



3/2007 ▶ Times of Change in Omani Oases ▶ Culture, Commerce and Image ▶ Faintly Falling Plaster ▶ The Limits of Growth ▶ Desert Dust over Europe ▶ Moving Like Worms: Without “Legs”



In this issue

Metropolises and Their Cultures

Culture is a solid factor affecting the appeal of a location. A key aspect of image policy is the need to present local history and architecture and the centres of commerce and culture in such a way that they also appeal to an international audience. Taking Berlin and Moscow as examples, ethnologists are studying how culture is turned into capital in metropolises. **Page 10**

Tracing the Footsteps of Prehistoric Giants

Sauropods were some of the largest land animals that ever lived. Despite the fact they were herbivores, these enormous dinosaurs could reach a weight of 50 tons. Now, researchers are trying to solve the riddle of how these immense organisms functioned and how dinosaurs were able to evolve to attain such a formidable size. **Page 16**

Desert Dust and the Continental Climate

The effects of Saharan dust on the climate and weather reach far beyond the region of North Africa. This has now been demonstrated by researchers, who tracked the path of a massive five-kilometre high cloud of dust as it travelled from Morocco to South and Central Europe. **Page 20**

Commentary

Matthias Kleiner

Our Word of the Year p. 2
Germany's Excellence Initiative: Benefitting science and society

Arts and Humanities

A. Bürkert, K. Hammer, E. Schlecht, J. Häser, S. Al Khanjari

Times of Change in Omani Oases p. 4
Changing land use strategies in remote mountain oasis settlements

Wolfgang Kaschuba, Alexa Färber, Cordula Gdaniec

Culture, Commerce and Image p. 10

Natural Sciences

Klaus Hinsch, Holger Joost

Faintly Falling Plaster p. 13
Acoustic-optical measuring enables remote detection of loose plaster

Martin Sander, Jürgen Hummel, Nicole Klein, Marcus Clauss

The Limits of Growth p. 16

Jost Heintzenberg

Desert Dust over Europe p. 20

Engineering Sciences

Klaus Zimmermann

Moving Like Worms: Without “Legs” p. 24
How magnetic fluids can be used to copy the movement of a worm

Portrait

Rembert Unterstell

“There Are Two Hearts Beating in My Chest” p. 27
Torsten Doerst combines clinical work with pioneering basic research



Cover: Andreas Bürkert

Oases in Oman

A view of the Balad Seet oasis in the al-Hajar mountain range, which has been inhabited for over 2500 years. Researchers are studying the changing subsistence strategies in remote oasis settlements, looking at mountain oases in particular.

Klimakatastrophe" (climate disaster) is the "word of the year 2007", at least according to the German Language Society (GfdS), which announced the results of its vote in early December. The German scientific community and the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation), in particular, however, have chosen a different word of the year.

Our word of the year is "Excellence Initiative".

Of course, this is by no means meant to imply that the scientific community and its largest national funding organisation only think of themselves and lead an isolated existence, far removed from real life. In fact, anyone who is in touch with reality is surely wondering why "Excellence Initiative" failed to be amongst the front runners in the vote. The GfdS justified its decision to pick climate disaster as its word of the year because it concisely defines the topic that had a major impact on the German population in 2007.

But if the point is to define what moved the country the most – literally, in terms of what helped it to move forwards – then Excellence Initiative really should take first place.

And this although even we at the DFG felt engulfed by the term at times, as the Excellence Initiative demanded so much of our attention, in addition to everything else that needed doing in the world of research funding. Yet, what an achievement the Excellence Initiative was became particularly evident towards the end of the year, about two months after the final decisions (for the time being) were announced and the initial jubilation at the winning universities and the initial disappointment at those which failed to be selected had faded, and the speculation about political influence and additional cuts in funding had died away. Now the actual significance of the competition is becoming apparent, and this extends far beyond the scientific community.

Raising research at German universities out of perceived mediocrity and restoring it to a leading position on the global playing field was the goal initially aimed at by politicians and the scientific community just two and a half years ago, when the Initiative for

Excellence was launched. Even that was ambitious, and was by no means restricted to the scientific community. After all, the scientific community has an impact on society and supports it – and where else should this be more true than in Germany, whose most important raw material, the frequently cited "intellect" – so any initiative to boost the scientific community is also, inevitably, aimed at boosting the country's ability to remain successful in the future.

What the scientific and political communities aimed to achieve was not only achieved by the two rounds of the initiative – it was exceeded by far. German universities developed and submitted a wealth of excellent ideas and strategies that not only impressed the reviewers in the preliminary and final rounds of the initiative, but also left them amazed and even delighted. This scientific excellence is far more widespread and pronounced than it may initially have appeared, or than some may have assumed. If you look at the three pillars of the Excellence Initiative – and not just at the third pillar of the "institutional strategies", which is especially attractive to both the media and the public – it becomes apparent that more than a third of all German universities have ideas or strategies that will be capable of competing at the cutting edge of international research within the next few years. At a regional level, although admittedly to a lesser extent in the new federal states, a diverse image of scientific excellence is also evident, also when it comes to the range of subjects offered, which is due in part to the great success enjoyed by the humanities in the second round of the initiative.

All of these excellent ideas and strategies will give the German scientific community a strong and rapid boost – one that will not be restricted to the scientific community, but will also invigorate the entire country and society too. Many of the ideas now being worked on in the projects and institutions selected under the Excellence Initiative will lead to innovations that in turn will generate economic growth and prosperity.



Illustration: Lichtscheit

Matthias Kleiner

Our Word of the Year

The Excellence Initiative is a great boost for the German scientific community and will also benefit the country and German society as a whole

The graduate schools will provide the right environment for training future leaders at the highest international level, both for science and research as well as for companies, associations and organisations. The clusters of excellence not only have the potential to facilitate new forms of cooperation between universities and non-university research institutions, but also between the scientific community and business and industry, which will help to accelerate the essential transfer of research findings into applications. And, last but not least, the institutional strategies to promote top-level research will enable the best universities to prove themselves as society's "workshops of the future" in the truest sense of the word.

The opportunities this presents have already been recognised, especially abroad – perhaps even more so than here in Germany. At least, this is how some of the comments by some of the international reviewers following

the decisions in the second round of the initiative in mid-October could be interpreted. Ekhard Salje, the world-famous mineralogist from the University of Cambridge, a Fellow of the Royal Society and President of Clare Hall, for instance, was presumably deliberately referring to the whole country when he said "As a foreign scientist, I am proud to have had the privilege of coming to Germany to be involved in the Excellence Initiative. I feel as if I have been involved in making history." Luc Weber, one of the most internationally renowned experts on political science and economics, also went beyond referring merely to the scientific community in underlining, "I am very positive to the Excellence Initiative. Germany will reach in a few years what many other countries have not reached in ten or twenty years."

Finally, the significance of the Excellence Initiative also extends beyond the scientific community in an entirely different way. Almost ten

years ago former German President Roman Herzog, in what may well have been his most famous speech ever, said that Germany needs to jolt itself into action. The Excellence Initiative has certainly sent this jolt through the German scientific community and especially through the universities.

It is impossible to emphasise strongly enough that it is particularly those institutions that are still seen by some as being inherently inflexible that were able to present themselves as being particularly innovative, as could only be wished of certain other, ostensibly innovative parts of German society. Especially the universities, which for many years have had to cope with ever worsening financial and staffing conditions and mounting changes that came hand in hand with increased freedoms that came at a high cost – they in particular have taken up the gauntlet, in a concerted act demanding great effort by all those involved, to face this change,

have bidden farewell to the fateful fiction of equality and opted for the competition of inequality that excellence brings to light. What some supposed was a rigid, immovable system has proved itself to be astonishingly flexible, and the seemingly antiquated as unexpectedly modern. If only the same could be said for the German health, tax and pension systems, then there would be no cause for concern about Germany's future.

This is another reason why it is essential to continue the Excellence Initiative: to spark a permanent atmosphere of competition, without which there can be no lasting excellence; to ensure that the universities that have now been selected as elite universities do not rest on the laurels of their excellence and thus inevitably squander it; to give those universities that have so far not been given a chance to excel, in particular those in the new federal states, the opportunity to improve their ideas and strategies that are already very good; and to prevent the German scientific community as a whole from getting stuck half way to the leading edge – all of these objectives are in fact one and the same.

Keeping the resulting stimuli for the country as a whole, its growth and its prosperity going and strengthening them is the second major goal to be achieved by continuing and developing the Excellence Initiative beyond what has been achieved so far. On the basis of the comments made by the politicians from the national and state governments responsible for the issue there are grounds for optimism. We need to act on this fast, and if, in a few years' time, the next rounds of the initiative generate similarly excellent results to those seen in the first two rounds, and the scientific community and society as a whole benefit from this again in the same way – then perhaps the Excellence Initiative will become what it actually should already be: the word of the year.

Prof. Dr.-Ing. Matthias Kleiner is President of the DFG.

Times of Change in Omani Oases

For millennia, highly developed oasis farming, alongside fishing, has formed the basis of life for the sedentary people of Oman. Researchers take a deeper look at the changing land use strategies in remote mountain oasis settlements

By A. Bürkert, K. Hammer, E. Schlecht, J. Häser and S. Al Khanjari

A view of the Balad Seet oasis in the Jabal al-Akhdar massif in northern Oman.

Famed as the origin of frankincense, a major copper producer in ancient times, and the birthplace of the legendary trader "Sinbad the Sailor", who represents the phenomenal wealth of oriental merchants, Oman was barely accessible to foreigners until 1970. As an enlightened Islamic Sultanate, the country has since experienced an uninterrupted process of cultural and economic transformation. In former days, Oman was a country of nomads who bred the fastest camels in the world, of oasis farmers, fishermen and of seafarers, who were already trading with India on a regular basis, using their sturdy boats made of reeds, and later wood, in around 3000 B.C. Today the society's welfare is based predominantly on the oil industry and on services. The traditional oasis economy as the material basis and key formative element of Omani culture has taken a back seat, becoming an exotic peculiarity and a tourist attraction. In recent years, many of the oases that have become easily accessible via newly constructed tarmac roads have turned into "housing estates under trees", while remote settlements have become weekend residences or have been completely abandoned.

Recent interdisciplinary studies have made it possible to represent and evaluate the way in which remote mountain oases in Oman function and have highlighted opportunities for their development. The study presented here looked at the mountain oases of Maqta in the Jabal Bani Jaber mountain range (a small "scattered oasis" settlement 1050 metres above sea level), Al-'Ayn and Ash Sharayjah (two small core oases at an elevation of 2000 m a.s.l.) in the massif of the Jabal al-Akhdar, the small oasis of Al-Sawjarah, which has only recently been connected to the road network and public infrastructure, as well as Balad Seet (a large core oasis at 1000 m a.s.l.) in the northern Al-Hajar mountain range.

All of these sites are characterised by their use of the "Aini Aflaj" water supply system, a spring-fed canal system developed in Oman in regions with an annual precipitation of 100-200 mm, whose origins are



believed to date back to between 1000 and 500 B.C., as well as by intensive interaction between terrace crop farming and animal husbandry. Observations of grazing goats, periodic GPS collar tracking and feed intake studies showed that once or twice a day, the herds with often a few hundred goats and some sheep are taken to graze the sparse mountainous pastures surrounding the oases that provide over 50% of their total intake; in the evenings their diet is supplemented with high-protein fish, high-energy dates, kitchen leftovers and alfalfa. The terraces, which are many centuries old, have been built up over the millennia with great care using 10,000s of tons of wadi sediments. They are used intensively for crop farming, which is characterised by large surpluses of added carbon and nutrients coming mainly from livestock manure. Studies of plant morphology and molecular genetics have revealed that the local varieties of wheat grown as landraces on these terraces, which are currently disappearing rapidly, are unique worldwide. The newly discovered five varieties of bread wheat and four varieties of durum wheat emphasise the ancient function of these mountain oases as sanctuaries for genetic resources. Comparative fingerprinting studies with wheat accessions from the world's germplasm collection pro-

vided evidence for the ancient trade relations Oman maintained with all major countries in the region.

Fruiting date palms are a common sight in many of Oman's mountain oases. Facing page: The impressive hanging oasis terraces on the steep slopes of the Jabal al-Akhdar massif in northern Oman. This aerial photograph was taken from a small remote-controlled airplane.

The first example is the territory of Maqta which extends over an area of about 25 square kilometres. To the present day, the central settlement with its 59 stone buildings, which are predominantly used for storage, retains its importance for Maqta's about 200 semi-nomadic inhabitants with their herds of sheep and goats as well as for the 16 terrace systems, fed by 22 tiny springs, which cover a total area of just 4.5 hectares. Due to below-average precipitation during the period studied (2002-2004), many cultivated terraces were abandoned and one of the ancient varieties of wheat discovered there has now become extinct. As a result of its isolation and the precarious water supply, this oasis settlement is acutely in danger of being abandoned completely, in spite of state infrastructure aid and transfer payments.

Irrigated farming in Maqta started only about 600 years ago. Prior to



this, the springs and pastures were used periodically by nomadic herds- men with their flocks. This is also visible in the archaeological record which does not show settlement remains but several tombs dated to the of Bronze Age and Iron Age (3000-600 B.C.). Famous are the limestone-built towers on the Shir plateau which were discovered in 1992. Due to comparisons with similar structures elsewhere on the Arabian Peninsula they could be dated to the 3rd millennium B.C. However, they were probably not only used for burials but also as markers in the landscape. They are situated on the Shir plateau where four main wadis originate and probably once were monumental territorial markers for the nomads.

Very close to the settlement of Maqta it was possible to find an undisturbed area of sedimentation in a depression where a 20 metres deep cut could be made for climatic studies. Such studies are most important for Oman to investigate whether the dramatic alterations in the settlement history over time could be partly explained by climatic changes. The sedimentation profile reaching over 18,000 years back into the Pleistocene era was used as a palaeo-climate record after successful radiocarbon dating of mollusc shells, luminescence analyses of quartz minerals and the evaluation of pollen diagrams. In contrast to earlier periods, when shifts of the Indian Summer Monsoon were reflected in large alterations of the moisture regime, the data gained from the profile provided evidence of only minor climatic changes since the tower tombs were built.

A second example: due to their spectacular location on the steep mountain slopes, the terraces on the Jabal al-Akhdar massif are famous as "Hanging Gardens" far beyond the borders of Oman. GIS-based analyses of high-resolution aerial photographs made with a small, remote-controlled airplane and ground measurements on the thousands of plots, some of which are as small as a single square metre, allowed a representative assessment of carbon and nutrient flows at the village level. The farmers who live

in the settlements of Al-Ayn and Ash Sharayjah cultivate a total area of 2.4 hectares as rose gardens (used to distil rose water of a very particular quality) and 10 hectares of terraces for pomegranates, walnut trees, limes, alfalfa, barley and onions for their own subsistence and for sale. According to the oases' inhabitants, in the past decade a third of the original area of terraces has been gradually abandoned, as a result of the increasing shortage of water. The farmers blame this

electric washing machines have become commonplace in many of the small mountain villages. A switch to (certified and thus marketable) organic farming methods, as would appear possible without much difficulty from a cultivation point of view due to the very sparing use of mineral fertilisers and the almost total absence of pesticides to date, would open up new marketing opportunities for the products from the oases, keeping the hard work in the gardens worthwhile. Levying entry



On the road with two donkeys: Transporting tools and liquid nitrogen for the conservation of soil samples to the study site. Right: A steep staircase leads to the Al-Sawjarah oasis in northern Oman. Facing page, above: A rope ladder hangs into a 20-metre sedimentation profile used as an 18,000 year old local climate record. Facing page, below: A neglected date palm grove in the north Omani town of Bahla.

on the steady decline in precipitation that has taken place over the past few decades, but 30-year old photographs of the area indicate that the perceived water shortage is more likely due to the rapid construction of new settlements on the high plain of the Saiq plateau and the accompanying intensive watering of domestic gardens coupled with an extension of tree cultivation on the terraces. The recent rapid growth of tourism will increasingly become another reason for the occurrence of water shortages. But the oasis dwellers themselves also use more water today than they did just 30 years ago as toilets, showers and



fees to the villages or for guided tours in the gardens by locals familiar with the area could also enable villagers to earn additional income from tourism.

The third oasis settlement of Al-Sawjarah is also located on the Jabal al-Akhdar massif. Six stone houses and a few goat stables snuggle up under a rocky ledge right on the mountain slope, overlooking a narrow, dry valley where walnut, pomegranate and peach trees grow. Due to the very low yield of the only spring in the village, just 0.7 cubic metres an hour, the farmers gave up cultivating plants requiring intensive irrigation such as wheat or fodder plants some years ago. The village, which today has a population of just 50, only became accessible by motor vehicles in 2004, when a gravel road from the main asphalt road was built. The last part of the journey to the village through the dry valley still has to be completed on foot, with a climb up large stone steps. Once their last inhabitants leave, the ancient buildings are likely to fall into ruin rapidly, as so many have done already, unless

they are preserved as a cultural and historical treasure serving as a museum village.

One final example: The oasis settlement of Balad Seet, with a current population of 600, on the western slopes of the Jabal al-Akhdar massif has – as proven by archaeological finds – been in constant use since the second Iron Age (around 1100 B.C.). Due to the large watershed, the dozen springs close to the oasis settlement still yield sufficient water even after several years of drought to allow dates and fodder to be grown, as has been revealed by regular measurements. Studies of the age of the water using tritium and sulfurhexafluoride as tracers suggest that the rain water seeps through the limestone and dolomite massif for five to six years before finally emerging at the oasis. This comparatively reliable water supply makes Balad Seet stand out among many other oases, in particular in comparison to Maqta, both in terms of the settlement history as well as its future prospects for development. The constant construction of new houses, the modernisation of old buildings and the installation of sanitary facilities as well as the connection of Balad Seet to the road and mobile telecommunications network make this village increasingly attractive for Omani weekend dwellers and individual tourists. An indiscriminate expansion of tourism in Balad Seet is likely to be accompanied by the same problems that have been observed elsewhere and were described above. This makes it all the more important to share the data collected on the biophysical functioning of Omani oases and their settlement history with the institutions responsible for national planning and political decision making.

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Culture, Commerce and Image

Theatre and art, music scenes and subcultures have become a "hard" location factor for the metropolis. Taking the examples of Berlin and Moscow, cultural scientists are investigating how to make capital out of culture

By Wolfgang Kaschuba, Alexa Färber and Cordula Gdaniec

Germany: A Summer's Fairytale: for Berlin, World Cup 2006 was the occasion of an extravagant staging of the city as host to "friends" from around the world. Meanwhile, in Moscow, the municipal managers were discussing a new strategy to create a positive image for their city. There was a connection between these things: in the global ranking of major cities and their standard of living, which is published regularly by corporate consultants for international tourists and business people, the capital of Russia has a regular spot among the lowest placed cities, while Berlin is always in the top twenty. It is time for the negative portrayal of Moscow in the western media, which is based as much on daunting visa procedures as on crime reports, to be transformed into a more "civilised" image, says Mayor Luzhkov. But Berlin also continues to promote its established image as an international cultural metropolis through the arts and event programmes. The two cities invest in different ways in "urban imagineering", in other words, in a strategic image policy that attempts to combine local history, architecture, the museum scene and the consumer and cultural offerings in the most attractive image that can be presented to an international audience. It is above all culture, creativity and the arts that are seen as a measure of urban potential and that give a city its distinct char-



Illustrations: Färber

Left: In Berlin, some spaces are being temporarily used for creative cultural offerings and bringing a fresh perspective. Vacant commercial premises in Wedding – in this case a home improvement store – are being used for exhibitions. Below: The former state bank of the GDR is used for theatrical productions. Right: In Moscow, the informal "Art Strelka" project has met with a positive response, and the annual "Art Moskova" likewise.

acter, making of it a real metropolis. At the same time, it is a question of hard economics and hard politics. Because culture and creativity are now considered to be a mainstay of effective regional policy, at least since the publication of the best-selling "The Rise of the Creative Class" by Richard Florida. Florida's conclusion, derived from a study of major American cities, highlights the importance of certain social and cultural groups to the sustainable development of major cities. The term "creative classes" refers to intellectuals and to those working in the media, in artistic occupations and in knowledge-intensive technology sectors, but above all to parts of the ethnic minorities and to urban gay communities and subcultures. Their visibility in the city and their commercial and cultural activities, in other words their "creativity", is considered to be in itself a decisive factor for sustainable economic development.

Perhaps that seems like a really simple and manageable formula for success. To cultural scientists, however, it sounds a bit starry-eyed. For this reason, one of the goals of a DFG-funded research project, with the title "Urban Culture and Ethnic Representation: Berlin and Moscow as Emerging 'World Cities'", is to take a closer look at Richard Florida's creativity thesis. A comparison of cities as diverse as Berlin and Moscow ought to reveal whether this programme is really applicable to the development conditions of all major cities. The project also inquires into the specific social and cultural living conditions that face immigrants today in such an ambivalent way in these two cities. The initially inviting "praise of diversity" and the flair of ethnic economies



Illustrations: Gdaniec

and gastronomies are always counterpoised by decidedly repellent debates about "parallel societies" and Islamic fundamentalism. In this way, the status of minorities also becomes a mirror of our self-perceptions. Using a research perspective that attempts to approach the social actors and their life-worlds, cultural anthropology can provide an insight into the social and cultural microsystems that make up society.

Since German reunification and the collapse of the Soviet Union, Berlin and Moscow have had to reposition themselves politically and culturally, to an extent that few other major cities have experienced. With regard to the use of urban culture, the two cities follow distinctly differ-

ent strategies. Moscow attempts to maintain or extend its position as an economic hub – now under the banner of aggressive capitalism. It thus glories in the construction of Europe's tallest building, and stamps residential areas, administrative zones and hotel complexes out of the ground, bringing about structural change in the city centre.

In comparison with Berlin, which long-ago established its central position on the world map of culture as a cosmopolitan and creative city, Moscow is rather slow and intermittent in opening the stages of the city to culture and the arts. There are historical reasons for this. In Moscow, the active international networking of the Russian art scene can only be



Illustration: Zitty

Commitment and stability are required: "I am the city" – a campaign that clearly states its position by the Berlin city magazine "zitty". Right: The Moscow shop window of a "Berlin Döner Kebab" take-away. In Moscow, too, city culture is indebted to many models and impulses from outside.

observed after the collapse of the Soviet Union. The best example of this is "Art Strelka", an informal gallery project in the unused garages of the "Red October" chocolate factory on the Moskva island directly across from the re-built Church of the Redeemer. The artistic director of Art Strelka describes this new space as Moscow's "SoHo", in reference to the legendary artists' quarter in south Manhattan. The municipal government has given its approval to the project. However, in spite of the positive response to this temporary artistic use of the premises, they have no further interest in the long-term presence of art at this central location. It is much more concerned with the relocation of the factory to the city limits, so that a luxurious apartment-office complex and recreational centre can be developed on this site, which is to be known as "Golden Island" and is intended



Illustration: Gdaniec

to boost Moscow's reputation as a commercial boomtown.

Berlin, on the other hand, against a background of wretched economic development, long ago discovered the value of culture as a central economic factor. In the city's self-portrayal, theatre, art, music scenes, fashion and knowledge institutions, which are considered to be the driving forces of the so called "creative industries", have been strategically upgraded from "soft" to "hard" location factors. It is true, that there is now a preponderance of small and micro enterprises, but this diversity of networks in culture and the arts appears open and attractive to people visiting or relocating to Berlin.

The city's administration and marketing department also stress these elements of Berlin's image. By declaring culture to be the city's central resource, they are reinventing the myth and reality of the cultural metropolis of Berlin: the scene cultures for younger and creative people, the historical and artistic European metropolis of the 20th century for the educated middle-class and the tourists.

This concept also entails a distinct emphasis on outstanding cultural events, pop culture, the gay and les-

bian street parade on Christopher Street Day, the Love Parade, youth and music scenes and the staging of ethnic diversity in the Carnival of Cultures. This strategy has even led to a new appreciation of immigrant and minority cultures. Today, they form one of Berlin's most notable drawing points and are considered to add to the commercial potential of the old and new cultural metropolis. In texts and photographs, in films and artistic productions they rejuvenate the city's atmosphere and climate. The "climate of tolerance" in Berlin counts as a decisive factor for newcomers to the city – for immigrant minorities as well as for international tourists or for Richard Florida's "creative classes". This ethnic diversity is also invoked by cultural activities. Against this background, a case study examines how local international artists critically engage with the theme of "strangers" in the metropolis. Others create new cultural and commercial Berlin labels. In keeping with this, Berlin was named the City of Design by UNESCO at the start of 2006 and shortly afterwards it proudly assumed the "Designcity" label as part of the "Designmai" festival. The culture industry has therefore already become a part of

the Berlin "product", and its professionals have long seen themselves as representatives of the city. That is "Imagineering".

Field research has shown the disparity between this situation and that in Moscow, which even today has hardly begun to advertise its cultural capital. In contrast to Berlin, the city itself has not yet become an object of representation. The cultural added value of being a Muscovite artist, designer or product rather seems to be taken for granted and does not serve as a label. Artists here are hardly concerned with the city itself and the topic of the city's ethnic, religious and sexual diversity appears in only a few works. In this respect, the city's public sphere still seems to be a politically regulated space, in which cultural diversity and any kind of cultural contradiction have very restricted opportunities for expression. Quite the contrary: in May 2006, the city received worldwide negative publicity, when the municipal government wanted to ban a gay pride event and then, when the participants gathered nonetheless, failed to protect them from attacks by right-wing extremists. That which is welcomed in other cities is subject to harassment here; imagineering in Moscow is often a throwback to the stone age. It may be said of Berlin and Moscow that culture, art and creativity are becoming ever more important, though this is always subject to global business cycles and local resources. Richard Florida's snapshot from the USA certainly cannot be transferred wholesale to the European situation, because local social and cultural conditions need to be more accurately reflected. The urban image cannot be arbitrarily planned and styled – even though peripheral culture has long become the principal thing, and not only in major cities.

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Illustration: Zehnder

Faintly Falling Plaster

Shocks and vibrations endanger historical frescoes. A new acoustic-optical measuring technique enables the remote detection of loose plaster

By Klaus Hinsch and Holger Joost

A significant proportion of the cultural heritage of mankind was painted on walls. Today these historical paintings are in need of care and protection in order to ensure their conservation. Salt crystals in the walls and external shocks and vibrations, from road traffic or earth tremors, for example, can loosen and damage the plaster. Conservators usually inspect the condition of wall paintings using the percussion technique, which involves gently tapping the painting, section by section, and deducing from the acoustic response where the plaster is loose. At such locations it sounds hollow. Using this method of inspection to plan the restoration of a large church is a cumbersome task, requiring complex scaffolding

and involving a detailed mapping of the painting's condition that can take months to complete. The obvious solution here would be to develop a measuring technique that can be used to perform this inspection quickly and automatically from ground level, allowing the experts more time to concentrate on the affected areas and their restoration.

The newly developed technique is based on the same fundamental principle as the percussion tech-

Cultural heritage at risk: The frescoes and wall paintings at the convent church of St. Johann in Müstair are a UNESCO World Heritage Site. In the 12th century, the Carolingian frescoes were covered by Romanesque wall paintings. These are now at risk, as old and more recent plasters break off.



nique. A loudspeaker is used to apply sound waves to the wall, so that loose areas stimulated by the vibrations can be detected optically. Depending on its size, shape and thickness a loose section of plaster exhibits a specific resonance pattern, known as an oscillation mode. This phenomenon is familiar to any driver who has experienced how loose parts of the car start to rattle

measurements at vibrations of less than 20 nanometres – less than one thousandth of the thickness of a human hair! To detect such minute movements, a high sensitivity non-contact measuring technique was needed.

A laser light wave, which is back-scattered from the wall, is used as a sensor. The light wave reaches the observer slightly earlier if the oscillating surface is

The size, shape and thickness of loose areas of plaster exhibit a specific resonance pattern, known as an oscillation mode

moving towards the observer at the moment it is scattered, and slightly later if it is moving away. This variation can be measured by superposing a second laser

light wave onto the light wave that is scattered by the wall. The interference pattern obtained from this superposition of two light waves depends on the time shift of the light waves relative to each other – a phenomenon referred to by physicists as the light's phase shift. If the peaks of two light waves coincide there is constructive interference and the light is amplified, whereas if a peak and a trough coincide there is destructive interference and the

two waves cancel each other out. If the light is coming from an oscillating surface, an interferometer detects cyclic brightness-variation at the oscillation frequency. Interferometers are capable of detecting displacements significantly smaller in magnitude than the light's wavelength. Under favourable conditions, the new instrument, which uses a digital video camera to record the interference pattern, can even measure vibrations of just a few nanometres.

The instrument works by recording a series of images in quick succession, which are then processed by a computer. The data is converted in such a way that already during the measurement procedure oscillating areas observed by the video camera can be recognised on the screen by their slowly flickering brightness. This type of display

gives the observer an indicative impression of movement. The physicists in the research team needed to learn to respect the uniqueness of historical structures and the conservators and restorers needed to be able to understand the results and gain confidence in the performance and reliability of this high-tech method. Final results produced by the computer are presented as a plot of the oscillating, i.e., loose areas.

The initial tests of the system were conducted on model walls, specially built by the conservator according to old construction methods. These tests proved that long-term exposure to the sound waves did not damage the plaster. Artificially created weak points, where contact between the plaster and stone was interrupted, were successfully detected and illustrated the oscillation patterns to be expected from loose sections of plaster.

The new technique was finally put to the test on the frescoes in a cemetery chapel at Kamenz, Saxony. The adhesion of the layers of plaster covering the walls and ceiling was examined one square metre at a time. The frequency of the sound was adjusted in steps of ten Hertz, and the reaction of the wall to each sound was recorded. For the evaluation it was calculated how often an oscillation was detected for each position on the wall. The data obtained was assigned colour values, so that all of the areas where there was no longer good adhesion to the substrate were eventually displayed in yellow or red. The new laser-optical technique also passed the test in comparison to results obtained using the conventional percussion method. It benefited from the advantage that the damaged areas shown on the video image could be located precisely and automatically. Manual mapping performed by a conservator, on the other hand, can easily contain errors that creep in during the mapping process.

Another example of where the new method has been applied is the church at the Benedictine Convent of Saint John Müstair in Grisons, Switzerland, which has been de-



Illustration: Universität Oldenburg

Left: The yellow and red areas indicate loose layers of plaster. Bottom left: The experimental setup for laser-optical inspection of historical frescoes. Bottom right: Areas of stucco that are shown as yellow or red are loose and therefore at risk. Below: A restorer checks for loose areas of plaster by gently tapping the surface.



Illustration: Universität Oldenburg

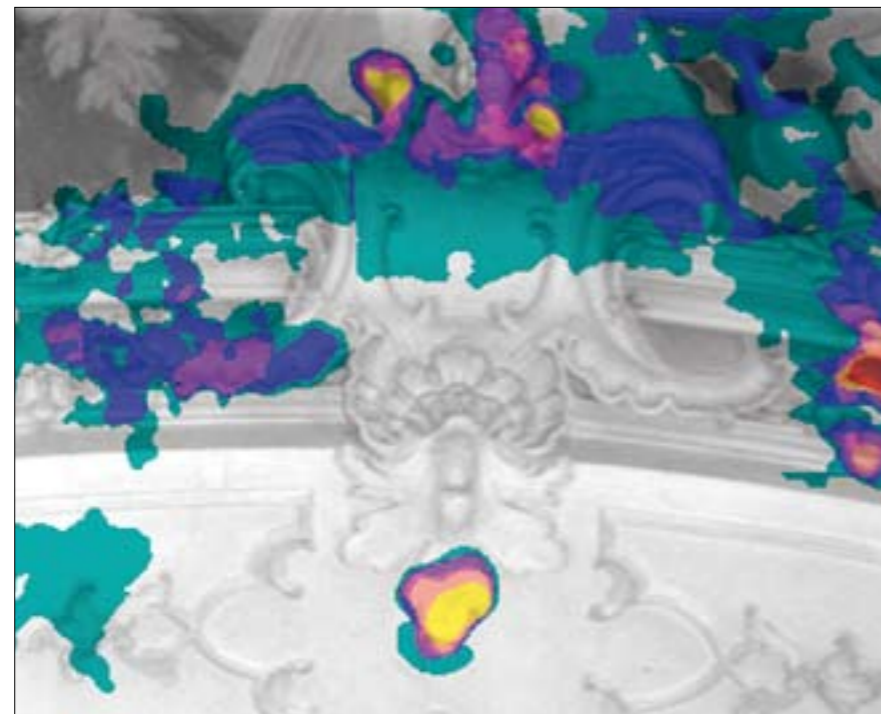


Illustration: Universität Oldenburg



Illustration: Zehnder

clared a UNESCO World Heritage Site because of its medieval wall paintings. In the 12th century, the original Carolingian frescoes, which had been painted 300 years before, were covered by a new layer of plaster and a series of Romanesque wall paintings. To roughen the surface in preparation for the new plaster, in parts even holes were made in the Carolingian paintings. Nevertheless, the adhesion between the older and the more recent plaster is poor in many places, which has already led to parts of the newer paintings falling off the wall. Using the laser-optical measuring technique, it has been possible to identify large loose sections in many places, which can now be kept under close observation by conservators. At some points, it may be necessary to reinforce their connection to the substrate. One alarm signal would be if these damaged sections were to become larger – possibly as a consequence of the minor earthquake that shook Grisons in 2001. This will now be confirmed by comparing the data recorded at that time with data from a repeat measurement.

Acoustic-optical inspection of frescoes and wall paintings would be an ideal method, if not for the annoying noise levels that it generates. Although the vibrations in the plaster are minute, the volume of sound needed to generate them is immense. This is also due to the fact that low frequency sound cannot be targeted at one specific area, but fills the entire church. What is needed, therefore, is a sound transducer that emits sound straight at the target area of the wall, something like the beam of car headlights. A device is currently under development that should emit ultrasound at two inaudible frequencies, which combine by nonlinearity on the way to the wall to generate the low frequency sound. This could finally allow the new technique to become accepted as a diagnostic tool for restorers.

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The Limits of Growth

Tracing the footsteps of giants: How the bodies of 50-ton prehistoric dinosaurs worked and the evolutionary steps that led to this gigantic size

By Martin Sander, Jürgen Hummel, Nicole Klein and Marcus Clauss

Apatosaurus and Brachiosaurus were two of the largest land animals that ever lived, the sauropods. These gigantic dinosaurs were several times heavier than elephants; the largest of them weighed 50 tons according to a conservative estimate. Every young child can easily recognise a sauropod and will point out the small head on the long neck, borne by a massive body with four legs, to less knowledgeable grown-ups. With the exception of the brachiosaurids and the camarasaurids, the long neck was probably held horizontally, with the long tail used as a counterbalance. Brachiosaurids and Camarasaurids, on the other hand, held the neck in an upright

position like a giraffe, and had a correspondingly shorter tail. The sauropods were herbivores (plant eaters), and enjoyed great success with this way of life for over 140 million years, from the Late Triassic (250 million years ago) until the end of the Cretaceous Period, thus surviving through almost the entire Mesozoic Era.

The greatest diversity and range of the sauropods lived in the Late Jurassic, with the most famous finds made in the North American Morrison Formation and the African Tendaguru Beds, which are now on display at the Museum of Natural History at the Humboldt University in Berlin. In the Cretaceous Period sauropods were less numerous on the northern continents, but they remained diverse and widespread on the southern continents until they became extinct, along with



Illustration: Oleschinski



Illustration: Luerweg



Illustration: Sander

the other dinosaurs, about 65 million years ago.

During the long period of their existence, the sauropods saw dramatic changes in global geography, such as the break-up of the supercontinent Pangea and far reaching changes to the contemporary ecosystems. This involved not only climate change and fluctuations in sea level (including the "Cretaceous Greenhouse World"), but also the appearance of angiosperms (flowering plants) from the mid-Cretaceous Period onwards.

A DFG Research Unit is studying how these gigantic creatures functioned as living organisms and, on the basis of this, how they were able to attain such an enormous size through the course of their evolution. This study is based not only on data from fossilised bones and skeletons, but also on the microstructure and chemistry of the bones and fossilised eggs and very often on comparisons with present-day animals. Understanding the sau-

ropods' energy metabolism plays a key role in understanding "gigantism" as a whole. It is not so much a question of what drove the evolutionary increase in body size, but of what limited it. Presumably the giant dinosaurs functioned far more efficiently, in terms of one or more of their vital functions, than other land animals. Two examples taken from the research group's project work illustrate this. In order to understand gigantism in evolution, it is first necessary to study the growth of individual animals. Although you could be forgiven for assuming that this would be impossible for animals that have long been extinct, a special feature of the fossilised bones does offer a window onto their lives: the microstructure, which is often perfectly preserved. When viewed under the microscope, thin slices of bone, referred to as thin sections, reveal not only the course of collagen fibres and of the vascular system, but even the remains of bone cells. Comparison with the bones of present-day animals, for which the growth and metabolic rate are known, allows far-reaching paleobiological conclusions to be drawn. This is because bone tissue of the same type is always deposited at the same rate. The studies have revealed that the sauropods – with a few isolated exceptions – had what is described as fibrolamellar bone tissue, which is only found today in large warm blooded mammals such as cows, elephants and pigs. Sauropods must, therefore, have grown at about the same rate as these animals. Annual growth rings, which appear occasionally, show that they sometimes grew at a rate of more than a ton a year!

But at what stage of their evolution did this rapid growth rate, which is almost unimaginable in anything but warm-blooded animals, begin? Investigation of the geologically oldest sauropod, *Isanosaurus*, discovered in Triassic deposits in Thailand, has shown that even this, the earliest known sauropod, must have grown at a very rapid rate. A comparison of the microstructure of the bones with a close relative, *Plateosaurus* from Germany (also known as the "Swabian lindworm"), has

The impressive skeleton of the *Brachiosaurus brancai*, on display at the Museum of Natural History in Berlin. Unlike most sauropods, *Brachiosaurus* held its neck in an upright position, and its forelimbs were longer than its rear limbs. It had a total length of 23 metres.

shown that *Isanosaurus* grew so large because it grew much faster than *Plateosaurus*.

How was a young sauropod able to achieve such an immense weight gain? Its diet and food intake must have played a key role. So far, however, it has only been possible to draw conclusions about what the dinosaurs ate from the shape of their teeth and jaws, supplemented by paleobiological studies of the flora of the Mesozoic Era. This research group has taken a different approach. Although we know that the large herbivores that exist today obtain sufficient nourishment from leaves and grass, it was necessary to investigate the nutrient content of the plants in the Jurassic Period. Since flowering plants had not yet evolved, the flora at that time consisted of gymnosperms such as conifers and ginkgos as well as ferns and cycads. Although most of these groups of plants have survived to the present day, they no longer play a significant role as a food source for animals, which would lead one to assume that their nutritional value may be too low for them to be of interest to cattle, antelopes or elephants. The researchers therefore decided to use methods from agricultural research to assess the nutritional value of this "dinosaur fodder" in comparison to modern-day forage crops and thus determine which of them would have been best suited as forage crops for dinosaurs. These experiments were conducted using the "HFT method" (Hohenheimer Futterwert Test), in which the digestion in an herbivore's stomach is simulated under controlled conditions.

Overall it was found that, in comparison to present-day leaves and grass used as fodder, the Mesozoic plants were perfectly suited for nourishing large herbivores. Also, several surprising findings enabled



Illustration: Heinrich

the researchers to draw conclusions about the sauropod's diet. Araucarias (such as the monkey puzzle tree from Chile or the Norfolk Island pine) have a high nutritional value, although the nutrients they contain can only be extracted by digestion after a prolonged retention time in the gut, lasting about three days. Because large animals have a longer digestive tract and thus prolonged retention times, these conifers, which were very common in the Mesozoic Era, would have been ideally suited as fodder. This sits well with the idea that the sauropods may have used their long necks to browse higher trees. Per-

haps the most surprising finding was that the primeval horsetail has the highest nutritional value, higher even than grass. In the Mesozoic Era these plants probably grew on the shores of rivers and lakes, rather like reeds today, meaning that a long neck would also have been useful for grazing in such locations. The question remains of why modern-day herbivores do not exploit this resource. One explanation would be that the high silica content of the horsetail foliage leads to rapid abrasion of the teeth (hence the old name, scouring rush, which refers to its former use for polishing metals). For sauropods this would

not have presented a serious problem, since their teeth were primarily used for plucking off foliage and not for chewing.

A consideration of the issue of reproduction, in addition to that of nutrition, perhaps brings us a bit closer to an explanation of gigantism. Every animal in a given population requires a certain fraction of the land area it occupies as its food re-

source base. The larger the species, the fewer individuals can obtain sufficient food in a given land area. The large animals that exist nowadays, such as elephants and tigers, consequently have a low population density, which leads to a greater risk of extinction, as the population is unable to regenerate fast enough after a catastrophic event has occurred. This problem is exacerbated

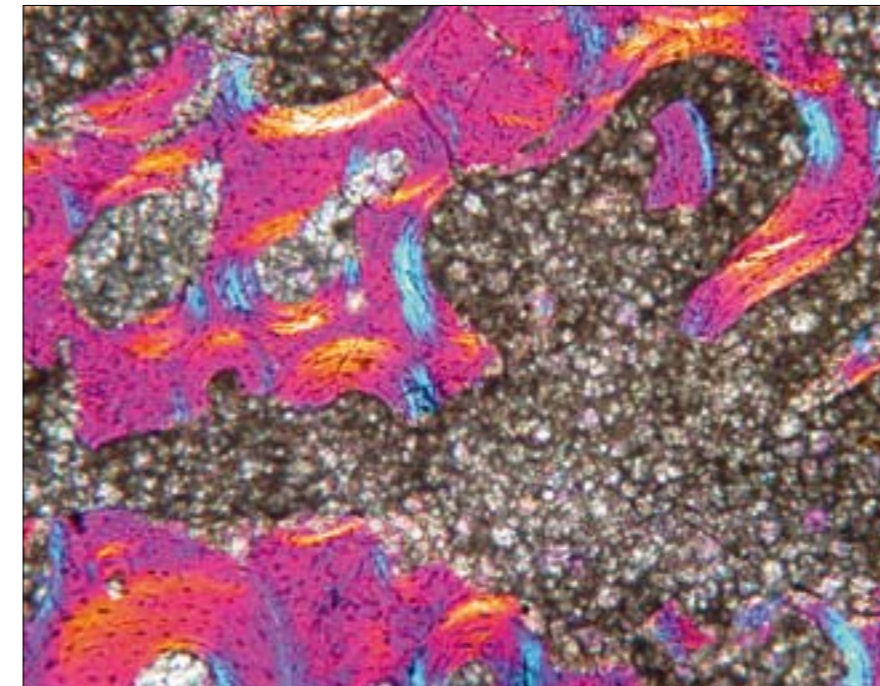
by the fact that the rate of reproduction drops significantly as body size increases. The maximum body size of land animals, therefore, seems to be determined by the size of the land mass on which they live. One way of overcoming the dilemma of population densities and reproduction rates that decline in response to increasing body size may be represented by the egg-laying of the dinosaurs. The number of offspring produced by birds, for example, does not decrease with increasing body size, but remains steady. Egg-laying thus could have allowed significantly faster population recovery in these very large animals than giving birth to live young, thus lowering the risk of chance extinction. Dinosaurs could thus have had stable populations at very low population densities, which would, in turn, allow for very large individuals, or indeed giants.

Eggs, and even entire sauropod nesting grounds, have been found in northern Spain and Argentina, for instance. Data on clutch sizes in these nesting grounds and on life history (deduced from the fossil remains found) can be used as a basis for model calculations on the rate of reproduction in sauropods and so to test the hypothesis that egg-laying permitted gigantism. This is just one of several exciting questions that the research group is still addressing. Although it will not be possible to shed a conclusive light on the evolution of gigantism, the understanding of the complex factors governing maximum body size has advanced considerably, and continues to do so.

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► www.sauropod-dinosaurs.uni-bonn.de



Illustrations: Sander

In the pink: Under the microscope, the thin section of sauropod bone appears coloured in polarised light. Below: The fossilised neck bones of a *Barosaurus* being excavated at a dig in Wyoming, USA. *Barosaurus* was one of the dinosaurs with the longest necks.



Desert Dust over Europe

From Morocco to Europe: Scientists are studying the pathway and weather effects of a five-kilometre-high cloud of Saharan dust in a large-scale experiment

By Jost Heintzenberg

The impacts of desert dust from the Sahara on climate and weather extend far beyond the expanses of the African desert region. To examine the numerous consequences of the impact of the dust, scientists from the SAMUM (Saharan Mineral Dust Experiment) Research Unit have, for the first time, followed the movement of a massive, approximately five-kilometre-high plume of desert dust from Morocco to Southern and Central Europe.

The researchers were supported in their work by the European Aerosol Research Lidar Network (EARLINET), which consists of more than 20 lidar stations located throughout Europe. Lidar stands for "light detection and ranging" and is used

to measure the distance and size of atmospheric features by means of laser beams. The first EARLINET station reported a four-kilometre-high dust cloud over Barcelona on 15 May 2006. The cloud continued to move to the northeast and was measured by the Leibniz Institute for Tropospheric Research at six to seven kilometres over Leipzig on 16 May 2006. The dust cloud then turned to the south and southeast and was sighted over Central and Southern Italy on 18 May. The Sahara dust was then also detected over Greece on 20 May.

Prior to the measurements in Europe, three light radar devices began their measurements at the first SAMUM station in Ouarzazate in Southeast Morocco on 12 May. This station houses the world's only six-wavelength lidar unit and two

so-called Raman lidar devices. At the same time, a second ground station near Zagora began its work as close as possible to the dust source area. The experiment was complemented by two research aircraft, the "Falcon" and the "Partenavia".

Why invest so much research effort in a climatically and logistically difficult area in Northwest Africa? Approximately 3500 million tons of atmospheric aerosol particles are emitted annually worldwide. Half of this large quantity of fine particles is the result of desert mineral dust. At 50 percent, the largest source of dust from a single desert is the Sahara, some 10 percent of which eventually reaches Europe.

The effects of the quantities of desert dust on processes in the earth system range from influencing weather and climate to the fertilisation of tropical rainforests. SAMUM is concentrating on the topics of weather and climate, as there are important questions on the significance of the impact of the dust which are still unanswered. Moreover, Germany has many years of research experience and is able to conduct a broad range of unique measurements.

The impact of the mineral dust on incident solar radiation and the thermal emission of the earth system affects weather and climate. The reflection of solar radiation by the dust results in an energy loss for the earth system. But dust also ab-

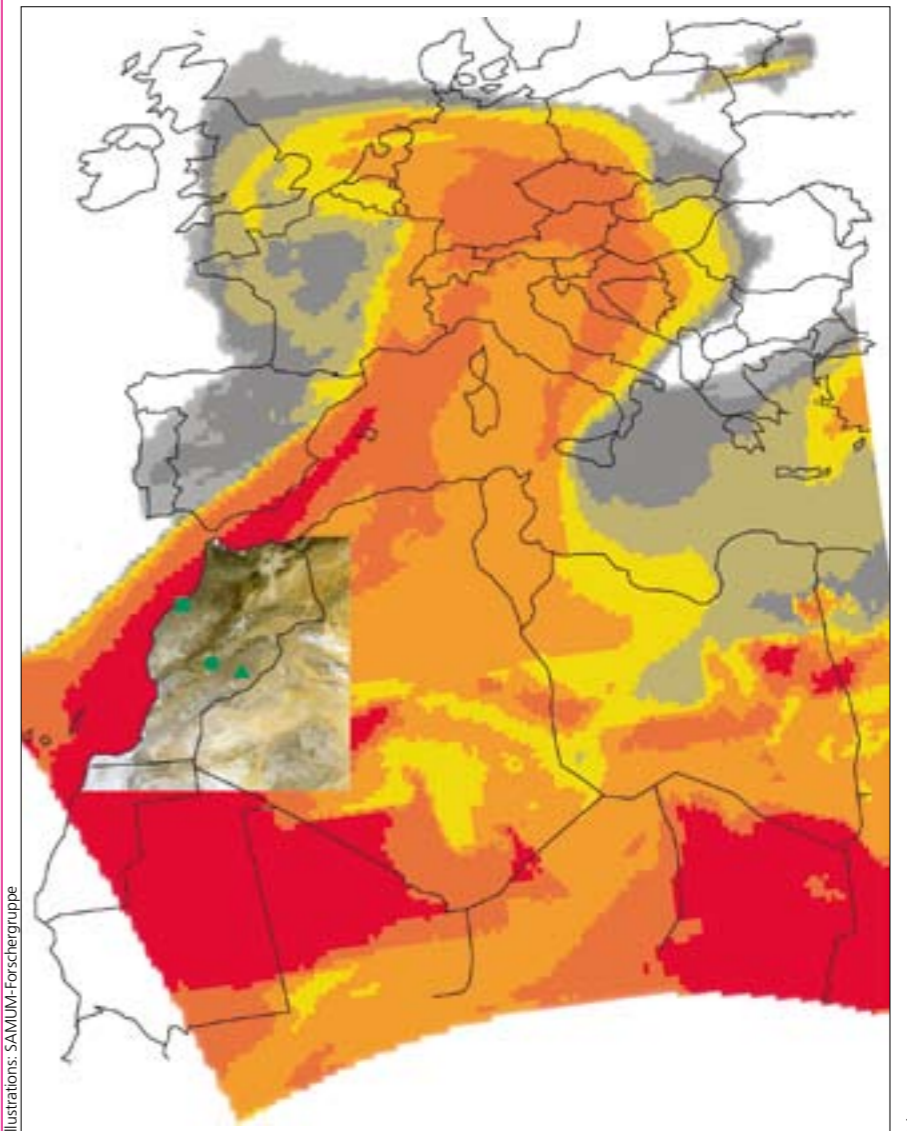
Left: Pending dust storm. Visible in the foreground is one of the SAMUM Research Unit's measurement stations in Morocco. Right: Sandstorm near Zagora. Below: Modelled dust distribution of a desert dust cloud as it advances from North Africa to Central Europe. Morocco itself and the three SAMUM measurement stations are visible in a satellite photo on a cloudless day.



sorbs solar radiation, which means an energy gain in the dust layer. The mineral dust absorbs radiative energy in the thermal spectral range as well. At the upper limit of the atmosphere, the net energy effect of the dust fluctuates around zero, though this does not mean that it can be neglected, since there are large energy losses close to the ground, which are important to the biosphere.

The overall effect of the dust is complicated by the feedback which occurs between energy balance, atmospheric dynamics and cloud processes. The energy gained through the absorption of radiation in the atmosphere influences the stability of the atmosphere and, thus, of wind movements in horizontal and vertical directions. The wind at ground level is the driving force that lifts the dust up into the air. As a result, this feedback influences the dust source. The formation of clouds and precipitation are dependent in a complex manner on the dust particles on which the cloud droplets form.

In order to determine the impact of mineral dust on the energy balance of the earth, a series of dust properties must be determined. This begins with the distribution of dust particle sizes. The particle diameters span more than three orders of magnitude, from 50 nanometres to over 50 micrometres. For this purpose, various measurement and collection processes were used at the ground station in Zagora and in the research aircraft. Following the field experiment, the researchers analysed the collected dust particles in the laboratory with spectrometers and an electron microscope. The optical material properties of the particles were also determined. The opti-



Illustrations: SAMUM-Forscherguppe

View from the "Falcon" research aircraft: Visible on the wing are two instruments used to measure dust particles. With the aid of state-of-the-art measurement techniques, numerous data associated with the moving desert dust cloud are collected both from the air and on the ground.



cal effects of the dust particles are dependent on, among other factors, the amount of water condensing on them at higher humidities, causing them to grow.

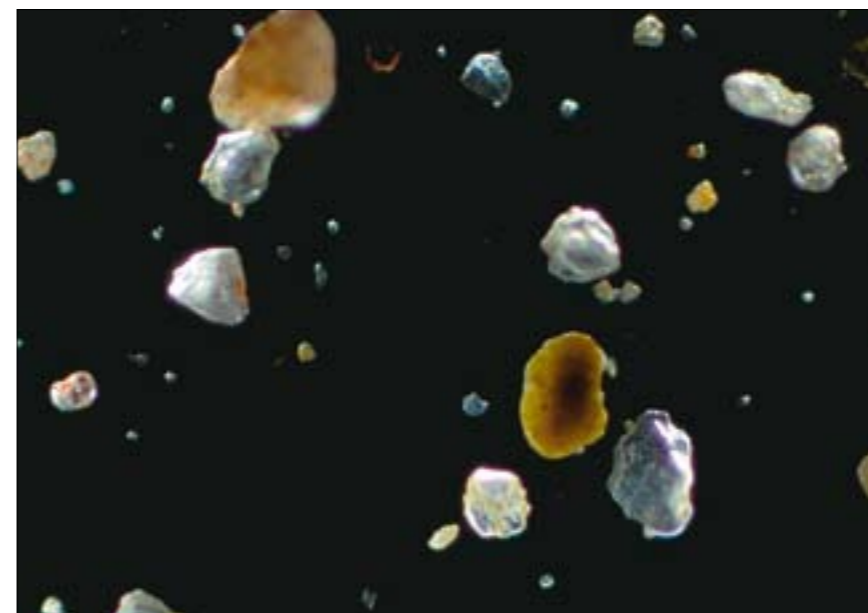
The work doesn't end with these measurements and analyses, however. The entire dust layer, which can extend from the ground to approximately four or five kilometres in altitude, was also characterised. Lidar serves as the backbone for these profile measurements. This method was able to register the spectral light reflection on dust particles. From these measurements, it was possible to deduce the height profile of particle concentrations and optical properties. Unlike cloud droplets and most smaller aerosol particles, dust particles are not spherical, but are rather irregular crystals – a factor which must be taken into account when considering their effects. Lidar was also able to supply new information on particle shape.

Although lidar devices are able to make measurements from the ground to great altitudes, they are only able to do so from a single location. For this reason, it was necessary to complement these measurements with data collected on the aircraft. With a lidar device directed downward from the "Falcon" into the dust cloud below, it was possible to measure vertical sections of dust layers along the flight path. In addition, the "Falcon" determined dust-size distributions and average radiative properties of the dust-filled atmosphere. The most important radiation measurements, however, were made with the "Partenavia", which is better suited for measurements of the lower atmosphere due to its slower speed. The "Partenavia" was able to measure spectra of incident and

reflected solar radiation at altitudes of up to three kilometres. The measured radiation profiles provide fundamental input data for computer models, which are used to calculate the energy transport in an air column above the measurement site or in an entire region. The computer models also clearly show the direct effect of the mineral dust on the energy balance.

In order to make statements on the global climatic effects, the temporally and spatially limited measurement data collected by SAMUM must be extended with satellite

data. The information content of satellite measurements is, however, limited. In a cloudless sky, satellite sensors over land primarily see the sunlight reflected on the ground. In order to precisely distinguish the small, additional amount of sunlight which is reflected by air molecules and dust particles from the surface reflection, the latter must be known with a high level of accuracy. By flying at low elevations on days with low levels of dust, the "Partenavia" was able to collect this information which is essential to the satellite meteorologists from SAMUM. On



Under the microscope: Dust particles are not spherical, but rather have an irregular, crystalline shape. Using laser beams, so-called lidar systems gather information on the distances and velocities of dust particles as well as on the various particle shapes. Below: A highly visible lidar beam in the night-time sky.



with the return of the particles to the earth's surface through sedimentation or by washing out through precipitation. The model also supports the simulation of the impact of the dust on the atmospheric radiation budget, and thus on temperature and precipitation as well as on the feedback of these effects on the dust creation processes. The dust model is driven by meteorological data which originated with the Deutscher Wetterdienst (German National Meteorological Service). With the aid of model calculations, the scientists can apply the results of the local measurements to the entire North Sahara region and calculate the impacts of the properties of the dust particles as determined by SAMUM on regional weather processes.

For 2008, the research group is planning another large-scale experiment on the Cape Verde Islands, which lie in the primary transport direction of the Sahara dust cloud off of the coast of West Africa. There, the researchers plan to examine the ageing and climatic effects of the dust as it travels long distances towards South America and the Caribbean. During the dry period in the West African winter, large quantities of soot and other aerosol materials mix with the mineral dust. As a result, the optical properties of the dust cloud and the associated climatic effects are influenced in a way which has not been explained up to now – the SAMUM Research Unit plans to examine this phenomenon.

three measurement days, the "Falcon" and "Partenavia" were able to fly directly one over the other as well as position themselves under a NASA satellite – over both of the ground measurement stations. Timing came down to a matter of minutes. The orbiting satellite crossed the SAMUM experiment area three times. It traversed the SAMUM area in just ten minutes. Thus, it was critical that the aircraft be precisely coordinated. Fortune smiled on the brave during the three flights: There wasn't a cloud in sight. As a result, the satellite was able to collect truly

unique data which will be of great importance in examining the significance of satellite measurements worldwide.

For the SAMUM dust experiment, a computer model was further developed which describes the temporal development of the regional dust distribution. This dust simulation programme calculates the "lifetime" of the dust particles in the atmosphere, beginning with the lifting of the mineral dust by the wind in the source area, continuing with the atmospheric transport by prevailing wind systems and concluding

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► www.tropos.de/samum

Moving Like Worms: Without "Legs"

A copycat of nature: The use of magnetic fluids opens up innovative, entirely new high-tech ways of creating an artificial worm. Worm-like motion systems can be both useful and inspirational in a wide variety of technical applications

By Klaus Zimmermann

Locomotion has always exuded immense fascination. Matching nature's feats of efficiency, flexibility and speed, for example the flight of the hummingbird, the speed and agility of the cheetah running, or the graceful swimming of the dolphin, has posed a challenge to engineers for centuries. Flight, in particular, is a form of locomotion which allows mankind to learn a lot from nature. Yet it is not the propulsion and lift generated by birds using their muscles that is copied in aircraft, but rather the secret of how lift is created using the shape of the wing that led to the successfully construction of artificial wings, which has enabled mankind to build so many different kinds of flying machines. Even now, mankind strives to develop ever-faster means of locomotion, albeit sometimes at immense energetic expense, to better nature's leading position in this field.

Planes, trains and automobiles have long allowed us to travel at high speed, yet "walking" motion and humanoid robots still constitute a major area of research when it comes to robotics inspired by nature. Alongside walking machines, the concept of "legless" motion, as demonstrated by snakes and worms, is receiving increasing interest amongst researchers, who hope that worm-like systems will prove an efficient form of locomotion in applications such as the inspection of pipes and sewers or for rescuing people buried by earthquakes. Applications in medical technology are also en-



visaged, for example for diagnostic systems or for minimally invasive surgery. Robots with legs or even wheels are particularly hard to imagine for use within the human vascular systems. Such applications make new demands on the systems' size, drive mechanisms and operating principles. One of the key criteria is that such robots need to work as autonomously as possible. In order to work efficiently in pipelines or areas that have been hit by an earthquake, the communication and power supply both need to be wireless.

The use of magnetic fluids, also known as ferrofluids, whose properties and flow characteristics can be controlled using magnetic fields, present a new solution to this problem. Researchers at the Faculty of Mechanical Engineering at the Technical University of Ilmenau are cooperating with partners from Russia to study wave motion. Such undulatory motion enables locomotion through interaction with the environment. Ferrofluids are suspensions of ferromagnetic particles typically about ten nanometres in diameter in a carrier fluid. Commercial ferrofluids contain magnetite (Fe_3O_4) particles suspended in carrier fluids such as water, kerosene or oil. For practical purposes it is important to be able to manipulate and steer the flow of ferrofluids using moderate magnetic fields. So far, such fluids have been used for a variety of applications including damping and sealing, in coupling systems and for magnetically induced hyperthermia for fighting cancer.

So what role do ferrofluids play in artificial worms? Theoretical and experimental studies have shown that the peristaltic motion (contraction and extension) of a viscous fluid brought about by a wave on the material interface sets up a flow in that liquid. This causes mass transport, a principle which is fundamental to the digestive system, but is also exploited in peristaltic pumps, for example. The challenge for the mechanical worm is to create such waveform surface deformation using ferrofluids in a magnetic field.

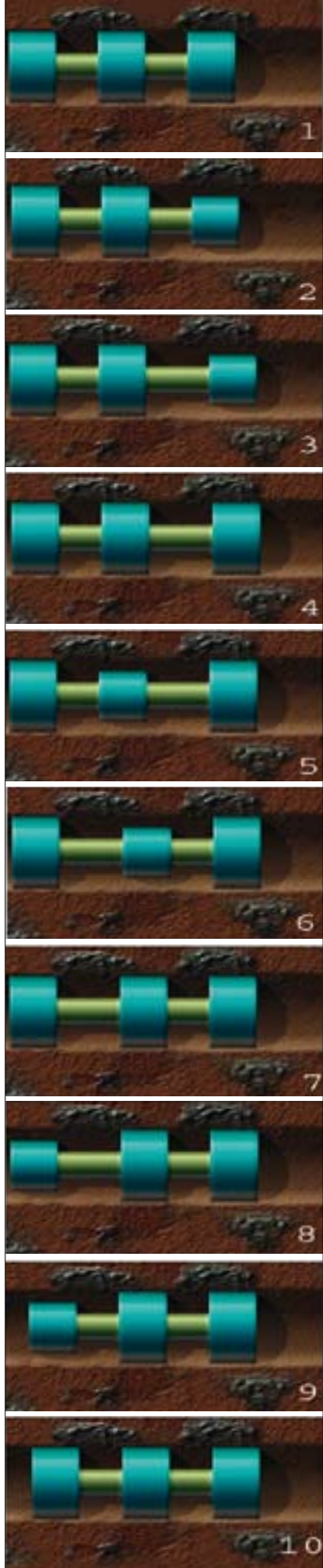
To accomplish this, a fluctuating magnetic field is used to create a travelling wave on the surface of a layer of ferrofluid. The field strength depends on a number of the fluid's properties. From a technical point of view, the ferrofluid needs to be encapsulated in an extremely thin membrane in order to prevent the membrane from reducing the waveform deformation of the surface and the transferable forces too much. The first applications are therefore based on the use of magnetic elastomers, which are plastics that are solid, but are

elastically deformable. One example is a worm made up of segments that can move along a tube using the well-known and much-used 'inchworm' principle (to put

Facing page: The fascination of motion: The development of a Formula 1 racing car demands a high degree of engineering expertise. For basic researchers, studying the methods of motion used in nature, such as that of the cheetah shown below, is becoming increasingly important. This has led to legless motion, like that seen in snakes or worms, attracting the interest of researchers.



Illustrations (3): Superbild



it simply: "long & thin and short & fat").

Employing the principle of concertina locomotion (the method of locomotion used by snakes) the magnetic elastomer moves when it is driven by a magnetic field. Examples such as this demonstrate that recognising and understanding nature's mechanisms for generating motion, force or transmission can inspire the development of technically feasible locomotion systems. If we don't want to stop at simply copying nature and building 'Heath Robinson' solutions, it is essential to build mathematical models and simulate selected biological systems of locomotion, modelled at various levels. Recent developments in microsystems technology and new materials and production technolo-

gies make it possible to turn new ideas into reality, particularly at the micro- and nanoscale. At a macroscopic scale, the biggest challenge scientists face is the need to save materials and energy in connection with transportation applications. Locomotion in the nanoscopic or the macroscopic world, as a slow worm or as a high-speed wide-bodied aircraft, based on a biological role model or using unnatural wheels, will remain an exciting field of research in the future, and is already a route to success.

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Illustrations (4): Zimmermann

Portrait

"There Are Two Hearts Beating in My Chest"

Torsten Doenst, a heart surgeon from Leipzig, combines his clinical work with pioneering basic research

The two worlds in which he moves couldn't be closer to each other. From Professor Torsten Doenst's charge office on the first floor of the Leipzig Heart Centre it is just a few steps to the laboratories in the cellar where his research group works. The 38 year old senior doctor, who was recently appointed as a Heisenberg professor by the DFG, combines his clinical work of being a heart surgeon with that of being a medical researcher – a combination which is as remarkable as it is unusual. As a heart surgeon Doenst operates on heart patients almost every day, and as a researcher he studies cardiac metabolism. Doenst and his group of nine are tracking down a possible abnormal regulation of the energy metabolism in the heart muscle, which may result in the heart pumping too weakly, a condition known as cardiac insufficiency. This is a matter of top priority, given that cardiac insufficiency is one of the most common causes of death in the West. Experimentally, and using the latest methods in their state-of-the-art cardiac metabolism lab, the researchers are attempting to analyse the molecular fundamentals and the causes for the suspected abnormal regulation in mice. "If the findings to date are confirmed," the tall cardiologist emphasises, "we could, in the long term, be able to develop new therapeutic and preventative methods for cardiac insufficiency." But there's still a long way to go.

Doenst started studying human medicine in Göttingen in 1988. An early decision with far-reaching consequences led to him spending a year at the famous lab run by the cardiologist and cardiac metabolism specialist professor Heinrich

Taegtmeier at the University of Texas – Houston Medical School from 1992 until '93. I had a flash of inspiration there and it became clear to me that I wanted to con-



Composite picture: Unterstell/Andreas Stein

tinue doing research," Doenst recalls. An exceptional dedication to science also made its mark on his thesis in biochemistry on the topic of cardiac muscle mitochondria.

After obtaining his doctorate in Göttingen in 1996 the young medic commenced his clinical training at the University Hospital of Freiburg. Once he had completed his time as an intern he finally qualified as a consultant cardiologist in 2003. Simultaneously, Doenst also pursued his scientific ambitions. A two-year research project took him back to the University of Texas – Houston Medical School as a postdoc and DFG research fellow. On his return to Freiburg he initially led an Emmy Noether independent junior research group from 2000 on-

wards. Together with the research group he had built up he studied the "protective effect of insulin in patients with ischaemic heart disease". "These studies revealed," Doenst explains, "the direct effect that insulin has on the energy consumption and performance of the diseased heart."

In 2004 Doenst then qualified as a university lecturer. It was at that time that he also assumed the position of a senior doctor in the Cardiology department in Freiburg. Previously he was able to broaden his experience – in particular in the field of heart valve surgery – at the University of Toronto. His most recent appointment to date was when he moved to the Heart Centre Leipzig in the autumn of 2006, where he was one of the first Heisenberg (research) professors appointed in Germany. This makes him one of the most outstanding researchers eligible for appointment as a professor, whom the Heisenberg Professorship – created by the DFG in 2006 – is designed to prepare for leading positions in science, while at the same time pursuing advanced research.

"I see the Heisenberg Professorship not so much as a distinction, but as an obligation," says Doenst. And he emphasises the freedoms this appointment gives him to pursue his work. Even though the time pressures resulting from combining clinical medicine with research are by no means to be underestimated, Doenst is convinced that the two are complementary. "Being able to research the problems I see on a daily basis on the operating table", Doenst underlines, "is just as challenging as it is important to me."

Rembert Unterstell

The Deutsche Forschungsgemeinschaft

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

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

Collaborative Research Centres are long-term university research centres in which scientists and academics pursue ambitious joint interdisciplinary research undertakings. They are generally established for a period of twelve years. In addition to the classic Collaborative Research Centres, which are concentrated at one location and open to all subject areas, the DFG also offers several programme variations. *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 con-



Illustration: Querbach

centrate 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*.

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

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

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

The legal status of the DFG is that of 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.

Impressum

german research is published by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation); Publisher: WILEY-VCH Verlag GmbH & Co. KGaA, P.O. Box 101161, D-69541 Weinheim; Annual subscription price: €55.00 (Europe), US \$ 59.00 (all other countries) including postage and handling charges. Prices are exclusive of VAT and subject to change. Address of editorial staff: DFG, Press and Public Relations Division, Kennedyallee 40, 53175 Bonn; postmaster@dfg.de; www.dfg.de

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

ISSN 0172-1518



Illustration: Hüskens

The "old world" of Europe meets the "new world": In 2007, the year of the humanities, the DFG took its exhibition "Tracing A Common Past: European History Between the Meuse and Rhine" to the USA. Visitors to the Goethe Institute in Washington were invited to go on a journey through time and space to see prominent highlights of western culture and history.