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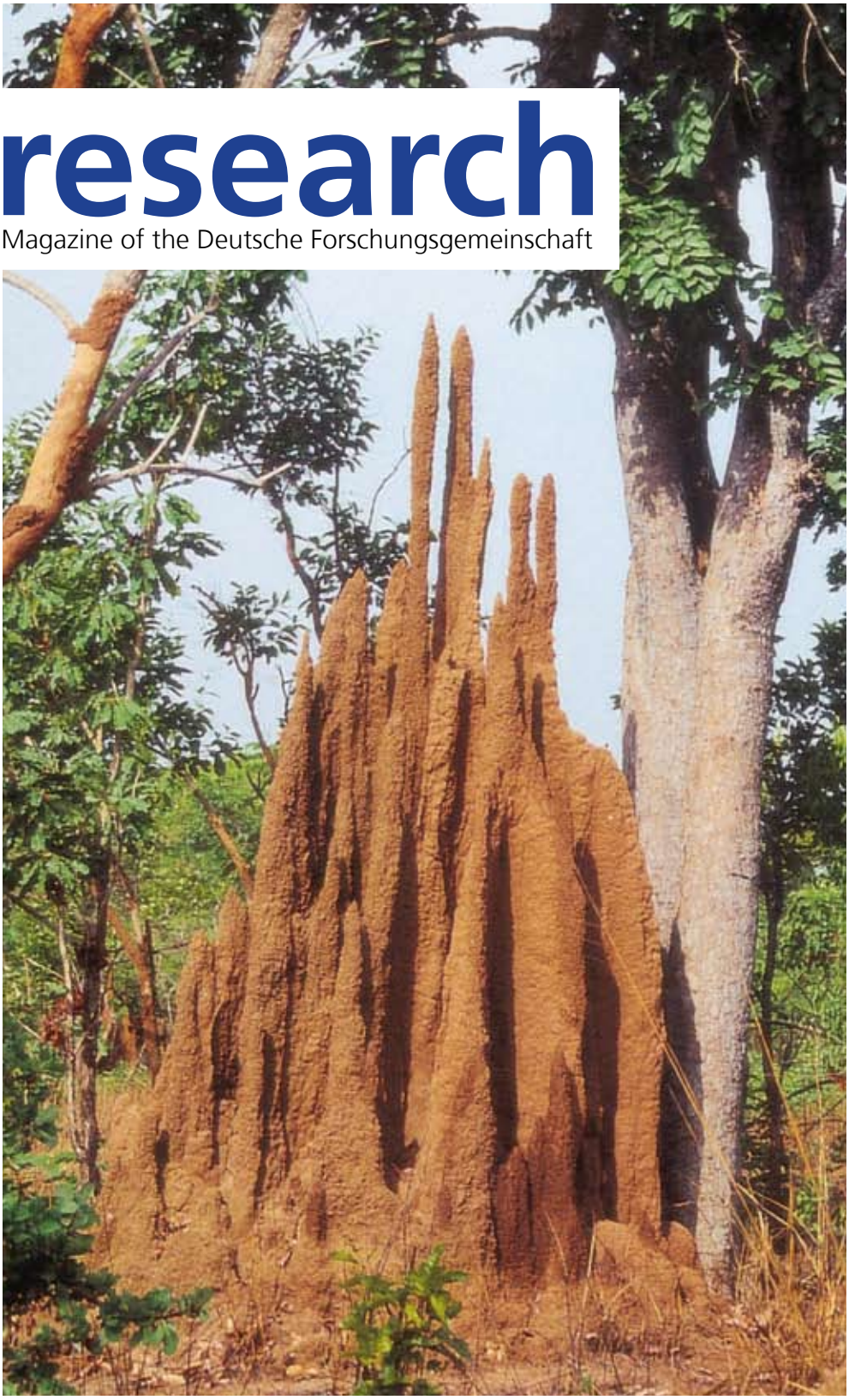

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► "Careers" in the Termite Colony ► Once Upon a Time on the Incense Road ► Diving Expedition to a Methuselah of the Sea ► The Fight against Malaria ► Adolar, Eoban and the History of a Cathedral

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At a Cultural Intersection

Tayma was one of the most famous Arabian oases of ancient times. Now, archaeologists are unearthing the settlement of Tayma. The digs that have been conducted so far, and the finds that have shed light on the settlement's history, reveal that the oasis developed at a remarkable intersection between various cultures. **Page 4**

On a "Dinosaur" of the Oceans

The coelacanth is an ancient sea dweller that has been around for at least 400 million years. Researchers are studying the various populations of coelacanths in the world's oceans and gaining new insights into the life of these nocturnal creatures that live deep in a hidden realm. **Page 14**

Reconstructing an Architectural Ensemble

In the Middle Ages Erfurt Cathedral developed into a major place of pilgrimage. Now, architectural historians are tracking down the traces of the past using state-of-the-art technology, and are uncovering a new and multi-facetted picture of the complex architectural history of this monument. **Page 29**

Cover: Korb

Fascinating Co-Existence

The cathedral-like mound, almost five metres in height, of a colony of termites in West Africa that grows fungi. Research has revealed how community life amongst termites follows certain rules.

Matthias Kleiner

Strengthening the Dynamics of Research in Europe

The internationalisation of research funding programmes relies on binding standards and transparent processes

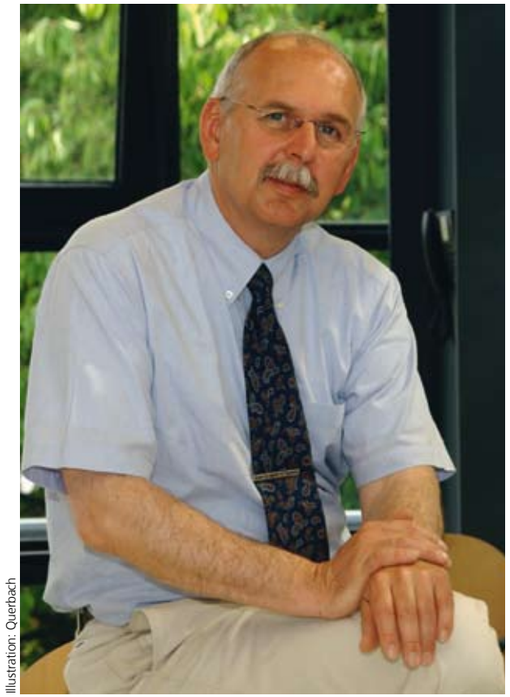

Illustration: Querbach

Europe is a world-ranking part of the global scientific landscape. When it comes to research and development, Europe is on a level playing field with the major regions of science and innovation in North America and Asia. At the same time, Europe is made up of national research areas that compete against each other, as well as globally, to attract the best minds and produce the best research findings. Research activity spans national borders and helps to break down the remaining boundaries to European integration. The increasing cooperation between researchers and scientists is an essential step on the road towards a Europe with a common European identity.

Europe's unique selling point when it comes to strong science and the capacity to innovate is rooted in the great variety of its research landscapes. Exploitation of the various systems with their differing approaches is still hampered, at present, by a lack of consistent conditions for everyone involved in research and teaching as well as by a dearth of common standards. Eligibility requirements and conditions for participation in the competition for resources and funding still vary significantly in some cases. These demarcation lines, regarded by the scientific community as artificial, restrict mobility and constrain the dynamics of innovation. To overcome this fragmentation, Europe is currently undergoing a restructuring process aimed at creating a unified European Research Area. Not only did the European heads of state and government commit themselves in 2002 to investing three percent of GDP in research and development until 2010, in order to close the gap between Europe and the USA. They also agreed to abolish the existing incompatibilities between national, transnational and supranational research programmes, and to bundle resources. One of the slogans of this process is the "Europeanisation of Research Programmes". This can only be effective if it serves the creation of knowledge and the promotion of innovation. In view of the complexity of science, the Europeanisation of funding programmes needs to address the specific needs of research and the requirements of scientists on a case-by-case basis. Achieving optimum distribution of resources across national boundaries and systems will be pivotal to the success of this endeavour.

The Europeanisation of funding programmes also needs to ensure the transparency of processes in the interests of maintaining the quality of research. This assumes the application of common standards to the peer review and funding system. Standards create a platform for competition and scientific excellence in a unified European Research Area and permit international comparison between competing research funding systems by measuring consistent performance indicators.

The European Commission deals with the need for common funding systems and standards in its Green Paper "The European Research Area: New Perspectives", published in April 2007. The Deutsche Forschungsgemeinschaft (DFG, German Research Foundation), as part of a European task force consisting of the European Heads of Research Councils (EUROHORCs) and the European Science Foundation (ESF), plans to comment on the Green Paper from the perspective of the national research and funding organisations in Europe. These organisations perceive a need to evaluate their own structures and processes, as well as those at the supranational level, to assess their future competitiveness, and hope to optimise these. This will enable them to participate in setting the course towards the Eighth Framework Programme, in order to achieve a sensible and effective balance of work between the national and supranational (European) funding agencies.

One current example of such a supranational funding agency is the European Research Council (ERC), which the DFG has lent its support to since its very inception. The principles of the ERC that were aspired to and have now been attained were, and remain, both a precondition for and a result of this support: excellence as the sole funding criterion as well as an independent and transparent peer review process.

The DFG sees the ERC as a partner organisation within Europe whose institutionalisation will act as a test case for the establishment of common standards in parallel to the intensification of competition in the area of pioneering and basic research. At the beginning of its operative phase the ERC has found itself confronted with over 9,000 proposals just for the first call for the newly introduced "Starting Independent Researcher Grants (SIRG)" scheme. This simultaneously represents a great success and a great challenge. The response from the scientific community indicates strong demand for funding opportunities in Europe. It is anticipated that the ERC Advanced Grants, intended to support projects that are initiated and led by established top researchers, the first call for which will be announced at the end of 2007, will confirm the continued interest amongst the scientific community. The challenge the ERC faces, in particular, is to meet the high expectations that the scientific community and the national funding organisations have of a European funding programme that is committed to excellence, which is efficient enough to be manageable. The challenge for the DFG and its European partner organisations is to support the ERC on the course it has set out on and to simultaneously face the intensified competition that this will bring with it. As their own programmes increasingly open up and their processes become more transparent, it will, in the end, be the funding bodies with the best reviewers, the most respected peer review processes, effective management structures and the lowest administration costs that will prevail. In a free market for research funding the scientists and researchers themselves will decide, through their funding proposals, which funding instrument best meets their need for unbureaucratic processes and high quality standards.

All in all, I see the European Research Area as having three main levels: the national agencies, the multilateral institutions consisting of the national agencies, such as the ESF, and the so-called supranational institutions, funded by the European Commission, such as the ERC. The European Research Area needs to utilise each of their particular strengths. Some, such as the DFG, have a very intimate knowledge of their own national scientific communities. Others, such as the ESF, are in a position to organise complex international processes and peer review systems at a high level. While others, such as the ERC, have the institutional flexibility to launch Europe- or world-wide calls for proposals, without the restriction of needing to take national quotas into account. Bundling these strengths in such a way that these levels can work in a complementary way, while remaining in constructive competition to each other, needs to be the common objective of everyone involved in this process in Europe. By the end we may then have a European Research Area where the scientists and researchers are no longer competing for financial resources from a specific funding agency, but rather for "funding rights", which could then be exchanged for research funds in the country of their choice – a kind of "European Research Grant Union", where the management would be divided amongst the various participants according to their abilities. Admittedly, that is a long way off, but the DFG is ready to face this challenge and encourage the competition towards this goal.

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

Once Upon a Time on the Incense Road

Tayma was one of the most important palm oases of Arabia, at which camel caravans rested and traded their goods. Archaeological excavations in the ancient settlement and new finds demonstrate that the oasis developed at a unique junction of ancient cultures

Illustrations: Hausleiter (pp. 4-5, 6-7 b.r.) / Cusin (pp. 6-7 a., c. and b.l.)

By Ricardo Eichmann, Arnulf Hausleiter and Thomas Götzelt

From an archaeological point of view, the north-western region of the Arabic Peninsula has until now remained one of the undiscovered territories of the Middle East. Nevertheless, it is widely known that one of the most important trade routes of the ancient world, the "Incense Road", traversed this region between southern Arabia and the Levant. On their way to the Mediterranean coast, the camel caravans made use of the Arabian palm oases – as places of rest and of trade. Tayma was one of the most important of these oases. It is found at an intersection of cultures, eloquent witness to which is given by archaeological finds and ancient inscriptions.

From the perspective of the ancient Near East, Tayma appeared in the Assyrian records no later than the 8th century BC, when these were trading with Arabs. Almost two centuries later, the last King of Babylon, Nabonidus (556–539 BC) took his residence in Tayma. When he had reached the city he not only killed their king and slaughtered the people's livestock, he also enlarged the city and built a palace, according to a contemporary propagandistic account against this king. It is true, this ruler in his records declares to have had a religious-political incentive for his grab at north-western Arabia, but Nabonidus also had an economic interest in the prosperous incense trade, which prompted him to conquer several cities, in order to control the exchange of goods from key locations.

Satellite images demonstrate that the location of the oasis is determined by the natural conditions: Tayma lies in a flat basin between the eastern foothills of the Hejaz mountain range in the west and the great Nafud desert in the east. Upstream from the settlement is a lake with an area of several square kilometres, which has become a dry salt pan (Arabic: sebkha). Water only gathers there after the extremely rare occurrences of rainfall. In modern-day Tayma, the quality and availability of the essential resource of water are highly variable. Nowadays, the ground water is found at up to 1.5 metres below the surface in some places, while elsewhere, it is hidden at a depth of 40 metres. Once extracted with diesel pumps, this water is used primarily for the artificial watering of gardens in the dry climate. Drinking water, however, is won from fossil water sources, which are found several hundred metres under the surface. There is a limited supply of this water as it is not involved in the cycle of rainfall and evaporation.

Today, the Tayma oasis is bristling with an estimated 80,000 date palms. The crop is thereby more than four times the size it was 50 years ago. Ancient textual sources, which can now be supplemented with archaeological and botanical findings, testify to the millennia-old significance of this crop in Tayma. The cultivation of suitable arable land presupposes the presence of a settled population that practices agriculture. It is one of the research goals of the German-Saudi-Arabian cooperative project to establish when this process began. In course of this project the settlement history of the site and its area from the Neolithic period to Islamisation are being studied.

The numerous petroglyphs, or rock carvings, from the region around Tayma provide information about the ancient population of north-western Arabia. Up to now, the images of men and animals have been dated to the end of the Neolithic, although there is as yet no completely reliable method of dating these stone carvings. It can be assumed that livestock-breeding nomads had reached the Tayma oasis by the third millennium BC,

① The head of an over life-size royal statue, ca. 4th century BC. ② Today, the palm oasis reaches from Tayma to the "sebkha", a dried-up salt pan. ③ Excavations in a massive stone building. ④ Coloured painted pottery shards depicting birds and geometrical patterns. ⑤ An ancient stone relief showing a bull. ⑥ The city of Tayma, which was expanded many times, was surrounded by fortification walls. Inside these walls were stairs and open battlements.

presumably to take advantage of the water supply that provided a guarantee of subsistence.

During which period of the Bronze Age the settlement at Tayma reached urban character can not yet be accurately stated. In Mesopotamia and its neighbouring regions, the process of urbanisation took its rise from the end of the fourth millennium BC. In Tayma during the second millennium BC, a perimeter wall with a height of up to ten metres was built using mud bricks and sandstone. It delimited an area of at least twenty hectares and created the means of survival for its occupants: the extended palm oasis. The wall system was extended during the following centuries to a length of over 15 kilometres. The Arabic historian al-Bakri could still be impressed by the size of the fortifications, which he mentioned in the 11th century.

Evidence of the earliest settlement discovered so far at Tayma was found directly at the outer-wall and in graves within this wall. Coloured painted pottery and wood and ivory findings decorated with incised ornaments point to the Late Bronze Age (at the end of the second millennium BC), a period characterised by intensive trade and interchange in the eastern Mediterranean region and the Near East. The findings suggest that Tayma may have been part of this trade network. At this time the outer-wall must have already been standing for a few centuries, because the buried settlement remains are found on top of these sand deposits.

The populated part of the city must have shifted towards the centre during the first millennium, as an inner wall with towers was built at a distance of approximately 100 metres from the original system. This concentration may have been in response to increasing conflict with the regional powers. Among the significant competitors faced by Tayma was the Kingdom of Lihyan, with the oasis of Dedan (ancient Dadanu), about 150 kilometres south-west from Tayma.

In the centre of the settlement, the occupation deposits are found at a height of six metres on an elevated part of the natural sandstone formation. By means of a layer-based (stratigraphic) analysis of the building remains and the deposits found in and around them, it was possible to identify five architectural layers that covered a period of at least eight hundred years from the middle of the first millennium BC onwards. This Iron Age settlement is characterised by stone buildings, which were adapted to different requirements by numerous structural modifications. Alongside a large, representative building with an area of about 500 square metres and a columned hall, there are some noteworthy smaller and medium-sized domestic dwellings, in which food preparation and handcraft also took place. The various chronological stages can be discerned with the help of the pottery and other findings.

Moreover, evidence for the use of the large structure as a temple was provided by the many objects found in and around the building. Buried in its fill was the head of an over life-size sandstone statue, which was monolithic and measured almost three metres in height. Comparable pieces are known from excavations made by the King Saud University in Dedan. At least two of these statues have been found in Tayma; the second figure is housed in the local museum.

A semi-circular stele, with a representation of a standing royal figure and some astral symbols, has been recovered from the rubble of the building. The iconography corresponds to representations of King Nabonidus on other monuments, and the fragmentary cuneiform script on the stele also points to this king, even if his name has not been preserved. This stele therefore provides further evidence for the presence of the Babylonian king in Tayma. In addition to this first evidence of cuneiform script in Tayma, if not all of Saudi Arabia, further stone fragments have since been found bearing Late Babylonian cuneiform inscriptions.

Illustration: Cusin

The settlement of Tayma during a sandstorm. Wind and sand particles contribute in many places to the erosion of archaeological remains. Large accumulations of sand covering archaeological deposits are frequent and present a significant challenge to researchers.

Illustration: Cusin

Any excavation requires team-work: A representative stone building of ancient Tayma, with an area of about 500 square metres, is gradually excavated and examined. It is probably a temple. In the background can be seen the modern city and oasis of Tayma.

Up to now, it has not been possible, on the basis of historical sources, to judge the extent to which the Achaemenids, as the followers of the Babylonians, actually controlled Tayma. At the end of the first millennium BC, north-western Arabia came under the influence of the Nabataeans. Although no evidence has so far been found in Tayma of the distinctive pottery of the Nabataeans, some inscriptions and several building elements, which are comparable to findings in Petra and the metropolis of Mada'in Salih (near to Dedan), indicate that the links between Tayma and the Nabataeans were stronger than has previously been thought.

> Archaeological research will both encourage and enable a deeper understanding of the Arabian Peninsula.

Quite apart from the ancient Near Eastern part of its history, Tayma was of great significance for the spread of Islam. The analysis of early Islamic remains in the urban area show clearly that not all areas inside the walls were densely populated. The central area with buildings from the first millennium BC was already in ruins when small homesteads were being built around the perimeter. Future excavations of pre-Islamic settlement remains will therefore attempt to prove the as yet hypothetical assumption of a horizontal relocation of the settlement.

By modelling surfaces of ancient settlements and surrounding areas it is possible to demonstrate not only continuity and change; new questions also arise from the combination of archaeological finds, scientific data and the analysis of geo-archives. The networking of research in Tayma with projects run by the German Archaeological Institute and with the activities of international research institutions in Middle Eastern countries will contribute to a better understanding of the outstanding significance that the Arabian Peninsula holds for neighbouring civilisations as a natural and cultural landscape.

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▶ www.dainst.org/index_32 58_de.html

An Alternative Evolutionary Biology

The modern view of biology was first proposed by Charles Darwin in the mid-19th century. However, there have also been numerous proponents of non-Darwinian theories of evolution, who attempted to explain the order of life differently

By Kay Meister, Georgy S. Levit, Uwe Hoßfeld and Olaf Breidbach

When the naturalist Charles Darwin left England aboard the "Beagle" in 1831 he could not have anticipated the groundbreaking idea his five-year voyage around the world would plant in his mind. It was in 1859 that he eventually published his findings in his now famous book "The origin of species by means of natural selection or the preservation of favoured races in the struggle for life". Darwin's research marked the beginning of a new way of perceiving the natural world and simultaneously marked the birth of a new way of thinking in evolutionary biology. To Darwin, the order of life could be seen as the result of a chronological process, progressing gradually by means of random phenotypic changes and directed by natural selection. This evolutionary concept formed the basis for a number of different natural and social sciences. The theory of evolution is thus a cornerstone used to justify our scientific view of the world.

Before 1900, however, there was a problem in that, although Darwin could describe the history of life, he could not explain it in ultimate terms. One of his contemporaries, Gregor Mendel (1822–1884), a monk at the monastery at Brno (in what is now the Czech Republic), had already discovered the principles of inheritance that were to form the foundation for modern genetics, but his work lay neglected in the archives and was ignored for decades. But without genetics, it was impossible to understand the mechanism of evolution. This was one of the crucial impulses behind the initial search for alternatives. The resistance to the Darwinism in German countries was especially strong, well articulated and influential.

Illustration: Haeckel-Haus

Cover of the book entitled "Tiere der Urwelt" (Prehistoric Animals), published around 1900. The author, writer and publicist Wilhelm Bölsche, who is also known as the creator of the modern textbook, popularised the knowledge of his age and was a proponent of the evolutionary ideas of Charles Darwin and Ernst Haeckel.

Around 1900, an increasing number of alternative theories rejecting Darwinian principles began to emerge. These approaches may be described as "alternative theories of evolution", which were seen as irreconcilable with Darwinian principles by his followers of the day, and were therefore interpreted as being competing theories. In modern biology the moniker "non-Darwinian" is often taken to be a synonym for "non-scientific". The history of non-Darwinian (alternative) theories was therefore neglected for a long time, although several of these theories played an important role in the development of modern evolutionary biology, and their influence can be traced right up to the present day. The DFG Research Unit at the Ernst Haeckel House in Jena worked on piecing together the history of these

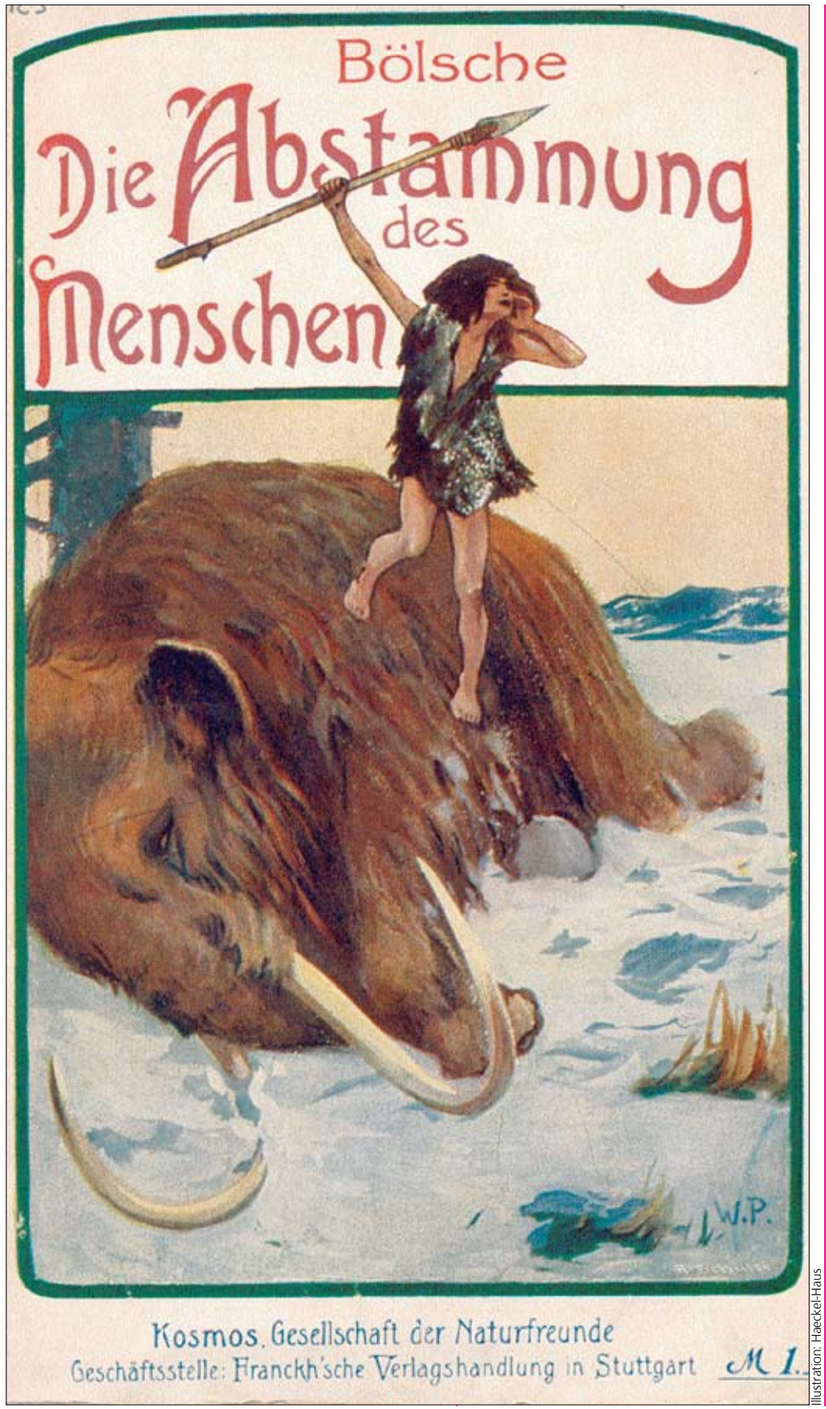

Illustration: Haeckel-Haus

The book "Abstammungsgeschichte" (The History of Descent) by Wilhelm Bölsche was published in 1904. Articles on evolutionary theory, whether Darwinian or non-Darwinian, attracted large numbers of readers, since they dealt with the fundamental questions of life and the development of life.

theories. In so doing, it continues the development of evolutionary biology beyond the age of its discoverers and first proponents, and past the turn of the 20th century, thus broadening its perspective. One alternative theory of evolution was the paradigm proposed by the French naturalist Jean-Baptiste de Lamarck (1744–1829), which became established as Lamarckism in the history of evolutionary biology. Lamarckism was based on the idea of the inheritance of acquired characteristics. Having studied Lamarckian inheritance, the Viennese biologist Paul Kammerer (1880–1928) attempted to draw attention to this theory with numerous spectacular experiments. His research concentrated on amphibians such as the Midwife Toad. His experiments attempted to stimulate changes in offspring by breeding them in environments that were contrary to their natural habitats. To adapt to the artificial habitat, the creatures had to change not only their appearance, but also their behaviour. In order for a behavioural change to be passed on as a new characteristic in subsequent generations of toads it needed to be inherited by the offspring. Kammerer claimed to be able to demonstrate precisely such inheritance of acquired characteristics.

A peculiar, ideologically motivated form of Lamarckian evolution was developed in the 20th century by the Soviet agronomist Trofim D. Lyssenko (1898–1976) and was also exported to the GDR as "Creative Darwinism". Lyssenko claimed to be able to control the development of plants and thus to be able to revolutionise Soviet farming. He made organisms – most notably wheat – inherit "learned" adaptations. To him, there were no genes. In addition to these striking examples, a great many biologists were involved in meticulous

and painstaking work studying the idea of heritable reactions to the environment by organisms.

Other approaches cast doubt on the idea that evolution had progressed gradually in tiny or infinitesimal steps. An example of such an approach was the theory of mutationism. Proponents of mutationism, including, for instance, the botanist Hugo de Vries (1848–1935), assumed that sudden jumps, or discontinuities, in development occurred, brought about by genetic mutation. This theory denies the importance of natural selection proposed by Darwin. No longer is adaptation and selection used to explain evolution, but rather random events on a genetic level. Another example of the mutation theory of evolution is the concept of "Hopeful Monsters" put forward by the geneticist Richard Goldschmidt (1878–1958). The idea of monsters lives on to the present day, particularly in fantasy stories. A mutation is responsible for bringing about an entirely new inheritable feature. According to Goldschmidt, this is how the different species developed over and over again. Evolution thus progressed through discontinuous variations. The theory known as saltationism also emphasised sudden changes from one generation to the next as a means of evolution. Palaeontologists such as Otto H. Schindewolf (1896–1971) thus postulated the explosion-like appearance of new types of organisms bringing into being new orders or even classes.

The proponents of idealistic morphology even went one step further in interpreting the nature of "types". For example, the botanist Wilhelm Troll (1897–1978) developed the concept of "proto-plant", although he described this not as the primordial root of all plants, but as a kind of registry of characteristic features, which contained every possible combination of forms. It would then be possible to order the wide variety of plants that exist now using this catalogue as a kind of dictionary. The individual nature of any given plant was, for him, a variation on a theme, just like the doctrine of ideas in Plato's philosophy. Tracing this variation back would, he proposed, make it possible to reconstruct the order of the living world. The order that came about by this method would not, however, have anything to do with the lineage of the plant. Comparative and phylogenetic studies were two entirely different things according to this theory.

The undirected nature of all evolutionary change was firmly rejected by creationist theories. Creationism works on the assumption that the biodiversity we see today was not brought about by natural causes, but by the intervention of supernatural forces. One early and influential proponent of the creationist theory of evolution was the ornithologist and priest from Wittenberg, Otto Kleinschmidt (1870–1954). His theory developed a structured system of separate lines of development, each with their own periods of emergence. Since there can be no common point of origin according to this view, there are no shared reproductive communities to act as points of origin for new species.

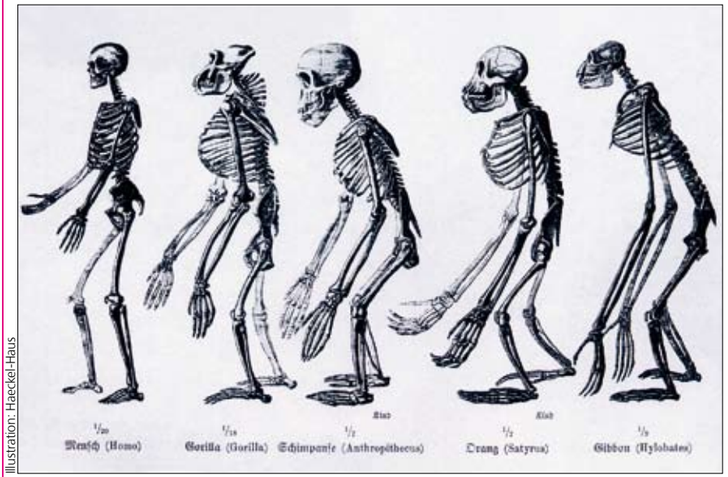

Illustration: Haeckel-Haus

Towards an upright gait – skeletal development in primates from the gibbon (right) to modern man (left). This poster is taken from the study "Der Kampf um den Entwicklungsgedanken" (The Battle for the Concept of Development), published by Ernst Haeckel in 1905, in which Haeckel not only pleaded in favour of Darwin's theory of evolution, but also dealt with non-Darwinian approaches.

Alternative theories of evolution have played a significant role in the history of evolutionary biology in almost every discipline in the 20th century. As the doubts about Darwinism delayed the uniting of genetics with descriptive evolutionary biology in Germany until the late 1930s, other approaches had time to develop during the early part of the century and continued to exert an influence on evolutionary theory even beyond the 1930s – at least when it came to detailed methodological questions. Traces of alternative approaches can also be found in modern times; for example, the methodology developed in early idealistic morphology can be detected in modern molecular genetics. The neo-Darwinian synthesis, which was established in the mid-20th century, did not amount to an all-encompassing new methodology for evolutionary biology. It thus remains to be clarified to what extent the approach of modern research to evolutionary studies is permeated by ideas originating from alternative theories.

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Interview

Tracking Down Hazardous Substances

Between basic research and policy advice: Helmut Greim, the long-standing Head of the MAK Commission, takes stock

He was once described, by the journal "Laborjournal", as "the most influential figure in modern toxicology": Professor Helmut Greim, born in 1935, the long-serving director of the Institute of Toxicology and Environmental Hygiene at the Technical University in Munich. From 1992 he also served as the Chairman of the Senate Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area (MAK), also known as the MAK Commission. At the end of March 2007, he passed the reins of chairmanship on to Andrea Hartwig, Professor of Food Chemistry from Berlin. We spoke with Professor Greim, who will remain as Chairman of the Scientific Committee on Health and Environmental Risks of the European Commission, about the work done by the MAK Commission and how it goes about it, about basic research and the provision of policy advice, and about the prospects for the future at home and abroad.

Illustration: Unterstell

german research: How can the results generated by the MAK Commission over the past 50 years or more help to contribute towards the protection of health in the workplace?

Greim: Year in, year out, the commission draws up recommendations for the maximum allowable concentrations of volatile chemicals and dusts in the workplace (MAK values), and for biological tolerance values (BAT values). It also classifies substances with respect to their carcinogenic, mutagenic or sensitising effects. This is done purely on the basis of scientific data and criteria.

The threshold values published in the lists of MAK and BAT values are presented to the German Federal Minister for Labour and Social Affairs each year. This is how the commission honours its obligation to provide policy advice, as is enshrined in the statutes of the DFG.

What does the work done by the commission consist of and what is essential to it?

Every classification it proposes has to be scientifically justified and reproducible – in the light of all toxicological data and studies into occupational health. The extensive documentation, which is compiled by the members of the commission with the support of the scientific secretariat, is just as essential to its work as the independence of the commission and its working groups. Only if it can work transparently and independently can the commission expect its scientifically based findings to be accepted and to meet a positive response – especially in industry and amongst politicians.

The scientific classification of hazardous substances is one side of the coin, political implementation of the results in occupational health and safety law is the other. Doesn't the legislation lag behind the state of scientific knowledge?

Yes, without a doubt. But political and social considerations do not concern the research community. It has become evident over the years, however, that many of the commission's classifications have not only been adopted by German legislation (such as the Ordinance on Hazardous Substances), but are also internationally recognised and drawn upon, for example, by the European Commission. The MAK Commission cooperates closely with other national commissions for the risk assessment of chemical substances, for example in the USA, which also founds its proposals on the MAK commission's detailed scientific argumentation, thus making the classifications applicable internationally. However, legislation does lag behind the state of knowledge, in some cases quite considerably. For example, the commission described the health hazards of nicotine and passive smoking as early as 1969 and reiterated this in 1985 and again in 1998, which makes the current debate all the more astonishing.

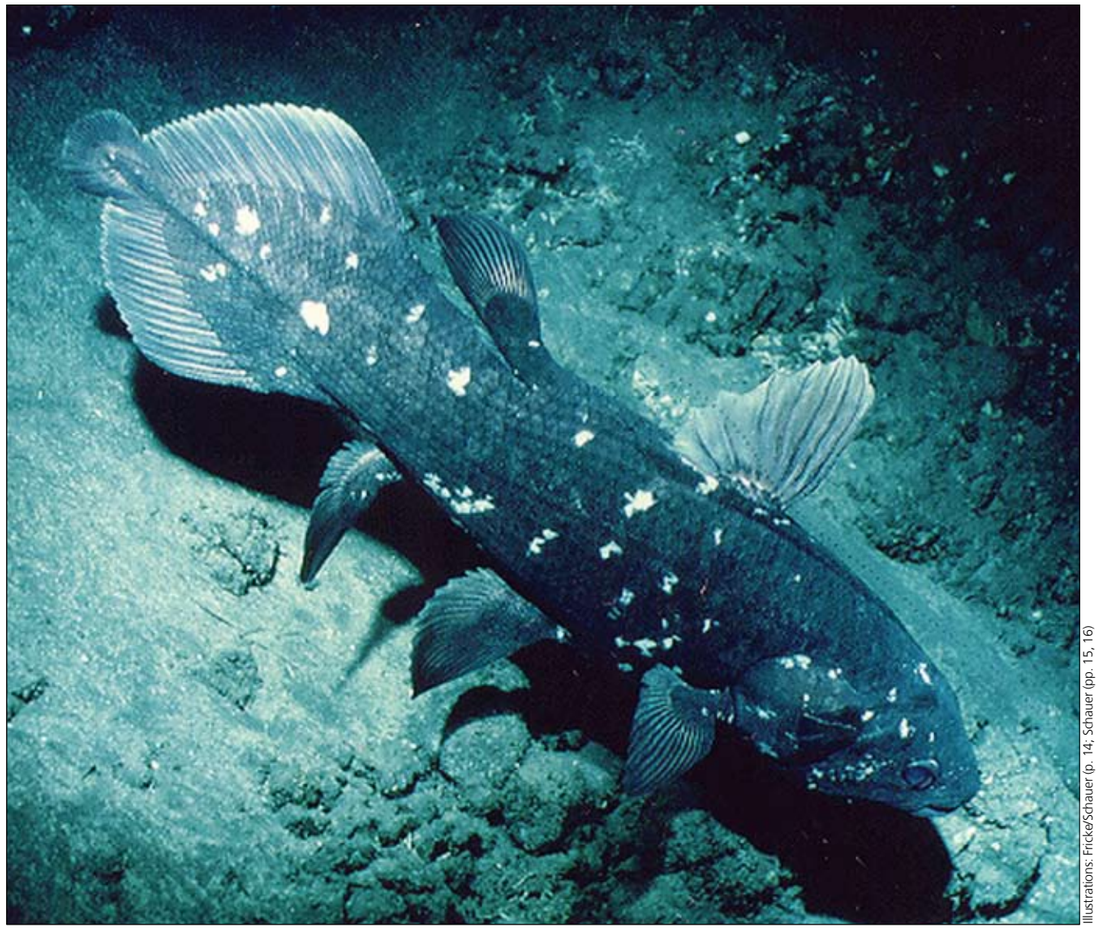
On the topic of "prospects for the future", where is the MAK commission heading?

The commission is now no longer only looking at substances in the workplace and assessing their risk, but is also involved in evaluating chemicals and their reaction mechanisms in other fields too. These activities include, for example, the development of new concepts for the assessment of carcinogens and the risk assessment of harmful substances in the air we breathe. The existing threshold values and the technical know-how of commission members can be very useful here, so there is much to be gained from expanding the focus and broadening the work of the commission beyond the workplace to include environmental issues.

The interview with Professor Greim was conducted by Rembert Unterstell

Coelacanths have been in existence now for more than 400 million years. Scientists have investigated the way of life of this ancient, nocturnal fish

Diving Expedition to a Methuselah of the Sea



Illustrations: Fricke/Schauer (p. 14; Schauer (pp. 15, 16)

They are living "dinosaurs" of the sea. A coelacanth swimming at a water depth of 200 metres, along steep volcanic slopes, off the Island of Grand Comoro, in the western Indian Ocean. Right: Using the submersible JAGO, in calm and stormy seas, the German scientific team studies the life style of a coelacanth population off the coast of South Africa.

By Karen Hissmann and Hans Fricke

There is an ancient inhabitant of the ocean, one that has maintained a cryptic lifestyle and remained largely in hiding: it is the coelacanth *(Latimeria)*, the only known representative of a group of bony fish extant since the middle Devonian (ca. 400 million years ago). Discoveries of fossil coelacanths have shown that this group of fishes, comprising more than seventy species in several genera, were common worldwide well into the middle Cretaceous. The fossil records indicate that these early fishes became „extinct", like their dinosaur contemporaries, approximately 65 million years ago. Therefore, the scientific discovery of a living coelacanth was a zoological sensation. Marjorie Courtney-Latimer, curator of a small museum in the South African town of East London, discovered the unusual looking fish in 1938, among the by-catch from a trawler. An ichthyologist, who later described the fish as *Latimeria chalumnae,* exclaimed „I could have hardly been more surprised had I encountered a dinosaur on the road".

An extraordinary feature of coelacanths is the presence of muscular lobed fins that are reminiscent of the legs of early terrestrial vertebrates. In fact, coelacanths and lungfishes are close relatives of those bony fish with limb-like fins that were the first vertebrates to venture onto land during the early Devonian. When compared to their fossil relatives, the living coelacanths have remained largely morphologically unchanged and are therefore of great significance in the study of evolutionary biology.

Fourteen years passed after the Courtney-Latimer discovery before the next coelacanth appeared. This time, fishermen from the Comoro Archipelago, using wooden dugout outrigger canoes, had caught a coelacanth as by-catch of their traditional deep-sea line fishing. Since then, the Comoro Islands, between East Africa and Madagascar, have been considered the home of this truly „living fossil". The local fishermen hauled up the large and heavy (up to 190 cm and 100 kg) fish to the surface, from depths of between 150 and 500 m. These caught specimens were sent around the globe to museums and scientific institutions. *Latimeria* thus became one of the anatomically most thoroughly studied fish species. However, the way of life of these unusual fishes remained virtually unknown.

This situation changed in 1987 when marine biologist Hans Fricke and his team from the Max Planck Institute for Behavioral Physiology in Seewiesen (Germany) brought a manned submersible to the Comoros and filmed the ancient fish in its natural habitat for the first time. The very first encounter indicated immediately that this heavy fish uses its pectoral and pelvic fins synchronised diagonally in an alternating rhythm, similar to terrestrial tetrapods, but not for locomotion on the sea floor. Instead, the coelacanth glides slowly over the rocky substrate, appearing virtually weightless. However, when suitable prey fish swim past their mouths, they can suddenly propel themselves forward with a single powerful stroke of their broad tailfin. With a lightning-fast combination of snapping and suction, facilitated by a joint between the upper jaw and cranium – which has since been lost in all other fishes – prey disappears within split seconds behind the sharp teeth of this predator. During the day, the nocturnal coelacanths retreat to caves, located between 150 and 250 m below the sea surface at the Comoros. In these, often spacious, caves coelacanths congregate in groups of up to sixteen individuals.

Because of their „sluggish" lifestyle in water temperatures which average 15 to 20 °C, coelacanths require relatively little food. This ena-

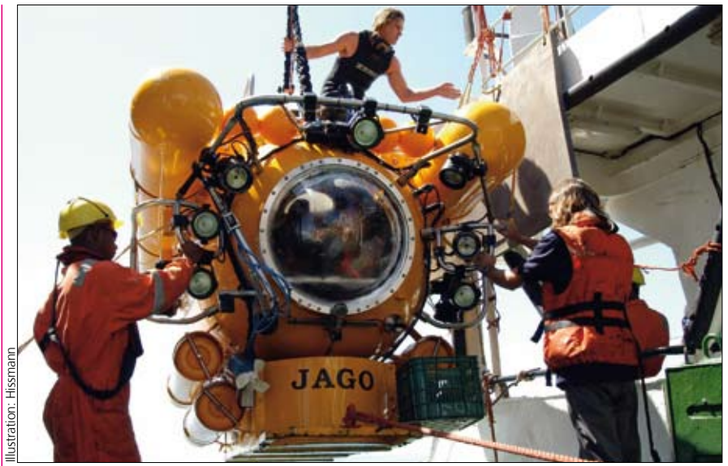


Illustration: Hissmann

Illustration: Hissmann

Illustration: Schauer

bles them to survive in a habitat of limited food availability. They have apparently found a perfect niche for their survival, far away from the more intensely competitive conditions in shallower water.

From the submersible, some coelacanths were tagged with ultrasonic transmitters that would be shed automatically after a few weeks. These experiments indicated that the fish leave their caves individually, shortly after sunset, to search for food at depths down to 700 m. With the first light of the morning they return to their respective caves. During this nocturnal foraging, they do not move more than a few kilometres away from their resting caves.

Coelacanths have a characteristic pattern of white spots making it possible to distinguish individuals and so to follow them over an extended period. Coelacanths are site-faithful; they have been observed to occupy the same caves over many years, possibly even for their entire lives, which may last longer than hundred years. The catalogue of described individuals, compiled by the submersible team, now numbers 127 specimens from the Comoros alone, and, over the years, some of these fish have become „old acquaintances". Indeed, the coelacanth community studied at the Comoro Archipelago, with an estimated 500 to 600 adult animals, is a small but stable population, as long as there are no dramatic intrusions into the habitat to threaten their survival.

It is not uncommon in nature to find that island animal populations are restricted in size and distribution. Thus, for a long time it was assumed that coelacanths occurred only off the Comoros; the specimen collected off South Africa in 1938 could have been a solitary stray displaced by currents. This theory, however, sustained the first crack with the accidental catch of a pregnant female off the coast of Mozambique in 1991, although genetic investigations did not reveal significant differences between the Mozambique specimen and specimens from the Comoros. Then, accidental coelacanth catches were also reported from the southwest coast of Madagascar, and finally, in 1997, an American couple made a surprising discovery of a coelacanth at a fish market on the Indonesian island Sulawesi. Shortly thereafter, and not far away, another specimen was caught in a deep-set shark gillnet. This catch removed all doubts: there had to be an independent coelacanth population in the western Pacific. Again, the German submersible team got involved, this time in Sulawesi. There, in a deep limestone cave, 155 m below sea level, the team found two coelacanths that were morphologically indistinguishable from the Comoran specimens. Molecular biologists found only minor genetic differences between the new Indonesian specimen and samples from the Comoros, but these were sufficient to distinguish the Indonesian fish as a novel species, *Latimeria menadoensis.* Since then there have been two known living coelacanth species, separated by 10,000 km.

> In order to study the lifestyle of coelacanths, the fish were fitted with ultrasonic transmitters and their behaviour observed.

In 2000, a team of deep-water divers – who dived regularly in the submarine canyons in the South African Saint Lucia Marine Reserve, south of the border with Mozambique – made the next coelacanth discovery. At the upper crest of a canyon, the divers observed several coelacanths in a karstic cave. This prompted the South African Government to establish a programme that was set up not only for environmental protection and educational measures, but also to study the lifestyle of coelacanths off the South African coast. The German coelacanth experts, with their submersible, became partners for three years in the „African Coelacanth Ecosystem Programme". It was found that the „sluggish" coelacanths are able to survive in an area strongly influenced by the powerful Agulhas Current because they find sufficient shelter in the submarine canyons along the continental shelf. Within these canyons, currents are reduced or absent. Like their Comoran cousins, the South African coelacanths spend their days in caves, however, in shallower water of only about 100 m.

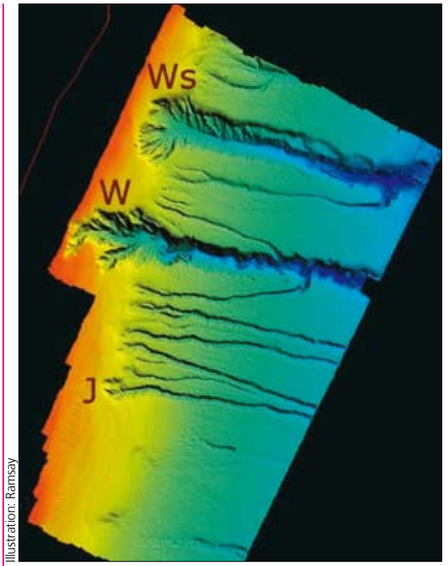


Illustration: Ramsay


Illustration: Stapley


Illustration: Stapley


Illustration: Schauer

One specimen tagged with a transmitter demonstrated that the South African coelacanths need not venture to great depth for foraging, because a sufficiently large supply of prey fish exists within reach of their daytime rest caves along the edge of the canyons. A specimen register currently includes 26 South African coelacanths, distributed over three submarine canyons.

Using their submersible, the German Team developed a non-injurious method for removing single scales from coelacanths for use in molecular genetic studies. In cooperation with the Biocenter of the University of Würzburg, almost fifty tissue samples of specimens from the Comoros, South Africa, Madagascar and Mozambique have so far been studied.

Left: A multibeam chart indicates the underwater canyons off South Africa. Next: South African schoolchildren receiving educational instruction onboard research vessel ALGOA. Bottom left: DNA being isolated from coelacanth scales for population genetic studies. Coelacanth marked with an acoustic transmitter.

Despite the differing origins of the samples, there exists considerable genetic conformity among the animals. Because very old and long-separated populations would be expected to be genetically far more variable, reflecting numerous mutations to their genetic material, these coelacanth populations must be relatively young and have separated only recently. The possibility that individual communities are in constant genetic exchange with each other becomes rather unlikely when considering both the West Indian Ocean current configuration and the strong site fidelity of the fish. A minor genetic difference within the Comoran population, which has a tendency towards inbreeding, further suggests that colonisation of these islands occurred relatively recently. American molecular biologists have calculated that *Latimeria chalumnae* and *L. menadoensis* have been genetically separated from each other by at least 4.7 to 11 million years. On the other hand, Grand Comoro and Anjouan, the two Comoran islands which are inhabited by coelacanths, are estimated to be only a few million years old. Thus, if formed only after the separation of the two *Latimeria* species, these islands may well have been colonised with coelacanths from another, still unknown population in the Indian Ocean. Therefore, more surprises are expected for the future.

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Illustration: Archive Müller

The Fight Against Malaria

Every year, around three million people die as a result of this infectious disease. Mosquito nets can provide simple yet effective protection

By Olaf Müller

Malaria, also known as swamp fever, jungle fever or ague, is an infectious parasitic disease common in many areas around the world. It is transmitted to humans by mosquitoes carrying the protozoan Plasmodium parasite. There are four Plasmodium species that cause human malaria, although *Plasmodium falciparum,* which causes the deadly "malaria tropica", is the most common in the tropics.

The history of malaria began in Africa in prehistoric times, from where the disease then spread around the world. The earliest accounts of ague originated in Ancient Egypt and China and date back to around 1500 BC or even earlier. However, plasmodia was first identified in human blood by Alphonse Laveran in 1880, followed by the discovery that it is transmitted by the Anopheles mosquito by Sir Ronald Ross in 1897, which paved the way to the effective treatment of malaria. Laveran and Ross both received a Nobel Prize for their discoveries.

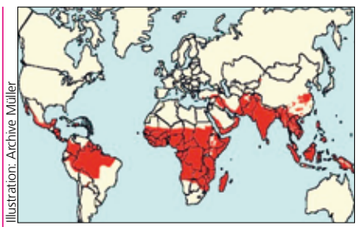

Illustration: Archive Müller

The current extent and distribution of malaria around the world. It is predominant in regions where the mosquitoes which transmit the infection have an ideal habitat. The financial strength of the countries is also decisive, however, in deciding whether they are able to combat it effectively or not. Most of the countries in southern Africa are too poor to be able to afford comprehensive control programmes.

The effectiveness of cinchona bark in treating malaria was first noted in the 17th century, and the highly effective drug quinine, which is still used today, was first extracted from it in France in 1820. In Germany, the development of synthetic antimalarial drugs such as chloroquine was given a significant boost by the First World War, during which many soldiers perished due to malaria. After the Second World War, the highly potent and well-tolerated drug chloroquine became popular worldwide and was the main antimalarial drug in use for decades. The development of antimalarial drugs was accompanied by the development of insecticides. The discovery of the highly effective dichlorodiphenyltrichloroethane, or DDT for short, in the late 1930s, by Paul Müller from Switzerland, for which he also won a Nobel Prize, marked another significant advance in the fight against malaria.

Left: In the worst case, malaria can be fatal. The parasites that cause malaria are transmitted by a sting from the Anopheles mosquito. Right: Children in the West African country of Burkina Faso. Young children are particularly at risk, accounting for the most fatalities due to malaria.

In the post-war atmosphere of euphoria and in view of the availability of very cheap and effective medicines and insecticides, the Global Malaria Eradication Campaign was inaugurated at the Eighth World Health Assembly in 1955, although sub-Saharan Africa was essentially excluded for logistical reasons. The widespread use of DDT, both indoors and outdoors, to control populations of the infectious Anopheles populations, combined with blanket treatment with chloroquine, did indeed lead to a rapid reduction of the incidence of malaria in the countries where the campaign was pursued. Within fifteen years, by 1969, malaria had been eradicated from most of the developed nations in Europe, North America and Asia as well as in Australia, but not in the poor countries of the tropics. In these countries, permanent eradication proved an unrealistic goal for a number of reasons.

In 1969 the World Health Organisation (WHO) revised its strategy, replacing the eradication campaign with a Global Malaria Control Strategy. This strategy was based on four elements: Firstly, the early provision of diagnosis and prompt treatment of the disease; secondly, the effective implementation of selective preventive measures, including the use of mosquito nets treated with insecticide; thirdly, the early detection, containment and prevention of epidemics, and fourthly the development of local capacities for basic and applied malaria research.

At the beginning of the 21st century, half of the world's population still lives in regions affected by malaria. The WHO estimates that there are between 300 and 500 million infections and 2-3 million deaths due to malaria each year, the vast

Illustration: Sauerborn

majority of which occur in Africa, mostly affecting young children. The greatest problem hindering the successful control of malaria is the strong resistance that *Plasmodium falciparum* has developed to what were once effective and cheaply available drugs. The WHO therefore now recommends the use of Artemisinin-based combination therapies (ACTs). In the 1970s, the effectiveness of the traditional Chinese medicinal plant *Artemisia annua* was rediscovered, and it has been used for the development of various highly effective artemisinin-based drugs. To avoid the development of resistances, the WHO has recommended, since 2006, that only combination therapies should be used to combat malaria. However, for the majority of sub-Saharan countries these drugs are simply too expensive without significant subsidies.

In the past 15 years, mosquito nets treated with insecticide have received a great deal of interest for their use in the fight against malaria. The availability of effective, but at the same time non-toxic insecticides has made a major contribution towards this development. The effectiveness of using this method to combat malaria has been demonstrated in a large number of scientific studies conducted since the early 1980s. This led to their more widespread and successful use in national malaria control programmes, for example in China and Vietnam. In the 1990s, large-scale controlled studies showed that this method is also an effective way of fighting malaria in Africa. These studies demonstrated that children protected with mosquito nets had a 50 percent lower rate of infection with malaria and childhood mortality fell on average by 20 percent. A controversial subject of debate at the time, however, was whether children who had been protected from malaria using nets at an early age may be more prone to infection with and death due to malaria later in life due to a lack of immunity that would otherwise have developed during childhood.

This question was looked into by the DFG Collaborative Research Centre "Controlling tropical infectious diseases". In Burkina Faso, a long-term study of the effectiveness of mosquito nets treated with insecticide, was also conducted alongside clinical trials of newly developed antimalarial drugs, studies on infant and childhood mortality, and health sector-related studies into the effectiveness of AIDS drugs in this rural area. This study investigated 3,400 new-born babies from 41 villages. The babies were individually assigned at random to either group A or group B. Those in group A were protected with a mosquito net from birth until the age of five years, whilst those in group B were protected with mosquito nets from the age of six months until they reached the age of five years. This was based on the theory that protection from malaria in the first six

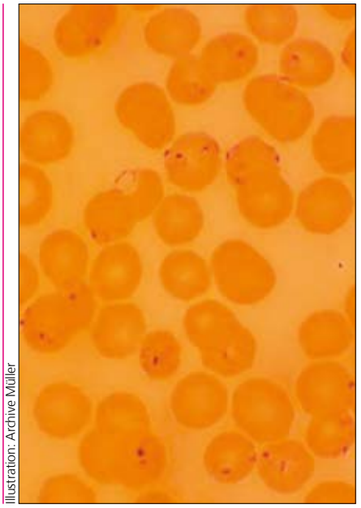

Illustration: Archive Müller

Illustration: Müller

A blood smear from a patient seriously ill with "malaria tropica." The red blood cells have been infected with the most dangerous species of malarial parasite. Below: The population is told about the malaria study that is about to begin at a meeting of the villagers in Burkina Faso. The long-term study covers 41 villages in Burkina Faso.

months may have a detrimental effect on the development of their immune systems. The consequence of this may be that the children would then be more prone to a serious or even fatal malaria infection in later years. This hypothesis was clearly refuted by the study. Indeed, the opposite proved to be true. Consistent protection with mosquito nets in this region, with a high rate of malaria infections, even improved the children's immunity during the early years of their lives and did not lead to higher mortality rates subsequently. These findings, in conjunction with the outcome of long-term observations of children in other studies in Africa, support the unrestricted use of mosquito nets treated with insecticide in malaria risk

Illustration: Müller

Illustration: Müller

Above: Tiring work for the young patients. In rural Africa, children suffering from malaria often have to travel many kilometres to reach the nearest health centre. Left: Much more than just a pretty canopy. Children who are protected by mosquito nets treated with insecticide contract the dangerous disease much less frequently.

areas. The only question remaining now, is how best to distribute the nets to the villages in southern Africa so that they can actually be used by the at-risk groups such as young children and expectant mothers. There is currently heated debate on the question of whether the "social marketing" method (subsidised sale) or free distribution through health services is the best option. The Collaborative Research Centre is also addressing this question. To determine the best distribution method, a large-scale controlled study is currently underway in the Nouna district (with a population of 300,000), with mosquito nets being distributed via "social marketing" and at health centres. The findings of this study will be very useful for health officials in Burkina Faso as well as other African countries to assist in decision-making on what is the best way in which mosquito nets can be used to provide cost-effective and long-term protection against malaria for the population.

Most of the countries in sub-Saharan Africa and their populations are far too poor to be able to shoulder the financial burden of effective anti-malaria schemes themselves. The WHO recently calculated that, in addition to the current 200 million per annum in external funding, another 2 billion per annum would be needed to fund an effective anti-malaria campaign in sub-Saharan Africa. Most of this money should be provided by the industrial nations through the "Global Fund to Fight HIV/AIDS, Tuberculosis and Malaria" initiated by the former Secretary General of the UN, Kofi Annan, in 2000. Since malaria continues to represent a serious part of the cause for the lack of positive development on the African continent, this would be a worthwhile and lasting investment in the future.

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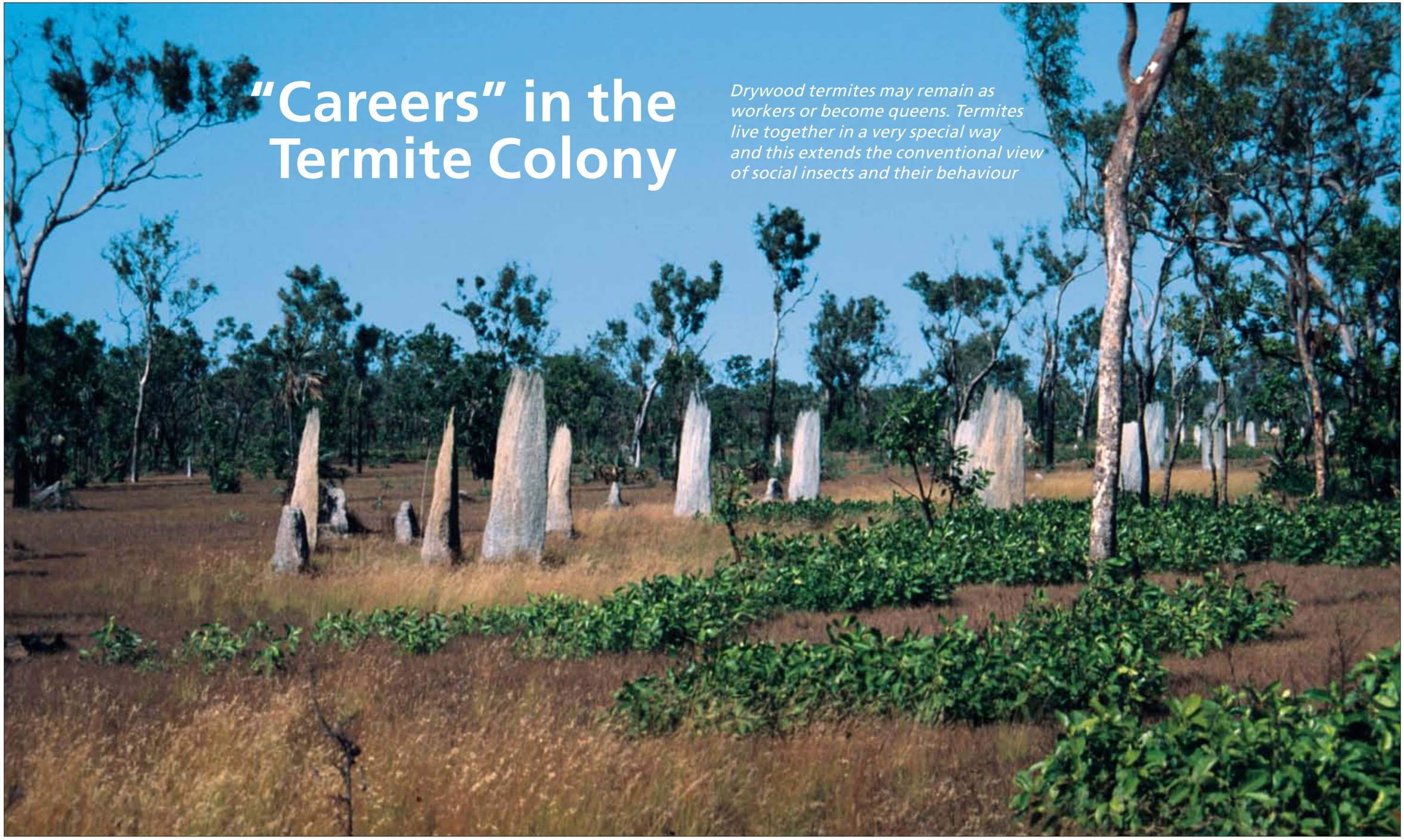
"Careers" in the Termite Colony

Drywood termites may remain as workers or become queens. Termites live together in a very special way and this extends the conventional view of social insects and their behaviour



By Judith Korb

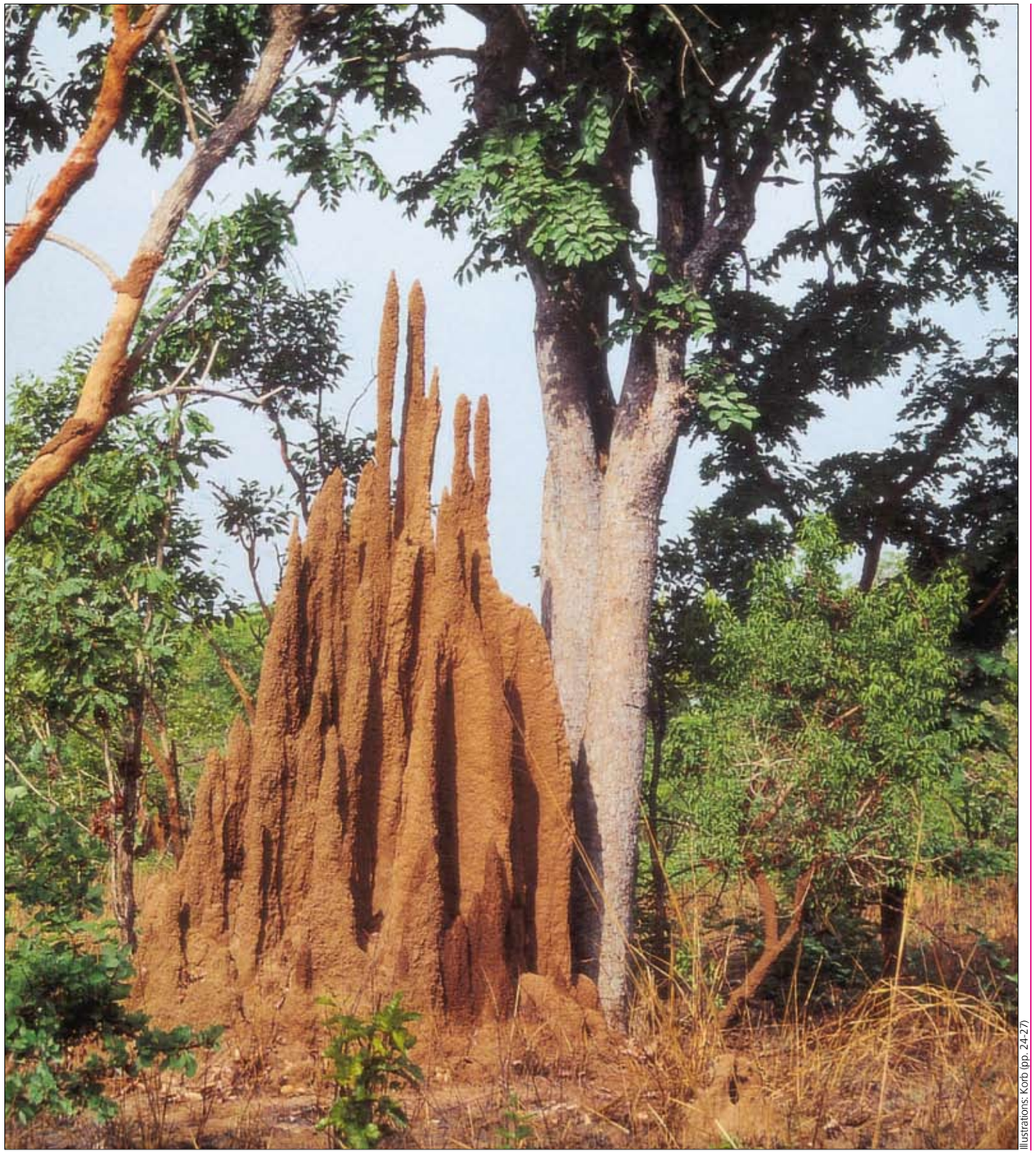
Ants and bees, wasps and termites, are social insects and the organisation of their social structure is highly fascinating to man. They are a prime example of cooperation, in which most individuals – like the worker bees – forfeit their own reproduction to help the reproductives – like the queen bee in a colony – to raise the young. This selfless and altruistic help is a challenge to classical Darwinian theory, which assumes that hereditary characteristics are selected which increase the individual's reproductive success.

A solution to this problem is offered by "kin selection," as formulated by the evolutionary biologist William D. Hamilton in 1964. According to this, altruistic characteristics can be transmitted indirectly by close relatives, when an individual helps a relative to have more offspring. Social insects have therefore acquired a special place in evolutionary biology, in testing of the predictions of the "kin selection theory."

These studies have concentrated on ants, bees and wasps, whereas termites – the second large group of social insects – have attracted less attention. Moreover, attempts to explain altruistic behaviour have concentrated on the close relatedness of workers and reproductives. Although ecological factors determine the costs and benefits of altruistic behaviour and are an established component of kin selection theory, they have been neglected.

It is however of key significance, whether the ecological situation presents an individual with the opportunity, for example, of founding its own nest. This is also seen in the example of termites living in wood.

Termites originated more than 130 million years ago and formed the first "welfare states" when the dinosaurs were still roaming the earth. All known termites – both living and extinct species – are social, and it is thought that they rapidly developed from coachroach-like ancestors. Termites with their social organisation have been very successful during evolution. About 2,600 species are known, many of which have not been described. They mostly live in the tropics and subtropics. In some areas of the savannah, they build monumental mounds resembling cathedrals, up to eight metres high, giving a direct impression of termites' ecological significance. In their distribution area, termites play a decisive role in nutrient cycles, as they break down plant substances, leading to the rapid provision of nutrients. They are so-called "ecosystem engineers," meaning that their activity influences basic properties, such as water availability or soil composition; this is indeed how termites structure their environment. There are other termites, which are less well known than the mound-builders. These so-called "lower" termites live retiring lives in pieces of wood, which serve them both as food and as living space. These termites never leave the nest to find new sources of food. They gradually eat up their nest, until the colony dies out. From the biological point of view, these animals are fascinating, as they offer a unique opportunity of studying cooperative behaviour and its causes. The individuals of these species have the possibilities of remaining "altruistic" workers, or of developing "egoistically" into reproductives. This is made possible by extraordinary developmental flexibility. The animals can remain as workers in one developmental stage, they can continue their development into reproductives or – and this is unique in the animal king-



Illustrations: Korb (pp. 24-27)

Imposing and effective: This cathedral shaped mound is almost five metres high and belongs to a West African termite which cultivates fungi. Termites play an important role in the savannah ecosystem, as they break down plant material, leading to rapid availability of nutrients in their environment.

Above: Chamber of a "higher" termite queen: The queen is about ten centimetres long and lays about 20,000 eggs a day. She is surrounded by workers who not only care for her eggs but also perform other social tasks. Left: A view into the colony of a "lower" species of termite living in wood. In this species, the workers do not help to raise the young larvae.

dom – they can regress to an earlier stage, as long as they are not yet fully mature adults. For the Australian drywood termite, *Cryptotermes secundus,* it could be shown that this development is greatly affected by the seasons. Once in the year, a so-called nuptial flight takes place, in which the winged reproductives fly out of a colony, to found a new colony as kings and queens. The workers develop into these winged reproductives, in a process that takes about seven months and goes through several stages.

There is a deadline for each of these developmental stages. If the individual has not reached this stage by the deadline, it regresses into a worker and remains in the colony for at least a further year. Whether an individual remains in the nest as a worker and how many individuals do this, are influenced not only by the season, but also by the amount of food available, which is linked to the potential life span of the colony. Once the quantity of wood falls under a specific threshold, the termites modify their behaviour and spend more time eating and less time on other activities, such as mutual feeding. At the same time, the workers start a precocious development into winged reproductives. As a consequence, more individuals reach the seasonal development deadline in good time and more workers become dispersing winged reproductives. The enhanced development of winged animals is apparently an adaptation to the nest's reduced life expectancy.

Aside from the possibility of becoming winged reproductives, the termite workers also have the chance of inheriting the parental nest as so-called replacement reproductives. When the king or queen of a colony dies, a worker of the same sex develops into the reproductive, to replace the king or queen. Workers could therefore remain in the colony to either, as is generally assumed, provide altruistic help in raising their siblings, or reproduce themselves as a replacement reproductive. Intensive behavioural observation and specific experiments have shown that the workers of the Australian drywood termite *C. secundus* are not altruistic helpers. There is no brood care and the few mutually cooperative activities within the colony hardly lead to costs to the individual. Thus, there is no dangerous cost intensive foraging, which is one of the main tasks of the workers of other social insects. For example, worker bees or ants must leave the protection of the nest to search for food for the developing brood. However, the drywood termites simply sit in their food, which is accessible to every colony member. Thus, in contrast to what has been assumed, these workers are not altruistic helpers and raising close relatives does not seem to be the evolutionary driving force for staying in the nest.

Why then do individuals remain in the nest, rather than founding their own families as reproductives? Long term field studies have shown that the chances of founding a new colony are very slight. More than 99 percent of the winged reproductives die without offspring. The chance of inheriting the parental colony as a replacement sexual form is of about the same order of magnitude. As a mathematical model suggests, the chance of inheriting the nest (without helping) can explain how many individuals disperse. These findings raise the question as to whether these workers can still properly be designated as workers. Perhaps it would be more correct to regard them as potential successors to the throne, waiting in the safe parental nest for the parental reproductives to die? The behaviour of these termites is more like that of some social mammals and birds, which hope for the chance to inherit the natal nest, as the chances of breeding elsewhere are very slight. Although these results were obtained with a single drywood termite *C. secundus,* they presumably apply in general to many lower termites living in wood.

These findings fundamentally change our view of social insects and the causes of their group life. Their behaviour is not always characterised by altruistic help. It must nevertheless be added that there is also one termite caste living in wood, which really is permanently altruistic. These are the "sterile soldiers." As they make up less than five percent of the individuals in a colony, they can be seen as an exception.

Workers of a termite species living in wood. New studies show that these termites do not live selflessly in the colony – in contrast to other social insects, such as ants, bees or wasps. Thus the termite workers do not give up their own reproduction to help raise their siblings in the nest.

Illustration: Korb

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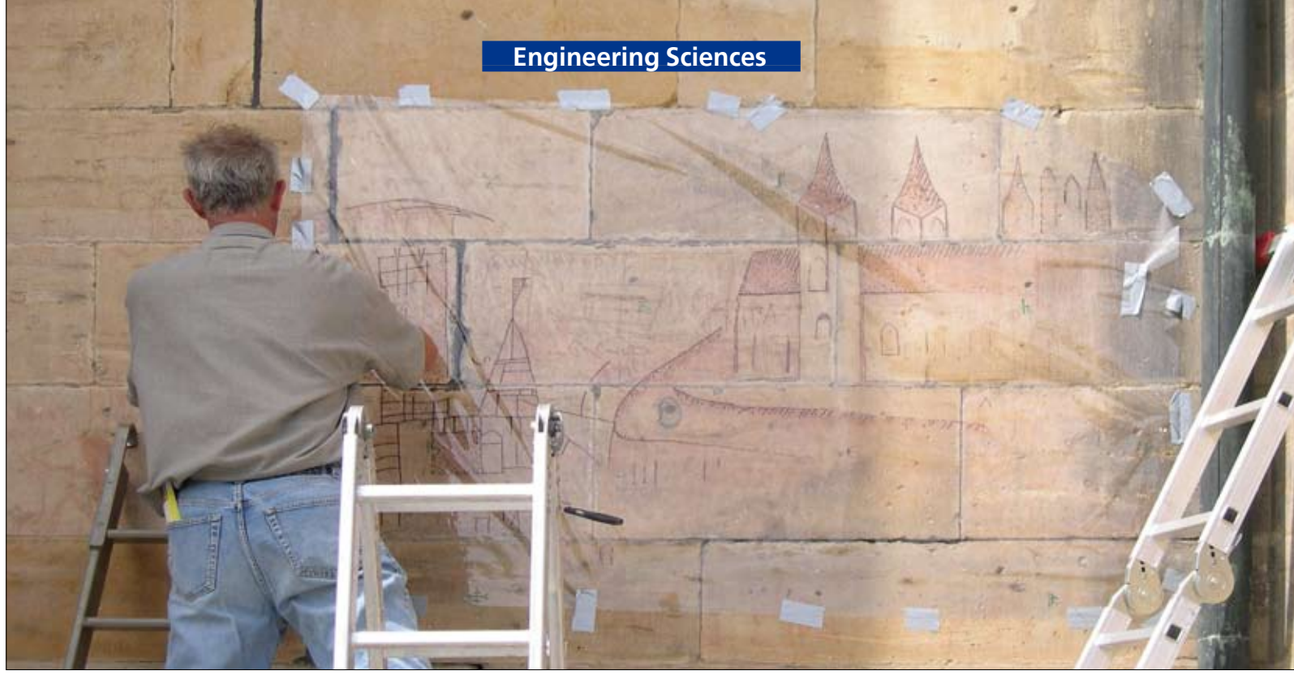
▶ www-evolution.uni-regensburg.de/ staff/koj/koj_e.html



Adolar, Eoban and the History of a Cathedral

On the tracks of medieval history of architecture: during the 14th century Erfurt Cathedral was enlarged, as it became an important place of pilgrimage

By Johannes Cramer, Manfred Schuller and Barbara Perlich

Three most distinguished representatives of the Catholic Church were beaten to death near Dokkum last night." This might be the way newspapers of today would report the martyrdom of Adolar and Eoban, who accompanied Saint Boniface on a missionary journey to Frisia in 754. Tradition has it that they were attacked and killed by an armed band of heathens. Whilst the remains of Boniface, also known as the Apostle of the Germans, were taken to the abbey of Fulda, the bodies of Adolar and Eoban were taken to Erfurt. Adolar was originally intended to become the bishop of a new bishopric of Erfurt; instead, a monastery and church were built to house the bones of the two martyrs, who had by that time been sainted.

On the dawn of the 400th anniversary of their martyrdom, the old church was demolished and construction of a new building began in 1154. During these building works, the relics of the two saints were "rediscovered" and restored to a place of honour in a well-secured and richly adorned chapel in the north tower of the church. The fame of the relics brought about an increase in the number of pilgrims, and this was accompanied by an increase in the number of canons.

Only a century after construction work for the new church had begun, the choir, the canons' prayer room, had become too small and thus was extended towards the east within only eight years. The extension, which consisted of seven sides of a decagon, was almost circular and as such was truly avant-garde for the Gothic era. Although it was demolished about 30 years later already, it has recently been possible to reconstruct the ground plan in detail on the basis of mortar impressions, minute elaborations in the masonry, a few fragments of the profile and what was left of the foundations.

In the early 14th century the canons spent all available funds on an extensive redesign of the church in Erfurt in an effort to create an appropriate place to house the holy relics, with the relics also being easy to access for the increasing numbers of pilgrims. The cathedral hill was completely occupied with the existing church by this time, however, so there was only one option – the hill had to be enlarged! Over the next 20 years the "cavata", huge substructions, 30 metres in length, 28 metres wide and 15 metres high were constructed in the east of the old church to support the new choir.

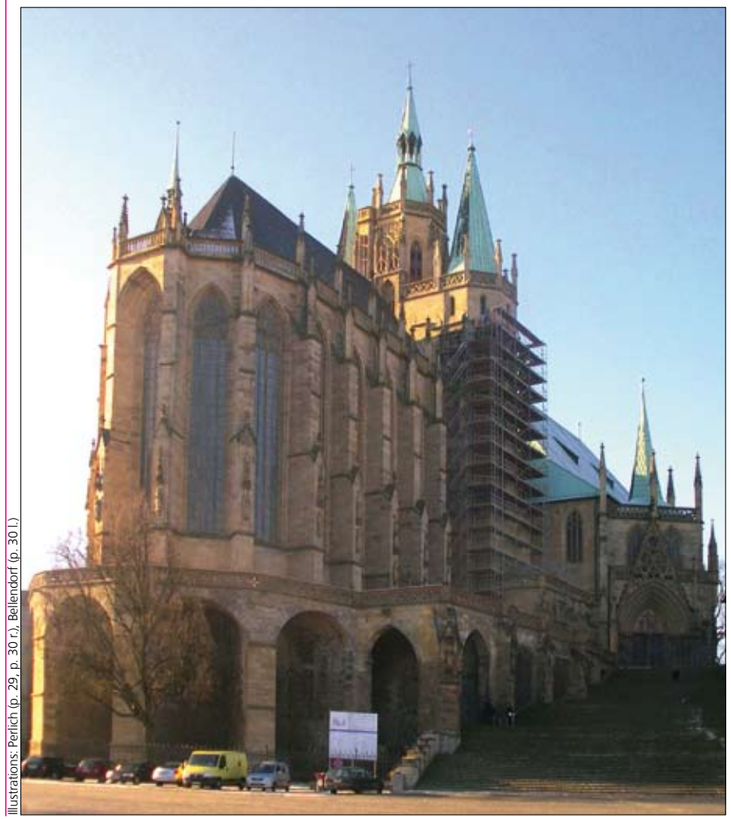
It was cleverly designed to include storage rooms as well as a crypt in the upper part of the construction. Here, just below the new choir, was the resting place for the relics of both of the saints, where processions and pilgrims would be able to pass by. The route the multitudes would take was not left to chance, however, but was meticulously planned: first passing by the newly built main portal and then crossing a broad terrace surrounding the entire choir, before entering the crypt through a door to the south, where they could finally pay their respect to the holy relics. Then, having finished their prayers, the pilgrims left the crypt through a door to the north. The architectural design thus adeptly incorporated a circuit of the church.

Above the crypt, which formed the heart of the new building, the High Choir, which remains a major feature of Erfurt's skyline, was subsequently built over the following years. The modernisation included the addition of a new main door on the north of the church. This triangle portal, also referred to as the "Triangel", richly adorned with statues and sculptures, was a masterpiece of Gothic architecture. That which even today, looking at the floor plan of the building, at first appears to be a simple triangle, on closer examination, turns out to be a highly complicated geometric structure, intended to be viewed in perspective, which projects its effect out into the town.

In addition to the actual building work, the canons also invested in furnishings and decorations for the church interior. Most important of all, the saints' bones required an adequate resting place. Around 1350, a stone tomb, called the "Tumba", was carved, in which the relics are resting to this day. As a memorial to their martyrdom, the missionary journey with Boniface and its tragic end are portrayed on the walls of the shrine, a heathen attacker raising his sword against Boniface. He, fully aware of his imminent death, is composed and ready to die as a martyr.

The pilgrims were greeted by colourful pictures not only on the tomb, but also as they approached it. Recent research has revealed that the entire outer wall of the High Choir was once covered by a fresco. What exactly was portrayed is unknown and left to our imagination. Except for the sketchy remains of an image of Mary and some recently discovered figures above the entrance to the crypt – who may possibly be Adolar and Eoban – the paintings on the wall are gone. The fresco was obviously impressive though, as testified by more than two hundred graffiti: as the pilgrims waited to enter the crypt, they expressed their admiration with red chalk on the walls. The canons also invested in their own purposes; for example, they erected wooden pews, decorated with plants and figures in the new and much enlarged choir. The bright, colourful stained glass windows tell stories from the bible, the lives of saints and the history of the church.

The whole wall of the choir in Erfurt cathedral was once covered with frescos. Below: Architectural historians examine the remains of these paintings as well as the numerous graffiti that have been traced in red. Right: The 14th century High Choir rises above the market place in Erfurt. The pilgrim's path once took them to the "cavata", which now stand empty and open to the market square.



Illustrations: Perlich (p. 29, p. 30 r.), Bellendorf (p. 30 l.)

Illustration: Gaasch

The unusual shapes found in the cloisters of Erfurt cathedral fuelled speculation that this part of the building may have been added in the 19th century. Now, architectural historians have discovered that the medieval structure is almost entirely intact.

Following expansion in the 14th century no major changes were made to Erfurt Cathedral for a long period of time.

Following the 14th century no major changes were made to Erfurt Cathedral for a long period of time. Although the western limb of the nave was demolished and rebuilt in the late middle ages and various fires caused some damage, the subsequent repairs did not disturb the basic structure of the cathedral. It was not until the 19th and 20th centuries that the nave became a bone of contention. For instance, the restoration work that was necessary in 1870 was used as a pretext to give the cathedral a medieval appearance with a neo-gothic high-gabled roof; this fell out of favour just 60 years later, and the decorative additions were removed. After World War II the neo-gothic roof was also finally removed and replaced by a new hipped roof in late gothic style.

Recently art historians working in cooperation with architectural historians, historians, archaeologists and monument conservation officers as well as experts from the cathedral office (Dombauamt) and the conservation authorities have been able to collate what initially seemed to be an insurmountable puzzle of details and assemble a new representation of the architectural history of Erfurt Cathedral. What had previously seemed like an almost random series of individual events now appears to be an exciting chapter in Erfurt's church history: the carefully and strategically planned organisation of a pilgrimage to the relics of Saint Adolar and Saint Eoban that constantly grew in importance over the course of several centuries. Last, but not least, this allowed the "headline" from the year 754 to maintain a permanent position in Erfurt's history.

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The Deutsche Forschungsgemeinschaft

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A pleasant break from everyday life at the office – the Bonn Science Organisation Chamber Orchestra strikes up in the courtyard at the DFG's Head Office. Once or twice a year the captivating tunes attract the office workers away from their desks and to the windows – making for an enjoyable lunch break.