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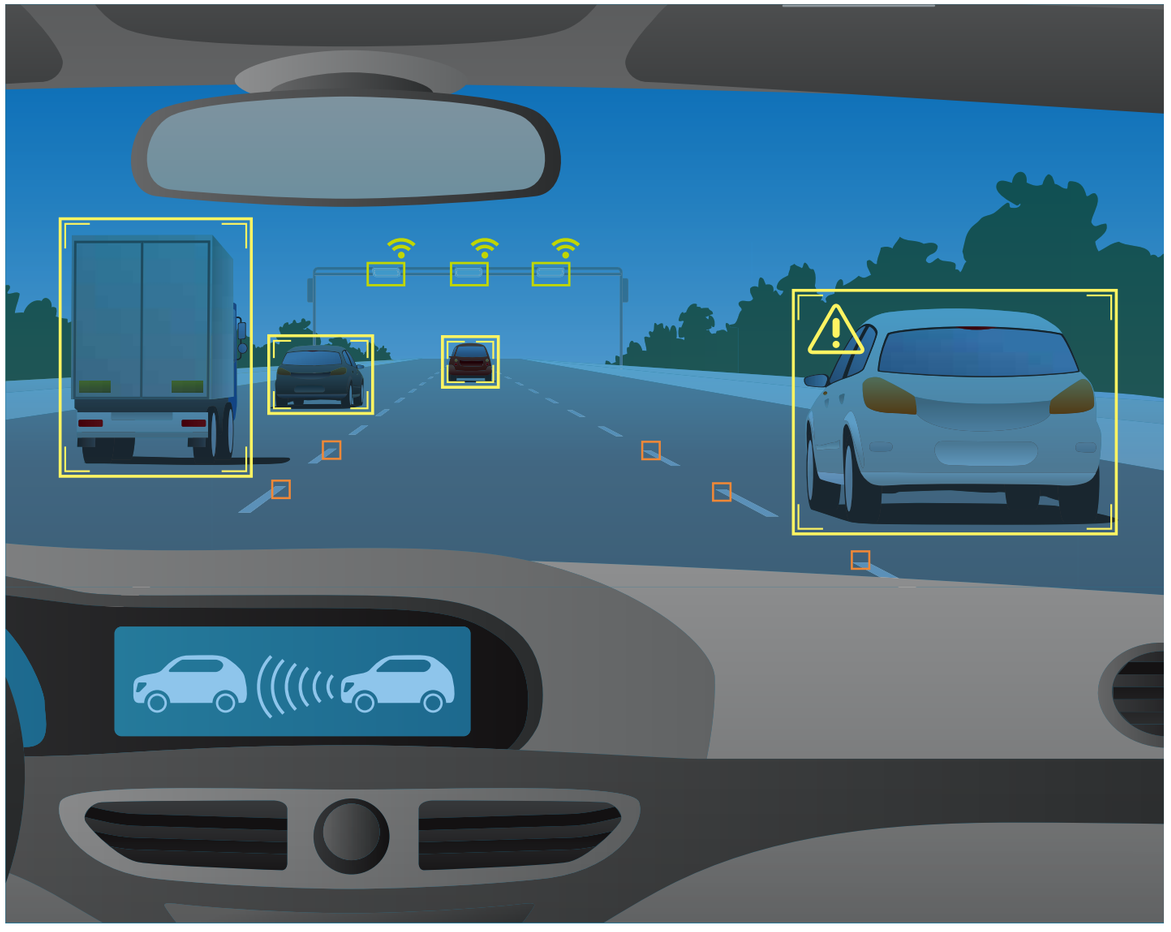

Sensor Technology for Everyday Life: Intelligent, Safe, Respectful | **Research System:** With Freedom Comes Responsibility | **CRISPR-Cas:** Attack and Resistance | **Maya City of Uxul:** In the Wake of the Great | **Biochemistry and Nutrition Research:** A Matter of Taste | **Dark Energy in the Universe:** Measuring the Invisible

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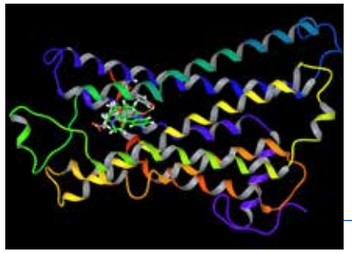
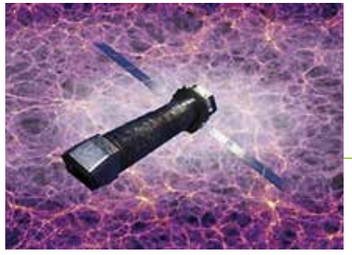
Cover: fotolia/chombosan

A head-up display with multi-channel information. Researchers are looking to improve intelligent sensor technology for everyday life, ranging from smart homes to smart cars.





Peter Strohschneider

With Freedom Comes Responsibility

It is incumbent on every individual in the research system – as it is on the system as a whole – to subject their own capabilities and limitations to critical reflection, particularly at times of increasingly rapid change in research and in the circumstances surrounding it. A statement on the occasion of the award of this year's Leibniz Prizes.

The DFG's Gottfried Wilhelm Leibniz Prize was awarded for the first time in April 1986 – 30 years ago. Since then it has developed very rapidly to become the most important prize awarded for research in Germany. Winners can use the very considerable prize money in any way they wish over a period of up to seven years for research projects which carry no expectations other than that they should be of outstanding quality.

The Leibniz Prize allows researchers freedom at a level rarely seen today, giving them the opportunity and time to structure their research as it suits them, with no pressure to submit proposals or supply reviews. The reason for this approach lies in the DFG's firm conviction that it is impossible to obtain scientific findings of the highest quality without such freedom.

It is clear that with special freedom comes special responsibility. Consequently, each year the award of the Leibniz Prizes gives rise to a number of questions: not only the question of what this freedom means and what can be done with it, but also how it can be used responsibly.

It goes without saying that responsibility in research has many facets and this responsibility is borne by as many people as there are facets. In a constantly expanding and increasingly complex research system, one of these facets is responsibility for the research itself.

This includes opportunity structures that will allow scientific curiosity and the methods leading to scientific findings to break new ground. These opportunity structures are partially of an intellectual nature. They are also of a financial and an institutional nature, which is where the makers of science policy and the research funding organisations, for example, have duties to discharge.

The DFG endeavours to fulfil this responsibility everywhere where excellent research requires funding: by constantly reviewing its own raft of funding instruments; by responding to the changing demands of research; by guaranteeing that review, assessment and decision-making procedures are fair and sound; and by formulating recommendations for the future development of the research system as a whole. Work on the DFG's funding portfolio is included here, as are its proposals for structuring a new initiative between the federal government and the federal states to develop the Excellence Initiative further.

A second facet of responsibility in research is the reliability of the research processes themselves. Research practice is and will always have to be prone to error. This is the risk associated with each attempt to move forward into new, uncharted or even unthinkable territory. A feckless approach to or violation of the regulations that are essential for good scientific practice is an entirely different matter. Too many results of research experiments nowadays appear to be non-reproducible, which has doubtless to do with the enormous refinement and complexity of modern experimental research. Furthermore, there must also be a dialogue on mismanagement in research – such as the preponderance of purely quantitative performance parameters – and also on scientific misconduct.

A third facet of responsibility in research is concerned with the direct or indirect consequences that scientific or scholarly knowledge can have for individuals as well as for society. The question of the extent to which research can be held responsible for these consequences must be revisited frequently. It might well be that the answers to such questions can be harder to find now than they were half a century ago. In many areas of modern science, the gap between research carried out at academic institutions and its application in a non-academic context is becoming so narrow as to be indistinguishable. There is a huge technological hurdle between the knowledge of atomic physics on the one hand and its application in nuclear power plants or atomic bombs on the other that must still be overcome (as demonstrated clearly by the conflict with Iran over the last thirty years). However, there is no longer a similar situation where digital algorithms and genome editing are concerned.

Problems with the dual use of research results are becoming increasingly acute: molecular plant genetics might be used to feed the world but it can also be misused for biological warfare; the linguistics of Arabic can improve our cultural knowledge yet also help with automated monitoring technology; psychology is required not only to treat neuroses, but also to perfect torturing techniques.

As research and non-academic applications come closer to each other, responsibilities shift even where scientific knowledge is used with the best intentions. Computer science and genetics, for example, are changing our world in such a way that we have barely started thinking through their consequences for the ethics of the individual and the moral implications for society: What is the subject? What about its dignity? What about its responsibility? How is power limited and distributed? How is society possible? And democracy? And research?

Responsibility for the consequences of unfettered research does not begin only beyond its boundaries. In modern research, the questions of its responsibilities become part of the research process itself. They are important, open-ended and difficult questions. And they are raised again and again. What conditions foster productivity and achievement in the best research? To what should consideration be given to ensure that bad research practice and scientific misconduct become as unlikely as they can be? What should research be permitted to achieve today? Must there be limitations to the quest for research findings? And where and how might they be drawn?

Questions like these apply to everyone and to the research system as whole. They are questions which can lead to a logical impasse yet researchers must not avoid them if they wish to fulfil their complex responsibilities. Indeed, only a research system which does not disassociate itself from these questions but reflects on them, even when it does not know the answers, is making the right use of its freedoms.

What is vital is an organisational structure of publicly financed research which gives research a framework through which to understand what it is doing and brings order to research practice without curtailing its freedoms. However, good role models are no less important: researchers, like the awardees of the Leibniz Prize, whose actions ensure reliable and responsible research because they understand how to combine a thirst for knowledge and a passion for discovery with the ability to engage in continuous self-reflection.

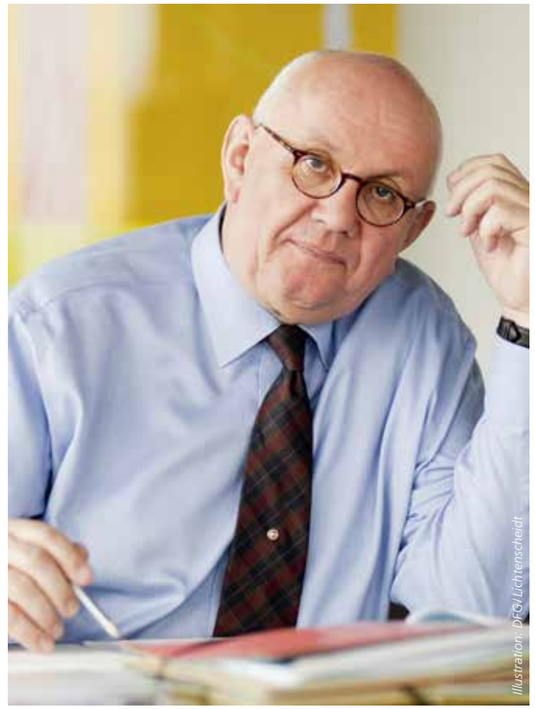


Illustration: DFG/Lichtenscheidt

Professor Dr. Peter Strohschneider
is the President of the DFG.

Abbreviated translation of a welcome address by the DFG President at the Leibniz award ceremony on 1 March 2016 in Berlin.

Africa: Strategies for Research Policy

Multinational conference in the Senegalese capital Dakar

Illustration: DFG/Bastorg

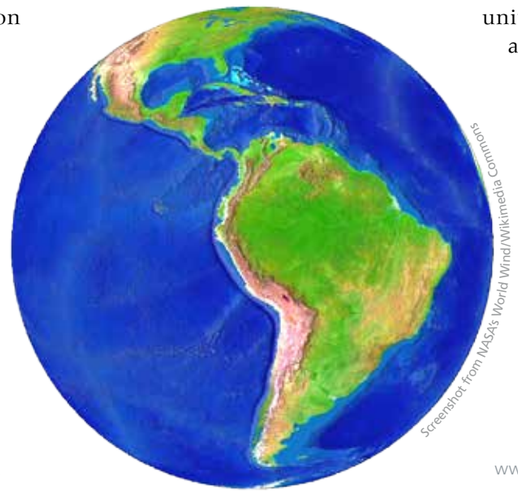
The next Einstein could come from Africa – this was the underlying premise and the motto of a pan-African conference held in Dakar, Senegal. For the first time, researchers in the MINT subjects from all over Africa came together in one place to attend the Next Einstein Forum where they met representatives of funding organisations and policymakers from every corner of the world. Discussions were held in a number of different panels, including a talk on how an African research policy might be formulated. DFG President Peter Strohschneider (centre) recommended that knowledge-driven basic research should be funded and an approach focussing on more than just the programmes should be taken. In his view, this meant that each country needed to take a balanced, science-led approach to decision-making.

The DFG had organised a workshop to bring together African and German mathematicians prior to the Next Einstein Forum and this collaboration will be continued into the future. **bb**

A Welcome Opportunity to Share Knowledge

Collaboration with Latin America – The first Experts' Day

The first Experts' Day on Research Cooperation with Latin America was held in the middle of December 2015 at the DFG Head Office in Bonn and brought together just under 70 delegates from universities, institutes and other research organisations from all over Germany. A lively interest was shown by research departments and international relations divisions within individual universities and institutions as well as researchers with direct associations with Latin America.


Screenshot from NASA's World Wind/Wikimedia Commons

As well as introductory talks on the status of the collaboration with the Latin American countries, there were presentations by individual researchers on their experiences of founding and establishing bilateral collaborative ventures. **RU**

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Animal Experiments in Research

New edition of the DFG information brochure published

The DFG Senate Commission on Animal Protection and Experimentation has published a revised version of the "Animal Experiments in Research" information brochure. Over 70 pages it provides comprehensive and generally comprehensible information on research and animal welfare in Germany. It is directed at members of the public with an interest in the issue, teachers at schools and universities, politicians, authorities and their representatives and also at researchers who use animal experiments in their work.

Animal experiments are essential to progress in basic research in biology and medicine and are used as a basis for the development of new technology, therapies and medication, for example. However, they are also associated with causing harm to animals and are therefore controversial.

In awareness of this, researchers have committed themselves to the 3R principle. This states that where possible, animal experiments should be replaced by alternative methods, the number of animals in experiments should be reduced and the experiments refined to reduce the harmful effects on the animals.

The German version of the brochure is available online; the English version will follow soon.

Illustration: laubertphoto

Discovering the phenomena of an era: *the topic at the heart of Steffen Martus' Leibniz Lecture in Bonn was "Discovering Tutelage: Philosophical Tastes in the Enlightenment". At the invitation of the Bonn University Club and the DFG, the Leibniz prizewinner and professor of literature studies at the Humboldt University of Berlin used the scholar and philosopher Christian Wolff as an example to illustrate the emergence of a new culture of argumentation and reasoning in the 18th century. Prof. Martus' inspiring delivery brought to life the way in which "Wolffianism" prompted a new approach to thinking in the philosopher's contemporaries.*

Andreas Kolb and Christian Köhler

Intelligent, Safe, Respectful

Detecting explosives, making driving safer, assisting with emergency rescue – sensors are being used in more applications all the time. Researchers are now developing automated systems that support users without intruding on their privacy.

A sensor system is adjusted to the colour calibration chart. This is achieved with a microcontroller board with a photosensor mounted on the sensor.

All illustrations and graphics: Kolb Working Group

It happens as she heads towards the living room. Every morning Maria Schmidt walks from the kitchen to the living room, a matter of a few metres. But on this particular morning she doesn't make it. A noise from outside startles her and she loses her balance, sways, falls to the ground and hits her head, losing consciousness. There is no one else in the house. 84-year-old Maria lives alone. No one saw her fall and there is no one there to help. Yet the emergency doctor is already on the way. The camera in the living room observed the fall and the sensor data processor identified the falling figure as a human body and alerted the emergency operator. Maria Schmidt lives to tell the tale – because her home is a smart home.

At the University of Siegen, the Research Training Group "Imaging New Modalities" is developing sensor systems for the smart home of tomorrow. Based at the Department of Electrical Engineering and Informatics and the NRW Centre for Sensor Systems (ZESS), the group has been funded by the DFG since 2009. The application for the research is civil safety and the central research area is sensors. The basic idea is to take an integrated approach to sensors and data processing. The development of new sensors and the processing of data are closely interlinked and the construction and use of sensors are coordinated to one another. The challenge is to develop processes that not only function in the lab environment, but also work in everyday life. Like Maria Schmidt's smart home, for example.

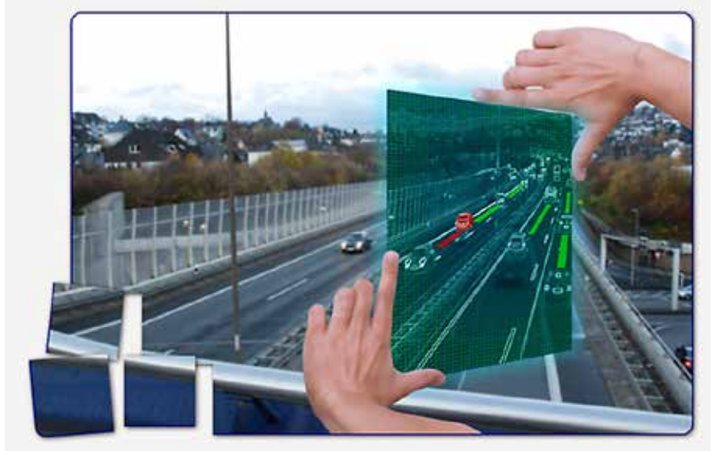
A system like this for the home can help older people to live independently for longer – an area of application known as elderly care. The researchers are working on the basic technology to make a smart home suitable for everyday life. Sensor systems don't just recognise people: they can also pick out a conversation from background noise and respond appropriately, for example by automatically dimming the lights to create a pleasant atmosphere. Sensors can also help to detect emergencies and initiate a response.

With the aid of modern computer graphics, a 2D photo becomes a 3D model. The model can even "map" missing areas, like the eye area of the face as shown here. Teeth are not represented in this model.

This is made possible by so-called multimodal sensors: different systems using different measuring techniques to obtain information about an object. Conventional cameras provide grey scale or colour images, thermal cameras distinguish a human body from other objects, and a terahertz system analyses materials. Material recognition with harmless terahertz radiation, which is between the optical and electronic wavelengths, is suitable for use in day-to-day life. A time-of-flight (TOF) camera also registers spatial depth. This 3D camera measures distance by sending out light pulses and recording the time it takes to travel to a target and back. The combination of these systems offers great potential, but there are also significant hurdles to be overcome if the combination of sensors is to obtain useful results.

For example, the researchers are developing a process to recognise a person's face even if it is only partially visible in a photograph with the help of a 3D model. In automatic face recognition based on 2D images the recognition rate depends to a great extent on angle, lighting and facial expression. The 3D morphable model technology in the project "Facial Recognition" allows a 3D model of a head to be produced, thus enabling much better recognition of individuals. In this model the different parameters of the 3D face model can be adjusted to match a specified photograph.

Above: The fast, reliable and safe recognition of hazardous substances is one of the research objectives of the Research Training Group "Imaging New Modalities". Below: Cars and road traffic are preferred areas of use for modern sensor technology. The image shows the measurement of the distance between vehicles on a highway.



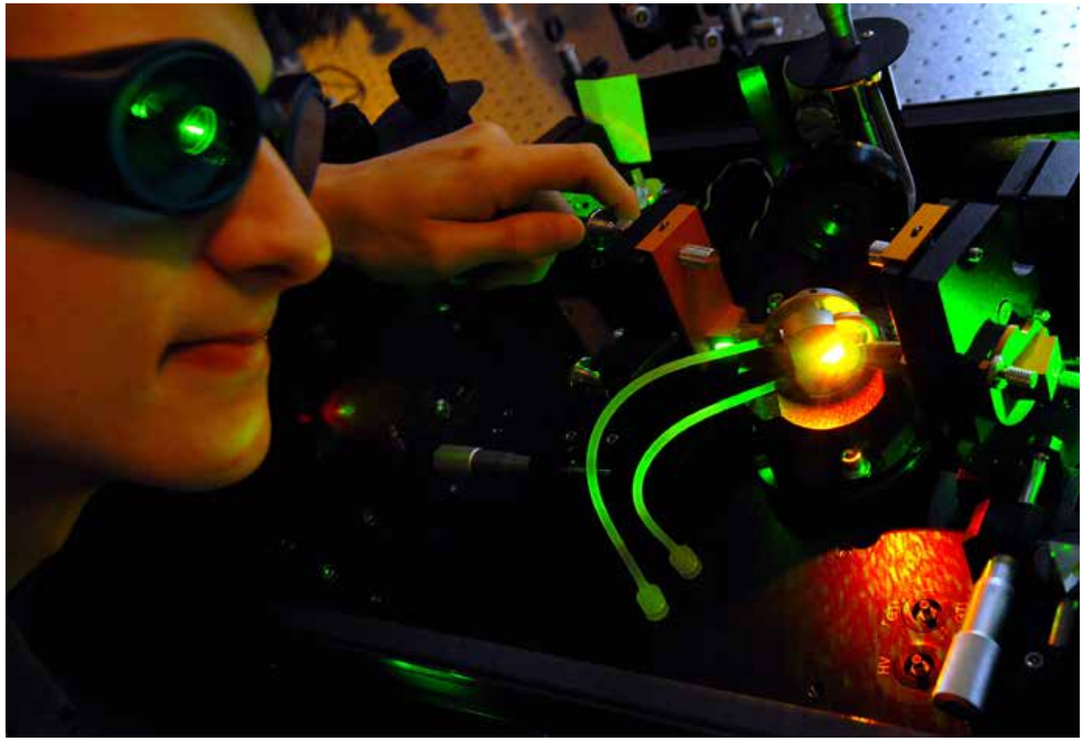
2D and 3D data are combined to allow faces to be automatically recognised from a wide range of angles and in very different kinds of lighting. The process makes identification easier, more accurate and more reliable. It can be used in all forms of traditional access control, for example admission to a building. One challenge is that it must not be possible to "fool" the system, for example with make-up or a mask. Another project focusses on the ageing of a

person and the associated change in their appearance. How can a face be recognised when it has changed because of wrinkles or other signs of ageing years after it was first photographed? Again, the objective is to enable robust, reliable recognition.

Highly automated sensor systems can also help to detect explosives or hidden objects, but they must satisfy very strict standards of information security, the protection of privacy and ethical considerations. This results in a dilemma. In the Research Training Group, ethical positions are explicitly considered to raise the researchers' awareness of them. Ethics courses enhance their awareness of the conflict between technical value added and personal freedom – because like many everyday objects, new technologies can also be used against people. A 3D printer, for example, is an innovative product but can also be used to copy guns. The aim of research and development is to make our lives safer and enhance quality of life by bringing safety technology into line with basic human needs. Obviously, technology delivers value added – but this must not be at the cost of individual privacy. For example, detectors at airports should only recognise explosives, not individuals. This avoids the need for direct control while protecting privacy. In this example the use of technology is justified because it does not restrict freedom.

The aim of developing intelligent sensor systems without restricting freedom was defined by the Research Training Group itself. Basic researchers have a duty to the public; there is no commercial sponsor and there are no specified development goals, only the primary intention to bring innovation to development processes. Researchers are motivated by the desire to develop new ideas, tread new paths and decide for themselves what path to take. Through methodical linking the group is able to continually initiate new processes within the individual research projects.

A terahertz femtosecond laser system generates terahertz (THz) radiation. Here, the system is being adjusted.



The magic of innovation: multispectral sensors with nanoscale structures are being developed to detect hazardous substances.

The excitement lies in the challenge of developing technology for the future: for example in cars. Road signs can be automatically recognised by cameras and the data then compared with the navigation system and digitally displayed on the dashboard. Stretches of road where overtaking is prohibited or there is a "no entry" sign are also recognised and accompanied by a visual and audible warning to help prevent accidents. Lane assistant, blind spot alert, adaptive braking system, automatic distance control or LED light system – these are just some of the applications, and the list of intelligent safety systems is long.

Various sensors can be used to register the spatial environment of a car. More recent requirements in interior and exterior monitoring demand better resolutions, for example to distinguish a harmless rubbish bin on the kerb from a child about to run into the road. In this area researchers are investigating the use of time-of-flight cameras, which in future could perform tasks inside the vehicle like controlling media systems or optimising airbag systems.

Intelligent sensor systems help to make our lives more comfortable, but first and foremost to make them safer. The researchers developing these systems must respond to very strict requirements, and the potential improvements to our everyday lives are far-reaching. Sensor research therefore plays an important role in the search for new technological solutions for the world of tomorrow.

Prof. Dr.-Ing. Andreas Kolb
holds the Chair of Computer Graphics and Multimedia Systems and is the spokesperson for Research Training Group 1564 "Imaging New Modalities".

Dr. Christian Köhler
is the coordinator of the Research Training Group.

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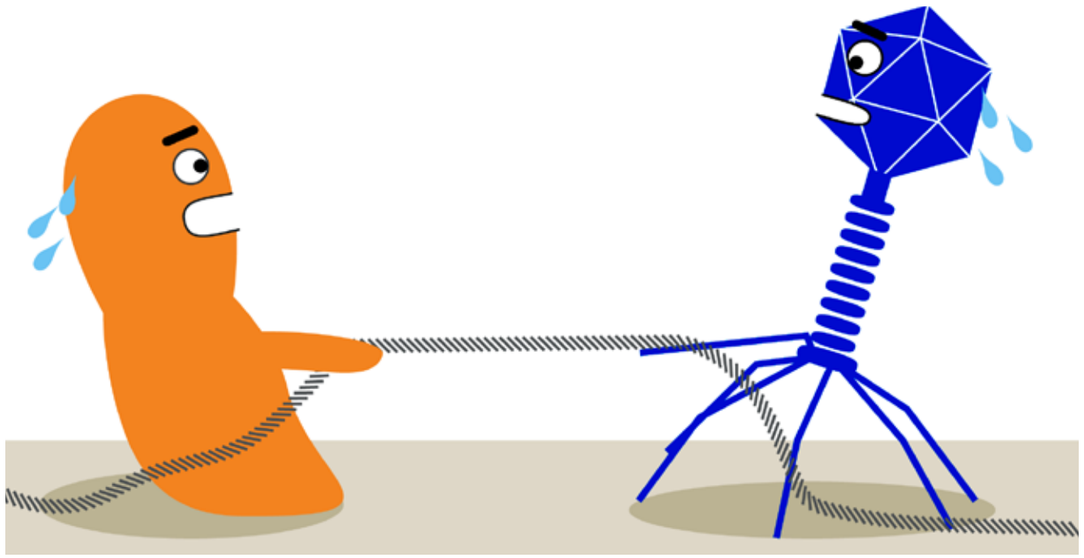
Anita Marchfelder

Attack and Resistance

CRISPR-Cas, identified as the defensive system used by single-celled organisms against viruses, is now being used as a genetic cutting tool. But how does this immune system, with its astonishing capacity to learn, actually work? A group of researchers is seeking to understand the fundamental mechanisms involved.



It's one of the oldest battles for survival on Earth. It is fought in salt lakes, hot springs and permanent ice: as bacteria and archaea defend themselves against powerful armies of viruses. To survive, the single-celled organisms need a few tricks up their sleeves. It has been known for some time that they have developed a range of strategies to prevent the docking and injection of viral genetic material. They can also destroy DNA that has successfully penetrated the cell or commit altruistic suicide to save the population.

But few would have guessed that bacteria and archaea possess an immune system capable of learning – and one that is inherited by the next generation. This defensive system, known as CRISPR-Cas, is what interests the DFG Research Unit "Unravelling the Prokaryotic Immune System".

But first things first: how does CRISPR-Cas work? The principle is a simple one, but the details are hard to understand. When a single-celled organism has survived a first attack by a virus, it incorporates parts of the viral DNA into its own genetic material – a kind of "wanted poster" of the enemy. If the virus approaches the cell or its offspring a second time, Cas proteins step in to counter-attack it and cut it. The unwieldy acronym CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats and refers to a particular genomic region where repetitions of sequences are followed by variable sequences or "spacers".

These spacers are the remnants of viruses and plasmids (small, usually ring-shaped, double-stranded DNA molecules) which have previously attacked the system. In close proximity to the CRISPR locus are the Cas protein genes (Cas stands for "CRISPR-associated"). If a (known) virus attacks the organism, the spacers and sequence repetitions in the DNA are translated into RNA molecules which, together with the Cas proteins, keep the attacker in check.

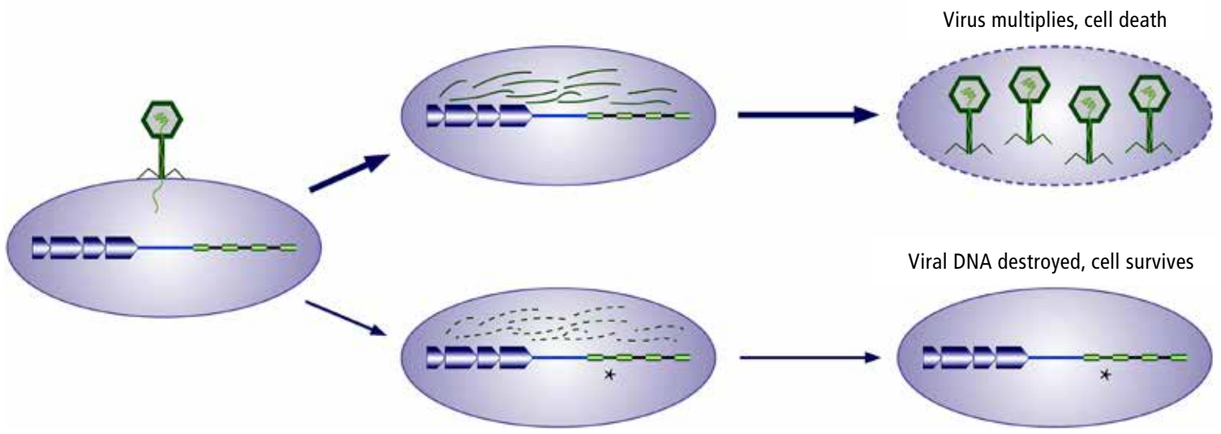
These remarkable sequences were first noticed by a group of Japanese researchers in the late 1980s. But it would be more than 15 years before their similarity with the attacking virus DNA was noticed and researchers began to suspect that this could be a previously unknown immune system. This has since been confirmed, and the Research Unit has made an important contribution to the fundamental understanding of CRISPR-Cas.

Over the last three years, the researchers in the group have compared the CRISPR-Cas variants of different bacteria and archaea. The more of these defensive systems are studied, the more natural variants are discovered. The group has studied CRISPR-Cas in various bacteria, for example cyanobacteria, and also in archaea. In the domain of the archaea, almost every organism has at least one individual CRISPR-Cas system. Archaea, which most people remember from school biology lessons, are single-celled organisms (prokaryotes) which have many similarities with eukaryotes (cells with a nucleus, like those in the human body) and were only recently identified as possible direct precursors of eukaryotes. The research team was able to describe both general and individual characteristics and also unravel the structure of central Cas proteins.

For their investigations the researchers use methods from molecular biology, genetics and biochemistry. There are seven subgroups focussing on microbiology, bioinformatics, structural biology and mass spectrometry and four associated groups, all of which work closely together. Structural biology and mass spectrometry investigations in the laboratory are essential in the unravelling of the structures and functions of Cas proteins. Not all of the jobs of the Cas proteins involved are yet understood, but it is assumed that they have other, currently unknown functions within the cell. Using bioinformatics methods it is possible to compare different CRISPR-RNA sequences and classify new CRISPR-Cas systems.

The studies show that basic research is not so very far removed from practical applications. The story of the discovery of CRISPR-Cas is continuing to be written in real-life contexts. Researchers in the dairy industry were looking for a "vaccine" for

Schematic representation of an infection with and without CRISPR-Cas defence. If a virus enters a cell, it can multiply inside the cell and the cell dies (top). But if the cell has the CRISPR-Cas system and is immune to the virus, the attacker can be repelled.



Illustrations: G.Hintze/U Ulm

the bacterial starter cultures that are used in the production of yoghurt and cheese. A viral infection in the bacteria can cause immense damage and destroy entire production series. In 2007, researchers at Danisco (DuPont) turned their attention to CRISPR-Cas and ended up launching it on an unprecedented career.

The idea is as simple as it is effective. When prokaryotes are brought into contact with viruses, a proportion of them survive the attack and build the viral DNA into the CRISPR locus as spacers. These bacteria are now immune to the attacking virus and so can be used as multi-resistant starter cultures. Through cell division, they pass on this immune system with its own 'memory' to subsequent generations. What is particularly interesting for the dairy industry is the fact that products made from these starter cultures are in no way genetically modified.

In 2013, another ability of the prokaryotic immune system caused the US journal *Science* to proclaim a "CRISPR craze". The craze was prompted by the ability of the Cas9 protein, together with short guide RNA (sgRNA), to recognise and cut specific sequences of DNA. This isn't just useful in the fight against viruses: the cutting tool can also be used to remove disease-causing gene segments from the genetic material, or create desirable mutations. Through the addition of sgRNA, the desired genes can be effectively targeted. This technique, which has already been used for genome manipulation in zebrafish and humans, is cheaper and less time-consuming than, for example, the use of zinc finger nucleases to modify plant and animal genomes.

One Cas9 variant can also function as a "road block", defining which genetic segments are read during

CRISPR-Cas for yoghurt and biofuel production: starter cultures are rendered immune to the attacking viruses.

Illustrations: G.Hintze / U Ulm

Intensive laboratory work: research into the CRISPR-Cas system soon resulted in the first practical application.

Illustration: E. Eberhardt / U Ulm

transcription. This does not damage the DNA in any way. The Research Unit is now also turning its attention to genome editing. However, the team will continue to carry out basic research and plan to study more CRISPR-Cas variants to unravel their molecular mechanisms in detail. This information is essential to the rapid improvement of applications.

But there is still a long way to go before CRISPR-Cas can be used in the human organism. There are concerns about "off-target" mutations: undesired follow-on mutations after the "genetic scissors" have done their job. This makes it all the more important to better understand the mechanisms of genome editing. For this reason, a pioneer of Cas9 research has joined the Research Unit. Professor Emmanuelle Charpentier, the co-discoverer of the cutting tool, worked at the Helmholtz Centre for Infection Research in Braunschweig (and is currently at the Max Planck Institute for Infection Biology in Berlin) and will continue to support and enrich the activities of the unit.

The career of CRISPR-Cas has led from the "primeval soup" to the dairy industry and into the genetic laboratories of the world. Now it looks as though the prokaryotic immune system could also help us to manufacture biofuels. The production of these fuels requires starter cultures of cyanobacteria fed from seawater, which is packed full of attackers. So the obvious next step is to treat the starter cultures with the method developed by the dairy industry – another of the unit's projects.

All in all, the CRISPR-Cas field of research is a perfect illustration of how important and surprising basic research can be – and how it can open up whole new avenues of investigation. Rarely has an application been developed so quickly from fundamental research as with the CRISPR-Cas system. The possibilities of genome editing and its modifications discovered over the last 18 months offer enormous potential. And it would seem that the applications proposed at the moment are only the tip of the iceberg.

Prof. Dr. Anita Marchfelder
teaches in the Department of Molecular Botany at the University of Ulm and is the spokesperson for Research Unit 1680.

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Nikolai Grube and Kai Delvendahl

In the Wake of the Great

When the Maya city of Uxul, a small kingdom in the rainforest, came under the rule of the powerful Kaan dynasty, it was the beginning of a blossoming that was later followed by their joint downfall. A team of German and Mexican archaeologists are excavating new evidence of this story of political power and the history of a city.

Looking into the princely grave below the entrance building to the palace in Uxul.

All illustrations and graphics: Archaeological project Uxul

Even the all-terrain vehicle with raised wheels can't make any more progress. The rainfall of the last few weeks has flooded the large area of swamp to such an extent that the trucks carrying the German-Mexican excavation team of archaeologists, labourers and students can go no further. There are just 8 kilometres more to go to the archaeological site of Uxul in the far south of the Mexican state of Campeche, but the sun has already disappeared behind the trees of the rainforest.

We decide to set up camp and wait out the night. For many of the students, it's their first night in the jungle. Hammocks are strung up between the trees with mosquito nets over them and large plastic tarpaulins to act as makeshift roofs for protection against the rain. Few of the team get any sleep, so loud is the screaming of the howler monkeys and so high are the expectations: What will the site look like, having been undisturbed by human presence since the end of the last excavation campaign nine months ago? What can the archaeologists expect from this year's dig season? And how will it change our picture of the occupation of this ancient city?

For the last seven years, an archaeology project team from the University of Bonn has been studying the Maya settlement of Uxul with the aim of investigating its relationship with the regional "superpower" of Calakmul, 35 kilometres to the northeast. The key question is how the social, economic and political structure of the settlement was changed when it was annexed under the rule of Calakmul. As yet, little is known about the political and social structures of the small kingdoms that fought for power and resources, waged wars and tried to conquer foreign territories during the heyday of Classic Maya culture (250 AD – 900 AD).

Excavation of a water reservoir in the settlement, which extended over three adjacent plateaus in an exposed position in a range of hills.

Top: Reconstruction of the Late Classic entrance building to the palace with the Early Classic temple beneath it. Below: Rain god as fisherman, mural from the passage between the two rooms of the temple; can be dated to around 300 AD.

Thanks to inscriptions at Uxul, we know that the settlement lost its earlier independence in the first half of the 7th century and became a vassal of the great royal dynasty of Kaan, which had its seat of power in the city of Calakmul. But what did the loss of independence and integration into a foreign dominion mean for the inhabitants of Uxul? Did they have to pay tribute to the Kaan dynasty of Calakmul? Did new settlers arrive? And how did the new rulers change the face of the city?

The ancient settlement of Uxul is spread over three adjacent plateaus of a hill range that extends from northern Guatemala to eastern Campeche in Mexico. To the east and west of these hills are expanses of low-lying land that turn into swamps during the rainy season. The central area of the city is situated on the highest and broadest plateau, approximately 50 metres above two artificial water reservoirs, almost 10,000 m^2 in size. The western flank of the hilly ridge falls away steeply and was therefore probably strategically important as a form of defence. While the extent of the site to the south, west and north can be clearly delimited by topographical boundaries and, especially, the transition to the low-lying swamp, the limits of the settlement in the eastern part are harder to define. Here there are smaller hills that could have provided suitable terrain for the simple

huts used by the ordinary inhabitants, which were made of perishable materials – and for which it is therefore difficult to find archaeological evidence.

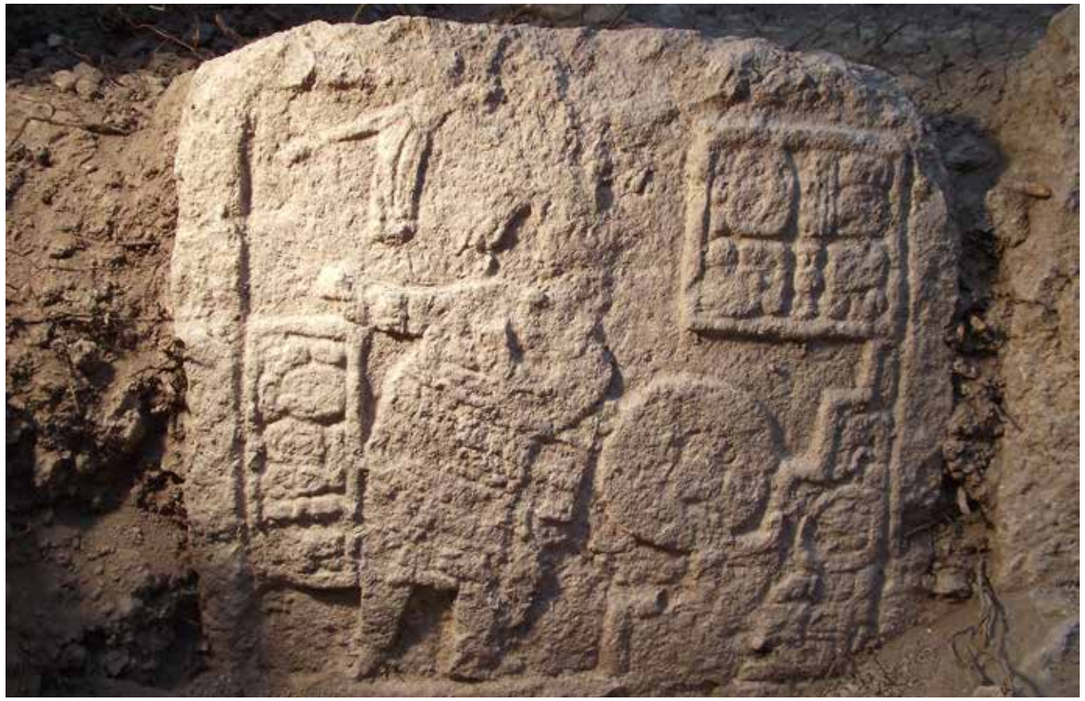
Since 2009, 3 km² of the settlement has been topographically surveyed and approximately 800 buildings and a number of natural and artificial landscape features have been discovered and measured. We now believe that during its heyday Uxul had a population of around 5000 to 7000 people.

More than 30 buildings have been partially or fully uncovered, the hydraulic system and the two large reservoirs have been studied, and more than 150 test trenches have been dug in all the residential groups of the settlement. We are now in a position to reconstruct the chronology of occupation in detail. We are helped by a ceramic sequence that stretches from around 400 BC to the early colonial period. In addition, the inscriptions on more than 30 stone monuments at the site tell us about the city's zenith in the Late Classic Period between 600 AD and 750 AD.

This period is of great significance in the history of Uxul. Between 630 AD and 640 AD, the city came under the rule of Calakmul. Whether this was the result of military conquest or a political-dynastic alliance cannot yet be determined from the finds. But it is clear that this foreign rule coincided with the most glorious epoch of Calakmul, during which three long-lived and charismatic kings reigned.

The dominance of Calakmul is most evident during the reign of the Uxul king Muyal Chaak ("cloud rain god"; 660 AD – ca. 680 AD) and the decades after. Excavations show that during this period, the urban centre was redesigned in imitation of Calakmul. This is very obvious in the eastern plaza in the centre of the city, which bears such a striking resemblance to the main plaza of Calakmul that it could be described as a copy of the city's design. The monuments from this period also follow an iconographic programme and conventions of portrayal known from other sites ruled by the Kaan dynasty.

A jovial motif on a stone wall tablet: King Yukno'm Yich'ak K'ahk' of the Kaan dynasty of Calakmul playing ball, 695 AD.



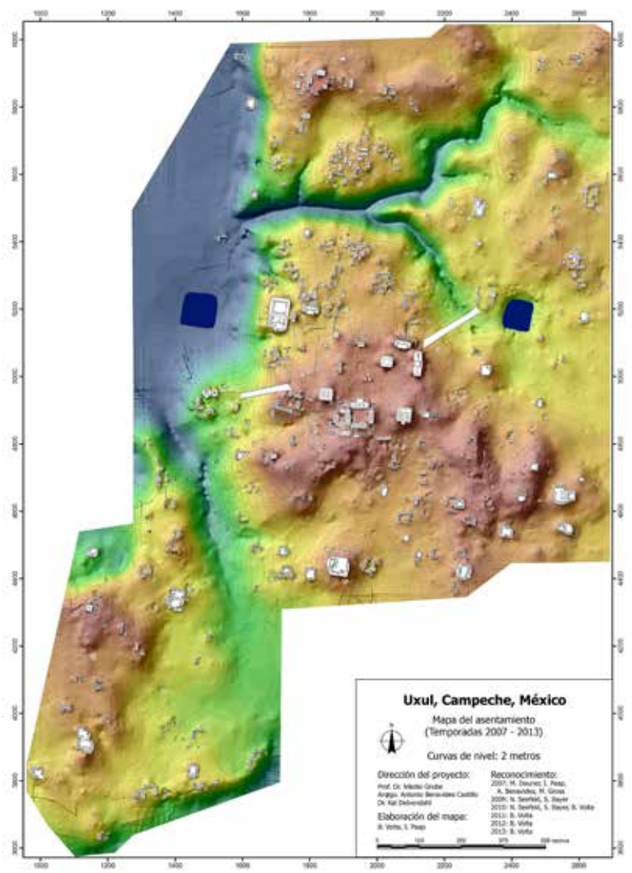
Patience and precision: two ceramic hand drums are reconstructed in the ceramics laboratory of the Mexican antiquities authority.

The impacts of foreign rule in Uxul could be especially accurately traced from the excavations in the royal palace carried out between 2011 and 2015. Out of the at least eleven buildings, several platforms and boundary walls of the palace complex, which measures 130 metres x 130 metres, the most intensive investigation took place in the entrance building, an impressive structure 60 metres long and almost 10 metres high. With a history spanning around 450 years but only two main phases of construction, it is representative of several historical key moments in the development of Uxul.

The first building phase took place during the period of early settlement and construction on the central plateau around 300 AD. A temple was erected, which may have been dedicated to a water deity. It consisted of two adjacent small rooms separated by a central passage. The façade and interior of the building were painted in brilliant pink, red and orange. Through the slightly raised floor of the temple run several partly open drainage channels, designed to carry water away during the rainy season from the higher areas south of the building to the lower areas north of the temple.

During the 2013 excavation campaign, on one side of the passage between the two rooms we discovered a mural depicting an unclothed fisherman with a paddle in one hand, a fish in the other and a basket full of fish. This is presumably a manifestation of the rain god Chaak, who was of primary importance to the Maya. With its modest dimensions, the temple is emblematic of the small but independent kingdom of Uxul in the Early Classic Period.

Around 650 AD the temple was built over with the large entrance building of the newly erected palace complex. When we uncovered the southern steps of this building we found a number of hieroglyphic tablets, several of which depict the powerful rulers of the Kaan dynasty engaged in a ritual ball game. This indicates the profound influence of Calakmul on ritual and political life in Uxul. In a trench in one of the rooms in the entrance building, a richly appointed burial chamber was discovered. The spectacular



Map showing the settlement of Uxul, a Maya city in the state of Campeche in Mexico.

grave goods, particularly the ceramics, some of which have relief and painted decoration, exhibit a striking similarity to those found in Calakmul. The inscriptions on the ceramic vessels indicate that the burial belonged to a prince who was not however in direct line to the throne.

The Early Classic temple and many other structures from the 4th, 5th and 6th centuries AD were built over during a period of positively bombastic monumentality under the powerful influence of the Kaan dynasty in Calakmul. This phase only lasted for about 80 years, but it completely changed the face of the city. Completely new buildings appeared, based on groups of buildings and main squares in Calakmul: pyramid temples, palaces, ballcourts and open spaces. In this respect, Uxul is a singular example: there are few other cities where the new rulers appear to have used architecture in such a way to express their power.

The archaeological finds also reveal the story of the end of the city's occupation. Around 740 AD, the steps leading to the palace were built over. The hieroglyphic tablets with the images of the Kaan rulers were used back to front in the steps and partially broken up – a dramatic and symbolic expression of their loss of power and their demise, and ultimately the demise of the city itself.

The discovery of many spear points and lanceheads in the most recent layer of the palace courtyard indicates that Uxul came to a violent end. The city's downfall may be connected to other violent conflicts that shook the whole of the Maya lowlands in the 8th century and finally led to the collapse of Classic Maya culture. The city of Uxul is therefore an excellent example of a small Maya kingdom that came under the rule of a large and powerful state but was ultimately pulled down by the collapse of the dominant state and finally abandoned.

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www.iae.uni-bonn.de/forschung/forschungsprojekte/laufende-projekte/uxul

Rembert Unterstell

A Matter of Taste

Biochemist Wolfgang Meyerhof studies the basic mechanisms of the long-neglected sense of taste. He also seeks to understand the relationship between taste and nutrition. We spoke to him about the world of bitter receptors, eating the abdomens of honeybees for sweetness, and taste preferences and aversions.

Illustration: Unterstell

In my area of research I regularly deal with a lot of experts – 80 million of them in Germany", says Wolfgang Meyerhof by way of introduction. This bodes well for our interview in his office in Potsdam-Rehbrücke.

For nutrition researchers like Meyerhof with an interest in basic principles, it's all a question of taste – and its consequences. In-depth research into the sense of taste only began 15 years ago, perhaps because in the hierarchy of human senses, taste (along with smell) ranks as one of the lower senses. Yet taste preferences and aversions determine what we eat and drink and therefore influence our health and wellbeing. The gustatory sense controls individual eating behaviour. The first question comes easily to mind.

german research: Mr. Meyerhof, for some people the best dish in the world is grilled salmon steak with vegetables and rosemary potatoes, while for others it's an organic cheese with a mixed salad, or maybe a simple but hearty cheese sandwich. What is your favourite food?

Wolfgang Meyerhof: I don't have one. I like anything my wife and I cook ourselves. It might be hearty German fare or traditional French or lighter Italian food.

What is your main area of interest as a taste researcher?

Profile

Professor Dr. Wolfgang Meyerhof, Professor of Molecular Genetics at the University of Potsdam, has led the department of the same name at the German Institute of Human Nutrition in Potsdam-Rehbrücke (DIfE) since 1994. Having obtained his doctorate in biochemistry and his habilitation in cell biochemistry, he initially studied structure-function relationships of G protein-coupled receptors before turning his attention to the molecular neurobiology and pharmacology of the sense of taste and thus the biological foundations of food choices. His extensive research, funded in several cases by the DFG, is internationally noted. Meyerhof is a member of the Leopoldina and the recipient of the International Flavors and Fragrances Award 2013, presented by the Association for Chemoreception Sciences, and the Excellence in Flavor Science Award, presented by the Flavor and Extract Manufacturers Association.

Illustration: Unterstell

We study the sense of taste with the aim of acquiring basic knowledge about it. We started by focussing on the bitter taste, and later we continued by investigating the perception of sweet and fat tastes. The reason we started with the bitter taste is that it is aversive, so you can study taste aversions and understand why people reject certain foods. Also, unlike the sweet taste, there are no caloric effects on intake to take into account.

For a long time you've been studying bitter receptors and modulators …

When we started working on taste 15 years ago, little or nothing was known about the underlying basic cellular and molecular mechanisms. We started with the receptors to unravel the physiology and pharmacology of taste one step at a time. We have since identified 25 bitter receptor genes – and thus discovered the basis for the perception of different bitter substances.

What result did you find surprising?

Perhaps the fact that there is a whole squad of bitter receptors but just one single sweet receptor – that surprised me.

Can you briefly summarise the systematic differences between the perception of sweet and bitter?

We are programmed to like sweet tastes; this serves the physiological purpose of making nourishment accessible in the form of carbohydrates. It is also natural, particularly for young children, to avoid eating bitter-tasting foods. From a physiological point of view, this offers protection against potential toxins in food. But the "eureka" moment for us was the discovery that not all bitter tastes are universally rejected.

What does this mean?

We eat bitter foods in various forms, for example an espresso or a vegetable like chicory. But overall, and this is a new perspective, the bitter taste seems to be more of a regulating sense that enables us to approach "suspicious" bitter substances with caution.

We don't just taste with the tongue, but also with the cortex, where the overall taste impression is formed …

The sense of taste involves not just the five different tastes – bitter, salty, sweet, umami and sour – but also the sense of smell. Many researchers refer to the combination of odour and taste as "flavour". The overall taste experience is then formed in the head.

What role do our genes play?

Genetics make little difference to sweet, sour and salty tastes. But with bitter tastes, there are distinct differences between individuals and varying sensitivities to certain bitter substances.

And what is the influence of culture on taste perception?

Although taste sensitivity is genetically fixed, the evaluation of taste is culturally dependent. Here in Germany, no one would contemplate eating the abdomens of honeybees as a sugar substitute. The idea of eating insects is not widespread here.

So it's a combination of genetics and cultural environment?

Yes, and of course individual experience plays an important role, starting in childhood. A child who eats lots of different foods in the early years will develop different eating behaviour from a child who never had that experience. This is where financial circumstances come into play. If you can't afford caviar, you don't eat caviar.

And once preferences have been learned, what consequences does this have?

It would be a good thing if parents were informed about the fundamental principles of taste preference formation. Then they would understand that they can't offer a toddler five spoonfuls of spinach if the child has never eaten it before. Until a child is weaned, it doesn't have to worry about the nourishment it is offered; then, from an evolutionary point of view, young children are fearful of new foods to protect themselves against poisoning. But when they realise that a taste is good for them, they become receptive to it – and they quickly develop preferences. In other words, parents can help to shape their children's taste preferences.

Are your research findings, for example relating to bitter blockers, used by the food industry?

It would be more accurate to say the flavour industry. There are companies which manufacture flavours and supply them to the food industry. Scientifically speaking, bitter blockers are interesting because in an ideal scenario they make it possible to determine the contribution of an individual receptor to a taste experience. Naturally, this is also of interest to industry. But our basic research is relatively unimportant to this. One of the bitter blockers we described is now being marketed. But I think the market potential of these substances is overestimated; the situation in the sweet sector is very different.

What challenges will taste research face in the future?

It starts with simple things. We still don't know how the sour taste works. And we only partially understand the processes by which information is received, transmitted and processed, from the tongue to the relevant areas of the brain and groups of cells. Researchers studying smell and taste are particularly interested in the so-called input-output coupling: Why does a bitter taste make us spit something out, but a sweet taste make us swallow? And why isn't it the other way round?

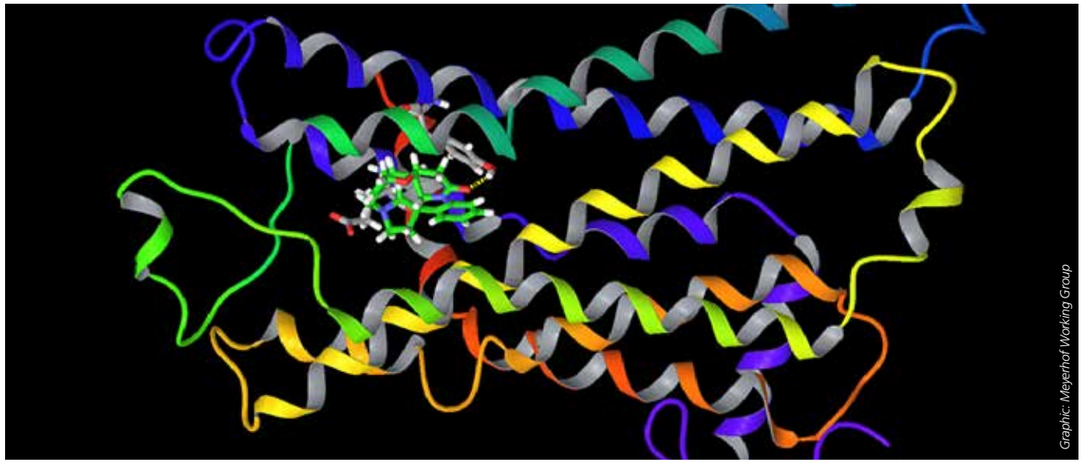
How will eating habits develop in the Western world?

There is a danger that the impacts of malnutrition will increase further: obesity, heart disease and metabolic syndrome, to name a few of the key ones. The reason for this is our changed lifestyles, particularly the hectic pace of everyday life. This began much sooner in North America. The danger is that we will follow the same pattern in due course.

Does the future belong to fast food or slow food?

Slow food isn't accessible to everyone because not everyone can afford it. There is a risk that the future belongs to fast food, but for the individual there are other options – choosing a varied diet and healthy lifestyle.

Interview: Dr. Rembert Unterstell,
Publishing Executive Editor of *german research*.



Graphic: Meyerhof Working Group

The sense of taste

There are five tastes: sweet, sour, bitter, salty and umami (meaty). There are special receptors for each taste. Receptor cells register the taste notes. The cells are located in the taste buds, which are embedded in the papilla of the tongue. When a substance docks on the corresponding type of receptor cell (the picture above shows a receptor with a bitter substance attached), the receptor sends a signal to the brain. The sensory impressions are "read" and evaluated by the gustatory cortex.

Thomas Reiprich

Measuring the Invisible

Dark energy makes up most of the universe, permeating distant galaxies and our solar system. Yet it remains largely unresearched. The international X-ray telescope consortium eROSITA is promising to deliver some spectacular insights into fundamental aspects of astrophysics.

The Abell 383 galaxy cluster. The X-rays emitted by the hot gas are overlaid on an optical image in purple.

Illustration: X-ray: NASA/CXC/CaltechIA Newman et al/Tel AvivIA Morandi & M.Limousin; Optical: NASA/STScI, ESO/VLT, SDSS

Illustrations: Max-Planck-Institut für extraterrestrische Physik

Top: eROSITA hangs from a crane. Bottom: the mirror module of the X-ray telescope, which is expected to be the main instrument on board the Russian satellite "Spektrum-Roentgen-Gamma" in 2016.

Dark energy has had a chequered history. The physicist Albert Einstein introduced it as a "cosmological constant" in his equations almost 100 years ago. He was motivated by a desire to show that the universe could be, to some extent, static. However, after it became increasingly obvious that the universe could not be static but was expanding, he withdrew the idea of the cosmological constant; indeed he regretted it. But why? Perhaps because the universe cannot be static even with the assumption of a cosmological constant or because he could have predicted the expansion of the universe without it, using only his equations.

The cosmological constant was to become of interest again later on, to increase the age that had been calculated for the universe when it seemed that globular clusters were considerably older than the universe itself. After the age estimates had been revised, the cosmological constant was dispensed with again. In 1997, observations of supernovae, explosions of stars, indicated that the value of the cosmological constant was close to zero.

In the following two years, this result was again revised and two teams came independently to the conclusion that the cosmological constant had a value greater than zero, for which they received the Nobel Prize for Physics in 2011.

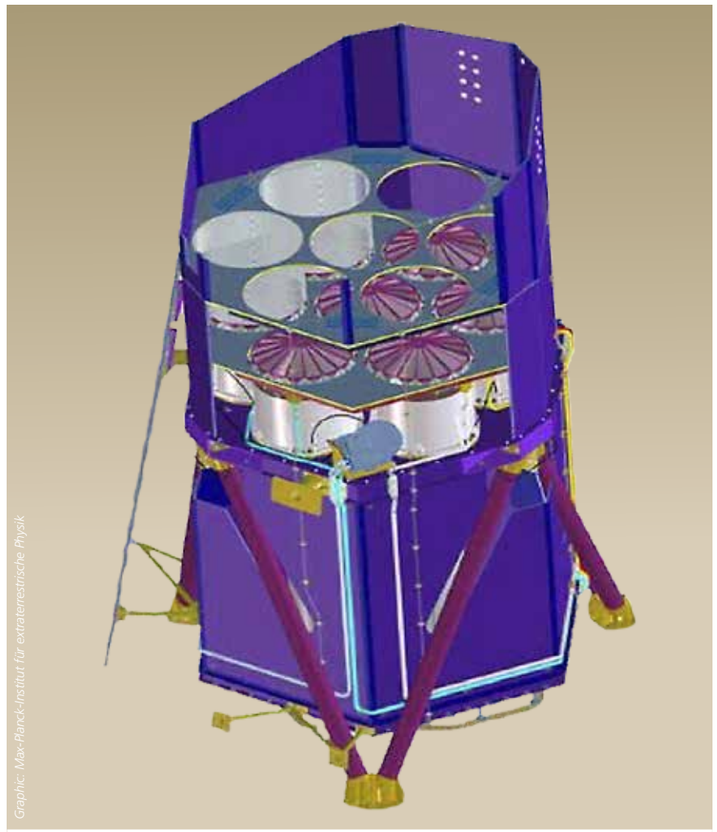
These initial indications have now been confirmed with other completely independent methods and as a result, most cosmologists

Above: Highest tech – eROSITA is made up of seven mirrors, each of which consists of 54 mirror shells. There is an X-ray CCD detector at the focal point of each mirror. Below: From the model to the real object – a front view of eROSITA.

now believe in the existence of dark energy. Observations of galaxy clusters and cosmic microwave background radiation in particular have played a part in this. Most measurements show that dark energy makes up around 70 percent of all the matter and energy in the universe.

Galaxy clusters are the largest and most massive components of the universe. They have diameters of 10 million light years and as much mass as a quadrillion suns. They are collections of hundreds or thousands of galaxies. Due to the enormously deep gravitational well pull, the gas between these galaxies is heated to a temperature of 10 to 100 million degrees Celsius and radiates particularly strongly in the X-ray range. Although it is invisible to optical telescopes, the gas weighs almost ten times as much as all the stars in all the galaxies in a cluster. Measuring the luminosity and temperature of the gas with X-ray satellites allows not only the mass of the gas to be determined, but also the total mass of the cluster.

A key result is that around 85 percent of a galaxy cluster is dark matter. The future of our universe is determined by dark energy. For example, it could cause a "Big Crunch" and the universe could collapse in on itself again. Or, if the dark energy can be described with the cosmological constant, the galaxies could continue to move further and further away from us until no more galaxies are visible.

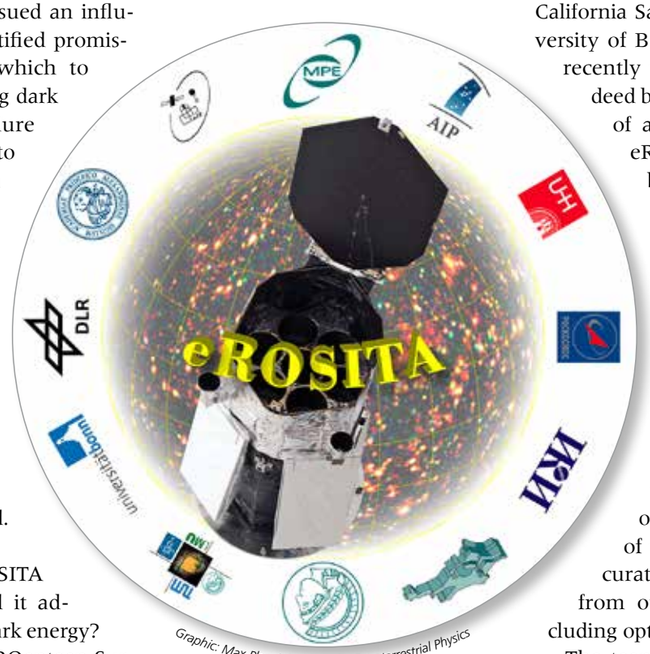


Graphic: Max-Planck-Institut für extraterrestrische Physik

Illustration: Herbin

Another possibility which observations have not yet excluded is the "Big Rip". In this scenario, an increase in the density of dark energy will cause all objects to be pulled apart until finally even atoms are destroyed – another reason why it would be interesting to find out more about the fundamental properties of dark energy.

In 2006, the US Dark Energy Task Force (DETF) issued an influential report. It identified promising methods with which to continue investigating dark energy. The procedure was broken down into several stages – from I (completed projects) to IV (the best major future projects). While initially conceived independently of the DETF, the German X-ray telescope eROSITA is expected to be realised as the first stage IV project in the world.



The logo of the German eROSITA consortium.

What is eROSITA and how will it advance research into dark energy? eROSITA (extended ROentgen Survey with an Imaging Telescope Array) is the main instrument on board the Russian satellite "Spektrum-Roentgen-Gamma" which is scheduled for launch into an L2 orbit from Baikonur in 2016. Its construction is being supervised by the Max Planck Institute for Extraterrestrial Physics in Garching; it is funded by the German Aerospace Agency (Deutsches Zentrum für Luft- und Raumfahrt, DLR) and the Max Planck Society plus several German universities. eROSITA will search all the sky at X-ray wavelengths and discover around 100,000 galaxy clusters, including all the massive clusters in the whole of the observable universe.

eROSITA follows ROSAT, the successful German mission of the 1990s, with which around 2000 galaxy clusters and a host of other astronomical sources of X-rays were discovered.

Structures in the universe are created from small objects which over time merge to form ever larger objects. The largest objects in the form of galaxy clusters are therefore still developing now. Whether a galaxy cluster can develop depends on the presence of dark energy.

To narrow down the properties of dark energy, the researchers will count and weigh galaxy clusters with eROSITA: both current galaxy clusters and others from the past, more than five billion years ago. The method is in principle as follows: Something invisible – dark matter in galaxy clusters – is measured to find out more about another invisible entity – dark energy. To do this scientists will examine galaxy clusters originating from a time before the formation of our solar system.

Will this succeed? A team of researchers from the University of California Santa Cruz and the University of Bonn was able to show recently that eROSITA will indeed be equal to the demands of a level IV experiment. eROSITA is expected to be able to determine the equation of state of dark energy, the "holy grail", to within a few percent. Nevertheless it will require considerable effort to really exploit the full potential. For example, it must be possible to determine the redshift (a measure of distance) and the mass of the galaxy clusters accurately. This requires data from other wavelengths, including optical surveys of the sky.

The team in Bonn was able to show that eROSITA will be able to determine the redshift and the gas temperature (a measure of the mass) for some of the newly discovered galaxy clusters directly. The algorithms for finding galaxy clusters in the X-ray data are highly significant in this process. So there remains a great deal of scientific preparation to be carried out before the launch, but the prospects for eROSITA are excellent.

In the final analysis, it is not only about narrowing down a few

Montage: JAVIER GARCIA NOMBELA-ARTEMES NETVOLKER SPRINGEL(MPA)/IRAP

The Athena X-ray observatory has been selected by the European Space Agency to support its next major scientific mission into space.

cosmological parameters. Theoretical considerations indicate that it might not be necessary to introduce this mysterious dark energy to explain current observations. As an alternative, one could assume that Einstein's General Theory of Relativity must be extended. eROSITA is eminently suitable for distinguishing between these two options (dark energy or modified laws of gravity) because the development of galaxy clusters is very dependent on gravitation. A better understanding of the effects we attribute to dark energy has the potential to shake physics to its foundations. It appears from this point in time that eROSITA will play an important role here.

Will all the puzzles of astrophysics and cosmology be solved? Certainly not. For one thing, it can be expected that the new findings will throw up new problems. For another thing there are already many fundamental questions being asked in astrophysics which can only be answered with a completely new X-ray telescope. This would have to be many times more powerful than eROSITA.

Meanwhile a team of several hundred astronomers from mainly European institutions have shown that the proposed new X-ray mission Athena could solve many problems in astrophysics – research questions which cannot be answered with any other research tool. With many other astronomers, the team in Bonn has shown that Athena represents a quantum leap for understanding the development of hot matter in galaxy clusters as it will penetrate as far as the first galaxy clusters in the deep young universe.

The astronomers around the world supporting Athena are thrilled that the European Space Agency has chosen Athena as its next major scientific mission.

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www.dark-energy.net

The Deutsche Forschungsgemeinschaft

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

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

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

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

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

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

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

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

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

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The DFG and social media: since the beginning of February 2016, Germany's largest research funding organisation has been tweeting via @dfg_public about its events, awards and exhibitions. The first event tweeted about was an evening talk entitled "Proofs, Errors and a Ham Sandwich" by mathematician and Leibniz prizewinner Günter M. Ziegler, whose description of a journey of discovery through the history of mathematics research delivered some surprising revelations. The talk was well received by an audience of around 250 in Bonn and didn't go unnoticed by the channel's first followers who now, just a couple months later, number more than 1,600. Information and debate in 140 characters: the microblogging service broadens the range of options for communication. The DFG's Press and Public Relations uses both analogue and digital media to create a productive environment for interaction. Tried and tested media formats such as press releases, the DFG magazine *german research* and the content at www.dfg.de/en all boast individual features designed to reach different target groups. The Twitter channel complements this spectrum and is intended to encourage public dialogue – which the readers of *german research* are very welcome to join!