RESEARCH *in Brief*

Sex-role reversal: A female African black coucal guards her territory.

Photo: Bernard Lanneluc

ORNITHOLOGY

Macho Tendencies in Females

In most animal species, the males compete for access to the females. In a few species, however, including the African black coucal, the sex roles are reversed. Scientists at the Max Planck Institute for Ornithology have now shown that the sex hormone testosterone, which occasionally makes males into machos, is most likely involved in aggressive and territorial behavior of female black coucals. (Developmental Neurobiology 67, 1560-1573, 2007)

To attract a partner, males must find a territory and defend it against rivals – a typical pattern found in many animals. Females, on the other hand, are choosy and often select a partner according to the quality of his territory. In contrast to males, females typically have much higher confidence in the fact that they are the actual genetic parent of their young. Therefore, it is primarily the females that take care of the offspring, supported to a greater or lesser extent by their male partners. Most female vertebrates actually raise their young all by themselves. However, in less than one percent of all bird species, the roles are reversed and the females aggressively defend their territories and compete for males while the males provide all the care for the young.

The African black coucal is one of these rarities. During the rainy season, females develop a magnificent breeding plumage and establish large territories. And their behavior becomes more macho in other ways as well: they constantly sing to advertise their possession of a territory, and aggressively drive away other females. At the same time, they welcome males – the more the better. Each female mates with up to three males.

Each of the male partners of a female territory owner builds his own nest. The female lays up to seven eggs in each nest, but this also marks the end of the care that a female gives to her brood. "Only the father incubates the eggs and then feeds the helpless nestlings until they leave the nest after two weeks. He then continues to feed the fledged young for a few weeks thereafter," remarks Wolfgang Goymann from the Max Planck Institute for Ornithology in Seewiesen and Andechs, describing the solicitous coucal father. In the meantime, the female lays more eggs for another of her mates or tries to attract further males. This kind of mating system is called classical polyandry.

These idiosyncrasies made the African black coucal an ideal model for Wolfgang Goymann and his colleague Cornelia Voigt to investigate how hormones modulate territorial aggression in females. When male birds establish and defend a territory and try to attract females, their gonads secrete increased amounts of testosterone. It would seem reasonable, then, to suppose that exchanging gender roles goes hand in hand with reversal of the testosterone concentration in the blood.

However, females of all classically polyandrous bird species investigated so far – the Wilson's phalarope, the spotted sandpiper and the African black coucal discussed here – express normal levels of testosterone: high in males, low in females. Nevertheless, the Max Planck researchers have discovered that this "male" hormone could still play a role in controlling aggressive behavior in classically polyandrous females.

Testosterone works by binding to what are known as androgen receptors. These then trigger a gene cascade which, in turn, influences the behavior. "Similar to changes in the concentration of testosterone in the blood, the androgen receptor represents another switch to regulate potential effects of testosterone," explains Goymann. Rather than increasing the production of the hormone, the organism could instead increase the number and density of the docking sites for testosterone. This may have the same effect on the behavior, and it appears as if this could be exactly what female black coucals do.

Brief motherhood: The females lay the eggs, but the males hatch them and care for the young.

Photos: Wolfgang Goymann (2)

The two ornithologists demonstrated that, compared to males, female black coucals express more androgen receptors in the *Nucleus taeniae* – an area of the brain that is involved in controlling territorial and aggressive behavior. Not only do females have more androgen receptor expressing cells in this area of their brain, but in addition, each individual cell expresses more receptors than do those of males.

"This means that female black coucals could be more sensitive to smaller amounts of testosterone than are males," explains Cornelia Voigt. This would make sense, because high concentrations of testosterone may prevent reproduction in female vertebrates. "By locally increasing the sensitivity for testosterone in the *Nucleus taeniae*, female black coucals may be able to avoid the disadvantages of elevated testosterone concentrations," explains Goymann. "In this way, testosterone may be able to influence aggressive behavior without having confounding effects on the reproductive physiology."

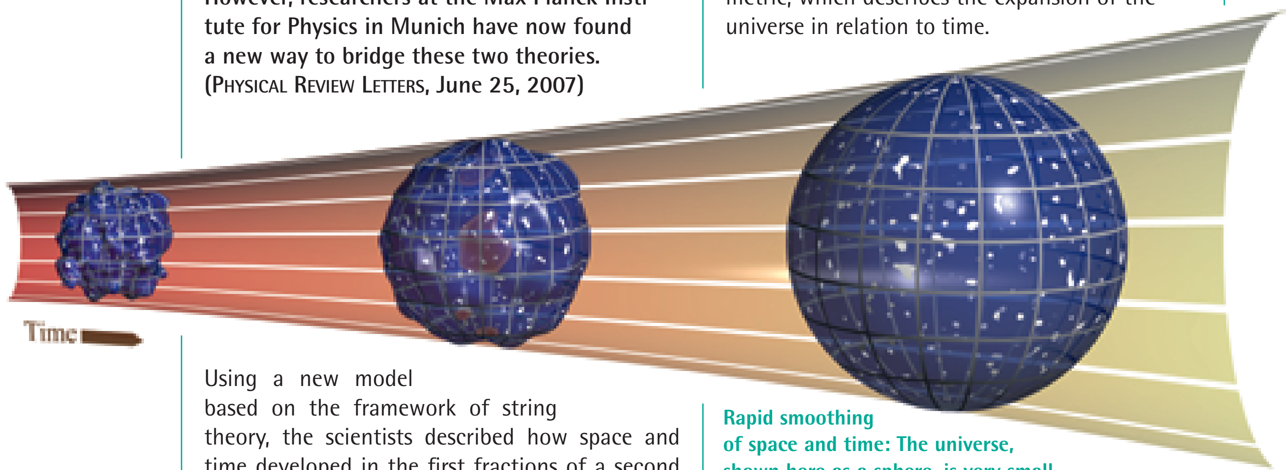
These findings represent the first indications of a potential physiological mechanism for the sex-role reversal in territorial and aggressive behavior. Interestingly, there is no comparative data for birds or other vertebrates with traditional sex roles – a surprising fact for Goymann: "No one has yet compared the expression of androgen receptors in males and females in such species. Only males have been examined, while females received little attention. If our idea is correct, we would expect that females of species with more traditional sex roles should express lower levels of androgen receptors in the *Nucleus taeniae*. The crucial test of our idea is thus still missing."

@ Contact:
Dr. Wolfgang Goymann
Max Planck Institute for Ornithology, Andechs/Seewiesen
Tel: +49 8152 373-119
Fax: +49 8152 373-133
e-mail: goymann@orn.mpg.de

Cosmology

A Bridge to the Big Bang

The beginnings of the universe bring Albert Einstein to the limits of his knowledge – the laws of the general theory of relativity, which describe the universe on a large scale, do not apply to the Big Bang. In fact, at its beginning, the cosmos followed the laws of quantum gravity: space and time behaved in accordance with the same quantum laws as the tiniest particles. However, researchers at the Max Planck Institute for Physics in Munich have now found a new way to bridge these two theories. (Physical Review Letters, June 25, 2007)



Rapid smoothing of space and time: The universe, shown here as a sphere, is very small and very hot just after the Big Bang; space and time are fuzzy due to quantum effects. As it increases in size, it very quickly becomes smooth and can be described by the theory of relativity.

Fig.: MPI of Physics – Felix Rust

Using a new model based on the framework of string theory, the scientists described how space and time developed in the first fractions of a second following the Big Bang. Their results show the way in which the universe moved from the quantum gravity phase to the era of the standard model of cosmology, as described by the theory of relativity.

At the birth of the cosmos, matter was infinitely dense and space-time curved infinitely into a single point. This singularity is the starting point for a theory of quantum gravity – which is where the Max Planck scientists in Munich began their work. The essential ingredient of their approach is the concept of a fuzzy space-time, as delivered by quantum gravity models. "That is why the universe seems rather shriveled just after the Big Bang," says project head Johanna Erdmenger. Consequently, it is not possible to determine the space and time coordinates of a point at the same time, and as a result, space-time itself is fuzzy and blurred. "The classical theory cannot be applied to fuzzy space-time," explains Erdmenger. She and her colleagues have used a new model to explain how classical space-time developed from this fuzzy quantum space-time with the help of string theory. "According to our model, the fuzziness of space-time in the expanding universe diminished extremely quickly," she says. Her calculations, and those of her team, approached the Big Bang to within a fraction of a second.

String theory does not describe the elementary particles as point-like objects, but as tiny vibrating strings. These strings can be closed or open. Closed strings are similar to a tiny rubber band, and open strings can be compared to violin strings under tension. The points to which these are attached are themselves objects that move in space-time and describe particles.

Physicists call them Dirichlet branes (D-branes). The researchers used open strings and D-branes to explain the nature of space-time close to the Big Bang. To do this, they used the Robertson Walker metric, which describes the expansion of the universe in relation to time.

As the Robertson Walker solution is the same at every point and in every direction, it describes a homogeneous and isotropic universe. In their model, the Munich-based physicists covered the Robertson Walker space-time with an imaginary network consisting of an infinite number of D-branes, and connected them to each other with open strings.

Erdmenger's team has now shown that, close to the Big Bang, the positions of the D-branes in the network could not all be determined simultaneously – which means that the standard model for cosmology does not work here. However, their model did reveal that this fuzziness rapidly decreases as the radius of the universe grows. Therefore, just shortly after the Big Bang, space obeyed the laws of the general theory of relativity again.

The new model just may be able to explain why astronomers have been examining images from the Hubble Space Telescope without finding the blurring that is supposed to occur with quantum mechanical fuzziness. These effects were apparent only fractions of a second after the Big Bang – and no telescope has yet been able to penetrate as far back as this period.

@ **Contact:**
Dr. Johanna Erdmenger
Max Planck Institute for Physics, Munich
Tel.: +49 89 32354-413
Fax: +49 89 32354-304
e-mail: jke@mppmu.mpg.de

Atmospheric Chemistry

Mercury from the Rain Forest

On-board laboratory: An Airbus A340-600 with the CARIBIC probe and sample container that analyzes the air worldwide under the aegis of the Max Planck Institute for Chemistry.

Photo: Max Planck Institute for Chemistry

Rain forests are polluting the atmosphere with mercury – when they burn. Researchers at the Max Planck Institute for Chemistry in Mainz and at the GKSS Research Center in Geesthacht have measured elevated mercury concentrations in the smoke from large forest fires in South America. According to these investigations, during the burning season, the forest fires release considerably more mercury than industrial sources in the southern hemisphere. (Geophysical Research Letters, April 2007)

There have always been traces of mercury in the atmosphere, which is how it accumulated in coal millions of years ago. Now, coal-fired power stations, smelters and heating systems are releasing this toxic heavy metal again. It also escapes where garbage is incinerated. Scientists based in Mainz and Geesthacht have now identified yet another significant source of mercury using the CARIBIC air observation system as it flew on board a Lufthansa Airbus from Frankfurt to Santiago de Chile via São Paulo: the burning rain forests in the southern hemisphere.

During the forest fire season from August to October, the fires emit even more mercury than is emitted from burning coal and garbage, or even from gold mining in the southern hemisphere. From the CARIBIC measurements, the researchers have calculated that up to 750 tons of mercury, or 11 percent of all mercury emissions, enter the air from forest fires throughout the world every year; 90 percent of these fires rage in the southern hemisphere.

However, anthropogenic sources, such as coal and refuse incineration, still make up three-quarters of emissions worldwide. "These sources, which are mainly in industrialized countries, are probably the reason why rain forests are so heavily polluted with mercury in the first place," says Franz Slemr, one of the scientists involved in this project at the Max Planck Institute for Chemistry. They are the reason why the atmosphere contains presumably three times more of the heavy metal today than in pre-industrial times. And because air knows no borders, it has also spread all over the southern hemisphere, where it falls to the ground with rain and migrates into the biomass.

For a long time now, atmospheric chemists have assumed that a lot of mercury is escaping into the atmosphere of the southern hemisphere with the forest fires – possibly more than from the anthropogenic sources. "Measurements in the plumes from biomass burning in Canada, for example, have indicated this," says Slemr. The suspicion also arose because 90 percent of all biomass burning occurs in the southern hemisphere.

Most mercury in the atmosphere occurs as an element vapor; it oxidizes very slowly to form non-volatile and water-soluble compounds that the rain washes out of the air. This is how it gets into lakes and oceans, where it is sometimes converted into the extremely toxic methyl mercury, which then accumulates in the aquatic food chain.

In some types of fish at the end of the aquatic food chain, such as tuna and pike, the methyl mercury concentrations are already at harmful levels. In Canada and Scandinavia, thousands of lakes are so polluted that pregnant women are warned to no longer eat the fish from them. And ocean fish, such as tuna and shark, should not be eaten frequently.

Since forest fires remobilize the mercury that the rain has already deposited from the atmosphere, they are making global pollution worse. "The cycle can only be broken by curbing emissions," says Franz Slemr.

@ **Contact:**
Dr. Franz Slemr
Max Planck Institute for Chemistry, Mainz
Tel.: +49 6131 305-423
Fax: +49 6131 305-436
e-mail: slemr@mpch-mainz.mpg.de

GENETICS

Fine-Tuning Flower Formation

Flower organs in many higher plants are organized in four whorls according to the same pattern: first come the green sepals, which protect the petals that are designed to attract insects or other pollinators. The stamens with their pollen sacs and the carpels, which later develop into a fruit and seeds, are hidden inside the flower. An entire orchestra of genes must be in tune to allow a flower to develop into this ordered structure. Scientists at the Max Planck Institute for Plant Breeding Research in Cologne working with colleagues from Nijmegen have now discovered that microRNA plays a key role in the formation of flower organs. (NATURE GENETICS, July 2007).

Unlike messenger RNAs (mRNAs), microRNAs consist of fewer than 22 nucleotides. They control the expression of genes by binding to complementary sections of an mRNA that are created when a gene is transcribed. Due to cleavage of the mRNA, or interference with its translation after microRNA binding, it is no longer possible to manufacture the relevant protein. In this way, various microRNAs regulate the development and metabolism of plants and animals.

Mutants for microRNAs are rare, yet researchers in Cologne and their Dutch colleagues obtained a snapdragon mutant and a petunia mutant in which a gene coding for related miRNAs had been modified. As a consequence, the mutants form petals instead of stamens. "In both of these mutants, the basic order has become confused, causing the wrong organs to grow in the wrong place," explains the head of the working group, Zsuzsanna Schwarz-Sommer.

How is this microRNA involved in the development of the flowers? The control of the identity of the four floral organ types is usually explained in textbooks with the help of the simplified ABC model. According to this model, different control genes are classified into three groups, A, B and C. Type A genes control the development of the sepals. Interaction between groups A and B produces the petals, while the stamens form from the simultaneous expression of groups B and C. The carpels are determined by group C on its own. A, B and C genes are active in distinct, partially overlapping areas of the flower, and the model assumes that A genes, which include the microRNAs examined, prevent the expression of the C genes in the two outer whorls of flower organs.

"This prediction has been refuted by our study," says Schwarz-Sommer. The regulation of flower development is indeed more temporal and dynamic than spatial. Instead of abolishing C gene expression in the outer whorls, the microRNA controls the level of activity of the C genes in their original area of expression in the center of the flower by a fine-tuning mechanism. In the microRNA mutants, the excess of C-gene product is transmitted to daughter cells during cell division, resulting in an outward expansion of the area of C-gene expression – converting petals to stamens. ●

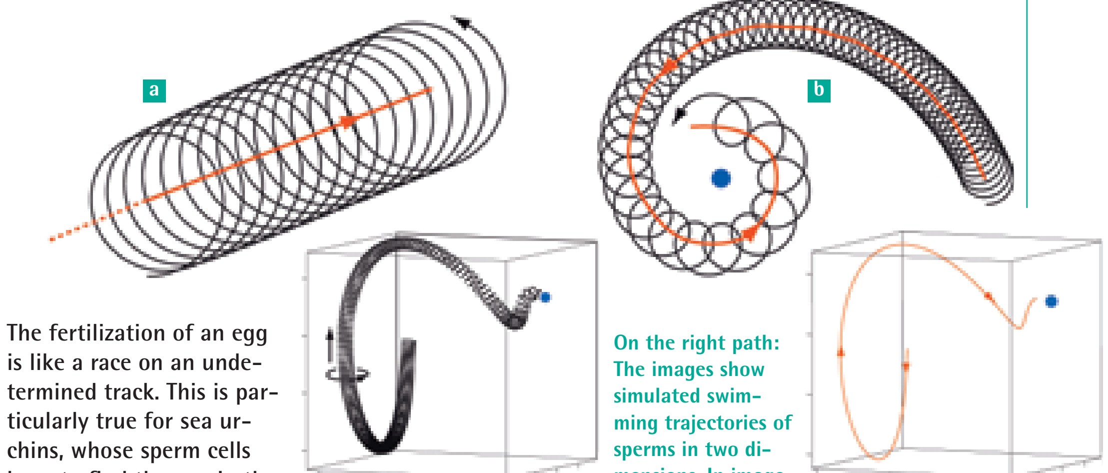
In the flowers of the petunia and the snapdragon mutants, the "basic order" of the flower is confused by the same genetic defect. As a result, the wrong organs are growing in the wrong place.

FIG.: MPI FOR PLANT BREEDING RESEARCH

@ **Contact:**
DR. ZSUZSANNA SCHWARZ-SOMMER
Max Planck Institute for Plant Breeding Research, Cologne
Tel.: +49 221 5062-140
Fax: +49 221 5062-113
e-mail: schwarzs@mpiz-koeln.mpg.de

BIOPHYSICS

Spiraling Sperms



On the right path: The images show simulated swimming trajectories of sperms in two dimensions. In image (a), the sperm is moving through a linear field of chemoattractant. It moves forward in a drifting circle (black line); the center of the circle (red line) drifts towards the signal substance. Image (b) shows a radial signal field. Here, the sperm is rotating along the spiral path, which points towards the signal (blue dot).

FIG.: MPI FOR THE PHYSICS OF COMPLEX SYSTEMS

The fertilization of an egg is like a race on an undetermined track. This is particularly true for sea urchins, whose sperm cells have to find the egg in the open sea. Their only aids to orientation are the chemical messenger substances, chemoattractants, that the egg cell emits. The sperm cells follow this chemical trail to their target on spiral trajectories. Researchers from the Max Planck Institute for the Physics of Complex Systems in Dresden have now described this process of chemotaxis in mathematical terms for the first time. (PNAS, August 30, 2007)

Sea urchins use several tricks to ensure that an egg cell can be successfully fertilized, even in the open sea. The females release eggs that are 0.3 millimeters in size, almost twice the size of human egg cells. The males of this crustacean species eject 10 billion sperm into the water – 100 times more than humans. Finally, a chemical trail leads the sperm, which follow a spiral path, to their target.

The researchers in Dresden have described how this chemotaxis works in a model that shows that successful navigation depends primarily on the right timing. The point at which the sperm processes the signal must be coordinated with its period of circular motion.

The 5-micrometer swimmers pick up the scent as they describe a circle, steered by the flagellum, or tail, and measure where on this circular path the chemical attractant is most concentrated. In response, they alter their course in this direction. The sperm swimming path becomes a circle drifting along a spiral.

In the open sea, sperm cells do not swim along planar circular paths, as is the case in most experimental setups, but along corkscrew-like helical paths. Nevertheless, they still pick up chemical cues, and the model of the Max Planck researchers still applies. "Although sperm swimming paths look much more complicated in three dimensions, they almost always lead the sperm cells to their goal," says Benjamin Friedrich, who worked on the simulation as part of his doctoral thesis. "Our model corresponds very well to observations made during experiments and also describes the mechanism of chemotaxis in three dimensions," that is, under real conditions. In open water, it is also possible for a current to create eddies in the trail of chemoattractants. This does not deflect a sperm from its goal, but rather simply realigns its paths.

In the model created by the scientists in Dresden, it misses the egg only when its biochemical control system reacts too quickly or too slowly to changes in the concentration of the chemoattractant. In this case, the phase shift between the incoming signal and the resulting movement is not correct.

It is precisely the discovery of the role that phase shift plays between the incoming attractant and the movement that provides a starting point for new experiments. "In order to examine chemotaxis more closely, one could use chemicals to intervene in the sperm's signal processing," says Friedrich.

Models similar to those developed by the researchers in Dresden could also help explain the movement of human sperm. These are also directed to the egg by chemotaxis, but swim along different paths. Their navigation mechanism still has some surprises to offer. ●

@ **Contact:**
BENJAMIN M. FRIEDRICH
Max Planck Institute for the Physics of Complex Systems, Dresden
Tel.: +49 0351 871-1216
Fax: +49 351 871-1999
e-mail: ben@pks.mpg.de

CELL BIOLOGY

Chemical Weapon against AIDS

To date, it has not been possible to cure an HIV infection. The currently available treatments that HIV-positive patients must take all their lives only delay the onset of AIDS and cannot remove the virus from infected cells. However, scientists from the Max Planck Institute of Molecular Cell Biology and Genetics in Dresden and the Heinrich Pette Institute for Experimental Virology and Immunology in Hamburg have now done this for the first time. They developed a special enzyme to separate genetic material of the HI virus from the cell DNA and render this material unusable. (SCIENCE, June 29, 2007)

The HI virus smuggles its genetic material into the DNA of body cells, mainly that of certain white blood cells. Immune cells produce new pathogens with this blueprint and thereby cause their own demise. Researchers working with Joachim Hauber from the Heinrich Pette Institute in Hamburg and Frank Buchholz from the Max Planck Institute of Molecular Cell Biology and Genetics in Dresden have achieved the first success in cutting HIV genes out of the human genetic material.

"We removed the virus from the cells, which was not previously possible," said the scientists. To do this, they used genetic engineering to manufacture a recombinase, an enzyme that functions like molecular scissors.

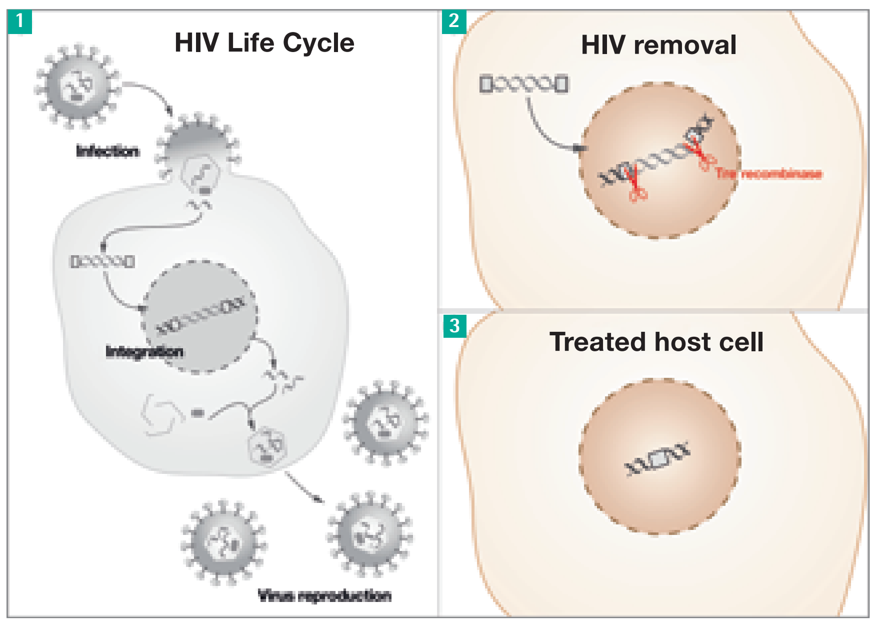
Recombinases split and reorganize DNA sequences. However, naturally occurring recombinases are not suitable for cutting the virus genes out of human genetic material. "They only work for base sequences that have been adapted for them," says Buchholz, "so we created a recombinase that recognizes the long terminal repeats of the virus, a sequence that flanks the HIV genes, to remove the virus in a targeted manner."

The molecular biologists created the molecular scissors for the HIV genome by imitating evolution in a test tube. As their starting point, they took an existing recombinase that recognizes and cuts out only certain DNA sequences. "This enzyme, Cre, recognizes a sequence that bears only a slight resemblance to the HIV LTR," explains Buchholz.

They bred Tre, the HIV-specific enzyme, by creating random mutants and shuffling selected beneficial mutations in over 120 generation cycles. The result of the evolution process was an enzyme that recognized and cut out a sequence occurring in the HIV genome.

So far, Tre has been tested only in human cell cultures. "However, our new approach provides a technical basis for using gene therapy at some point in the future to remove the virus from patients infected with HIV," explains Hauber. But that's still a long way off. First the scientists want to make the enzyme more specific and more active.

"Then we will investigate how effectively and safely we can get the recombinase into infected cells in the human body," says Buchholz. Viruses that act as gene ferries are one possibility for steering the blueprint for the best molecular scissors into infected cells. However, the enzymes might also be provided with appropriate molecular door openers and smuggled directly into infected white blood cells.



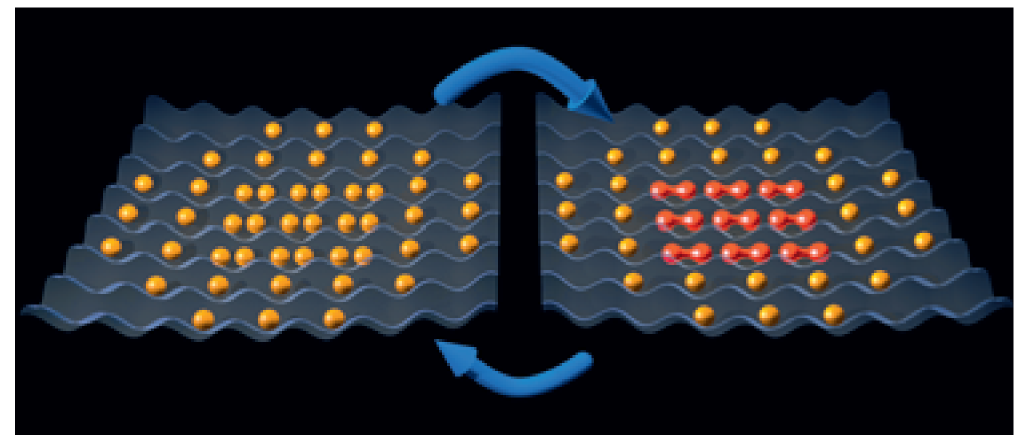
Breaking the vicious cycle: After the HI virus has infected a cell (fig. 1), it integrates its genes into the cell genome and is reproduced. The newly cultivated Tre recombinase recognizes the HIV sequence in the cell genome and cuts it out (fig. 2), leaving a host cell without the HIV genome (fig. 3).

FIG.: BUCHHOLZ - HAUBER

@ Contact:
DR. FRANK BUCHHOLZ
Tel.: +49 351 210-2888
Fax: +49 351 210-1289
Max Planck Institute of Molecular Cell Biology and Genetics, Dresden
e-mail: buchholz@mpi-cbg.de

Panorama

GENES MAKE LEGS FIDGETY: Restless Legs Syndrome (RLS) is closely associated with a number of genes that control the formation of the extremities and the nervous system during embryonic development. This discovery, made by an international team that included scientists from the Max Planck Institute for Psychiatry in Munich, was made when the researchers subjected the genomes of RLS patients and healthy controls to a comparative analysis. The suspected gene is present on three chromosomes and controls the development in the embryo of muscle cells and the nerve pathways that conduct pain and touch stimuli. One of the genes is also known to control the production of the neurotransmitter dopamine in the adult organism. This is a particularly important indication, as dopamine preparations are the first choice for treating RLS. However, it still remains to be explained how the genes in question contribute to the development of RLS, and why this agonizing urge to move the legs usually occurs only in later years.



Between partnership and singledom: In the center of the Bose-Einstein condensate are pairs of atoms (yellow) that convert to molecules (red) and back again. This spatial arrangement can be repeated periodically.

FIG.: MPI OF QUANTUM OPTICS

HYBRIDS OF ATOMS AND MOLECULES have been observed for the first time by researchers at the Max Planck Institute in Garching. To do this, the scientists captured rubidium atoms in an optical trap and cooled them to a few billionths of a Kelvin. The scientists then used a three-dimensional lattice made of standing light waves to arrange the approximately 60,000 atoms in this Bose-Einstein condensate in a regular structure, similar to eggs in an egg carton, with two rubidium atoms in each depression in the lattice's interior. They then excited these pairs of atoms with an external magnetic field so that they oscillated between a solo existence and a molecular bond. In the states between these two forms, the particles are both atom and molecule at the same time.

THE RADIOACTIVE IRON 60 ISOTOPE has been detected in the interstellar gases of the Milky Way for the first time by scientists at the Max Planck Institute for Extraterrestrial Physics in Garching. A spectrometer on board the European gamma satellite INTEGRAL supplied the characteristic signals that arise with the disintegration of iron 60 which, with a half-life of 1.5 million years, first disintegrates into cobalt 60 and then, with a half-life of 5.3 years, to stable nickel. This evidence will give astrophysicists insight into the interior of massive stars, which go through a sequence of phases of nuclear fusion of initially light to increasingly heavy elements, and therefore develop an inner structure reminiscent of an onion skin. Radioactive aluminum 26, which was shown 30 years ago to be in interstellar space, also occurs in the same star types, but in different regions and phases of development. It is hoped that a comparison of gamma radiation from aluminum 26 with that of iron 60 will allow testing of the models for the creation of heavy elements in massive stars, which postulate certain values for the relationship between these two isotopes. Mapping the distribution of iron-60 is however a job for the next generation of gamma-ray instruments.

ENZYME DOPING FOR PLANTS that supply biofuels is almost within reach. Scientists at the Max Planck Institute for Biochemistry in Martinsried have found the molecular "assembly chaperone" for the Rubisco enzyme, the most commonly occurring enzyme in nature. It binds carbon dioxide from the air and feeds it into the sugar synthesis process in plants and blue algae – that is, into the production of biomass. Rubisco consists of eight large and eight small components that must bind together correctly to form the complete enzyme. This does not always work properly, which is why Rubisco binds the carbon dioxide in sugar molecules only in three out of four reactions. With the discovery in Martinsried of the enzyme – called a chaperone – that is responsible for assembling Rubisco, and the insight into the way it works, it has been possible to optimize Rubisco in a genetic process and increase its effectiveness. Plants that have been subjected to this tuning process will grow faster without artificial fertilizers and could supply biofuel with a better carbon balance.

www
Further information is available at www.maxplanck.de