

# forschung

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# german research

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1/2003 ▶ A Treatise on Life with Camels ▶ Of Krauts and Frogs: Stereotypes and their Uses ▶ Only at the Start is Everyone Equal ▶ In the Cockpit of the Fly ▶ How High can a Range of Mountains get?

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**Paths to Professional Success**

Women are still underrepresented in top positions in business, academia and politics. The paths taken by their careers differ from those of men. With a view to discovering the reasons for this, a study group in Erlangen has been conducting a long-term comparative investigation into the professional progress of male and female academics, in the course of which career patterns are starting to emerge. **Page 4**

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How do national stereotypes arise? A cultural study group investigated this question using the effective concepts of foreigners held in England in the 18<sup>th</sup> century. Over 500 caricatures, satirical prints and illustrations in history and geography books were studied. These have furnished fresh information on past and present clichés and their impact. **Page 7**

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Amongst the Raika pastoralists in India the dromedary commands great respect and care. Hence in this traditional herding culture man and his animals live in particularly close association. (Page 15)  
Cover photo: Superbild

**Impressum**

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Since the beginning of this year, funding has been provided for 16 Emmy Noether career development groups in the field of computer science. This is the outcome of the "Aktionsplan Informatik", the computer science action programme, approved by the Grants Committee in February 2002. In launching this measure, the DFG is responding, on the one hand, to the severe shortage of junior scientists ready to enter a profession in computer science, and on the other, to the fact that, in its previous form, the Emmy Noether Programme met with hardly any demand in computer science. The same applies to the entire area of engineering. For example, from when funding started in 1999 up to 2002, out of a total of 790 applications received for Emmy Noether grants (excluding the computer science action programme), a mere 26 came from the engineering area, and just 10 from the subject of computer science.

Quite obviously, the reasons for this low response are that while the previous framework conditions of the Emmy Noether Programme have been tailored very favourably to the qualification track of natural scientists, the characteristics of supporting young academics in the field of computer science and engineering sciences have not been sufficiently considered. The following modifications have therefore been introduced for the subject of computer science in the course of a three-year trial phase:

- Phase I (abroad), which used to be obligatory, is no longer required,
- the maximum age of applicants has been raised to 35 years,
- there is a phased selection procedure carried out by a group of reviewers within which applicants introduce themselves personally in the final round, and
- the programme is intensively advertised via publications in the field of computer science.

These modifications resulted in an unexpected success in the first round of applications, with 77 applications being received 11 of which came from German scientists currently living abroad and three from



Prof. Dr.  
Jürgen Nehmer

# An Impetus for Engineers and Computer Scientists

*New options for junior  
scientists and scholars to qualify –  
early independence and  
international networking are being promoted*

foreign scientists. The rate of approval of 20.7 percent (related to the applications received) corresponded to the Emmy Noether Programme's average rate of approval in other subjects.

Experience gathered with the computer science action programme can be applied to the entire field of engineering. It provokes the question how the situation of junior scientists in the engineering subjects and computer science differs from the neighbouring disciplines and how the DFG can address this situation more effectively.

So far, as a rule, between 10 and 20 percent of the Diplom graduates have gone on to do a doctorate in the engineering sciences and computer science. This is considerably less than in most of the natural sciences, but it obviously corresponds to the requirement industry has for this additional qualification.

A period of four to five years has proved to be suitable for the doctorate in most of the engineering sciences. Similar figures apply to computer science.

The greater length of the doctorate, which has occasionally been criticised from the angle of other scientific disciplines, is due to the application-oriented nature of research and is quite commonplace abroad. So the resulting higher age of engineers and computer scientists graduating with a doctorate should not create any disadvantages for them in applying for funding or awards for junior scientists.

In the past, many graduates with a doctorate had the opportunity to obtain further scientific qualifications in the research sector in industry as well and network with the international scientific community. This pool of experienced industrial researchers formed the reservoir from which higher education lecturers in the area of engineering were preferably recruited (in contrast, appointments from industry are still relatively rare in computer science).

With industrial research departments having concentrated more

strongly on their short and medium term core activities over the last few years, careers with industry centring on science have become significantly rarer, resulting in a considerable shrinkage of junior higher education lecturers ready to be appointed.

So higher education and society are called upon to develop new qualification tracks for junior scientists in these areas. Here, special support programmes for junior scientists focusing on the period after the doctorate are going to play a crucial role. The aim of such programmes has to be to promote independent scientific work and international networking on the one hand and, on the other, to reinforce relevance to applied contexts and links to industrial practice. However, the precondition for the acceptance of such a programme is that it qualifies candidates equally for an academic career at a later stage and for activities with industry. So research projects are attractive that are carried out as co-operative ventures between a higher education institute and an industrial company and are linked to a distinguished executive role.

However, what is less essential for engineers and computer scientists is Phase I of the Emmy Noether Programme, which provides for a stay abroad at a foreign research institute. This is why it has been omitted from the computer science action programme.

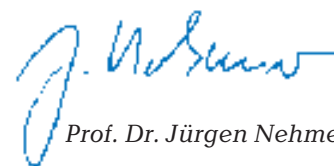
With the opportunity to apply for a position of one's own, the DFG has already created the conditions for funding scientists with a doctorate in a distinguished position of the project they themselves have applied for. In contrast, what still remains largely an unknown quantity is the funding of joint projects run by higher education institutions and companies in the framework of funding junior scientists. While all of the DFG's funding programmes can, to a degree, be applied flexibly with the aim of transfer, the transfer projects in the concluding phase of a collaborative research centre are

currently the DFG's only funding instrument with detailed elements in this respect. Here, more developments are called for.

In the case of junior scientists involved in a project run jointly by a higher education institution and a company, a DFG stamp of quality for the joint research project can be crucial to their future prospects of being appointed. At the same time, projects of this kind bear the advantage of creating direct access for engineers in industry to new research developments outside their more restricted core competences.

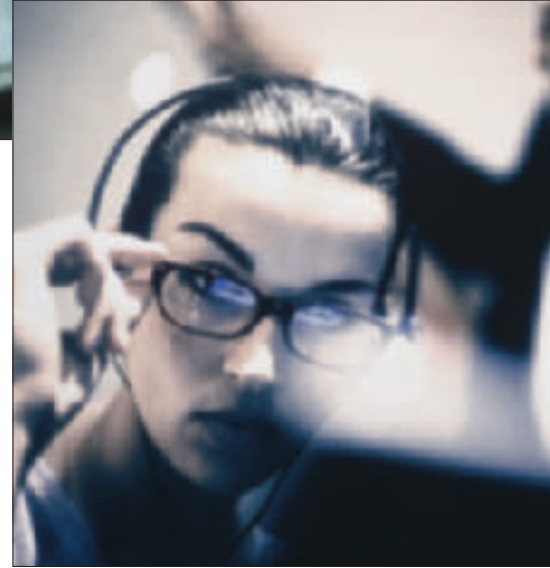
The junior scientists who have qualified according to the above model should, as a rule, also have spent a certain period with industry before they are appointed. This can either be the case before or after the scientific qualification phase. Industrial activity after the post-doc phase has the advantage that applicants are then, as has been the case in the past, appointed from a fixed position with industry to a higher education institution without a tenure track or bridging measures becoming necessary for scientists ready to be appointed but not yet having been appointed.

To industry, anyone with such a level of qualifications (e.g. with a "Habilitation", the qualification required in Germany to become a university lecturer) will still be attractive in spite of his or her higher age. And this could be reinforced by the research co-operation schemes in the framework of qualifying junior scientists as suggested above.



Prof. Dr. Jürgen Nehmer

Jürgen Nehmer, Computer Science Department, University of Kaiserslautern, is one of the Vice-presidents of the Deutsche Forschungsgemeinschaft. In writing this commentary, the author has co-operated regarding its contents with Gerhard Eigenberger, Institute for Chemical Process Engineering, University of Stuttgart, also a Vice-president of the DFG.

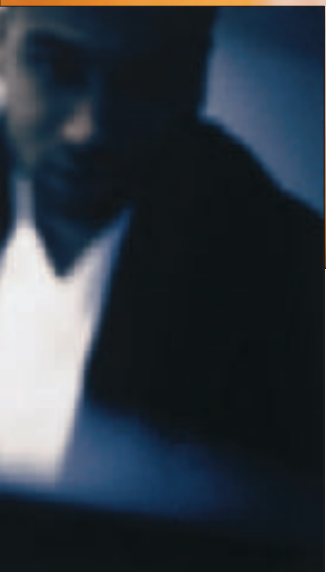


The modern woman has an excellent educational biography, but a comparatively lean professional one. Girls make up over 50 % of "Abitur"<sup>1</sup> students, but the percentage of females declines continuously from university degrees (around 42 %) to Ph.D. (around 32 %), and to "Habilitation"<sup>2</sup> (around 14 %). In the top posts in business, academia and politics women still have only a marginal status. Despite the fact that there have never been so many

women holding top positions as there are today (estimates vary between eight and eleven per cent), the increase in their percentage is rising much more slowly than might be expected from the numbers of women being educated. The ideas, theories, statistics and cross-sectional data on the possible reasons for these discrepancies are legion. Person-orientated approaches question the professionally relevant variables distinguishing men from women, for example, whether

# Only at the Start is Everyone Equal

*The careers of men and women still take different paths.  
The career patterns of male and female academics also differ.  
Scientists are studying and comparing the reasons for this*



In the transition from middle management to top posts there still appears to be an impenetrable "glass ceiling" for professional women.

women pursue different professional interests, or have different traits or skills, whether their careers are less important to them than they are to men. Contextually-related approaches emphasise unfavourable social framework conditions for combining the pursuit of a career with having a family, such as the lack of whole-day schools, or the individual reservations harboured by employers regarding women in career positions. Especially in the transition from middle management to top career posts there appears to be an impenetrable "glass ceiling". Finally, transactional approaches

stress the interplay between these individual and contextual conditions with respect to career development, embracing such points, for instance, as differences in the processes of en- and discouragement, or conflicting chronological overlaps between the life tasks (phase of professional establishment and the simultaneous bringing up of small children).

The validation of these approaches requires prospective longitudinal studies. These studies involve analysis of the long-term development of a respondent group with respect to particular areas of interest.

One such longitudinal study is the DFG-supported Erlangen Profile Study (BELA-E). The participating scientists are studying the career development of academics of both sexes over an extended period of time. In the course of two sets of surveys (graduates of the years 1994/95 and 1996/97), written questionnaires were sent to approx-

imately 2,000 graduates of both sexes covering the entire spectrum of disciplines at Erlangen-Nuremberg University. Amongst the aspects investigated were private and professional life-planning, self-assessment, attitudes and motives. The same individuals were then surveyed a second time around one and a half years post graduation, and a third time three years later. The fourth set of surveys is currently in process.

It is planned to repeat these surveys at longer intervals, which will enable us to describe, and partially also to explain, long-term individual career patterns.

Regarding the career patterns of men and women, we assume that there is a gradual "parting-of-the-ways" effect, in other words, the differences in the professionally relevant variables immediately post graduation are negligible, and the entry upon a career takes a basically similar form. But then comes a gradual parting of the ways in their career development. This parting of the ways is particularly marked in the case of mothers, whereas for women without children and mothers with day-care for their children it is much less marked and occurs only later on. We hypothesise that, in first place, this gradual parting of the ways is nurtured by contradictory role expectations imposed on women both by society and the women themselves. On the other hand, we assume that even in the case of highly ambitious and appropriately dedicated women "glass ceiling" effects can still be observed as their careers develop. Below are some selected results from the first three surveys.

Directly following graduation, all the respondents considered their profession to be just as important in the planning of their individual lives as their private life. The differences between men and women in the values and goals they intended to realise in the course of their careers were negligible. The same was true with regard to professional self-confidence. There were also no sex-differences in grade point averages or in study duration.

Differences concerning aims in life set by men and women were negligible as well: love, achievement and friendship were the top priorities, whereas power and prestige were only "also-rans". Regarding their ideas on private life, there was a high degree of concurrence with respect to the wish for partnership and children. Differences between men and women emerged with respect to child-care preferences. Around one third of the female graduates (34 %), but only a very small percentage of male graduates (2 %), were prepared to make any clear reduction in their working time if they had a baby. Men were generally more sceptical regarding the reconciliation of career with family life, and they were less in favour of equal burden-sharing in family work than were women.

In the second questionnaire various indicators of contemporary professional success were assessed and related to the measures of the first survey. According to these data predictors of a successful career start were high professional self-confidence, a short study duration, a good grade point average, and career-related goals embracing both status and power aspects as well as aspects of learning and achievement. These relationships are the same for both men and women. At this stage, childless women are similarly successful as are men with and without children. Mothers, in contrast, often stay at home with their babies.

Regarding the development of professional values there is one important difference between men and women: men showed an increase in career-, prestige-, and power-orientation from the first towards the second survey, whereas women remained unchanged. Consequently, well over half of the men, but only one third of the women, were convinced that their careers would lead them upwards.

Analysis of changes in personal variables is also interesting. For example, a successful start to a career causes a concomitant rise in "instrumental" qualities, such as decisiveness, assertiveness, and general activity both in men and women, whereas a less successful one leads to a decline in these qualities. Success does – to a certain extent – affect personality.

By the time the third survey was taken, 90 % of all respondents were in occupations adequate to their education (78 % in industry and commerce, 12 % in universities or research institutes). Also, three years after graduation a person's professional self-confidence, his/her achievement-related goals and his/her grade-point-average were significant predictors of career success.

Women, again, were less successful in their profession if they had small children. 96 % of the fathers, but only 40 % of the mothers in our sample held occupational positions adequate to their education. Regarding respondents without children, the figure was 87 % for the women and 92 % for the men. [The small difference of 5 % is not due to the respondents' study majors].

Thus at the beginning of their careers, parenthood is indeed the most important determinant for the divergent career development of male and female academics. The figure of 40 % unemployed mothers is still higher than the figure of 34 % women, who had from the start decided to stay at home whilst their children were small. Contradictory role expectations both from society and from the women themselves seem to be at work here. It is true that the figure of childless professional women academics (at the time of the third survey 80 % of the

female respondents with an average age of 30 were still childless; in the case of the – more or less same-aged – men, 78 % were still childless) were similar to that of the men, but these women viewed their professional future with clearly less confidence. In some fields they were also exhibiting signs of discouragement, for example in Medicine and technical disciplines, which was not the case with their male colleagues.

In summary, the results so far suggest a "transactional" understanding of the partially different career development of men and women: there are no

starting conditions that differ between male and female academics; neither are there any clear disadvantages for non-mothers to which women at this stage of their careers might be exposed; instead this gradual parting-of-the-ways effect in career development is a process which is promoted by the contradictory role expectations directed at well educated young women, the contradictory role ideas of the women themselves, the sceptical attitudes of their partners to the reconcilability of career and family, and discouragement processes in professional life. No "glass ceiling" effects can as yet be discerned in their careers. Finally, the demographic aspect must be stressed: young female academics are only going to achieve similarly good integration into their careers as their male colleagues if they are prepared to postpone their desire to have children until they are past thirty years of age or, possibly, if they refrain completely from having children.

*Prof. Andrea E. Abele-Brehm  
Universität Erlangen-Nürnberg*

<sup>1</sup> Abitur – the school leaving examination; general qualification for university entrance  
<sup>2</sup> Habilitation – qualification as a university lecturer or professor

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### A poor start to a career reduces activity, decisiveness, and assertiveness

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### Well over half of the men, but only one third of the women, are convinced of their chances of promotion

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# Of Krauts and Frogs: Stereotypes and their Uses

*Seen through the eyes of an Englishman travelling in 18<sup>th</sup> century Europe: historical caricatures and illustrations provide an unexpected insight into contemporary and current clichés and their contexts*

Sauerkraut and sausages, roast beef and eels, cheese and herring or frogs, snails and garlic – the culinary preferences in the various European countries have apparently been familiar features since time immemorial, yet are still a field of national stereotypes today. How do such clichés arise, and what purpose do they serve? The telling pictures familiar in 18<sup>th</sup> century England, together with their origins and their traditions, furnish the key to answering these questions. In order to reconstruct the images in the minds of these Englishmen we examined over 500 pictorial sources from caricatures to anonymous satirical prints, children's lotteries and illustrations in history and geography books. These pictorial sources were augmented by political and ethnic documentation.

Following along the Grand Tour which Englishmen would have travelled in Europe in the 18<sup>th</sup> century we investigated the pictures they had in their minds of the countries with which England had cultural, economic and political relations. The journey started in the Low Countries, specifically in the province of Holland. Since the 16<sup>th</sup> century, the Dutch and the English had formed a Protestant alliance against the Catholic powers in Europe, and had also cultivated close trade relations with each other. Despite this, the picture of the Dutchman in the eyes of an Englishman was not exactly flattering: they were greedy, unreliable, totally self-seeking, lacked all honour and pride, and were of vulgar peasant origin. The background



An English caricature of "The German": stuffing down his sauerkraut, in his voracity he has bound the tablecloth round his neck as a serviette

to this stereotype of the greedy and opportunistic Dutchman was the political situation in Europe: in 1579 England had stood by the Dutch against the Spaniards, but later on the Dutch had not repaid this loyalty. This lack of loyalty and integrity was to become a constant source of criticism by the English. In the eyes of an Englishman, the Dutchman's appearance was in line with his peasant origins: he was plainly clad in baggy breeches and a round

Dutchman's hat. He was plump and heavy of stature, his facial features were gross and coarse. His stance was characterised by straight legs placed together, high shoulders and hands concealed deep in his trouser pockets. The passive sluggishness so portrayed can often be interpreted as political passivity, the simple clothing and the coarse facial features as a side-swipe at his alleged peasant origin.

The Englishman's concept of Germany was primarily influenced by his actual contacts with that country: the personal union between the House of Hanover and England, established by the coronation of the Elector Georg Ludwig von Hannover (1660 – 1727) as King

(George I) of England, ensured that English soldiers would protect the Electorate of Hanover, and that, in their turn, German soldiers would be stationed on the south coast of England as protection against the French. Hence, initially, the picture of the German in the minds of the English is that of the soldier, tall and strong, with a prominent moustache and, in individual cases, a striking similarity to Frederick II. His culinary attribute was the inevitable sauerkraut, but his preference for sleeping under eider-downs was also a national characteristic in the eyes of the English observer.

In addition to this picture of the German as a soldier, there was a further national stereotype in the form of the German as a natural scientist and faith-healer with supernatural powers. Germany was considered a dark and mysterious country from where pamphlets and broadsheets often carried details of out-of-the-ordinary events such as earthquakes, storms and celestial manifestations, murders and miscarriages, zombies and ghostly happenings. Germany was also a favoured scene for the gothic novels of the 18<sup>th</sup> and early 19<sup>th</sup> centuries.

In this context of the Mysterious, one figure made an indelible impression on the Englishman's picture of the German – Dr. Faustus. His story had not only been known since Christopher Marlowe's play „Dr. Faustus“ was first performed in 1594, but innumerable

broadsheets and chap-books had since made this sage from Wittenberg into the epitome of the German sorcerer.

But the most widely met of all nations in the English sources was Catholic France, England's arch-enemy. The rivalry between the two countries is more recent than might be supposed. In the 16<sup>th</sup> and 17<sup>th</sup> centuries, Spain was considered to be the major threat, both to English trade and to the Englishman's Protestant faith. It was only in the early 18<sup>th</sup> century, and then particularly during the Seven Years War (1756 – 1763), that such a well estab-

Pictures in the minds of Englishmen: caricatures in the shop window of a print-shop hold onlookers spellbound.

lished stereotype of the Frenchman formed: a stylish, mostly aristocratic, dandy, consumed by his elegant appearance and the numbers of his amorous conquests, effeminate and weak. This association with femininity is illustrated by a common motif – the Frenchman gets the worst of a brawl with a London fishwife. In this respect fish – in contrast to “manly” roast beef – has a feminine connotation, and the Frenchman is made a laughing stock in his tussle with the woman. Critical commentaries are made regarding the absolute power wielded by the French kings and Catholicism. They are held responsible for the impoverishment and brutalisation of the people, personified in the haggard, rag-tag soldiers, whose sole pleasure is a weak broth.



Both pictures of the Frenchman, that of the elegant aristocrat and that of the woebegone soldier, co-existed side-by-side in English propaganda. Only during the French Revolution did the bloodthirsty soldier displace the stylish fops. The revolutionary sansculottes are haggard, bestial figures who will stop at nothing to achieve their ends. The English attitude to the Revolution is clearly revealed in their depiction of the sansculottes, in which the chaos and madness of the confusion surrounding the Revolution are unequivocally condemned. Rather unusually for national stereotypes, female figures are included in the picture of revolutionary France, as if

this would add to the impression of hysteria and madness prevailing at this time. But by around 1800, the Frenchman as a brutal soldier was already being replaced by the figure of Napoleon – a particularly provocative character for the caricaturists. After the Napoleonic Wars, the figure of the ragtag-and-bobtail soldier is once again replaced by that of the effete Frenchman, evidence of the fact that stereotypes are part of the history of mentality, and quite independent of any political events.

The highlight of any Grand Tour in the 18<sup>th</sup> century was Italy. The country, as such, was of only minor interest as Italy stood first and foremost for art and music. In London, Italian opera was considered especially modern and chic, and the sums of money being paid as wages to foreign castrati and composers were a thorn in the side of patriotic Englishmen. Italians were one and all associated with music, whether it was with opera or street music. In the political context, Englishmen accused them of undue subservience to Napoleon, and of being generally effeminate and cowardly in character.

Since the 16<sup>th</sup> century Spain, a major power, had been considered England's declared enemy. Its chief characteristics were the cruelty and brutality with which the Spaniards had acted in America and during the Inquisition. As Spanish power declined in Europe, attitudes towards the Spaniards changed, too. Although the stereotype of the Spaniard in his typical court attire of the 16<sup>th</sup> century remained – the large hat with its feather, the divided doublet and the short balloon breeches in black – the way in which he was being depicted became increasingly ironic. The Spaniard was considered to be old-fashioned and back-



In a brawl with two fishwives an elegant Frenchman, categorised as effeminate, gets the worst of it.

ward, too proud to dirty his hands with work, sober and serious, but prepared to fly into a rage over nothing, hot-headed, and ready to engage in a duel at the drop of a hat. Especially this latter characteristic could be attributed to the figure of the Spanish Capitano in the *Commedia dell'Arte*.

**S**o what functions does this type of stereotyping fulfil? How is it that clichés survive over such long periods of time? Fixed concepts of foreign countries and their peoples arise at the moment of confrontation between one's own group and an alien one, in other words, at that moment when we feel ourselves threatened and called upon to make a clear distinction between ourselves and some other identity. The growth of na-

tional ideas regarding foreigners in 18<sup>th</sup> century England, which in the struggle for power in Europe perceived itself to be under constant pressure and threat, furnishes evidence for this thesis. Thus one function of this stereotyping of ideas regarding foreign countries and peoples is to justify and confirm one's own identity. A second function also derives from the creation of stereotypes. Stereotypes arise in the confrontation with a complex and confusing world for which regulating categories and patterns are required. Thus they are attempts to produce a system of order which will reduce the ever-expanding environment to something which can be experienced and comprehended. Perusing the national clichés found in the English propaganda

sources leads inevitably to the picture the Englishman held of himself. In his picture of the Frenchman, the Englishman is presented as freedom-loving, self-assured, stable, pragmatic and natural. Whereas his (negative) picture of the Frenchman leads, through its contrasts, to a (positive) picture of the Englishman, the stereotype of the German serves a very different purpose. His soldierly qualities on the one hand, and his supernatural ones on the other, have no place in the enlightened English citizen's self-image, and are therefore projected onto his historical and political ally, the German nation. According to this, the German is considered to be almost the Englishman's alter ego. Hence stereotypes exist to help people to find their own identity within a complex world. Typical English, or typically human?

*Prof. Ruth-E. Mohrmann  
Silke Meyer, M.A.  
Universität Münster*

In many fields of performance small brains, such as that of the fly, can completely outclass large ones, to say nothing of technical systems. One aspect is the rapidity of visual image processing. Thanks to a broad spectrum of research effort we are now beginning to understand the neuronal mechanisms underlying this process.

Anyone who has observed two flies chasing each other will be conversant with the breath-taking aerial acrobatics these tiny pilots can produce. Whilst the human eye is scarcely capable of even following their flightpaths, the pursuer fly is quite capable of catching its speeding prize. To do this it relies to a great extent on its large, faceted eyes, which give it almost all-round vision. The continuous images these eyes deliver to its brain are evaluated in fractions of a second and transformed into navigating signals.

In order to learn what the fly sees during these breath-taking manoeuvres let us imagine we are sitting in the fly's cockpit. Immediately after take-off our environment starts to move past both our eyes from front to rear. Suddenly, the fly makes a sharp turn to the left, whereupon the environment in our field of vision moves temporarily to the right. Then, without any warning, we find ourselves approaching an obstacle. This appears to keep on growing in size, and its contours shift from the middle of our field of vision to the edges. By another sudden turn to the right, accompanied by broad image shifts to the left, the fly succeeds in avoiding the obstacle. Now the target, another fly, comes into view. It, too, is moving, but at a speed different from that of its environment. The resulting relative movement makes the prize visible against its background. The chase can begin.

A succession of images such as this is not confined to flies' eyes, but also occurs with our own eyes, for instance, when driving a car. However, the changes in the in-flight image-flow of flies is many times faster than that experienced by human beings. This is true even of Formula-1 racing drivers or the pilots of jet aircraft. Thus flies can

# In the Cockpit



# of the Fly

*Small brains can completely outclass large ones in their performance. Thus the fly has proved to be an outstanding model system for image processing in the brain*



make up to ten sudden turns per second, during which they reach angular velocities of up to 5,000 degrees per second – velocities which no human body could even begin to withstand.

The fly has proved to be an outstanding model system for tracing the activities in the brain which serve to process image-flows proceeding from the eyes. On the one hand, the visual system of the fly is optimised for the performance of this task and, on the other, experimental analyses can be conducted here employing a broad spectrum of methods. Every method of investigating neuronal circuits can be applied to a largely intact creature, thus making it possible to study the processes occurring in the brain during the actual reception of its natural sensory inputs.

**W**e are now at least able to study basic aspects of the neuronal circuits which evaluate the moving images on the retina of a fly. These moving images are not perceived directly by the eye. The fly's eye, rathermore, sees just a continuously changing array of brightness. From this, the brain has to go through a series of steps to evaluate information on the image movements. In this manner, the flood of information contained in the retinal images is reduced to its essentials.

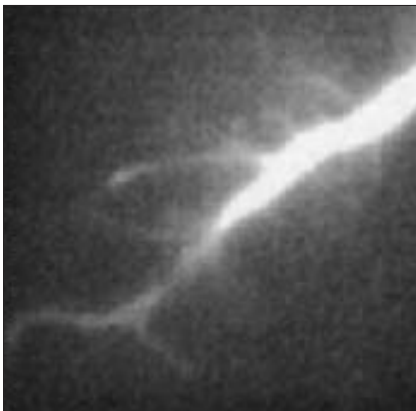
The light-perceptive cells on the retina of a fly only register the brightness of its environment. The next higher group of nerve cells, the local movement detectors, compare the brightness data of adjacent light-sensitive cells and react only to a spatial or temporal change in brightness. Movement is signalled when two adjacent light-sensitive cells report the same brightness value in immediate succession, for example, bright-bright. During this process, each motion detector reacts

Thanks to its spherical, faceted eyes, the fly has almost complete all-round vision. This enables it to pursue other flies in flight and at high speed.

with maximum strength to movement in a given direction. The information from numerous local motion detectors is summated by integrating neurons. These are able to recognise characteristic relationship situations, such as occur, for instance, when a flying body changes direction.

We gained our knowledge about this from studies based on relatively simple stimuli, such as black bars moved in front of the fly's eyes, whereby the neural networks for visual image processing were subjected to electrophysiological analysis. For this analysis, fine measuring probes are introduced into individual nerve cells to register their electrical activity. However, these experiments cannot tell us how information relating to the environment

The nerve cell of a fly has been filled with a fluorescent dye. The stained cell is most sensitive to small moving objects. Below: An image-creating process elucidates neuronal information processing. Left, the ramified exit region of a nerve cell can be seen. If something should move in the fly's field of vision, calcium will flow into the nerve cell. In the image-sequence this is revealed by the increasing intensification of the yellow tone.



in its normal context, for instance, when simply flying around, is processed.

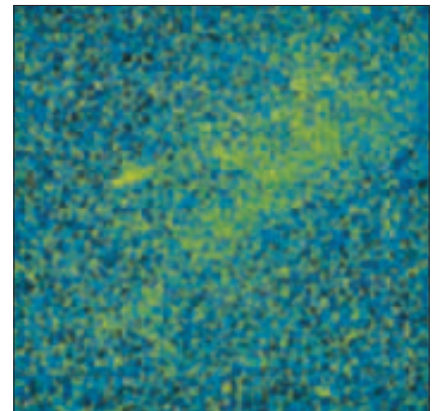
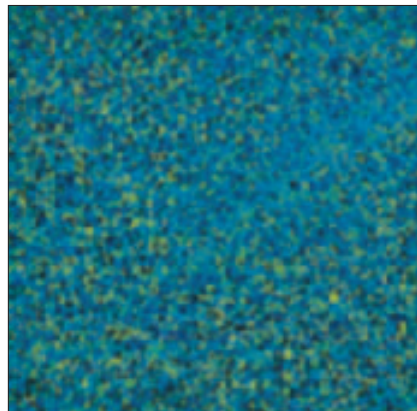
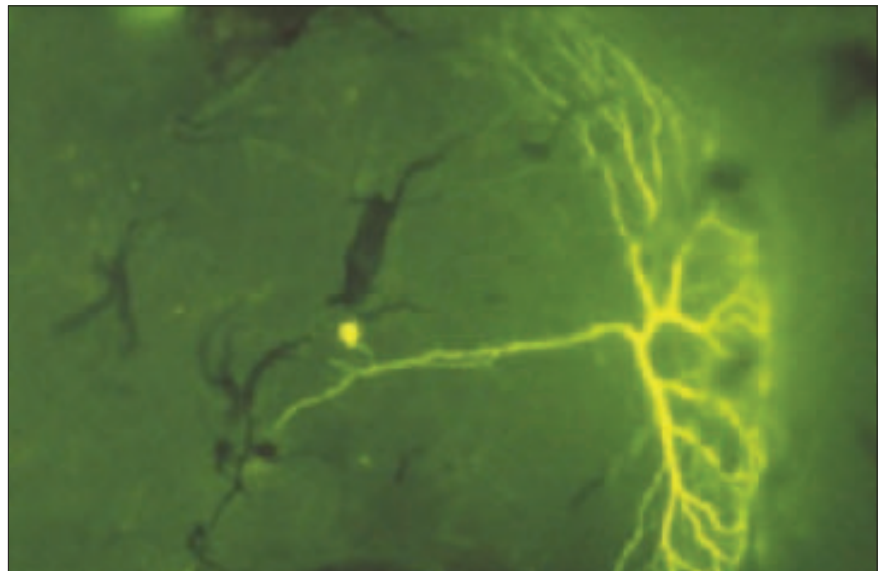
The scientist wishing to study how these natural visual impressions are processed must bear two aspects in mind. First, neurons, at least compared to technical computational elements, are extremely un-

reliable, in other words, they react very differently to the repeated presentation of a stimulus. Secondly, visual stimuli in real behavioural situations are not, as in an experiment, predetermined by an external source, but are determined by the manner in which the creature moves.

In order to study the neuronal processing of natural visual stimuli we developed a sort of panorama cinema for flies ("FliMaX"), which now, for the first time, permits the image-flow seen by flies in free

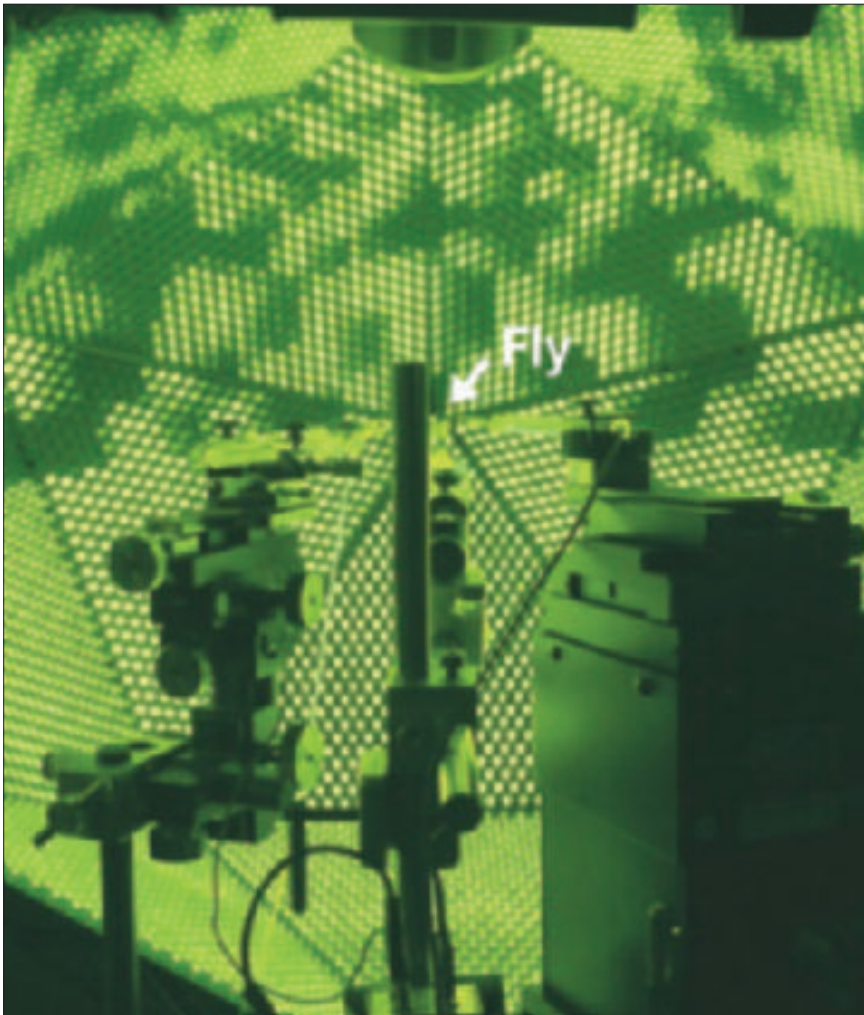
images is much greater than that of a human being. Hence the film in our "FliMaX" is played at a speed of 370 images per second. At this speed the image sequences fuse in the fly's eye to a natural impression as would be seen by the eyes during a rapid flight manoeuvre.

Current studies in the "FliMaX" suggest that the mechanisms for visual image evaluation in flies are only able to present the brain with the necessary information on the environment so rapidly and efficiently because they require rela-



flight to be relayed to a fly under physical restraint, and simultaneously to register the activity of its nerve cells. With human beings, sequential images of a cinema film begin to fuse into a natural impression already at 25 images per second. However, the temporal ability of the fly's visual system to resolve

tively few computational elements. Although these simple mechanisms do not function under every possible condition, they are nevertheless especially effective when the fly is within its normal behavioural context. The processing of the visual impressions is thus optimally adapted to the specific conditions of the



The "FliMaX" panorama cinema was developed specifically for studying the brain performance of flies. The fly is located at its centre and looks onto the screen. Fine measuring probes are introduced into its brain from behind.

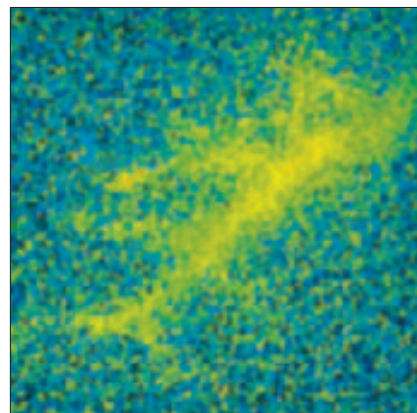
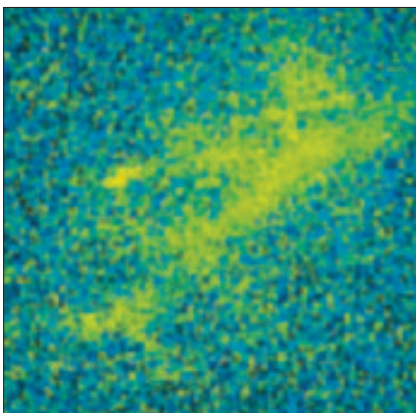
ing in normal behavioural situations. At the moment, we are continuing this development to transform our "virtual fly" into an autonomously acting agent capable of navigating in complex environments with degrees of efficiency and virtuosity similar to those of a real fly.

Even if the development of this "virtual fly" is being pursued primarily for reasons of scientific interest, the mechanism of biological information processing could provide valuable leads for the development of technical systems. This has, in fact, already happened in diverse study groups in Europe and the USA, where scientists are using models developed for parts of the motion vision system of flies to develop computer chips for use in robot control. Despite this, there is still no technical system at the moment which can meet the demands of flight control so quickly as a fly.

Mechanisms for autonomous navigation, the avoidance of obstacles and the pursuit of moving targets are of crucial significance in the technical sphere, especially when they are relatively simple and efficient.

This is the case with the fly, for it produces its performance with a brain weighing no more than 1 milligram(!). This is most assuredly only possible because the neuronal circuits have had a very much longer test-phase than is possible with any technical system. Or should 200 million years of evolution not have sufficed in the interplay of mutation and selection to lead to optimally economical and adequately sophisticated solutions for equipping the cockpit of the fly?

*Prof. Martin Egelhaaf  
Dr. Roland Kern,  
Dr. Rafael Kurtz,  
PD Dr. Anne-Kathrin Warzecha  
Universität Bielefeld*



fly's way of life. Whether these considerations are correct or not will have to be tested using detailed modelling. For this purpose our research group has developed a computer programme which simulates the neuronal processing of the retinal images of flies in free flight. In doing this, we took into account

what we had already learnt about neuronal processing of images, and the fact that nerve cells will not always react identically to the same stimulus. With the very first version of a "virtual fly" we were able to explain essential aspects of visual image processing, including those found under the conditions obtain-

# An Early Picture of Cancer

*Novel optical techniques are making it possible to visualise enzymes responsible for the spread of cancer cells*

In the age of the decoding of the human genome, our knowledge of the functions and dysfunctions of the human body has significantly increased. In the field of carcinogenesis, especially, many molecular-biological interdependencies have now been clarified, leading to the development of new therapeutic approaches.

Biomedical research is showing increasing interest here in image-creating techniques for visualising molecular processes in the human body. What we are learning from this can be used for the early detection and differentiation of cancer.

A study group at Harvard University's Center for Molecular Imaging Research has recently succeeded in developing a new optical image-creation technique for the highly sensitive detection of so-called "tumour proteases" in the body. The formation of these proteases, protein-splitting enzymes, is an early stage in carcinogenesis as they act like small scissors which "cut through" the surrounding tissue to create room for the cancer cells to spread. This promotes the growth of malignant cells in nearby vessels and, finally, metastatic dissemination.

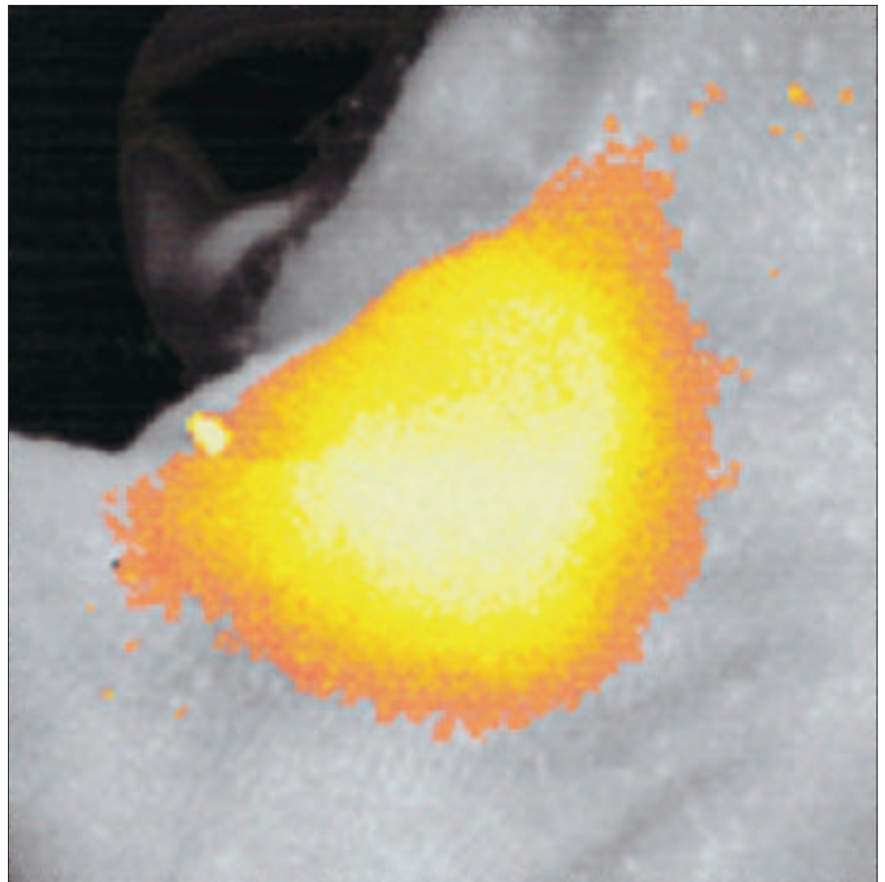
Intense activation of the contrast medium can facilitate the detection of a tumour. Our illustration shows the right-hand breast region of a nude mouse. The fluorescence has visualised a tumour approximately two millimetres in size.

Using "intelligent" optical contrast media, the study group succeeded in obtaining images of tumour proteases. The optical contrast media, similar to a small light bulb, are selectively "switched on" by tumour-associated proteases. In this manner, using a light signal, locations in the body can be detected where proteases occur. Scientists engaged in laboratory experiments have been able to recognise tumours in the submillimetre region.

These optical probes also made it possible to project individual types of protease selectively as images. This new technology is raising hopes of improvement in the differentiation of malignant excrescence. For, as a rule, a tumour is the more aggressive, the more enzymes it generates, thus increasing the risk of broad metastatic spread, and hence of patient mortality.

Scientists in a number of clinical studies are currently engaged in developing therapeutic approaches to inhibiting the functioning of tumour proteases. First results show that the so-called "protease inhibitors" are able to provide a useful supplement for chemotherapeutic medication. The inhibitory mechanism of these substances has already been demonstrated experimentally using the new optical technology.

Since light does not spread very effectively in tissue, the employment of optical contrast media on patients demands detectors which can localise optical signals within the body. In recent years, vital ad-





# A Treatise on Life with Camels

*Traditional herding cultures consider close social association with their animals to be a central pillar of their culture*

vances have been made in optical image-creation: firstly, significant progress has been made in light-creation using new laser technologies and, secondly, modern cameras can now register light signals with much greater sensitivity. To these technologies must be added the employment of innovative mathematical reconstructive calculations. For the first time these are enabling tomographic principles to be employed in optical image-creation, and cutaway sections of the body to be obtained which are comparable to those made in computer or magnetic resonance tomography. Taken in combination with the contrast medium technology described above, a three-dimensional registration of protease occurrence is now conceivable in the near future which would obviate any recourse to surgery.

In view of the light absorption in tissue, the most likely application of optical image-creation will be in the sphere of breast cancer diagnosis. In our initial clinical experiments we have succeeded in performing a cutaway section examination of the breast using so-called "diffuse optical tomography" (DOT). This technology will also, in principle, permit examination of brain and lung tumours or malignant tumours of the extremities.

Further applications will become possible when this technology is applied in conjunction with endoscopic or surgical diagnostic processes, such as in the optical presentation of minor intestinal polyps, the acknowledged precursors of intestinal cancer.

As supplements to current magnetic-resonance or computer tomography, these new technologies could furnish important additional information regarding other syndromes in which protease expression plays a role, such as arteriosclerotic changes in vascular walls in connection with the diagnosis and prevention of cardiac infarction or immunological diseases such as rheumatoid arthritis.

*Dr. Christoph Bremer  
Universität Münster*

Our society is characterised by a very divided attitude towards its domesticated animals. House pets, such as dogs and cats, are treated almost as fellow species in terms of affection and veterinary care – but emotional bonds with our farm animals are practically non-existent. Scientists, especially, are increasingly prone to regard them as mere machines whose existence can be expressed in terms of figures and productivity indices. Only since the BSE crisis began have the ethics of animal husbandry once again become the subject of debate.

An interesting and instructive contrast to this typical lack of emotion displayed towards our domesticated animals by our industrial and post-industrial societies is presented by the traditional herding cultures. Known in English as pastoralists, these are societies dependent upon livestock breeding for their existence, whose close social ties with specific species of animal are acknowledged as the central pillar of their culture. For these peoples, their animals are fellow creatures with whom they live in close physical contact, which command their respect and care, and to whose requirements they have adapted not only their way of life, but also their social structures.

Examples of such peoples are to be found in many African ethnic groups, such as the Fulani who, according to the myth surrounding their genesis, were created by God to look after cattle. Being the provider of all life's necessities, they revere the cow as their quasi "moth-

er". Other cattle-raising cultures, such as the Masai, the Dinka and the Nuer, and even the Hindus, have similar credos.

But cattle are not the only animals which enjoy the deep respect of many traditional cultures. For the Mexican Tzotzil Indians, for example, the sheep is a holy animal, and the single-humped camel, the dromedary, inspires enormous esteem in cultures which have specialised in its breeding. Such an attitude can be seen, for instance, with the Raikas, a Hindu caste native to Rajasthan in western India which has for generations been devoted to dromedary breeding. According to their belief, their founding father was specifically created by the god Shiva to care for the first dromedary, which Shiva's wife Parvati had just formed out of clay. Hence the Raikas of today still feel themselves responsible for the well-being of the camel, and it is inconceivable that they should slaughter them or eat their meat. For the Raikas, the use of the camel is in any case constrained by numerous "taboos". Thus, the milk may not be sold as it is reserved for their own use and can, at the very most, be given to the needy. An ancient law declares that "Selling milk is like selling children". The further processing of milk to yoghurt or cheese is unacceptable. Neither can the wool or the products of a dead camel – leather and bones – be used for commercial purposes. The sale of female animals is also frowned on as these are regarded as a sort of common property which may not be passed to anyone outside the caste. Camels may only 15



change hands as a wedding dowry. On the other hand, the sale of male animals and dung is allowed.

How did these – apparently irrational – taboos and restrictions on use arise? Are they religious in nature – are they a sort of passing on of the Hindu reverence for the cow to another animal, or are they a reaction to specific ecological and economic factors, which would make them rational in origin? In order to get to the bottom of this question, we first compared the Raikas' relationship to the camel with that of other camel pastoralists. This revealed that dromedary breeders, who inhabit the area from Mauritania in the west to the Indian Thar Desert in the east, can be divided into three main groups regarding the manner in which they utilise their animals.

In the case of the Cushitic tribal groups, such as the Somalis, Rendilles and Gabras in East and

North Africa, milk production is the prime factor, and animal-rearing is designed to maximise this product. All the other by-products are of only secondary importance. Although camels are also employed as beasts of burden, riding them is taboo. One special feature of the non-Islamised groups in this region is their use of the blood of living animals.

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### Amongst the Afars, the death of a camel is more bitter than the death of a son

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These tribes, too, have a highly ritualised relationship to the camel – for example, women and sexually active men are not allowed to milk camels, and many of the activities associated with camels may only be performed on certain days of the week.

In contrast to this, in Arabia and amongst ethnic groups of Arab origin in North Africa, a pragmatic multi-purpose system prevails; in addition to milk and meat production, the range of uses to which camels are put includes their employment as pack and riding ani-

mals, the production of dung as fuel, wool, bones, leather, and even the ticks are used for feeding the falcons. Depending on the requirement, practically every product – apart from the blood, which is forbidden by Islam – is utilised to varying degrees.

Amongst the few ethnic groups in Asia specialised in camel breeding, in contrast, its primary use is always that of a means of transport. Despite these differences, there is much common ground, too. Like the Raikas, all the other ethnic groups have also developed internal codes of conduct to prevent the purchase or disposal of female camels outside their societies. This is their way of adapting to the reproduction rate of this species, which is lower than that of human beings. Such regulations are thus a prerequisite for securing their own long-term survival. This explains why camels can only change hands when a certain phase of life begins, such as a birth, circumcision, wedding or on the death of parents.

The Raikas share their extreme reverence for the camel with other



The reproduction rate of camels is lower than that of humans. Hence the Raikas – like other ethnic groups – have developed canons to prevent trade with female camels outside their community. Consequently only male camels stand on sale in the camel market in Pushkar in India. Female animals are only brought to weddings for the bride to take into the marriage as her dowry.

ethnic groups. For the Ethiopian Afars, the death of a camel is a more bitter stroke of fate than the death of a son; in Rajasthan and amongst the Tuareg, the camel symbolises love; amongst the Arabs, only the camel knows the thousandth name of Allah. This high regard most certainly results from an extreme dependence which forges a bond between humans and their camels in their common struggle for survival.

But why is the dromedary in East Africa primarily regarded as a source of milk, whereas in India it is mainly used as a means of transport? In order to answer to this question, we traced the relationship between man and his dromedary back to its

origin – domestication – and reconstructed the way in which it had subsequently spread. The domestication of the dromedary took place in the south of the Arabian Peninsula in the third millennium B.C., but archaeological documentation is sparse. However, it appears probable that, apart from its initial use as meat, the possibility of utilising its wool and dung were also driving factors in its domestication. Even before the discovery of its use as a means of transport, the dromedary had appeared in the Horn of Africa, where its milking potential became recognised, and the outstanding adaptation of this newly domesticated animal provided a better basis for survival than was possible with any of the other species of cattle.

On the continent of Asia, the spread of the dromedary was primarily attributable to its military uses. Confronted by Moslem intruders, the maharajahs of the desert kingdoms in present-day Rajasthan discovered the potential of this animal for desert warfare, and initiated – probably only from the 17<sup>th</sup> century on – the systematic breeding of camels. This was then entrusted to the Raikas. Whether the specialised knowledge acquired by the Raikas developed locally, or whether it arrived in Rajasthan together with the dromedary from the west (Afghanistan or Iran), can no longer be ascertained, although some elements of their myths would suggest that the second option is more likely. The fact remains, however, that at the beginning of the 20<sup>th</sup> century, the maharajas ceased their camel breeding activities, and passed the camels into the possession of the Raikas. The military significance of the camel had now, of course, all but disappeared, but a new role emerged for it as a draught animal for two-wheeled carts, thus guaranteeing future sales. Under closer scrutiny, many of the restrictions placed on its use lose much of their mysterious character. They originated during the emergence of Indian dromedary herding, when this was unilaterally orientated towards the rearing of transport camels and embedded in an environment characterised by Hinduism, to the exclu-

sion of Islam. The slaughter taboo and the renunciation of any practical exploitation of the dead animal can be explained by the basic Hindu tenet, whereby these would breach the purity canons anchored in this religion. The limitations on the use of the milk arise from a variety of factors. Thus, intensive use of the milk would run counter to the system's explicit goal of raising the maximum number of young animals. Another reason for the ban placed on the use of by-products from the milk might also lie in the technical problems this would raise.

The example of the Raikas is an impressive demonstration of the fact

increasingly difficult for the Raikas to meet this demand. Over the past 20 years, the expansion of agricultural irrigation and the increase in nature preserves have severely restricted their traditional grazing grounds. Lack of grazing opportunities has led to a drop in the reproduction rate, and the meagreness of the income obtainable from camel breeding is driving many of the young Raikas into the cities as unskilled workers.

Herding cultures like that of the Raikas have always been the stepchild of politicians, and also of agricultural scientists and some development organisations which



Ancestors are depicted as camel riders and are so honoured, as here on this commemorative stone in memory of an especially revered ancestor.

that animal husbandry systems are not only characterised by agricultural and ecological conditions, but, above all, by the historical processes attending their emergence. They are complex structures which have arisen from the interplay of an ethnic group with its native philosophy, a particular species of animal, its ecological framework conditions, and its macro-economic environment. In modern Rajasthan camels are still in considerable demand as draught animals and it is becoming

hold these systems to be outdated and unproductive. Of course, their capacity for producing cash products, such as milk or meat, cannot even begin to compare with that of technically sophisticated high-performance systems. But if they are viewed as a whole, then herding systems are able to compare reasonably favourably. Unlike large-scale livestock farming they produce no environmentally harmful emissions or side-products – in fact, quite the contrary, the dung they produce contributes considerably towards the preservation of soil fertility. Concentration of animals in the hands of the Few is also avoided – thus maintaining rural incomes. From the aspect of animal welfare, moreover, they have the advantage,



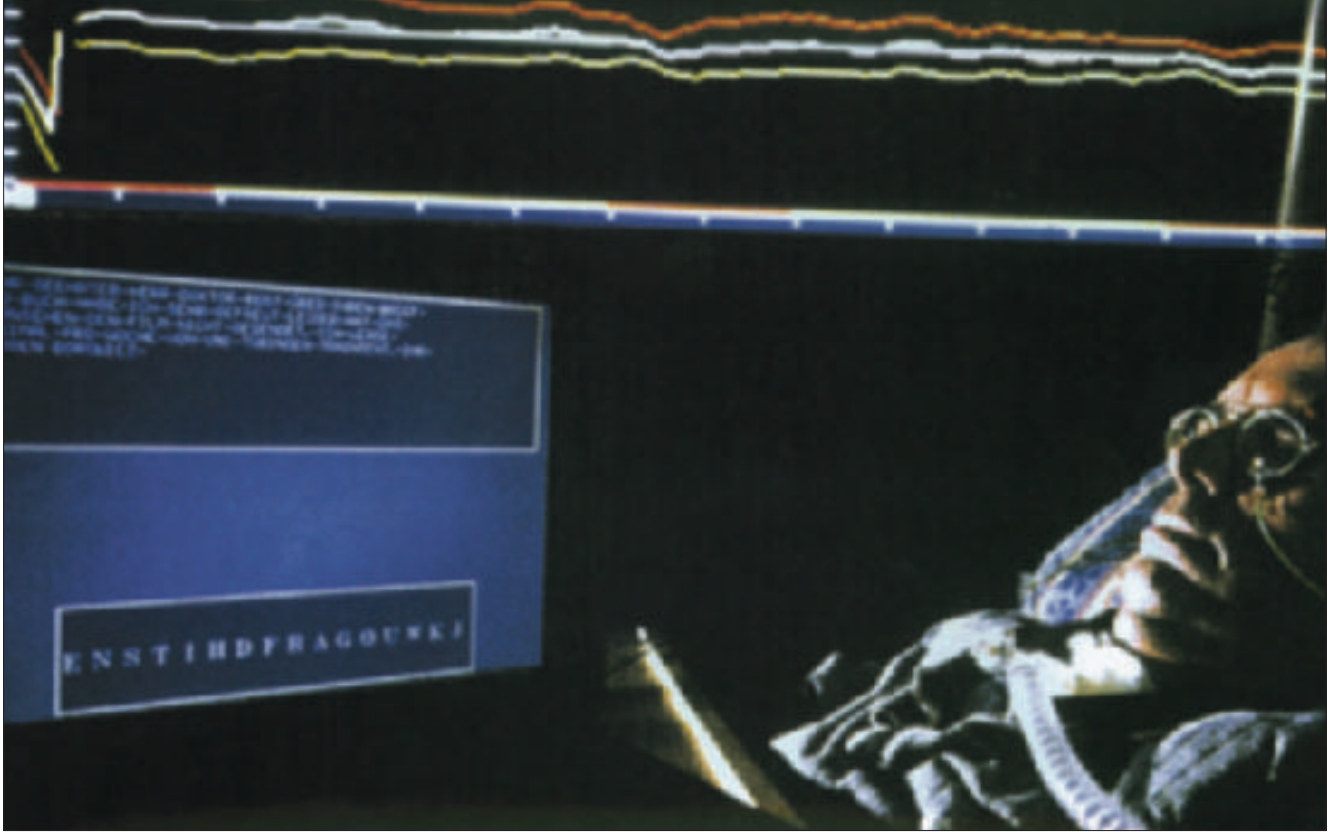
On the move in India: humans and their animals live here in an especially close community. For the Raika shepherds in the west of the country, for example, dromedary breeding is much more than a mere living.

as shepherding places few restrictions on the animals' natural patterns of behaviour.

However, as globalisation progresses, the pressure on these traditional systems will continue to rise. A "livestock revolution" is being predicted over the next 20 years which will match the eating habits of countries in the south to those in the north in terms of animal products. It is planned to meet the increased demand for meat and milk by establishing factory farming in urban environs – a development which lies in the interests of the north, as it will create a market for its surpluses of feed grains and high-performance animals. But it is also expected that this development will contribute to the economic decline of many traditional systems of animal husbandry, and their ethically superior attitude towards ani-

mals. In the interests of preserving levels of rural employment – and also as a useful model for a relationship between man and his domesticated animals – it would be worthwhile checking what potential there may be for reorganising these traditional systems along the lines of recognised ecological or organic farming methods. As far as Indian camel breeding is concerned, too, there is little interest in supporting the traditional system, and thus of retaining the camel as a long-term locally adapted source of energy, independent of any oil production. Camel carts are regarded as old-fashioned, and in the views of many politicians they should be replaced by tractors or trucks. But these people forget that the latter are only affordable for the rich upper class of society. For the poorer families, on the other hand, the possession of a single working camel guarantees, even today, an income sufficient to feed it – to say nothing of the ecological advantages it may offer.

*PD Dr. Dr. med. vet. habil.  
Ilse Köhler-Rollefson  
Ober-Ramstadt*



# Communication with the Locked-in

*An electronic system for thought translation is opening up the world again to the paralysed*

The thought of using electrodes to “tap” the human brain and making the thoughts running through it visible on a computer is a disturbing one for many people, conjuring up, for some, visions of Orwell’s “1984”, the description of a totalitarian political regime in which the ruler, “Big Brother”, could read the intentions and thoughts of his subjects. This concept, in animal experiments at least, has taken a step further towards becoming reality. In 2001 and 2002, scientists in two American research units demonstrated that by implanting just a small number of electrodes in the motor cortex, the “imagined” motions could be transmitted to a robot hand or a computer screen. In this

manner, the monkeys were able to serve these machines while completely motionless, just by using their electric brain potentials. Neurophysiological systems of this nature are called brain-computer interfaces (BCI).

Up to now only two human beings have so far had electrodes implanted in their brains. An American research unit implanted them into completely paralysed patients suffering from amyotrophic lateral sclerosis (ALS). The plan was that, using the nerve impulses registered by the electrodes, they would be able to choose from letters and words presented to them on a computer. One patient died before he had begun to communicate, the other one suc-

ceeded in choosing letters, but preferred to signal his wishes with a slight movement of his eyes.

In his book, “Diving Bells and Butterflies”, written shortly before his death, the French journalist Jean-Dominique Bauby described his experiences after suffering a stroke which completely paralysed every muscle in his body. Only by opening and closing his eyelids was he able to give “yes-and-no” signals. In his book, the result of a year-long dictation based on eye signals, he writes: “It is as if my body is being held captive in a gigantic invisible diving bell”. Large numbers of people find themselves in this dreadful situation, not only after brain injuries, but also in the course of progressive neurological disorders, too, and especially amyotrophic lateral sclerosis (ALS) in its advanced stage. These patients are often no longer capable of moving their eye muscles, and are thus precluded from any chance of communication, even though their perception, sense of touch and ability to think remain unimpaired. Such patients are described as being “locked in”, completely “walled up”. With ALS, all the nerve cells controlling voluntary movement die. Faced with the prospect of complete deprivation of contact with

their social environment, despite being fully conscious, many patients choose to die and refuse artificial respiration.

Thanks to a DFG research project which has been running for over two decades at Tübingen University, this situation has now undergone a fundamental change. In the course of this project a BCI system has been developed which enables locked-in patients, and others suffering from a critical inability to communicate, to continue their exchange with those around them. This system was designated "Thought-Translation-Device" (TTD) because, like the BCIs developed in the animal experiment, it receives the electrical brain potentials associated with thoughts and ideas, and translates them into signals for a computer. In contrast to the invasive animal experiments, which involved brain operations, and the rather un-

communication can be sustained. The decision regarding the prolongation of their lives can then be taken jointly by the patients, their doctors and relatives free from the pressure being "struck mute".

**B**ut how is it possible to communicate whilst circumventing the required muscles and without operating on the brain? The first step was to select some electromagnetic activity in the brain involved in the generation of thought and behaviour. This can be tapped into using small metallic electrodes located on the scalp, from whence, in the case of human beings and the

Only with the aid of his brain waves can a completely paralysed patient on artificial respiration select letters and compose them into a message (top section of the screen).

thought processes demanding a rise or fall in the level of excitation of the nerve cells in certain locations in the brain. Both mobilising (negative) and inhibiting (positive) potentials were observed in numerous areas of the brain, and their physiological significance analysed.

This was followed by many years of experiments in which healthy and sick people were to learn how to exercise voluntary control over these brain potentials. These experiments proved surprisingly successful, despite the fact that human beings are not able to perceive their own bioelectric brain activity subjectively. During this process, the patients observed their slow brain potentials displayed in the form of a ball of light on a computer screen, or they heard swelling or fading acoustic signals. The brain potentials were recorded from a series of electrodes placed at various loca-

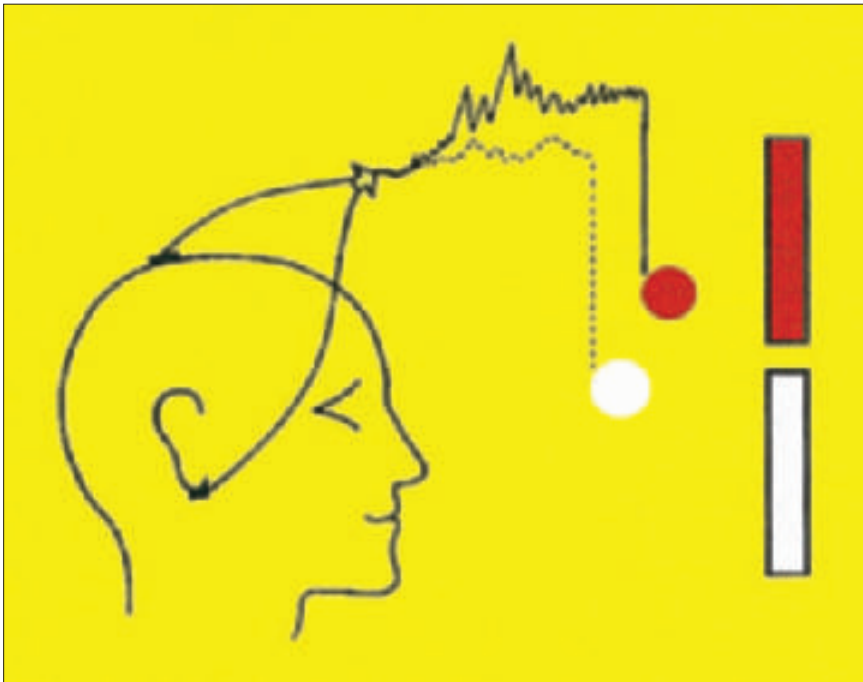


convincing invasive human experiments, the patients in this case are not required to undergo surgery. At this stage, the objection is often heard that it is pointless to prolong the lives of these incurables or help them to accept artificial respiration. Surprisingly, there is no difference in the long term between the quality of life of patients who are being artificially fed or who are on artificial respirators and healthy people if

higher mammals who have received psychological training, it can subsequently be generated on demand.

**I**nitially, these slow brain potentials were recorded under the most diverse conditions using electroencephalographs (EEG) and magnetencephalographs (MEG). The scientists in the Tübingen unit demonstrated that these slow potentials occur prior to behaviour and

tions on the head, and were then transmitted to a computer. A sound repeated at regular intervals indicated to the subject that he or she was to transform his or her brain potentials into the direction of the light or frequency of the tone within the next few seconds. If this was done, the ball of light moved to a bottom "goal". If the brain reaction reached a certain intensity, causing the ball of light to enter the goal, the person 21



was immediately rewarded by the computer. A friendly face smiled and informed him or her that they had been successful. This was repeated many hundreds of times an hour. As their achievements improved, so the degree of difficulty, in other words, the strength of the required electrical brain signal, was increased accordingly.

This psychological learning procedure, known as shaping, also promotes the improvement of achievements which occur only rarely in the early stages. The paralysed patients are trained up to the point where, after a series of sessions, they are able to generate 80 to 90 per cent correct brain potentials themselves. This may take a few days, weeks, or in some cases, months. After this, using an individual speech programme, they are in a position to communicate. This programme presents the test patients, for example, with the letters of the alphabet in the bottom goal on the screen. If the desired letter is in the message space on the screen, they have to use their brain waves to steer the ball of light or the noise into the bottom goal. If the brain reaction is sufficiently intense, the letter space is halved. If the desired letter is amongst the letters remaining on the screen, the patient has to score



The thought-linked slow electric brain potentials of completely paralysed patients are made visible on a computer screen. The signals are transformed into movements of a coloured ball of light or a tone which the patient can observe on the screen.

another goal with his brain potential, thus halving the space again. This process is continued until the correct letter remains alone on the screen.

If two or three letters have been selected the programme will automatically augment them to form the desired word. To be able to do this, the programme will have stored the personal vocabulary of the individual patient, gleaned from biographical information and his or her previous communications. In this manner, it takes a patient around 16

seconds to select a letter or word using his brain waves. If a mistake is made, the programme will query a correction of the last choice at 6-second intervals. With a new deliberately generated brain potential patients can undo their last choice or erase the last letter.

Six ALS patients have been trained so far, four of whom, after over a year's training, are now able to communicate verbally using the TTD. The other two have made a prophylactic start to training for as long as they are still able to communicate by motions of the eyes and head.

Thus, taken in its entirety, the research programme encompasses the training of patients on their home ground (these patients are not fit for transportation), the psychological and medical care of people who are completely paralysed and dependent upon artificial respiration and full-time nursing, the development of portable devices capable of interference-free registration of scarcely measurable brain waves in the microvolt range, the programming of training sequences, and a semantically and syntactically "trained" computer. The achievement of presentable results required years of co-operative studies by psychologists, natural scientists and doctors. The TTD is also currently being tested in Peru in Spanish, and in Israel in Hebrew.

The first BCI to be developed for human beings and tested on patients, however, has not yet achieved the high degree of specificity attained in the animal experiments using large numbers of implanted micro-electrodes. On their way from the nerve cells to the scalp, the brain potentials become scattered and weakened, preventing any accurate visualisation of intended individual movements and ideas. The scientists in the Tübingen research unit are co-operating with a unit in Albany (USA) in an attempt to solve this problem in conjunction with new technologies.

*Prof. Niels Birbaumer  
Dipl.-Biol. Dr. Andrea Kübler  
Universität Tübingen*



# How High can a Range of Mountains get?

*Rocks from the depths of the Earth can be found on its surface. They provide information on the thickness of continents and permit conclusions to be drawn regarding orogenic processes*

Of all the rocks which geoscientists have so far discovered in mountains, those formed under ultra-high-pressure conditions are certainly the most spectacular. Despite all that we have learnt about them over the past 15 years, they still remain an enigma for geoscientists in many respects. Just how high a mountain range can get is largely dependent on the thickness of the Earth's continental crust. This consists for the most part of light-coloured rocks rich in quartz and feldspar, whose mean density lies at around 2.8 grams per cubic centimetre. The continental crust is normally 30 to 40 kilometres thick and lies just above sea-level. It rests on the solid subcrustal mantle, approximately 100 kilometres thick, with a density of around 3.3 grams per cubic centimetre. This subcrustal mantle contains heavy minerals such as pyroxene and olivine. Taken together, mantle and crust form the solid external shell of the Earth, the so-called lithosphere. The radical density difference between the various rocks is also attested by the fact that seismic waves (earthquake shocks) move at higher velocities in the lithosphere than in the crust. The boundary surface along which this jump in velocity occurs is called the Mohorovičić discontinuity,

or Moho for short. In general, geologists assume that the Moho reflects the boundary between the different rocks of the crust and the mantle. Below the lithosphere lies the so-called asthenosphere, comprising partial mantle melts on which the plates of the lithosphere move. When lithospheric plates collide, the continental crusts are thrust over each other in the collision zone. In this manner an extra thick mountain root forms which causes the uplift of mountain chains. Icebergs might be used as an analogy for the uplifting of

mountains. The density of ice is approximately 90 per cent that of water. Hence an iceberg can float in the water with so-called isostatic equilibrium (flotation equality). This inequality in density explains why around nine tenths of an iceberg lie under water. The height of the iceberg is governed by the amount of light ice under the surface of the water: the more ice lies under the water, the higher the iceberg. Mountain ranges also act according to this principle. In this case, the light continental crust "floats" on the heavy mantle. Studies of seismic



In the course of orogenesis, the granites of the Dora Maira massif in the Western Italian Alps were transported down to great depths, where gigantic garnet crystals formed.

waves have revealed that the Moho occurs down to a maximum depth of 70 kilometres, postulating a mountain root of maximum this thickness.

Assuming a state of isostatic equilibrium exists between the mean densities of the Earth's crust and mantle, calculations have shown that a 70-kilometre-thick mountain root will create a mean elevation of the range of approximately four kilometres. As a rule of thumb, the mean elevation of a mountain range is half that of its highest peaks. At a mean elevation of 4,000 metres, the mountains peaks might be expected to be around 8,000 metres, as is the case with the Himalayas.

The study of rocks which have formed in the lower region of the mountain root through metamorphism, and have then reached the Earth's surface, also enables us to gain valuable insights into orogenic processes. Metamorphism in the geological sense means the transformation of rocks in their solid state under the influence of changing conditions of pressure and temperature.

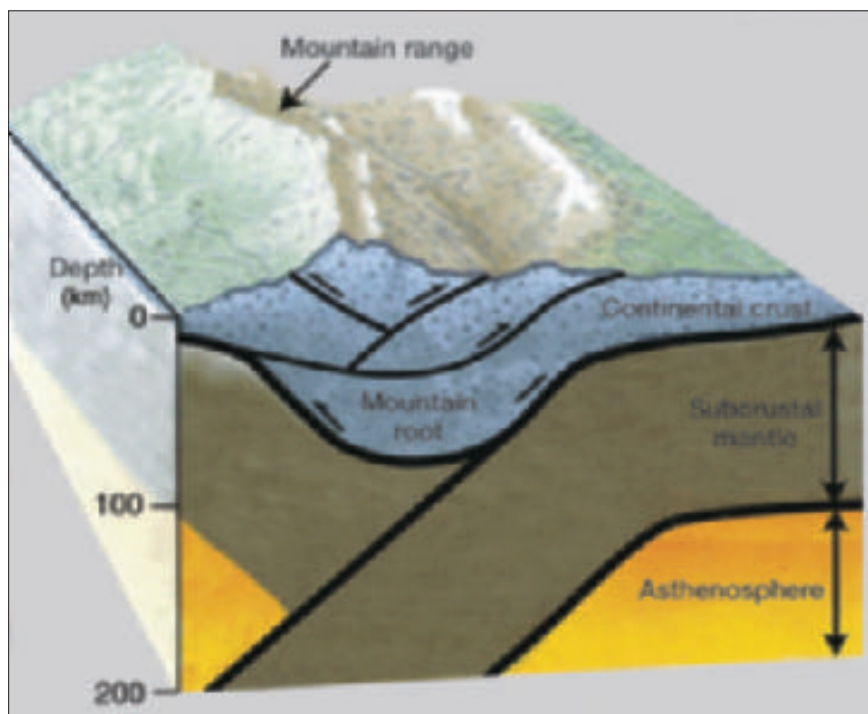
Given the density of the rocks in the continental crust (2.8 grams per cubic centimetre), the downward pressure exerted by the superimposed masses of rock increases by



The mighty Himalaya Mountains.

It is assumed that the underlying light Earth crust is around 70 kilometres thick. This crust (shown in blue in the diagram) together with the much heavier subcrustal mantle (grey-brown) forms the "lithosphere". The continental crust under mountain ranges is thicker, and forms the mountain root.

one kilobar every three and a half kilometres. In this case, rocks from the base of the mountain root would have undergone metamorphism at pressures of around 20 kilobars – high-pressure metamorphism. If the concept is true that mountains are borne on a mountain root of maximum 70 kilometres in depth, then





no continental rocks should be found in mountains whose mineral content was formed at pressures exceeding 20 kilobars.

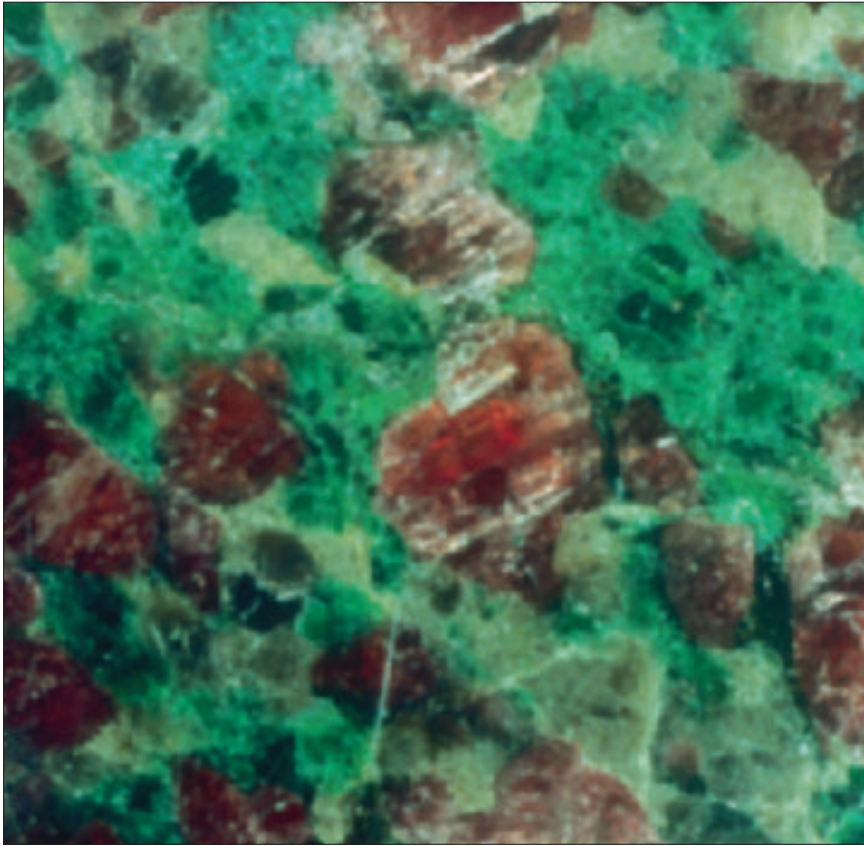
Viewed from this perspective, a discovery made in the Alps by the French geoscientist Christian Chopin must rank as epoch-making: he found some granites in

which, in the course of rock metamorphism, the mineral coesite had formed. Coesite is a high-pressure modification of quartz, which had up to then only been found in meteorite craters, where the impact of the meteors generates extreme pressures over a brief period of time. Later, Russian colleagues even

found metamorphically formed diamonds in rocks which had originally been close to the Earth's surface. Coesite and diamonds form at pressures exceeding 25 kilobars at depths of over 100 kilometres. So the question now is whether these ultra-high-pressure rocks were formed within the Earth's crust or in its mantle, and what conclusions may be drawn from this with respect to orogenesis. At a temperature of 800 degrees Celsius, coesite requires a pressure of 28 kilobars, and diamonds, over 35 kilobars. This is irreconcilable with an ultra-high-pressure metamorphism within the continental crust, where the normal rock density is 2.8 grams per cubic metre. At such pressures the crust would have had to have been 100 to 120 kilometres thick, which would not accord with a mean mountain range elevation of eight to ten kilometres and peaks of 15 to 20 kilometres. The continental crust, howev-



The iceberg principle also applies to mountain ranges: the more of the Earth's crust lying below, the higher they can become. With icebergs, too, the proportion above water increases, the more ice there is underwater.



er, is not strong enough to support such an elevation over periods of thousands of years. Within no time, the range would collapse under its own weight.

An initial hypothesis states that a part of the subcrustal mantle contributes to the formation of the lower part of the mountain root. Before any ultra-high-pressure metamorphism of continental rocks at the base of the mountain root can take place, ten to forty per cent of the subcrustal mantle must go to form the mountain root, and at the same time the subcrustal mantle rocks in the mountain root must have mixed with continental material. If the contribution of the subcrustal mantle to the formation of the mountain root reached 40 per cent, metamorphic pressures ex-

Eclogite, the heaviest rock in mountain ranges, comprises mainly garnet (red-brown) and pyroxene (green) – both very heavy iron-magnesium silicates. Below: Rocks (harzburgite and gabbro) from the upper mantle lying exposed on the Earth's crust in Oman.



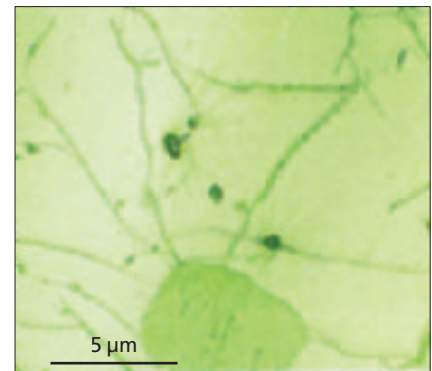
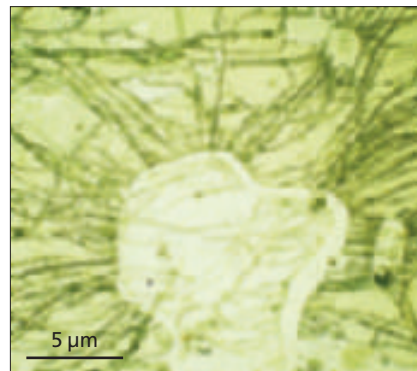
ceeding 40 kilobars could then be attained at the base of the root. Ultra-high-pressure metamorphism of the continental rocks would in this case take place in the upper mantle, in other words, in the lower 40 per cent of the mountain root.

If this model concept is correct, then an explanation must be found as to how the crustal rocks, after their metamorphism into ultra-high-pressure rocks, separate from the subcrustal mantle and are transported quasi "alone" to the Earth's surface. For the fact remains, that ultra-high-pressure rocks are not normally found together with mantle rock. Hence geophysicists postulate the possibility that, due to its greater weight, the lithospheric mantle part in the mountain root sinks into the asthenosphere below it within the space of geological ages. In the course of this "separation process" the light crustal rocks from the mantle separate and are taken back to the surface by the forces of buoyancy.

A second postulation assumes that the crust embraces a lower

lower crustal rock, in view of its seismic wave velocities, must be regarded as "sub-Moho" rock. The Moho would separate the thickened upper crust from the eclogitised lower crust, and not, as is generally supposed, the crust from the subcrustal mantle.

Assuming a maximum Moho depth of 70 kilometres, the original 25-kilometre-thick upper crust and the 15-kilometre-thick lower crust could be shortened by around 65 per cent. In this case, the mountain root would be 112 kilometres thick, which would give a pressure of ap-



Above, left: In this microphotograph, coesite can be seen in the centre of the illustration within the garnet. Above, right: Tiny diamonds can be found in many rocks, as in former granites from the Erzgebirge (Ore Mtns) in eastern Germany. Left: the pink-coloured minerals are garnet, in which the mineral coesite is enclosed.

crust approximately 15 kilometres in thickness, whose main constituent is heavy dark-coloured material with a density of around three grams per cubic centimetre. Our knowledge of the composition of the lower crust is very limited as it is seldom directly accessible on the surface. If the heavy lower crust were transported into greater depths, its original mineral elements would undergo a metamorphic transformation due to the rising temperature and pressure. The newly formed high-pressure rock would be eclogite, with a mean density of around three and a half grams per cubic centimetre. This would signify that eclogite, as a

proximately 33 kilobars at its base, enough to stabilise coesite. Diamond, in contrast, could only be expected at temperatures below 700 degrees Celsius. In this model, the mean elevation of the mountain chain would only be about one and a half kilometres. The extremely heavy base of the mountain root would most certainly be unstable and predestined to separate from the lighter portion of the mountain root. The eclogitised portion of the mountain root would possibly be so "soft" and unstable that it would immediately sink into the asthenosphere.

Finally, it would appear that the first model, due to the greater me-

methods of exploring the depths of mountain ranges will always permit the Earth's crust to be differentiated from the subcrustal mantle. On isostatic grounds it would appear plausible that a relatively great amount of heavy material (dark lower crust and/or subcrustal mantle) is involved in the build-up of the mountain root – if this were not the case, the mountains, in their efforts to reach dizzy heights, would very quickly implode. However, one question remains open: how do ultra-high-pressure rocks from great depths reach the Earth's surface?

Prof. Dr. Uwe Ring  
Universität Mainz 27

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Additional possibilities for assistance for qualified young academics exist under the programme for the promotion of university lectureship qualifications, the Heisenberg programme and the Emmy Noether programme.

In the new federal states in eastern Germany humanities research centres and centres of excellence have been established to improve the research structure in those areas. These are temporary institutions for promoting interdisciplinary research.

The DFG also finances and initiates measures to promote academic libraries, equips data processing centres with computers, provides large and small items of apparatus for research purposes, and reviews applications for equipping research centres with apparatus under the law for the improvement of university facilities. At the international level, it has assumed responsibility for representing science in international organisations. It co-ordinates and finances the German contribution to major international research programmes and fosters international academic relations.

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## Authors' Addresses

*Professor Dr. Andrea Abele-Brehm*  
Institut für Psychologie,  
Universität Erlangen-Nürnberg,  
Bismarckstraße 1,  
D-91954 Erlangen

*Professor Dr. Niels Birbaumer*  
*Dr. Andrea Kübler*  
Institut für Medizinische Psychologie  
und Verhaltensneurobiologie,  
Universität Tübingen,  
Gartenstraße 29,  
D-72074 Tübingen

*Dr. Christoph Bremer*  
Institut für klinische Radiologie,  
Universitätsklinikum Münster,  
Albert-Schweitzer-Straße 33,  
D-48129 Münster

*Professor Dr. Martin Egelhaaf*  
*Dr. Roland Kern*  
*Dr. Rafael Kurtz*  
*PD Dr. Anne-Kathrin Warzecha*  
Lehrstuhl für Neurobiologie,  
Universität Bielefeld,  
Postfach 10 01 31,  
D-33501 Bielefeld

*PD Dr. Dr. med.*  
*Ilse-Ulrike Köhler-Rollefson*  
Prageatostraße 20,  
D-64372 Ober-Ramstadt

*Professor Dr. Ruth E. Mohrmann*  
*Silke Meyer, M.A.*  
Seminar für Volkskunde,  
Europäische Ethnologie,  
Universität Münster,  
Scharnhorststraße 100,  
D-48151 Münster

*Prof. Dr. Jürgen Nehmer*  
Fachbereich Informatik,  
Universität Kaiserslautern,  
Gottlieb-Daimler-Straße,  
D-67663 Kaiserslautern

*Prof. Dr. Uwe Ring*  
Institut für Geowissenschaften,  
Universität Mainz,  
Becherweg 21,  
D-55099 Mainz

## Illustrations

Superbild (Cover); Querbach (p. 2); ZEFA-Ansgar (p. 4); ZEFA-Krüsselmann (p. 4/5); ZEFA-Vera Nowotny (p. 5); British Museum Catalogue (p. 7, 8, 9); ZEFA-Rauschenbach (p. 10/11); Universität Bielefeld (p. 12, 13); Bremer (p. 14); Köhler-Rollefson (p. 16, 17, 18, 19); Universität Tübingen (p. 20, 21, 22); Ring (23, 24, 25, 26, 27); Superbild/Sayama (24/25); Hüsken (back)



**T**hai students present themselves as "space girls"

in front of a poster from the "King Mongkut Institute of Technology" in Bangkok. Dressed in their homemade costumes, they are acting as hostesses at the opening of the international version of the DFG's exhibition "The New Way into Space" in Bangkok.