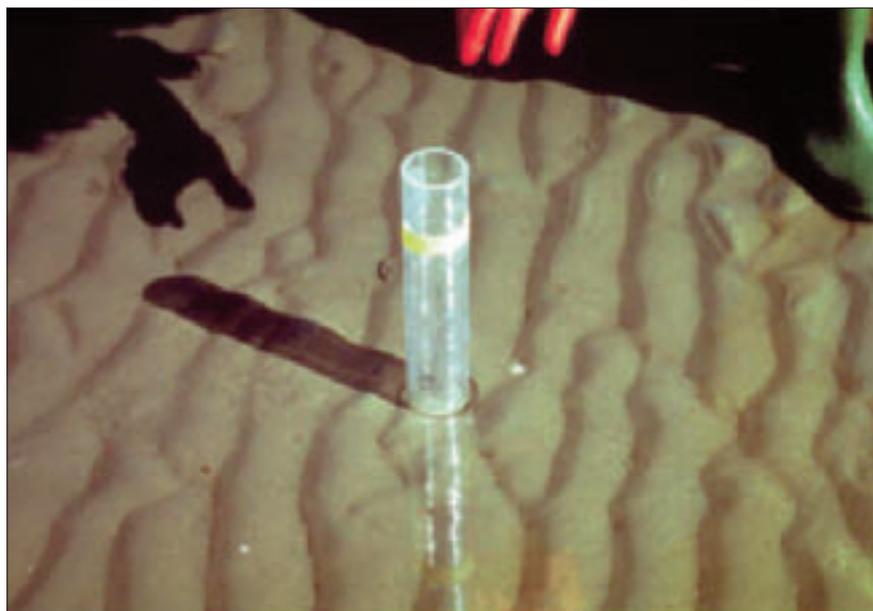
fishing and tourism. Strong political efforts are being made to promote the Wadden Sea, as the tidal flat zone of the southern North Sea is called, to the status of a World Heritage Site.

The North Sea's flat relief and pronounced tides have created extensive tidal mud flats along its coast. The tide raises water by between about one and three meters between low tide and high tide in the eastern North Sea. The tidal flats habitat encompasses the salt marshes, dunes and beaches that are above the average high tide mark, the actual flats that are exposed at low tide, and the tidal creeks and depressions (*Priele* and *Tiefs*) that are permanently under

ed by storm tides. The islands and the tidal flats that lie inland from them are young formations in geological terms. During the most recent ice age about 18,000 years ago the coastline ran far out in the North Sea. The coastline only reached the current shores when the continental ice masses melted about 9,000 years ago, forming today's coastal area through a rising, and intermittently retreating, sea level.

Humans only began to protect the coastline with dikes during the Middle Ages.

Within the Wadden Sea a distinction is made between mud flats, mixed mud flats and sand flats, based on the characteristics of the sediment. They provide a variety of



water and run like rivers through the tidal landscape.

One of the largest continuous tidal flat zones of the world extends along the North Sea coast from Blåvands Huk in Jutland, Denmark, in the north along the coasts of Schleswig-Holstein and Lower Saxony in Germany to Den Helder in the Netherlands. Particularly characteristic are the barrier islands, which were created a few thousand years ago by sand deposits off the coasts of Lower Saxony and the northern Netherlands, whereas the islands off the coast of Schleswig-Holstein are mainly remnants of a former land mass that have not been erod-

The surface of the sandy tidal flat has an impressive structure. Top: Drilling is required to obtain new data. In the process sediment cores of up to a length of six metres are extracted. Using a flat bottom boat that can "run aground" on the tidal flat surface, researchers travel to their study area and stake out the study plot.

habitats for the organisms living in or on the sea bed of the tidal flat.

Complex biological structures arise from the interaction between these organisms. In specific regions of the Wadden Sea certain life forms predominate, for example the lugworm, with its typical spiral casts,



the sand mason worm, which lives in extended dense colonies, and banks of blue mussels. In addition to the 60 or so animal species that are a few millimetres to centimetres in size, a smaller fauna of several hundred species that live between the sand grains is an important element of the biodiversity. The food chain is based primarily on microalgae living on the bottom and in the water column. Apart from the manifold "predatory relationships" amongst the fauna of the tidal flat seabed, the interactions between the organisms also extend to the higher levels of the food chain. Many young fish and shrimps live on the rich food supply in the tidal flats. They, in turn, provide nourishment to the large flocks of migratory birds that visit the mud flat twice a year on their way from their arctic breeding grounds to their tropical winter feeding grounds and back again.

The dynamic processes that have formed the tidal flats and continue to change them are exceedingly complex. The sediment budget is still an unsolved question. Since the quiet run-off zones of the water were lost as a result of dike building, it is assumed that tidal sediments are increasingly deprived of fine-grained materials. The mud remains in suspension and cannot settle. However, this has not yet been confirmed by experimental measurements taken from ships. Mathematical models, however, show that from wind force eight upwards – when coastal research vessels can no longer be used – sediment is lost from the tidal flats to the sea.

Similarly, the effect of hard winters, when ice floes freeze to the surface of the sediment and possibly carry this layer out into the open North Sea during flood tide, is also not yet fully understood. By the establishment of a permanently measuring time-series station between the German islands of Spiekeroog and Langeoog in August 2002, studies of the transport of suspended material in the water column even under harsh weather conditions have become possible. Long-term changes in the sediment budget will

also affect the ecosystem because conditions for colonization on the sea bed will change. It is therefore important to be able to differentiate between the delayed effects of dike building and the effects of long-term sea level rise due to climate change and human influence.

Interest in the role of microorganisms in the water column and in sediment has only just begun to crystallise. As well as filter feeders such as mussels, microorganisms are the sewage treatment system of the tidal flats. They decompose the remains of dead plankton and other creatures and return the products to the food cycle. This is mostly done by the bacteria in the water column

and in the upper sediment layers, which are often only a few millimetres thick and still contain oxygen. The aerobic bacteria ensure that the anaerobic zone below does not extend to the surface, causing the tidal flat to deoxygenate and black spots to appear on the surface. On a small scale these black spots do not pose a problem, but a chain of natural phenomena caused large black areas to form following the hard winter of 1995/96, resulting in the death of large numbers of mussels and worms due to lack of oxygen. However, the tidal flats were even able to recover from this situation by the next summer thanks to their strong self-healing capacity. The role of the bacteria that live in the anaero-

bic sediment zone below the surface remains a complete mystery. Many are unknown organisms, which are difficult to grow in culture and whose physiological characteristics have not been studied. It is not evident whether they extract their nourishment from hard-to-decompose organic matter that is left over by the surface bacteria, or if the pore water in the sediments provides them with nutrients that can be utilised more easily. They may, perhaps, be relatives of bacteria that live in similarly inhospitable conditions under more than a thousand metres of sediment in the oceans.

The many manifestations of tidal flat systems make it difficult to recognise the basic principles according to which the flats react to external changes, such as the weather over the seasonal cycle, changes in sea level and lack of oxygen. To gain a new understanding of the processes occurring in the tidal flat system, a materials budget will be determined, taking the backbarrier tidal flats of the North Sea island Spiekeroog as an example. The currents, composition, hydrodynamics and morphology of tidal flats as well as the biogeochemical processes on particles in the water column, at the sediment-water interface and in the tidal flats will be investigated using an array of modern analytical methods. At the same time, mathematical models will be developed for the numerous subprocesses in the tidal flat system. These will form the basis for a mathematical model that will describe tidal flats as a whole and which can be used to follow their development. After an appropriate generalization, it should become applicable to tidal flat systems anywhere in the world.

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A time-series station was established in the North Sea off the southwest tip of Spiekeroog. The working station rides mounted on a strong 40-metre tube, a third of which is buried in the tidal flat sediment. It is supplied with instruments and accessories by boat.



On Truth, Dignity and Reconciliation

*What are the conditions associated with political reconciliation?
A theological study shows that working through the past between victims and perpetrators always requires a conscious effort to overcome guilt*

When a nation is working through its past, the call for reconciliation is often expressed. Konrad Adenauer and Charles de Gaulle hoped for a German-French reconciliation. Nelson Mandela spoke of the reconciliation between black and white people in South Africa after the end of Apartheid. After the fall of the Berlin Wall there was a call for reconciliation between perpetrators and victims in East Germany. Global hotspots point to the explosiveness of the topic in the present: be it in Iraq, the Middle East, Afghanistan, East Timor, Central Africa or the Balkans – the problem of overcoming guilt is universal in the effort to establish a peaceful post-war order. The question then arises: to what extent can theology still provide guidance in concrete conflict situations?

The theological project “The political dimension of reconciliation” started from the observation that reconciliation as a central theme in Christian theological teaching recurs in the political realm. Reconciliation is spoken of in both theology and politics. But does it mean the same thing in both contexts? Is there a commonality of meaning in addition to the common usage of words like guilt and reconciliation in politics and theology? Where and under what conditions is it possible to translate from theological language into political and vice versa? The universal nature of the biblical promise that God reconciled “the world” to himself (2 Corinthians 5:17-21) at first seems to legitimate a

correspondence in political reality with this idea of reconciliation. One might ask whether the elements of the Christian concept of reconciliation, such as the forgiveness of sins, the wiping away of guilt, the overcoming of hostility through friendship, and the rebuilding of community can be found in the political reconciliation process.

The objective of this project was to study the conditions for reconciliation in the political realm by way of examples and to reflect on the political aspects of reconciliation in all its theological solemnity. The ethical interest is directed at a theological “quality check” of the political talk of reconciliation that took place while working through the past after the changes to the political systems in Germany and South Africa.

The causal relationship between the transition processes in South Africa and Germany was established by former South African President de Klerk in his famous parliamentary address of 2 February, 1990. He announced the release of Nelson Mandela, noting that after the fall of the Berlin Wall the Apartheid system was no longer necessary to protect against communism as before. In the question of reconciliation “outside” Christian doctrine, there were first methodological problems to be dealt with. How can a status description of po-

litical reality succeed without religiously instrumentalising the process to be examined, i.e., without making theological understanding a selection criterion in perceiving political reality from the outset? For the methodology, it helped to utilize case studies, a technique which has been applied in the social sciences for some time now. The case studies method makes it possible to disentangle the portrayal of political reality from its interpretation. The case study analysis was further refined in the transfer to the theological project by applying additional methods from qualitative social research. Interviews were used, for example, in addition to textual analysis.

The so-called transformation research in history and law suggests the analysis of political transition processes alongside five options for action: Depending on the power rela-

The conditions of reconciliation in the political realm may be analysed through the use of case studies

tionships, a young democracy can introduce criminal proceedings against the prior injustice (option 1), proclaim amnesty (option 2), shed light on the matter through truth commissions (option 3), introduce a policy of reparations to the victims (option 4) or attempt severe sanctions outside criminal law – such as cleansing and rationalisation of the civil service (option 5). The option finally carried out depends decisively on the nature of the system change.

The options listed above are associated in the political debate with a specific understanding of reconciliation, which was then examined for agreement with the Christian concept of reconciliation. Internal associations should be made between the manifold connections of political reconciliation with the theological doctrine of reconciliation. An insurmountable gap appeared to open up between the political concept of reconciliation analysed in the case studies on the one hand and the teachings on the idea of reconciliation that can be traced straight through the Christian tradition on the other hand. The latter all have to do with the relationship between God and humanity, the former with the relationship between one human being and another. In both cases it is still a matter of overcoming guilt through reconciliation. However, the social and political dimension of the reconciliation of God and man was not considered in the theological doctrine of reconciliation through the centuries. As it turned out, this dimension could not be connected with a theological interpretation of political reality.

The reconciliation doctrines based in traditional history were less suitable for theological interpretation than the analysis of paths of reconciliation from the Biblical tradition.

What moments are essential in an interpersonal reconciliation process according to the relevant Biblical reconciliation stories? To what extent are they

reflected in reconciliation paths between perpetrators and victims in political forums, such as in the South African Truth and Reconciliation Commission? The analysis showed that central elements of the Biblical reconciliation path, such as offering reconciliation in the form of an admission of guilt, its acceptance in the form of forgiveness, and the new relationship of those who are reconciled in the form of restitution, reoc-

cur in the societal and political context. It was found that the successful reconciliation path cuts across all stages biblically and politically. When, for example, there is no admission of guilt on the part of the perpetrator, the prospects for reconciliation on the part of the victim are slim in all but the rarest cases.

Reconciliation includes working through guilt – in the hope of forgiveness. “Working through” describes a process of the spiritual diffusion of the past with the objective of freeing the shared future from this burden. A critical light fell on the debate, staged effectively for the media, regarding the level of guilt of unofficial Stasi (colloquial abbreviation for “Staatssicherheit”, meaning “State Security”, the main security and intelligence organisation of the German Democratic Republic (East Germany)) collaborators because it did not demand a one-time admission of guilt, but rather a sort of “permanent contrition”. The prospect of reconciliation was eclipsed. Forgiveness was impossible. Theologically, such an understanding cannot be legitimised either by Protestants or Catholics.

As well as *interpersonal* reconciliation, *intra-personal* reconciliation was also suitable for theological interpretation. With this aspect of reconciliation, it is a matter of recon-

ciliation with oneself, or more precisely with one’s own, often traumatic history of the degradations experienced in a repressive system. The personal memories need to be cleansed. This reconciliation does not demand recompense between the conflicting parties, but rather an acknowledgement of the reality that affects the offended or afflicted person, of his or her “fate”. The stories of the victims at the forum of the

South African Truth and Reconciliation Commission are about degradation. The Reconciliation Commission is supposed to contribute to the *restoration* of their dignity. What especially makes an impression there are the symbolic processes that accompany the commission. When a victim enters, everyone present stands up. This process can be interpreted as a symbolic representation of the fact that the dignity of the person is inviolable, even though it has

been “trampled upon”. In the process of publicly telling their stories, the victims appear as authentic commentators about what happened to them. By naming names they

become distinctive persons. The names of the more than twenty thousand victims who told their stories to the commission are impressively listed on 80 printed pages in the final report. It is worth mentioning that the memorial design of the inquest commission “Overcoming the consequences of the SED (SED is the German abbreviation for the Sozialistische Einheitspartei Deutschland, or Socialist Unity Party of Germany, which was the governing power in East Germany) dictatorship in the process of German unification” also plans to list the names of the victims – according to the Biblical verse: “I have called you by name; you are mine” (Isaiah 43:1). The result is that political transition processes contain elements that refer to a reality in which reconciliation is already real.

The Kingdom of God does not end at the church walls. There are connections between political reconciliation and reconciliation as a theological concept. The societal defining power of theology thus has three dimensions: first, it clarifies the possible conditions of reconciliation. Reconciliation can be seen as a sign that points beyond the material things of this world to another world. These signs appear like “falling stars” and can be perceived as tangible traces in political reality

Reconciliation can be viewed as a sign that extends beyond the materialism of the world as we see it

Reconciliation encompasses both dealing with guilt, and the hope for a path to forgiveness



Images of political reconciliation that stick in the mind: Helmut Kohl and François Mitterrand seal the German-French friendship with a symbolical handshake in Verdun. Willy Brand unexpectedly kneels in penance at the memorial for the victims of the Warsaw Ghetto Uprising – a gesture which caused a sensation and drew him respect from around the world.



but do not produce their own reality. There is no method for predicting when they will come or where they will shine.

It, secondly, reminds us to keep human rules "open" for an occurrence that is outside its possibilities. The means of criminal punishment as a "human rule" should also in present and future transition societies be connected with setting up a truth commission that allows the interpersonal contact between perpetrators and victims. One reason to avoid the death penalty for perpetrators after political upheavals is that it forever precludes the possibility of reconciliation. This view, finally, makes a clear judgment in theological perspectives on the negligent use of the word "reconciliation" in political speech: Whoever demands reconciliation must be completely clear that it is not a "cheap" concept. It must not be confused with "let bygones be bygones". Reconciliation includes framework conditions that cannot be quickly dispensed with. These include, for example, willingness by the perpetrator to take personal responsibility and willingness by the victim to forgive. Encounters between perpetrators and victims within the framework of a truth commission can also help to start a process in which victims begin to come to terms with their fate and the perpetrators are beginning to regain their humanity.

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The World of the Living and the World of the Dead

Archaeologists discovered Syria's first untouched royal tomb during excavations of the palace complex of Qatna. The burial chambers allow new insights into the ancestral cult and burial practices of the ancient Near East

The excavations in the Syrian palace of Qatna, one of the largest palace complexes of the ancient near eastern world, were supposed to finish in October 2002. But then there was a find that caused a major sensation: the first untouched royal tomb in Syrian archaeology was discovered. This suddenly offered a wealth of new information on the world of the living and the world of the dead in the kingdom of Qatna.

Qatna was a royal residence in the second millennium before Christ. It lies buried in a mound of ruins in what is today called Tell Mishrife. The site is close to the modern city of Homs in western Syria, where the fertile agricultural

plains meet the vast expanse of the Syrian-Arabian desert steppes. Qatna lay at the crossing point of major transport routes.

Therefore the power of its kings was based above all on trade. These kings reigned over a state that reached its farthest extent between 1800 and 1600 BC. During this period, the kingdom's influence could be felt as far as Ebla in northern Syria and to the south as far as Damascus. Even cities in northern Palestine sometimes found themselves under Qatna's domination.

In later years, between 1600 and 1340 BC, the kings of Qatna were dependent on the powerful Mittani empire in northern Mesopotamia. This of course sharply reduced

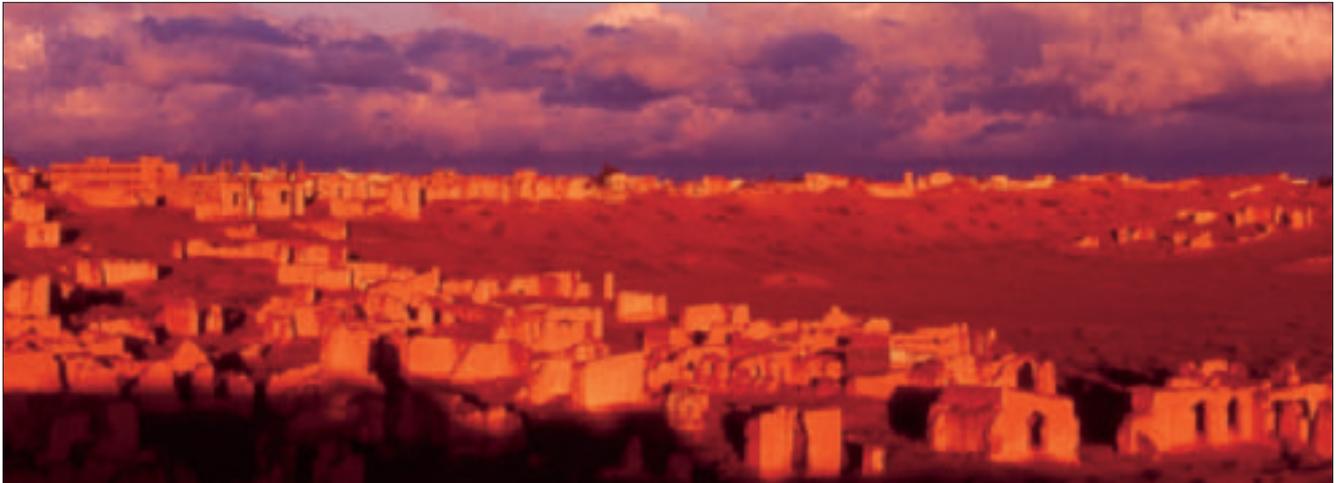


Left: Archaeologists found a basalt sarcophagus in the main chamber of an underground burial complex. The bones of the royal dynasty of Qatna were laid to rest here. The intensive excavation work in the Syrian palace of Qatna, one of the largest palace complexes of the ancient near eastern world, was always accompanied by ongoing documentation. Below: The ruins of the modern village of Mishrife, whose residents were relocated to allow the excavation of the Bronze Age palace.

Qatna's political significance, but it retained its wealth during this period, certainly thanks to its continuing importance in trade. Qatna was therefore also one of the objects in the struggles for domination in Syria between the Hittite empire of Anatolia and the Egyptian Pharaohs. Qatna was destroyed in the course of the Hittites' campaigns in Syria, probably around 1340 BC, its palace plundered and the city abandoned in their wake.

However, this tragic fate for Qatna spelt good luck for the archaeologists. The destroyers set fire to the building, the heavy cedar roof beams collapsed and the walls of the building fell on top.

The palace was already excavated 80 years ago: French archaeologist Count Robert Du Mesnil du Buisson led excavations between 1924 and 1929. In 1999, an international joint venture was established to excavate Qatna, offering new op-





Magnificent burial objects were discovered in the royal grave of Qatna, including two duck heads of beaten gold, a slender hand shaped from gold leaf and an artistically made small box in the shape of a lion's head. Right: Two basalt statues representing dead kings sit on either side of a stone door that leads to the main chamber of the burial complex.

foundations from the bronze-age palace?

The main starting points for studying the palace building are the foundations. These are made of mud bricks and are laid four to five metres deep. They are an unmistakable indicator of where the former walls ran, and thus of the entire outline of the palace. The palace can be retraced room by room by uncovering the foundation walls. A large hall was most likely used for audiences. Its inside dimensions of 36 x 36 metres are greater than the dimensions of any previously known bronze-age palace. The roof over this enormous room was held up by four large columns, which were spaced twelve metres apart to form a square inside the room.

There was also a cistern inside the palace, which ensured the water supply for the residents and attendants. Its enormous storage capacity results from the hole punched in the rock beneath the palace. On all sides of the cistern, large terrace walls support the adjacent rooms

opportunities for investigation using modern scientific methods. This joint venture was made up of groups from the Syrian Directorate General of Antiquities and Museums, the Italian University of Udine and a team of archaeologists from the department of the Ancient Near East at the University of Tübingen. Since 2000, the middle and western part of the palace ruin was excavated by the Germans and the eastern part by the Italian archaeologists. The Italian and Syrian scientists are also successfully investigating other parts of the extended ruins site of the old city of Qatna.

The initial impression during the new excavation work, however, was disappointing. Du Mesnil du Buisson had excavated in the biggest parts of the building down to the floors of the rooms and salvaged the foundation where it existed.

After the excavations were completed, the residents of the village that arose atop the ruins had removed all remnants of the walls that remained above ground, formed them into new mud bricks and erected their modern houses directly on the old floors of the palace. What would be left of the original

behind them. One of these rooms collapsed into the depths, after which the terrace walls toppled nearly completely down. This most likely occurred in connection with the final destruction of the palace. The floor plates of the room, the rest of its fixtures and in particular the murals painted on the walls of the room ended up within a debris cone inside the cistern.

The fragments of the murals have created a sensation among researchers. Their colours and motifs are reminiscent of the Minoan paintings in the Cretan palaces and the houses on the island of Thera in the Aegean from between 1800 and 1550 BC. Their technique proves that they are original Syrian creations and were not made by Cretan

artists. Nevertheless the paintings of the palace of Qatna make clear the close relationships between the Aegean and Syria in the middle of the second millennium BC. The spectacular discoveries of the excavation campaign of 2002 began when a corridor walled with mud bricks was found leading downwards from the throne room of the palace into the palace foundation. First there was a long staircase leading down with steps made of mud brick overlaid with wooden planks. At the end of the stairway, about four metres below the palace floor, was a door whose frame and wall anchors were still clearly delineated in the shape of charred timbers. Behind this door, the corridor continued approximately 30 metres wide

between narrow foundation walls. The debris from the fire on the ground floor of the palace had fallen here. Below this were 73 clay tablets with cuneiform writing in a mixture of Accadian and Hurrian words. All of these texts were part of the archive of King Idanda, most likely the last ruler of Qatna before the destruction of the palace. The cuneiform tablets must have been stored in flat ceramic bowls above the subterranean corridor. The texts provide extensive insights into the political events and activities of the palace in the time just before 1340 BC.

The cuneiform tablets had fallen into the corridor. However, they had nothing to do with the former function of the subterranean passage.



The surprise was that the corridor ended in the anteroom of the royal burial chamber.

It took a great deal of labour to remove the fire debris that filled the pit. The first surprise was revealed on the floor: two statues of basalt depicting the seated portraits of dead kings. They were venerated as ancestor portraits in front of which a few broken offering bowls still lay. Between the two figures set side by side there opened a rock door providing the access into a large rectangular chamber of rock. Three more chambers went off from this on

ously in Egypt, had to be ruled out. The samples did not exhibit elevated levels. Nevertheless, all of the air was completely exchanged before the complex was entered for the first time.

In the first large basalt sarcophagus, the anthropologist of the team from Tübingen could distinguish the bones of at least three different individuals. The situation in the second sarcophagus was similar. This indicated that this was not the grave of one king, but must be the burial site of the royal family. The bones of adults and children, women and

main chamber. Other burials were once conducted on these. Their bones were not well preserved, but were strewn with burial objects for that purpose: a small ivory box in the shape of a lion's head, a round decorative rosette of gold with inlaid sard and ivory, small golden decorative plates with representational reliefs, numerous beads of gold, glass and stone, which were scattered on the biers, bundles of bronze spearheads, the golden lining of a quiver, also decorated with reliefs, roller seals and other things.

Stone benches stood around the edges of the main chamber. These were for sitting on during ritual ceremonies. Animal bones thrown carelessly under the benches are signs of ritual meals. Storage vessels and food bowls on the benches also show that food must have been stored and consumed here. The living and the dead took their meals together in the main chamber. This is connected with the ancient idea of "kispu": that meals must be fed regularly to the dead for a long time to maintain their positive powers for the afterlife. The kispu ritual has never been as clearly proven in Near Eastern archaeology as here.

In one of the side chambers was a dense deposit of bones. Here was the final resting place of the bones of the royal dynasty of Qatna. Here, too, the dead were given meals as shown by offering bowls found on top of this mountain of bones. An amassing of evidence suggests that the underground vault was used continuously as a royal burial place for 400 years.

The finds of the 2002 campaign, 1900 individual objects from the burial chambers alone, will be followed by a long phase of documentation, analysis and interpretation. But it is already clear today that two new scientific chapters in the study of ancient world and Syrian cultures can be opened: one on ancient near eastern burial practices and the ancestral cult associated with them and the other on the art history of western Syria in the second millennium BC.

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different sides. The first glimpse inside the chambers was breathtaking. They were not filled up, and they contained two sarcophagi, vases, ceramic vessels and pieces of golden decorative items. This made it clear that the grave had never been plundered!

Before the work could be started inside the chambers, air and mould samples were taken and analysed with the help of the Robert Koch Institute in Berlin. The risk from dangerously elevated mould spore concentrations, which caused the death of the discoverers of the Tutankhamen grave 80 years previ-

The five-metre deep antechamber to the underground burial complex of Qatna. The archaeologists found the decisive clue in the autumn of 2002 when they came upon a corridor leading downwards from the throne room to the foundation of the palace. Numerous labourers were needed to clear first this corridor and then the antechamber.

men could be distinguished. Calcite vessels, ceramic bowls, a golden bowl, an ivory sceptre and decorative gold discs were deposited in the sarcophagi.

The remains of wooden biers could be clearly recognised in the

When Dr. Ulrike Zeshan bends her index and middle fingers several times while moving her hands downwards, you may think that she is performing some kind of finger exercise. In fact, she is communicating in the language of hands: sign language. The sign for the word "research" clearly demonstrates the depth of exploration that this activity entails. When the young philologist, nicknamed "The European Lady in Indian Dress", introduces herself, however, things become more complicated. The sign for her nationality is the only memorable one: placing her fist on top of her head with the index finger pointing straight up, the 34-year-old indicates that she comes from Germany. In German sign language, the upwards-pointing index finger symbolises the Prussian spiked helmet. "But in Indian or Chinese sign language, the sign looks completely different", the hearing linguist (pictured right) explains enthusiastically with a mischievous smile, adding quickly: "There are several hundred different sign languages in the world today. The exact number is still unknown; there are also local and regional dialects."

Sign languages are the driving force for the DFG Emmy Noether fellow, who returned to Europe from Australia in October 2003. At the Max Planck Institute for Psycholinguistics in Nijmegen in the Netherlands, she is now working on a project entitled "Sign Language Typology: The Comparative Philology of Sign Languages". She aims to discover how sign languages are similar to one another and how they differ. "And what can we learn about

human language from them?" Zeshan asks, thoughtfully.

In the second phase of her Emmy Noether Fellowship, Zeshan set up her own working group in Nijmegen. "It was particularly important to me to attract deaf team members – after all, they're the experts!" Currently six in number, her colleagues from Turkey, South Korea, China, Uzbekistan and the Netherlands bring with them not only their expertise in their own sign language, but also "language material" which

studies had also had an international flavour: Linguistics, Oriental Studies and English Philology at the University of Cologne, at the University of Jordan in Amman, and at the State University of New York at Stony Brook. She then performed research at the Australian Universities of Canberra and Melbourne.

"Sign languages are wrongly equated with gestures which accompany spoken language", says Zeshan. This means that people often think that sign languages

do not have a complete linguistic system. "That's absolute nonsense", she declares. "In fact, every sign language has its own grammar and syntax". Many countries, however, do not allow deaf children to be taught an appropriate visual language. Even in Germany, sign language was not officially recognized until 2002.

"The biggest problem for deaf people is education", Zeshan emphasises. One of her project's goals, therefore, is to strengthen deaf communities, particularly in developing countries. She therefore provides voluntary

support to the Indian Ministry of Social Justice and Empowerment in Mumbai, helping to develop teaching materials for schools for the deaf and to train sign-language teachers. Her pioneering spirit and commitment are recognized by many, and her team's reaction is unmistakable: they raise both thumbs high in the air. There are, after all, some signs which are universally understood.

Rembert Unterstell

In this column, we publish occasional articles on outstanding young researchers.

Listen with Your Eyes, Talk with Your Hands

Ulrike Zeshan and the philology of sign languages



they had previously collected and recorded in their home countries. To this is added a huge amount of field research which Zeshan carried out in Pakistan and India, in Lebanon and in Turkey. This research, consisting of video material, linguistic "transcriptions", and grammatical information, is stored in a database. This will enable forty sign languages to be documented and compared.

The Erlangen-born linguist took her first steps towards blazing a trail into the jungle of sign language in her dissertation "Sign Languages of the Indian Subcontinent" at the University of Cologne. Her previous

Zhuangzi and the Cultivation of Life

*What is the intellectual consciousness of the Chinese culture?
A philosophical and literary masterpiece of Daoism gives us an insight
into ancient Chinese philosophy – “The Perfect Book of Nanhua”*

As soon as we turn our attention to the influential literature of any other – non-European – culture, questions arise that are impossible to even pose precisely, let alone answer. What if the language is written in an abstract logographic script, whose symbols may have more than one meaning? What if the intellectual consciousness of a culture, such as that of China, has been moulded by completely different formative experiences over the course of millennia? From its very earliest writings one discovers that Chinese philosophy has been governed by the experience of change and transience. Daoist (Taoist) philosophy assumes that change reveals a ‘divine order’ that is referred to as the *dao*, which means ‘road’, ‘way’ or the ‘course of nature’.

This linguistic-cultural difference becomes especially apparent in the most comprehensive and complex foundational text of Daoism: the “Perfect Book of Nanhua” of Zhuangzi (pronounced jwong-dz), written between about 400 and 300 B.C.

In this scripture, also simply named *Zhuangzi* after its author, the second chapter, entitled “Discussion on Making All Things Equal” (*qí wù lùn*), a radical-sceptical stance on the subject of speech and reality is found. According to this argument, reality can only be perceived and described in a relative way. Any attempt to define a view of reality in its entirety as the one true way leads to self-alienation and a loss of spontaneity. Hence Zhuangzi concludes that there are

22 always numerous ways of perceiv-

ing reality, depending on the given time and place. For this reason, his writing contains a variety of forms of perspectival thinking – a word, a sentence or a parable can often be interpreted in various ways, all of which are right. The reason for this is that Zhuangzi incorporates the multiple meaning of individual words, making them stylistically fertile, like in poetry, he is able to create many levels of being which illuminate each-other in a highly poetic way.

Zhuangzi also frequently takes recourse to the dream metaphor to portray the bewildering relationship between language and reality: “Confucius and you are both



dreaming! And when I say you are dreaming, I am dreaming, too. Words like these will be labeled the Supreme Swindle.” (Zhuangzi II, transl. by Burton Watson).

If this situation is itself taken to be a dream then what the narrator says can only be referring to reality to a limited extent. It is important to recognise this restriction and not to try to gain command of reality arrogantly. Zhuangzi’s main intent is to disrupt accustomed ways of thinking and speaking and to encourage the reader to directly relate their own thoughts (“theory”) to their experience (“things”). This is made particularly evident in the parable of the Dream of the Butterfly, familiar to every educated person in the far east.

“Once Chuang Chou (that is, Zhuangzi) dreamt he was a butterfly, a butterfly flitting and fluttering around, happy with himself and doing as he pleased. He didn't know he was Chuang Chou. Suddenly he woke up and there he was, solid and unmistakable Chuang Chou. But he didn't know if he was Chuang Chou who had dreamt he was a butterfly, or a butterfly dreaming he was Chuang Chou. Between Chuang Chou and a butterfly there must be some distinction! This is called the Transformation of Things”.

Fundamental concepts such as dreams and reality, identity and its

What if the intellectual consciousness of a culture, such as that of China, has been moulded by completely different formative experiences over the course of millennia?

boundaries (difference), the change and perception (knowledge), these are all interwoven in these few sentences to form a complex parable.

If one can no longer say precisely, who the butterfly is and who Zhuangzi is, if, behind the descriptions, a hidden reality changes imperceptibly, then the descriptions are also no longer able to describe this reality: The reader can no longer rest assured in the knowledge that he knows who's who. The longer he reads the passage, the more he will find himself question-

thought and speech also has to change. This does not mean, however, that Zhuangzi fundamentally belittles the value of perception and knowledge, as he has often been falsely accused of. It simply means that knowledge is only useful if one has learned how to apply it appropriately in any given situation.

The chapter "Discussion on Making All Things Equal" calls for a language that adapts itself to change, that becomes malleable and allows for mutual resonance, whose terms are not set in stone, but instead are

"What I care about is the Way, which goes beyond skill. When I first began cutting up oxen, all I could see was the ox itself. After three years I no longer saw the whole ox. And now – now I go at it by spirit and don't look with my eyes. Perception and understanding have come to a stop and spirit moves where it wants. I go along with the natural makeup, strike in the big hollows, guide the knife through the big openings, and follow things as they are. So I never touch the smallest ligament or tendon, much less a main joint", (Zhuangzi III, transl. by Burton Watson).

This story is a parable for how to deal with life. If one fits in to life and learns to overcome difficult situations quickly and efficiently "with the spirit", then the spirit does not become exhausted by unnecessary worrying, but stays "as good as though it had just come from the grindstone". This is where the practical aspect of Daoism becomes clearly apparent. To spontaneously and intuitively act appropriately requires many years of experience. Zhuangzi describes this aspect primarily through parables about craftsmen and artists, who combine this art of living ("The Secret of Caring for Life") with their art.

The "Perfect Book of Nanhua" is a scripture which incorporates cosmology, linguistic philosophy, morals and the philosophy of life in a way which is even unique and idiosyncratic in Chinese philosophy. In order to be able to comprehend and interpret this scripture, new methodological approaches are required. In doing so, it is not only possible to develop new approaches for understanding other Chinese philosophical scriptures, but new and unexpected ways of looking at the fundamental topics of occidental culture emerge, for instance on the issue of existence and time, or of body and spirit.

This allows this work to make a contribution towards intercultural dialogue for which there are many willing participants waiting on the oriental side.

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Under the roofs of an unfamiliar culture. Chinese philosophy is guided by experiences of change and transience.

ing his own identity. So it is not all about a "truth (of being)" that needs to be recognised and discussed, but about a "truthfulness" that constantly needs to be attained (cheng – one of the basic concepts of Confucian philosophy), which is the expression of agreement with change.

According to Zhuangzi, the urge to find proof is the origin of the never-ending argument between philosophers, as they attempt to get closer to reality by categorising things as either "true" or "false". Since this reality is not unique, however, and since it is continually changing in our perception, our

able to express new meanings depending on the situation. The experience of change permeates Zhuangzi right through to its very style – which gives it its unity of style and content that have made this work a philosophical and literary masterpiece.

Following the basically theoretical second chapter comes a chapter entitled "The Secret of Caring for Life". Here we find the story of the cook Ding, which demonstrates the practical application of Daoist principles. Zhuangzi describes how the cook has mastered the art of cutting up an ox over the years, so that the blade of his knife is "as good as though it had just come from the grindstone". When asked by Lord Wen-hui, how he achieved such perfection, the cook gives the following reply:



The Sound of Colour

In our subjective perception, visual and acoustic impressions are linked. Sounds and pictures – a new study of their interaction provides a basis for product optimisation

The subjective evaluation of a product normally involves all the senses. For example, a potential purchaser might judge a new car that has attracted his attention with almost all his senses – sight, hearing, smell and touch. Optical design plays a very important part but the satisfying thud with which the door closes can also signal quality to the potential buyer. The nose recognises the typical smell of a new car and we know at once whether the steering wheel feels right. Research into the psychophysics of individual senses is already well-advanced and there are models that enable a fairly precise prediction of how a particular group will judge, for example, the sound quality of a car.

Significantly less research, on the other hand, has been carried out into so-called multimodal interactions. Thus, for example, the perceived loudness is not only influenced by what is heard but also by the accompanying visual impression. This article discusses examples of such audio-visual interactions. In a first series of experiments, the influence of colour on the perceived loudness of a passing train

was investigated. The sound of a passing high-speed train was recorded on digital magnetic tape and played back to subjects through headphones. After each playback, the subjects were required to judge how loud the passing train was. In addition to the acoustic playback, the subjects were presented with the image of a high-speed train on a 3x3-metre screen. This image was first presented in the original colouring of the train, white with a red stripe. It was also presented with the train coloured bright red, light blue and light green, using the Paintbrush computer program. Although the noise of the train was always played back to the subjects at the same level, the red train apparently seemed louder to them than the light green one. We thus have a scientific demonstration of an audio-visual interaction that has long been put to practical use. The power and performance of sports cars is also intended to be heard and they are frequently painted bright red. A light green sports car, on the other hand, is only available by special order. Hence, this "amplification" of the loudness by an appropriate colour is already used in prac-

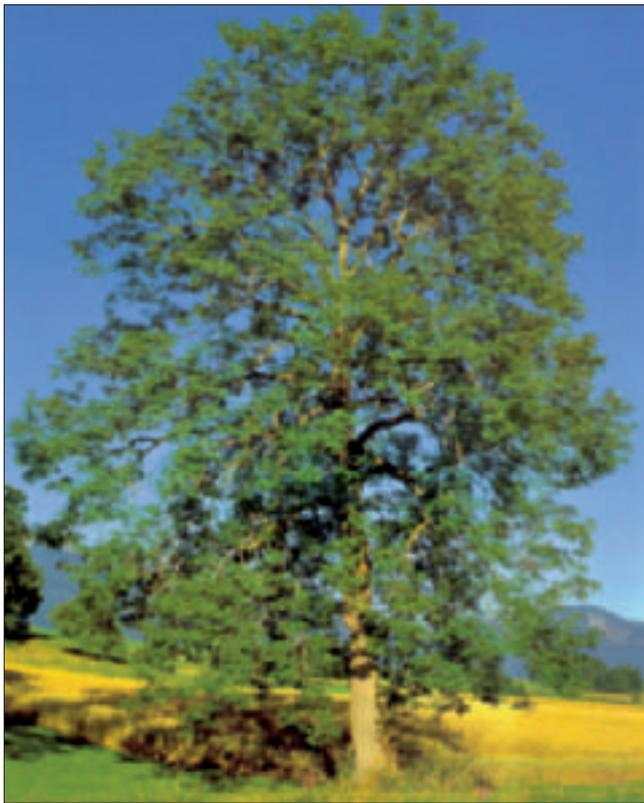
tice, although – from a scientific point of view – the psychophysical and neurophysiological backgrounds to these audio-visual interactions have so far been but little investigated.

Whereas, in the first series of tests, the sound and picture "matched", a second series of tests was carried out to investigate the influence of "unrelated" pictures on the perceived loudness. The sound of the passing train was played to the subjects through headphones again. At the same time, they were shown unrelated still pictures, such as a tree in summer or winter.

Although the subjects heard physically identical sounds, they had the impression that the sound of the train was quieter when they

Whether it is a car or a train, a red colour can apparently influence its perceived loudness. This is also confirmed by subjects to whom a high-speed train was presented in various colours on a screen while the sound of it passing by was played back to them through headphones at constant level. The astonishing result: subjectively, the red train is perceived as being louder!





Studying the interaction between visual and auditory stimuli. The picture of a tree in summer and in winter is presented to subjects with an "unrelated" noise, i.e. railway noise.

were shown an unrelated picture. This reduction in loudness was greater when the picture was of a tree in a winter landscape than when they were shown a tree in full summer leaf.

Obviously the view of a winter landscape reminds the subjects that, in winter, sound can be "absorbed" by snow. This mixing of visual and auditory information in the brain could be the cause of the quieter perception of the winter scenario.

While the tests described so far all used still pictures, the next test series was to find out whether video pictures would give rise to an even greater audio-visual interaction. The sound of the passing train was played to the subjects through headphones again, but this time they were shown pictures using 26 video goggles. The first picture was

a still picture of a goods train and this was followed by a video of the same train.

As expected, the still picture of the goods train already reduced the perceived loudness. However, if the subject is shown a corresponding video to accompany the sound of the passing goods train, the perceived loudness is again significantly reduced. Audio-visual interactions are apparently stronger with moving pictures than with still pictures.

The above experiments all placed the subjects in the position of a static observer.

In further experiments, the subjects were set in a dynamic point of view in order to involve them still more closely in the audio-visual scenario presented. The audio and video recordings used were made in a car in various situations (stopped at traffic lights, 30 km/h, 50 km/h, main road, motorway, tunnel). Once again, the acoustic stimulus was held constant and, in a first series of experiments, the visual stimulus was presented in a sound proof booth using video goggles. In a further series of tests, the experiment

was carried out in a simple driving simulator with the video sequences projected by beamers, placing the subject in the position of the driver.

In this series of experiments, the influence of the pictures on the perceived loudness is evident as well. It is found that subjects experience a simulated car journey as significantly quieter than when experiencing the same sounds and pictures as static observers. The results are even more significant in the driving simulator, where the sounds can be experienced as up to 50 percent quieter than in less realistic situations at the same level.

In summary, the experiments are an impressive demonstration of how the relationship of sound and pictures influences human perception. Although early experience with the phenomenon has already been used in product optimisation, the scientific understanding of the underlying psychophysical and neurophysiological mechanisms is still in its infancy.

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The Eating Instruments of Spore-Feeders

Biologists find research on insect mouthparts revealing because the complex interaction of food preferences and body structure provides insights into the process of evolution

How do insects manage to collect minute food particles like fungal spores? Have their mouthparts adapted to this food over the course of evolution?

Over a 400-million year evolutionary history, insect mouthparts have been transformed in a myriad of different ways. More than 34 different basic types developed as adaptations to specialised diets and techniques of food intake. As a result of this enormous variety, insect mouthparts constitute ideal model systems. They can be used for studying the effect of body structure on animal evolution and ecology. Comparisons of the mouthparts of different insect groups provide evidence with respect to the extent that particular food preferences require particular body structures. Inversely, one may ask to what extent a given mouthpart structure requires or even restricts the use of the food supply.

Beetles of the superfamily *Staphylinoidea* exhibit particular diversity in their food acquisition. With more than 57,000 described species worldwide they are altogether one of the most species-rich animal groups in the temperate and tropical zones. Each year zoologists describe some 700 new species in this group of beetles alone. This group only has a body size of a few millimetres and lives hidden on the ground in debris. The beetles are either predators or live on dead and decaying organic material and on fungi. Among the fungus-eaters, some species of featherwing beetles, round fungus beetles and rove

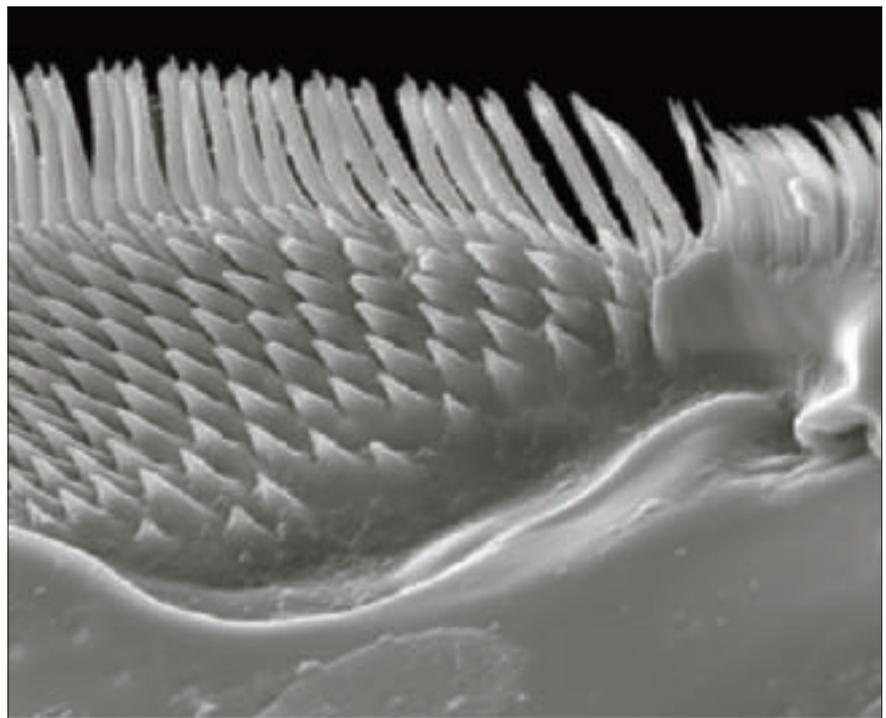
beetles specialise on collecting fungus spores.

Fungi are dispersed, for example, by single celled spores. Usually, these spores are enclosed by a tough cell wall that protects them against drying out. The inside is very rich in nutrients and, therefore, attractive to spore-feeders. However, they must first break the cell wall open by mechanical or enzymatic means.

Beetles encounter spores in very different guises. In one large group of fungi they are found in a special fruiting layer, which is contained in the narrow tubes of polypores or free on the surface of lamellae in gill

mushrooms. Surface-growing fungi like slime moulds, moulds and mildews form spores in special fruit-bodies that are attractive to specialised insects. Also, some beetle species are specialised in feeding on pollen. Pollen assumes the male role in plant fertilisation. Therefore, many of these beetles are found on

Evolution as architect: this rove beetle mandible adapted to its food over millions of years. With the comb-shaped structure in its mouth the beetle mostly collects fungal spores that it cracks like nuts.





Face to face among the flowers: rove beetles gather on blackberry flowers in spring and summer to eat their tasty pollen and to meet willing mates. Below: this rove beetle female is from Mexico and, just like its European relatives, feeds on pollen.

flowers during the spring and summer months.

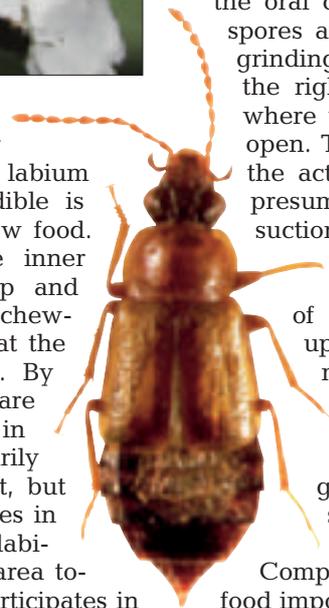
Feeding on spores and fungi can be proven simply and beyond a doubt through analysis of intestine content. Various adaptation problems must be solved in the process. The spores are often loosely scattered over the surface and must literally be swept in. But spores may also be integrated within a fruiting layer from which they must be harvested. Additionally, the spores need to be concentrated in the oral cavity and transported to digestive regions close to the mouth opening. Finally, their transport to the foregut must be ensured. Usually, their wall must first be broken open using special implements.

To identify the various solutions to this problem, the mouthparts of all evolutionary lines of spore-eating *Staphylinoidae* were examined using a scanning electron microscope. It was important to continuously compare spore-feeders and non-spore-feeders, especially among closely related groups, for the sake of a meaningful analysis.

The mouthparts of insects are appendages of the head capsule that are moved by muscles. In general they consist of a strong, paired set of

mandibles (upper jaws), paired maxillae (lower jaws) and an unpaired labium (lower lip). The mandible is used to grasp and chew food. For this purpose, the inner edges are often sharp and have teeth. A rasp-like chewing surface is located at the base of the mandible. By contrast, the maxillae are much more complex in structure and are primarily used for food transport, but also assist the mandibles in chewing the food. The labium blocks the mouth area towards the back and participates in transporting the food.

Spore-feeders have developed a variety of fine structures for the individual tasks involved in food uptake. Functionally, they resemble tool types like brushes, combs, brooms, rakes, rasps, shovels and various grinding surfaces. In some species grooves surrounded by bristles direct the food flow towards the mouth opening. Brush-, broom-, rake- and shovel-shaped parts are primarily used to brush in fine spores from the fungus surface. Therefore, these structures are especially found at the tip of the mandibles, the inner and outer



lobes of the maxillae and the terminal sections of the labium. From there the spores are transferred further inward by simply being brushed off to brush fields and bristle combs on sections of the mandibles, maxillae, labrum (upper lip) and labium located deeper within. These features prevent the spores from escaping to the side by concentrating them at the centre of the oral cavity. From there the spores are swept between the grinding surfaces at the base of the right and left mandibles where their walls are broken open. The final transport into the actual mouth opening is presumably accomplished by suction created in the foregut.

The rasp-like rows of teeth between the top of the mouth and the upper side of the mandibles and the comb- and broom-like structures on the inside of their grinding surfaces are supporting structures in this transport.

Comparisons show that the food import path and associated tool types are not unique to spore-feeders but are part of the basic blueprint of all *Staphylinoidae*. Most representatives of these groups also feed on fine materials but have a broader dietary range. This especially includes fungal mycelia, fine material from dead plants and animals as well as the microscopic flora and fauna that lives in it. In many groups this nutritional type is the starting point for the evolution of spore-feeder mouthparts. This basic pattern can also be found in an unmodified form in the majority of more specialised spore feeders. When food preferences change,

body structures do not necessarily have to change. Rather, physiological and behavioural changes are initially decisive.

But in certain taxonomic groups some mouthparts that are used for collecting and then grinding the spores have undergone special modification. Because many have repeatedly developed in various groups of exclusive spore-feeders, they may be identified as special adaptations to this nutritional type. In the maxillae this particularly applies to the equipment of the inner grinding surfaces with their



The gills of this Australian oyster mushroom offer ideal conditions for rove beetles. Several thousand of the two-millimetre large beetles may colonize a single mushroom at once to feed on its spores. They will also lay their eggs there.

fine protrusions and teeth. This includes particularly complex “spore brushes” in the area of the maxillae that make it possible to brush in large quantities of spores. It is astonishing to see the high degree of agreement of even the finest structural details have developed in completely independently ways in various subgroups of these beetles. Biologists call them convergences – similarities that are based upon the

same function but do not share a common origin.

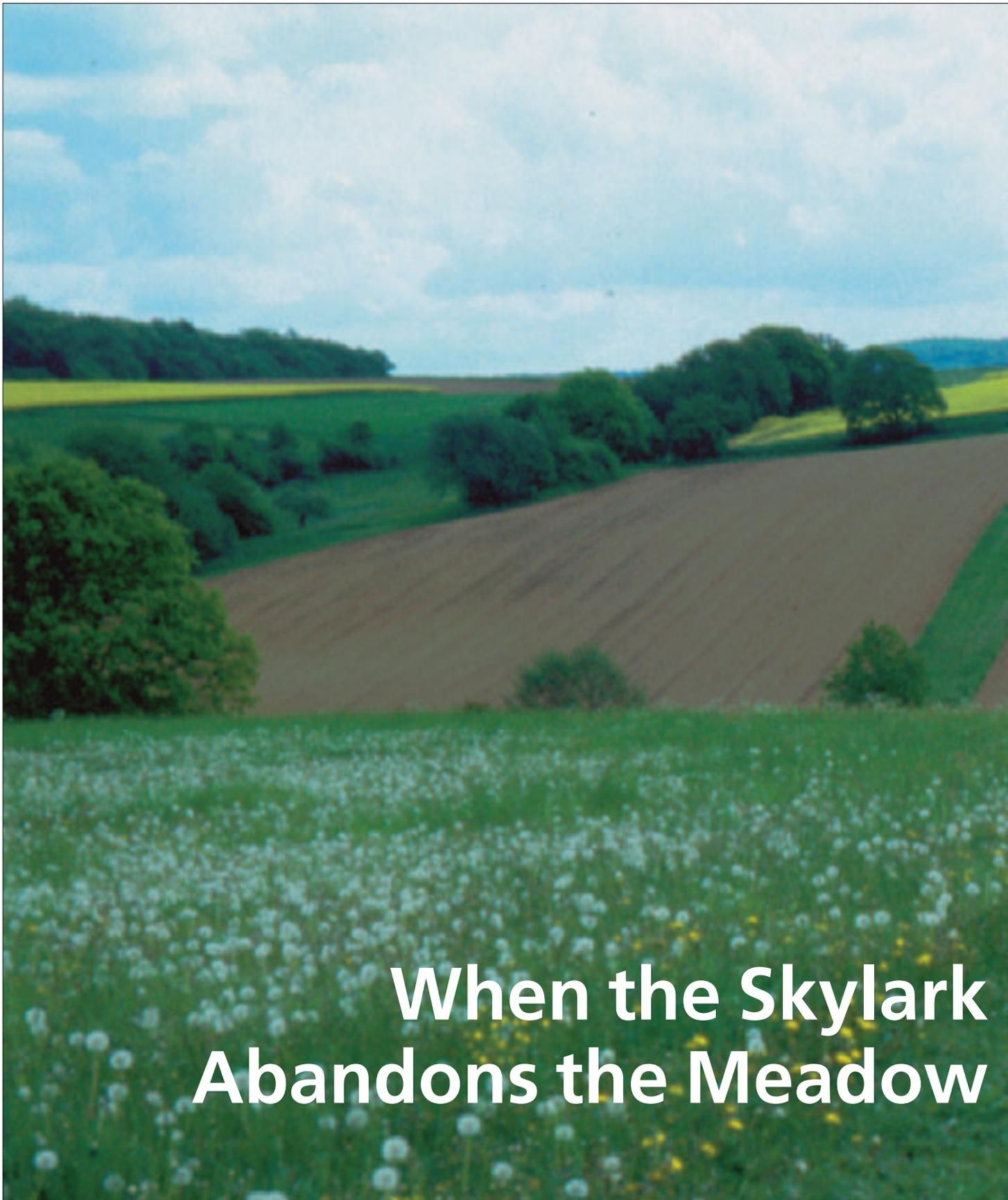
A different initial situation is found in spore-feeding representatives of the rove beetles, which are younger in terms of evolutionary history. These groups shifted from detritus eating to predation. In this respect extensive grinding surfaces on the mandibles were no longer needed and, consequently, often reduced. This situation obviously represented a far greater hurdle to the evolution of spore-feeders than to groups that feed on fine plant material. But predatory mouthparts that originally lacked grinding surfaces on the mandibles were no insurmountable obstacle to developing spore-feeder mouthparts. Several species have developed secondary grinding surfaces on other parts of the mandibles and even the maxillae.

The *Gyrophaenina* are a special group of spore-feeding rove beetles.

They are usually found in large numbers between the lamellae of gilled mushrooms. Since the ancestors of this group were also predators, the grinding surfaces had to be developed from scratch. However, they are not located on the inner side of the mandible but on its under side. This means that the spores are not – as is usually the case – ground between the grinding surfaces of the right and left mandible but between the under side of the maxilla and a part of the labium. For this purpose the latter is formed like a mortar that first collects spores and then grinds them. This unusual design required an extensive reshaping of the feeding mechanism. It is also a good example of the fact that there are often several solutions to the same functional problem in the animal kingdom.

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When the Skylark Abandons the Meadow



Modern agriculture harms animals and plants by endangering biodiversity. New computerised models help to design a land use model that meets human requirements as well as preserving the ecosystem

Humans have been altering the appearance of the European landscape for centuries, and agriculture is responsible for a significant part of these changes. Although the impact was initially on a restricted local and regional level, it increased in scale and intensity, in pace and extent until the present day. At first, the creation of open countryside increased the diversity of plant and animal species. This primarily affected species at home in meadows, pastures and fields – that is to say open country species. Unfortunately, this positive development stopped in the 1950s. Propelled by increasing demand and production of agricultural goods, agriculture was intensified and extended. This has resulted in a loss of animal and plant species as well as leading to a monotonous landscape. Presently, about 25 percent of the Earth's surface has been transformed into areas of agricultural production, with a mere 10 percent of the original landscape remaining unaffected by humans. Sustainable land use models are urgently required, but they must take into account the economic and social needs of people as well as the preservation of ecological diversity. Models can be a useful means of representing these complex interrelationships and assessing risks. The Collaborative Research Centre "Land use options for peripheral regions" at the Justus Liebig University of Giessen is developing interdisciplinary approaches to this type of modelling.

This change in land use has a multitude of ramifications: changes in the landscape directly affect the structure and function of ecosystems as well as the systems linked to them. These complex processes and especially their changes and consequences can often only be empirically recorded with great expenditure of time and money. This is where ecological modelling is beneficial. Models represent reality in a simplified form and, therefore, make complex relationships more transparent. Over the course of time, these simple models can be implemented to include additional processes from natural systems. Bio- 31

diversity research studies biological variety on our planet whereas population ecology examines fluctuations in the number of individuals within species. Models in these two disciplines analyse both complex structures and processes of ecosystems as well as very specific questions such as the chances of survival for select species of plants and animals. In conjunction with Geographical Information Systems (GIS), models are already being used as important planning and decision-making tools in environmental and landscape management. They enable us to describe the effects of the changing economic, technical, legal and climatic framework of land use. The more different models from the various disciplines are interlinked, the more accurate the results. The central hypothesis of the studies is that when agricultural areas are no longer used for agriculture, then the countryside ceases to fulfil essential functions. Which landscape functions are affected, to what extent, what areas and what political measures are suitable to counter these developments – all these questions are answered by means of interconnected models.

The region being studied is the Lahn-Dill upland in central Hesse. There, the distribution and survival probabilities of several animal species, such as the fox, skylark and yellowhammer, were simulated under different land use scenarios. This was based on digital land use maps derived from satellite pictures. These maps were linked with computer models to establish the spatial reference to the landscape. Changes in land use were simulated and the resulting potential distribution of animal species was calculated.

The skylark is a typical inhabitant of open landscapes. How does increasing the proportion of green areas in the landscape (the green belt scenario) affect its population size? Will the habitat in which it can breed increase as a result? Simulations of the green belt scenario led to surprising results. Although the proportion of forest – which the skylark avoids – was reduced in favour of fields and arable land, its potential breeding territory diminished



in the examined area. Obviously, other factors, for example the segmentation of the forest, had a larger effect on breeding territory selection than the simple enlargement of the open countryside. Ecologists have suspected for some time that the composition and spatial pattern of the landscape rank highly in determining the species number and biodiversity of an area, and recent results indicate that the spatial arrangement of habitats is of great importance for population stability. This means it affects both the lark's chances of survival and its distribution in the region. However, how the diversity of animal and plant species as a whole develops in landscapes of differing character is still largely a mystery.

The ANIMO model is designed to probe this phenomenon. The model's basic framework consists of virtual landscapes consisting of 100 by 100 parcels of land. Each parcel is equivalent to a habitat plot of 25 by 25 metres in the field. These habitats consist of fields, grassland

Green areas such as the Lahn-Dill upland in central Hesse (top) are sensitive ecosystems. The traditional cultivation in small plots has produced a man-made environment of considerable significance for conservation efforts. These areas are a habitat (right) for a variety of species but they are threatened by the decline of agriculture.

and fallow, which represent the main land use types of the Lahn-Dill upland. By changing the relative area and the spatial distribution of these three land use types, different landscapes were computer-generated and the resulting effect on biodiversity studied. For this purpose, the relative areas of the three land use types were changed, ranging from an equal representation of all three types to the predominance of one. Patterns of spatial use ranging from a relatively regular distribution to strong clumping were examined.

Each land use type was allocated a specific assortment of animal and plant species, with some being gen-

eralists that are widespread and abundant, and others specialists restricted to a particular habitat.

The relative proportions of the so-called habitat specialists and generalists were varied in different simulation runs. In advanced simulation runs the data of ecologically oriented subprojects that were recorded in the field were incorporated to ensure that the results approximate reality. It was demonstrated that the arrangement and distribution of the three land use types has a decisive influence on biodiversity in a habi-

tat: the larger the areas of a specific type of use are in the landscape, in other words, the more neighbouring parcels belonged to a type of land use, the lower the species number per parcel and the more similar the species inventories of adjoining parcels in composition and number. In addition, the ratio of generalists to specialists was relevant: as expected, the biodiversity per parcel increased with a growing number of generalists in a landscape.

The data on the study area's flora and fauna was also incorporated

into simulation runs. Apart from the spatial arrangement of various land uses, the relative area of the different uses, especially of the most species-rich land use, was particularly decisive for biodiversity. In a further step the model will be amended and applied to real landscapes.

These examples demonstrate how important it is at the present state of research to combine data from different disciplines – in this case landscape ecology, animal ecology, economy and modelling – into integrated approaches. As a result, a deeper understanding of the influence of the complex and dynamic agrarian landscape on biodiversity may be achieved than would be possible by field studies alone. Interlinked models or so-called coupled modelling approaches have become instruments of landscape analysis. They allow the representation of processes on the scale of regions in a simplified form while linking economic and ecological factors. The use of such models makes it possible to represent the driving and controlling variables of land use so that the effects of politically motivated intervention on land use, biodiversity, water and nutrient budgets can be predicted and assessed.

A changing framework of agricultural policy, a more critical consumer behaviour, new assessment criteria for awarding farming subsidies in the EU and other factors have rendered it necessary to predict the consequences of land use and its changes. Simulation models can be an important part of decision-making. In addition, they supply useful hypotheses for further field studies in all environments and help develop simple structures from a complex assortment of information. In future they will contribute to significantly reducing the recording effort.

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Computers and Operation Cranium

Titanium implants are inserted with high precision to close gaps in the cranium. The procedure can be assisted by computer-aided methods and robots that are developed in close collaboration between medical surgeons and engineers

About a decade ago a procedure for the repair of cranial defects established itself in clinical practice. Since then, gaps in the cranium have been closed using titanium implants, individually manufactured on the basis of CT scans. Electronically controlled milling machines work layer by layer to reproduce the bone contours from the image data. Appropriate skull models are used both for documentation and visualisation, and also for planning operations. High-precision implants are made in advance so that they are available during the operation.

Against this background, a working group in Bochum, Germany, set itself the task of using computer-aided methods throughout the process to avoid the intermediate step of making models. This would allow additional materials and standardised design principles to be used. The scientific work on this question was favoured by three factors in particular: since the early nineties, developments in computer tomographic techniques, especially spiral computer tomography, have made it possible to obtain data within seconds rather than minutes. The quality of the images obtained was also improved by the ability to more effectively eliminate distortion due to movements of the organs being visualised. In addition, further hardware and software developments in the area of Computer Aided Design (CAD) have kept the amount of time and money needed to handle large quantities of data that are produced in a CT scan of the cranium (up to

200 megabytes) within an acceptable scale. Finally, the physical proximity of medical specialists (oral and maxillofacial surgeons, neurosurgeons and radiologists) and mechanical engineers (design and production systems) at the Ruhr-Universität, Bochum, favoured the establishment of an interdisciplinary working group.

In 1991, a method for computer-aided prefabrication of individual skull implants was thus developed. Since then, numerous surgical interventions using those implants have been successful, both nationally and internationally. Given that the process was still unique in the world, all of its steps had to be coordinated carefully. Amongst these were the CT data acquisition; the checking, transfer and evaluation of these data; CAD construction; the fabrication of the implant from a block of pure titanium on a computer-controlled milling machine (Computer Aided Manufacturing – CAM); documentation of the process

and quality assurance. So far, approximately 330 such implants have been implanted in more than 40 departments in Germany, Europe and the USA. The majority of the patients who received these implants had previously been operated on unsuccessfully using other techniques. In many cases, the defect had a diameter of more than 20 cen-

timetres. For cranial defects, the priority was the protection of the brain where it was no longer surrounded by bone. If parts of the viscerocranium were missing, aesthetic questions gained a greater significance. Overall, this is a highly successful scientific development that has established itself in clinical practice. However, there are two significant issues that still pose a problem: suitable materials and the treatment of diseased parts of the skull that were not defective before the operation. Pure titanium is still the main material used for such applications. A surface oxide layer is applied to make it highly bio-compatible. However, when used as a permanent implant, it will always remain as a foreign body in the organism. Suitable materials to solve this problem would seem to be composite materials

consisting of polylactides and calcium phosphates which are combined with proteins that promote bone growth. Since the principles of CAD/CAM also

support the production of hollow forms, suitable biomaterials can be processed using the newly developed technique. In contrast, the treatment of diseased parts of the skull – without mechanical defect – gives rise to entirely different problems. The need, for example, to remove large areas of tumour-infiltrated skull bone requires a more complex reconstruction. The

The most challenging task was to develop a state-of-the-art, fully computerized medical process

technical solution is based on differentiating between diseased and healthy bone by means of the CT data. In this manner, it is possible to define by means of a conical boundary the area of bone to be removed

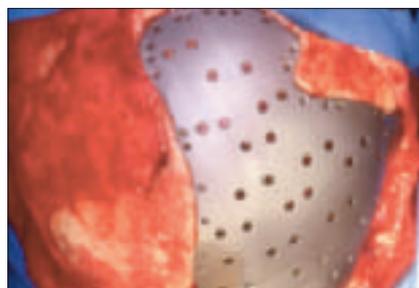
In a serious dockyard accident, this patient lost a considerable amount of bone from his cranium. An individually fabricated titanium implant was inserted in the opening. In addition to the protection of the brain, the intervention led to a significant aesthetic improvement. Below right: an X-ray image of the skull after the implantation.



in CAD. This information is then used both to design a template to guide the surgical saw, and to define the shape of the corresponding implant. The surgeon removes the diseased bone using the pre-fabricated template and obtains an opening that, without any further measures, can be precisely closed with the implant. This technique of template-guided removal and si-

multaneous reconstruction also has been successfully used in various departments.

But why should the stored geometric data be used to make an operating template? In an age where operation robots are being used increasingly, would it not also be possible to do away with this intermediate step and use the data directly in the operating theatre? Basically, this seems to be possible. In a preliminary study, surgeons from Bochum, Heidelberg and Karlsruhe carried out a skull bone removal on a sheep's cadaver using an operation robot and another using the template. To close the defects, they used both a titanium implant and a hollow-form implant made of absorbable polylactide. Although the



conventional procedure with the template and the titanium implant led to a more precise fit, the robot and the alternative material also achieved sufficient clinical precision. In the first study, the work was carried out in three stages, between which the navigation system recalculated the boundaries of the area to be removed. Optimised planning made it possible to carry out the pro-

cedure in a single step in subsequent studies. In direct competition with the resection templates, the robot has not yet shown its superiority from the point of view of precision, practicability or economics. The current research project

A long-term goal is to develop a more efficient robotic system to improve surgical procedures on crania

"Robot-assisted craniotomy with and without individually prepared immediate reconstruction" funded by the DFG is therefore devoted to the development of a more efficient

robot system, which is smaller, cheaper and more reliable than the existing system, and which is, above all, feasible for use on the cranium and viscerocranium.

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Interview with the Sociable Honeybee

Honeycombs support the exchange of information in a bee colony. In the darkness of the beehive signals are transmitted and received. This results in a communication network that could easily measure up to a modern telephone network

Honeybees spend most of their lives on their honeycombs. These combs are used as a space for storing food and rearing offspring but they also play a major role in the flow of information in a bee colony, a fact that has previously been underestimated.

The topic "Nesting materials as carriers of communication signals among social bees" was taken up within the framework of a research project which investigated the combs' physical and chemical properties relevant to communication as well as related aspects of nest building and communication behaviour.

A few simple factors led to the honeycomb becoming a part of the information flow over the course of evolution. Bees spend most of their lives inside the hive. For summer bees this means three of four weeks of their adult lives, and for winter bees, four months, while the queen bee spends just about the whole of her life, which spans several years, in the hive. This means that the bees living together in the hive can, and indeed need to, communicate in a confined space. Honeybees exercise complete control of their hive. They synthesize wax as their construction material and are their own architects.

Wax is a fantastic building material that is produced by four pairs of glands on the ventral side of the bee's abdomen. The chemical composition and structure of the wax crystals can be studied by means of gas chromatography, mass spectroscopy and x-ray structural analysis. It was discovered that beeswax

is subject to a rapid aging process and that the ratio of the main components of wax shifts continuously. As a result, a chemical patchwork comes about because the individual combs in a bee colony are built as and when required. It is precisely this feature that allows the bees to find their way around in the dark hive.

If one touches a bee's antenna with a drop of sugar water, it sticks



Home building in the bee kingdom: bees produce wax platelets from four pairs of glands on the ventral side of their abdomen. The combs, which are constructed from this wax, are not only indispensable for storing food and brood rearing, but also for the internal communications of the bee colony.



its “tongue” out in a reflex reaction. If the sugar water stimulus is paired with another, initially neutral stimulus, the two become linked. As a result, the initially neutral stimulus alone will be sufficient, after a few training sessions, to make the bee stick its tongue out. The resulting behavioural tool can be used – in a manner of speaking – to interview bees.

If bees are now asked in this simple behavioural experiment how well they can differentiate between wax types, the results are startling: they can recognize differences be-

tween various types of wax and are able to recognize how old they are with a precision that is comparable to technical methods such as gas chromatography. However, in doing so they do not use all of the substances of the wax in the same way but react especially sensitively to certain groups of substances. This enables them to determine their position in the dark hive at any time, or at least to tell which comb they are on.

The dance floor is a special place in the beehive. It takes up no more than about 100 square centimetres

of the total comb area of about five square metres, and is the place where the forage bees meet to exchange new information on the location of food sources. Relocating the dance floor within the hive causes the dancers to start searching. It may be assumed that the method used for finding the dance floor in the dark hive is also based on chemical marking. Apart from the wax, which they produce themselves, bees also use plant resins – the propolis – as a foreign construction material. Structural analysis has shown that the propolis is not just



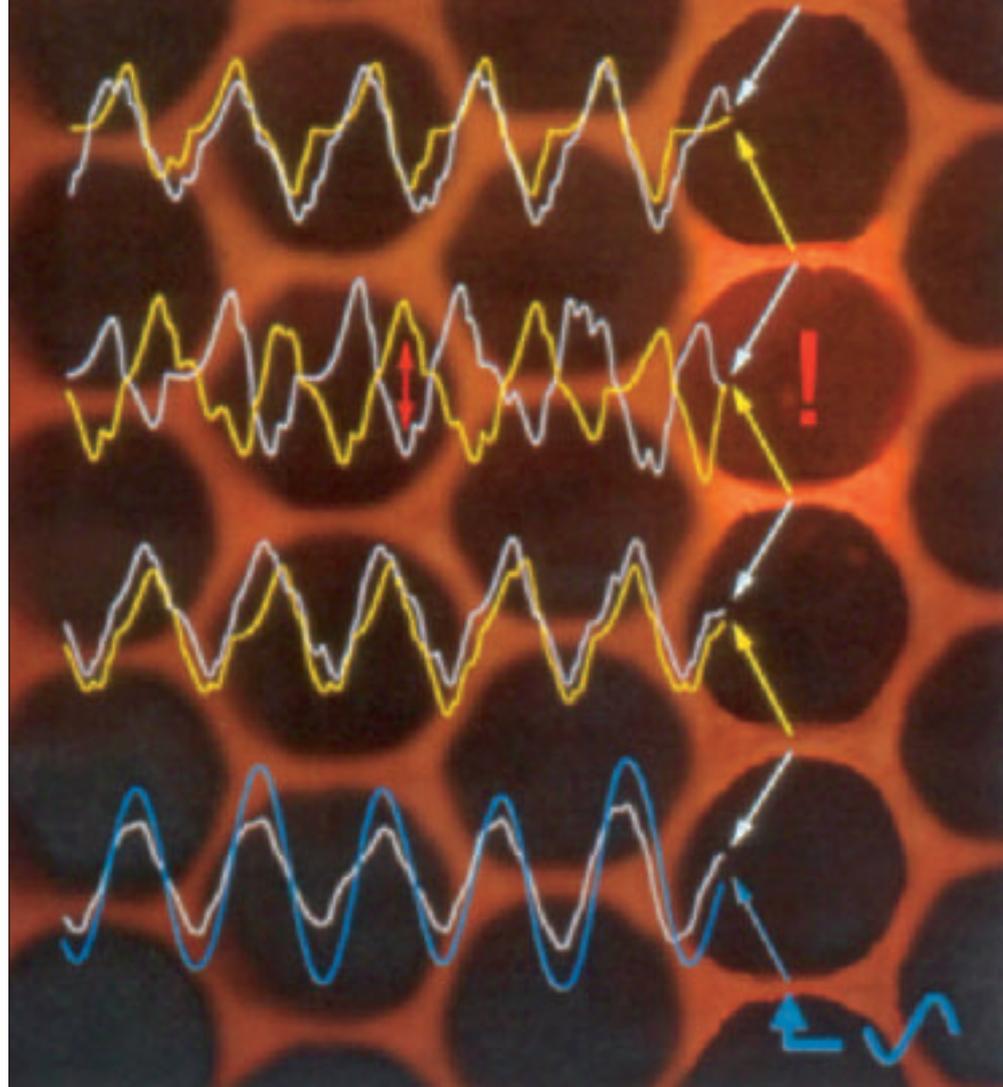
used in lumps over large areas to seal "draughty" spots in the hive, but is also incorporated in and layered on the wafer-thin walls in microscopic quantities. Use of these properties in this way is done to include antibacterial substances in the hive, but also to change the mechanical properties of the comb.

These mechanical properties are important for the comb's role as the conductor of vibrational signals. Mechanical signals that are transmitted over long distances are especially important in the dark hive. General alarms in the colony and "intimate" dance communications are also based on comb vibrations. Measurements with sensitive vibration meters have demonstrated that the comb has highly complex mechanical properties. It is a communication network in the truest sense of the word. If one looks at a comb (or section of a comb) consisting of empty cells, it is evident that the upper edges of the cell walls are thickened. These bulges achieve diameters of up to 0.5 millimetres while, in contrast, the cell walls are only about 0.07 millimetres thick. These thickened areas are the bees' "catwalks". The thickened parts of the comb as a whole can be seen as a grid consisting of hexagonal cells. Mechanical vibrations are transmitted across this grid, these are most easily spread in the form of movements of the cells parallel to the surface of these. These vibrations are generated by the dancing bees' flight muscles during the waggle dance. During the lively dance they cling to the cell edges with their legs.

During idle flights the bee's thorax vibrates at about 260 Hertz. The waggle dance movements only generate vibrations of about 15 Hertz, a mechanical trick is probably used to enhance the bee's attachment to the comb and, therefore, effectively incorporate the 260 Hertz wave.

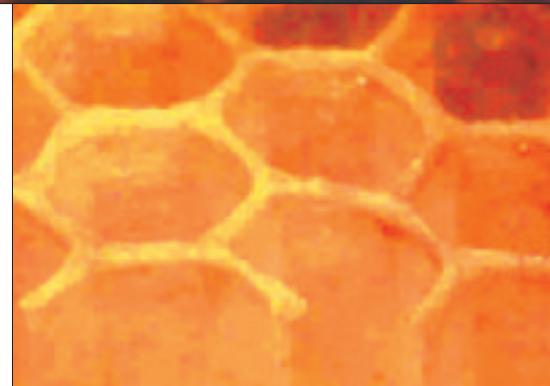
If vibrations are transmitted through the comb artificially during a physical experiment, it is possible to measure which frequencies are transmitted well and which are not. It was found that vibrations can spread across the entire width of the

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only a fraction of a honeybee's strength. At certain frequencies larger amplitudes result after a certain distance than at the source of the transmission. It is particularly noticeable that a frequency of about 260 Hertz is established that is transmitted particularly well. It is most remarkable that this is precisely the frequency produced in pulse clusters by dancers during the waggle dance.

The modern beekeeping practice of using wooden frames for the combs dampens the transmission of vibrations. Since this procedure is an essential part of commercial honey production, the beekeeper inadvertently disrupts the bees' means of communication using their "telephone network". It is astonishing, however, to observe how bees react to this intervention. They don't remain "speechless" but instead gnaw larger or smaller gaps between the comb and the wooden frames. These gaps restore the



The comb as a means of communication: vibrations arising during the waggle dance are transmitted across the entire comb. While they are being transmitted, the oscillations (top) change and the changing frequencies function as a direction sign. Individual information pulses are transmitted by a network on the comb consisting of wax bulges. Right: In this way information reaches individual honeybees before the waggle dancer in the colony resumes her dance.



comb's full ability to transmit vibrational stimuli.

The simultaneous activity of thousands of bees on the same comb creates a constant background noise level against which bees need to be able to recognize these weak signals. An unexpected mechanical property of the comb can evidently help the six-legged bee: if two special vibration meters are used and measurements of the vibrations at the cell edges are taken at least two positions simultaneously – which bees can do at six positions – a clear geometrical pattern emerges. This pattern can apparently help a bee that is interested in foraging to recognize the presence of a dancer.

Colony-forming insects have communication mechanisms to coordinate their activities of a complexity that is unrivalled by other invertebrates as well as most vertebrates. Social insects are, therefore, outstanding subjects for investigating issues regarding the mecha-

nisms and evolution of differentiated, content-rich signals. In behavioural biology, biocommunications requires a very broad methodological approach. The quantitative recording of the signals produced and their transmission is more heavily dependent on the state of physical and chemical measurement methods and systems available than other aspects of biocommunications research. The use of state-of-the-art methods has demonstrated the outstanding manner in which honeybees have coordinated their wax honeycomb, the vibration signals and the transmission of these signals to each other over the course of evolution. As a result, the wax beehive functions as both a "chemical memory" and a "telephone network".

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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 area of basic research through to applied research. Particular attention is paid to promoting young researchers. Every German scientist and academic is eligible to apply for DFG funding. Proposals are submitted to peer reviewers, who 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 12 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. Transregional 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.

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 focuses 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*.

Humanities Research Centres were created in the new federal states to improve the existing research infrastructure. These centres have been established for a specific time period and serve to promote interdisciplinary research.

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 submitted within the framework of the *Hochschulbauförderungsgesetz*, a legal act which provides for major equipment and the construction of institutions of higher education in Germany. 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 a private association. Its member organisations include research universities, the Academies of Sciences and Humanities, the Max Planck Society, the Fraunhofer Society, the Leibniz Association, the Helmholtz Association of National Research Centres, research organisations of general importance, 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.

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Private (p. 3); Albert-Einstein-Institut (pp. 4/5, 6, 7); dpa (pp. 8/9); Reuter (p. 9 b.); Rullkötter (p. 10); Engelen (p. 11 a.); Höppner (p. 11 b.); Kotzur (p. 12); dpa (p. 15); Wita (pp. 16-20); private (p. 21); Hüsken (pp. 22, 23); Bernd Dücke/Superbild (p. 24); Fastl/Patsouras (pp. 24/25, 26); Betz (p. 27); Thayer (p. 28), Newton-Thayer (p. 29/both Field Museum of Natural History; SFB 299/Universität Gießen (pp. 30/31, 33 a.) Gross/NABU (p. 31 b.); Steiner/SFB 299 (pp. 32, 33 b.); Eufinger (p. 35); beegroup (Fiola Bode, cover; pp. 36-39); Querbach (back)

a.= above, b.= below



This isn't a cat on a hot tin roof, as it may at first appear, but is actually a sculpture by the Berlin sculptor Hans Scheib, "crowning" the new extension to the DFG's Head Office in Bonn.