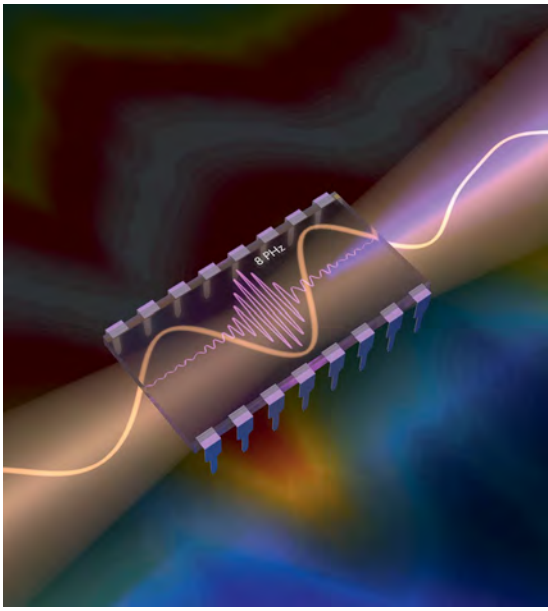
Electronics at Record Speed

Ultrashort laser flashes generate current a million times faster than in modern microprocessors

Electronic components could be made to run much faster by accelerating their electrons with light. Using extremely short laser pulses, researchers at the Max Planck Institute of Quantum Optics in Garching recently made electrons oscillate at petahertz frequencies – around 1,000 times faster than the clock speeds of modern microprocessors. The current produced in the process doesn't fit the classical model of charge transport. As a quantum current, it doesn't simply flow from the negative pole to the positive pole of a battery. Instead, the electrons oscillate extremely rapidly in the quantum realm. This state can't be achieved with ordinary current sources, as atoms, which also vibrate, cause the electrons to oscillate out of sync. Ultrashort laser flashes, on the other hand, stimulate the electrons so quickly that the relatively slow atoms no longer cause interference. Not only is the current generated a million times faster; the conductivity of the material increases by a factor of ten quintillion – that's one followed by 19 zeros. The researchers also discovered a way to detect the quantum current: the electrons emit light at their oscillation frequencies, which is easier to measure than the current itself.
(www.mpg.de/10805872)



Laser pulses (large sine wave) generate electric currents at petahertz frequencies (small sine waves in the electronic component sketched here). Currents are revealed by the UV radiation emitted.

My Contribution to Arctic Sea Ice Melt

Measurements reveal the correlation between CO_2 emissions and summer ice shrinkage

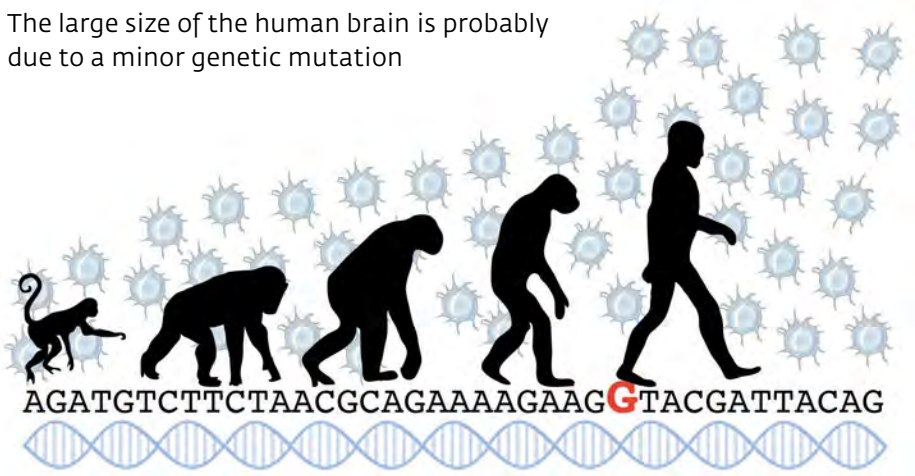
Every ton of carbon dioxide released by humans on the planet causes the summer sea ice in the Arctic to shrink by three square meters. Dirk Notz, a scientist at the Max Planck Institute for Meteorology, and Julienne Stroeve, a researcher at the US National Snow and Ice Data Center, came to this conclusion by analyzing measurements. They also discovered that, because they underestimate the increase in thermal radiation in the Arctic, many climate models predict a slower rate of ice melting than is observed in real life. The data also clearly shows that limiting global warming to two degrees Celsius, as called for by the most recent UN climate conventions, won't be enough to prevent summer ice melt in the Arctic Sea.
(www.mpg.de/10817029)

Scientists, including researchers from the Max Planck Institute for Meteorology, taking samples of Artic Sea ice near Spitzbergen for later analysis.

Graphic: MPI of Quantum Optics (top); photo: Dirk Notz (bottom)

Scrambled Letters with Consequences

The large size of the human brain is probably due to a minor genetic mutation



The swap of a single letter (red) in the code of the ARHGAP11B gene resulted in modern humans producing more stem cells in the brain than apes.

About one and a half million years ago, a tiny but fateful misspelling occurred in the three-billion-letter-long text of the human genome: a C was replaced by a G in the ARHGAP11B gene. This gene causes stem cells to multiply and form new nerve cells. ARHGAP11B was created by a partial doubling of a predecessor gene after the evolutionary lines of humans and apes separated. It occurs only in humans and our closest, now extinct, relatives, the Denisova hominids and the Neanderthals, but not in chimpanzees. After the mutation, the ARHGAP11B gene was able to develop its full potential. According to researchers at the Max Planck Institute of Molecular Cell Biology and Genetics in Dresden, the point mutation caused more stem cells to form in the cerebrum of modern humans. Consequently, our brains grew in size, endowing us with the intellectual skills that characterize humans, such as language and thought. (www.mpg.de/10851125)

A Nose for Oxygen

Mice have specialized neurons in the nasal mucosa that let them detect the oxygen content of the air

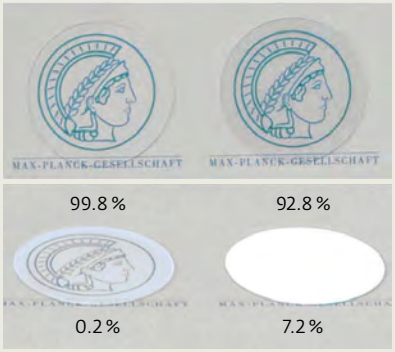
The mouse's keen sense of smell is hardwired in its genome: more than a thousand genes are dedicated to synthesizing receptor molecules for the olfactory sense, including one for a gas that we humans wouldn't normally think of as having an odor: oxygen. According to scientists at the Max Planck Research Unit for Neurogenetics in Frankfurt, mice can sniff out the oxygen content of the air with the help of type B neurons in their nasal mucosa. These cells are activated in response to a decrease – however slight – in the oxygen concentration of the air. The rodents can therefore smell a decrease of an odor – an ability that has yet to be found in any other animal. The key to this ability lies in the Gucy1b2 and Trpc2 genes, which contain information for molecules involved in signaling pathways in type B cells. However, it is still unknown exactly which receptor detects the oxygen content. Nor do the researchers know whether type B cells that respond to low oxygen levels also occur in humans. (www.mpg.de/10843354)

Graphic: MPI of Molecular Cell Biology and Genetics (top), Zhaolu Diao (bottom)

Superlative Coating

A surface with two-micrometer-high nanocolumns transmits almost all of the incident light

Antireflective coatings will soon be a lot more effective. Researchers at the Max Planck Institute for Intelligent Systems in Stuttgart have found a way to produce, on glass surfaces, nanostructures that reflect almost none – and transmit almost all – of the incident light. They have developed a method to produce conical columns measuring around two micrometers high on surfaces. Along surfaces coated with such columns, the refractive index changes continuously. Most light in the visible and shortwave spectrum is therefore able to penetrate the surface over a relatively wide range of angles of incidence. Conventional antireflective coatings and shorter nanoscale columns are antireflective only within a narrow range of the light spectrum and work only at very limited angles of incidence. The new antireflective coating could find applications in high-power lasers, cameras and microscopes, as well as in touchscreens and solar modules. (www.mpg.de/10797830)



A glass plate on which nanocolumns have been etched (illustrations on the left) reflects just 0.2 percent of light falling on it at an angle of 30 degrees and is transparent to the remaining 99.8 percent. At the same angle of incidence, a plate without the surface nanostructure (illustrations on the right) transmits only 92.8 percent of light, reflecting 7.2 percent.

Guided by Light

Microswimmers can be precisely guided to targets

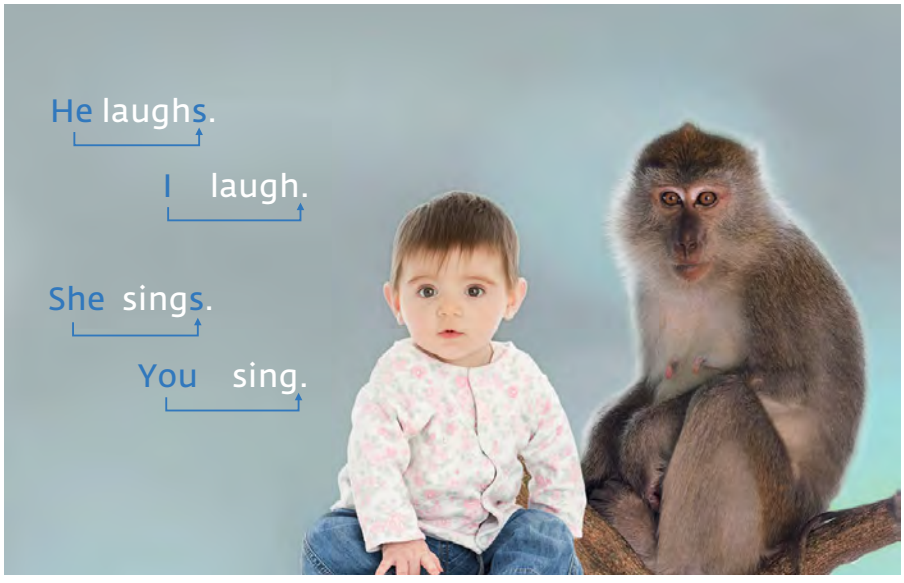
Tiny swimming objects can now mimic an ability that many microorganisms possess: in water containing a dissolved organic substance, they are able to move toward a light source or away from it, as required. To endow microswimmers with this ability, known as phototaxis, researchers at the Max Planck Institute for Intelligent Systems in Stuttgart and the University of Stuttgart use glass microbeads coated with carbon on one side. Upon exposure to light, the carbon layer and the liquid surrounding it warm up. As a result, the water and organic substance partially separate. This gives rise to a gradient in the solute concentration between the uncoated side of the bead and the carbon-coated side. To compensate for the concentration differential, water flows from one side of the microswimmer to the other, propelling it away from the light source. This orientation mechanism makes it possible to use a light source to guide microswimmers through liquids. (www.mpg.de/10756646)

Traveling toward the darkness: Glass beads coated on one side with carbon navigate autonomously away from a light source.

Monkeys with a Knack for Language

Macaques process complex sequences of syllables in a manner similar to babies

Even babies have a sense of grammar: three-month-old infants already recognize the rules for combining syllables and notice when a rule is violated. Scientists at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig have now discovered that monkeys also possess at least the rudiments of this ability. The researchers measured electrical brain activity on the scalp of macaques while the animals listened to meaningless but rule-compliant strings of syllables. They discovered that the electrical activity pattern of the animals' brain is similar to that of a three-month-old baby. They could also tell from the macaques' brain patterns that the animals notice when a syllable string is incorrect. This ability must therefore have arisen before the human evolutionary line split off from that of other primates. However, even humans lose this ability as adults: they no longer recognize language patterns by merely listening, like babies or macaques, and have to actively search for the rules. (www.mpg.de/10821435, only in German)



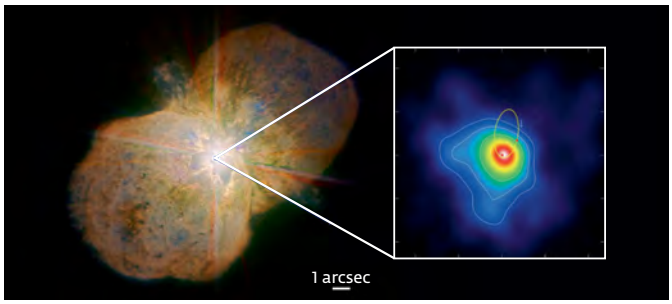
In many languages, syllables follow specific rules. In English, for example, the initial syllables "he" and "she" are followed – at variable distances – by an "s", whereas "I" and "you" aren't. Macaques and three-month-old babies recognize these rules, though the monkeys learn them more slowly than humans.

Graphic: Celia Lozano/MPI for Intelligent Systems/University of Stuttgart (top), photo: MPI for Human Cognitive and Brain Sciences (bottom)

The Turbulent Heart of Eta Carinae

Detailed images of the binary star system show the collision zone of the stellar wind

Eta Carinae is a massive and very bright binary star system. The heavier partner is one of the biggest and brightest stars in the sky, weighing in at around 100 solar masses. A team headed by Gerd Weigelt from the Max Planck Institute for Radio Astronomy in Bonn has studied Eta Carinae with the help of near-infrared interferometry for the first time. They obtained images of the area between the two stars in which the stellar winds from each star crash into each other at speeds of more than ten million kilometers an hour. Within the collision zone, the temperature rises to many tens of millions of degrees – hot enough to generate X-rays. Until now, it wasn't possible to spatially resolve this central region. The astronomers used a new image processing technique, which they applied to images taken by the AMBER instrument of the European Southern Observatory's Very Large Telescope Interferometer (VLTI). (www.mpg.de/10794673)



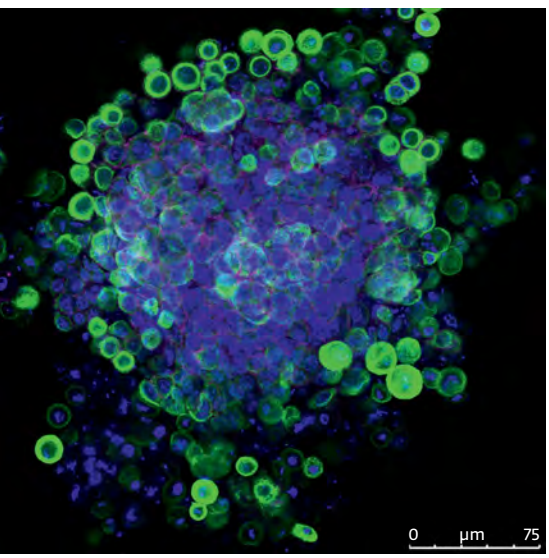
Interstellar storm: The left image shows the Homunculus Nebula around the massive binary star system Eta Carinae. On the right is a high-definition image of the wind collision zone in the central area of the system. This area is around 100 times larger than the diameter of each of the two stars. The yellow ellipse shows the orbit of the binary star system. The two red dots indicate the positions of the two stars at the time of the observation.

Photos: ESO (top left) and Gerd Weigelt/MPIfR (top right); MPI for Biology of Ageing (bottom)

Skin Stem Cells in a Test Tube

New method could reduce animal research

Wounds have to be healed; lost hairs have to be replaced. To achieve this, the skin uses stem cells in the hair follicles. If it were possible to successfully cultivate such stem cells in the lab, one of the benefits would be to make a lot of animal research superfluous. Until now, scientists searching for the causes of skin cancer have had to conduct research on mice. Scientists at the Max Planck Institute for Biology of Ageing in Cologne have now succeeded in cultivating mouse skin stem cells in the lab. Supplied with growth-promoting chemical messengers, skin stem cells survive for long periods in a gel consisting of natural skin proteins. In addition, the researchers found that the method can also be used to cause mature cells to revert to the stem-cell state. In the future, researchers could carry out experiments with such stem cells instead of on living skin, and even use them to test the effects of new cancer drugs. The Cologne-based scientists now hope to adapt their technique to human cells.
(www.mpg.de/10866807)



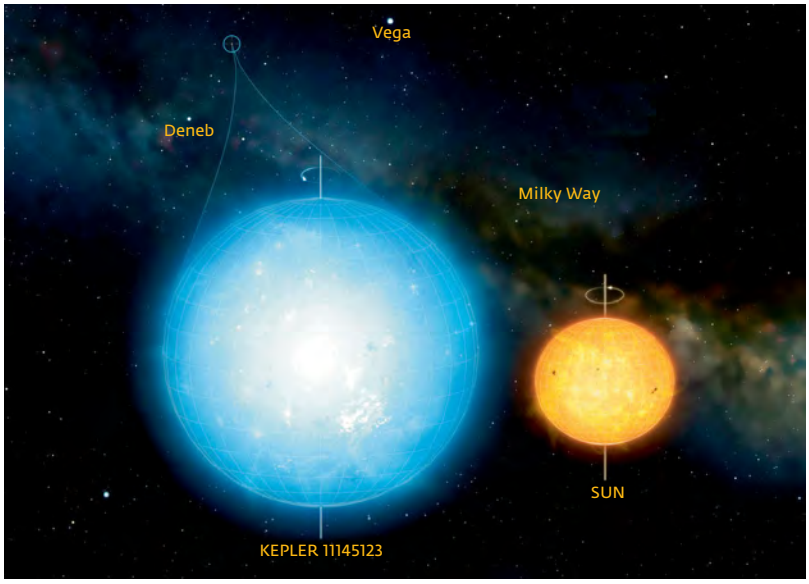
Hair follicle stem cells in cell culture under the microscope (blue: cell nucleus; green: keratin; red: actin).

Pushing the Boundaries of Microscopy

It is now possible to observe individual proteins at work in cells. To achieve this, a team of researchers headed by Stefan Hell, Director at the Max Planck Institute for Biophysical Chemistry in Göttingen, have developed the MINFLUX fluorescence microscope, which can resolve two fluorescent proteins even if they are separated by only a few nanometers – the limit of what is possible in living cells. The team achieved this feat by cleverly combining two Nobel prizewinning methods: they identify individual fluorescent molecules by randomly switching the molecules on and off, and then determine their precise positions by stimulating them with a doughnut-shaped laser beam. The researchers exploit the fact that they know the precise intensity profile of the laser beam. The whole process takes place so rapidly that it is even possible to follow the path of a protein through a cell. And the resolution is determined only by the size of the fluorescent molecules.
(www.mpg.de/10878921)

A Well-Rounded Star

Researchers measure the shape of Kepler 11145123 with unprecedented accuracy



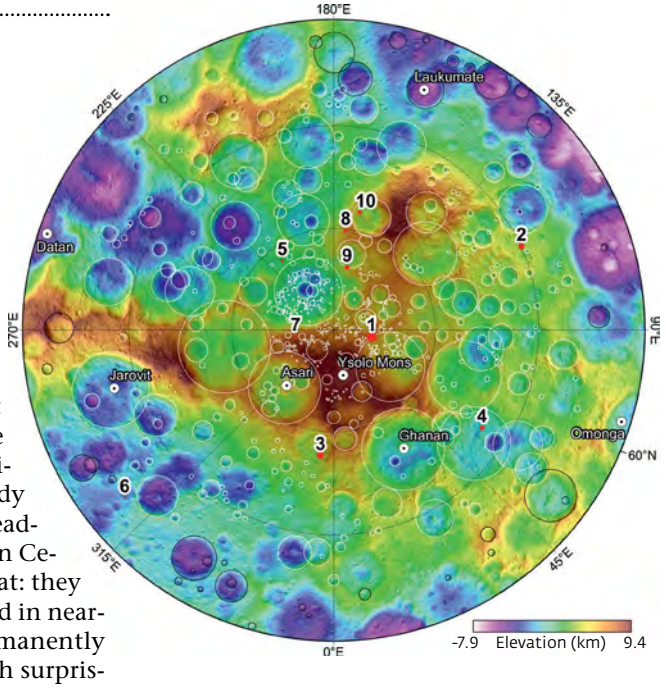
The star Kepler 11145123 is the most perfectly round natural celestial body that has ever been measured. The star's oscillations show that the difference between the equatorial radius and the polar radius is just three kilometers, making this star much rounder than our own Sun.

Stars aren't perfect spheres. As they spin on their axis, centrifugal force tends to flatten them somewhat. A team headed by Laurent Gizon from the Max Planck Institute for Solar System Research and the University of Göttingen have now measured the flattening of a slowly rotating star with unprecedented accuracy. They found a difference of just three kilometers between the equatorial radius and the polar radius of Kepler 11145123, an object located 5,000 light-years from Earth. This difference is astonishingly small in relation to the star's mean radius of 1.5 million kilometers. In other words, the gas ball is extremely round. For their measurements, the astronomers exploited the fact that the star oscillates. They compared the frequencies of oscillations that are more pronounced at the equator with those that dominate at higher latitudes. From this, they calculated the difference between two measurements: the distance from the center of the star to the pole and the distance from the center to the equator. (www.mpg.de/10827169)

Water Ice in the Eternal Polar Night

The cameras of the Dawn space probe are surveying the northern polar region of the dwarf planet Ceres

The US space probe Dawn has been orbiting the dwarf planet Ceres between Mars and Jupiter since March 2015. The probe has pointed its on-board cameras from the Max Planck Institute for Solar System Research in Göttingen at the celestial body and has now almost completely mapped its surface. A team headed by Göttingen-based scientists recently published a report on Ceres' high north. The two framing cameras achieved a special feat: they were able to photograph deposits of water ice in areas shrouded in nearly eternal darkness. Among 634 identified craters with permanently dark areas, the researchers found 10 craters on the images with surprisingly bright areas in their interior. In one relatively young crater measuring 3.8 kilometers across, the bright deposits extended beyond the permanently dark zone into a region that is sometimes exposed to direct sunlight. (www.mpg.de/10861571)



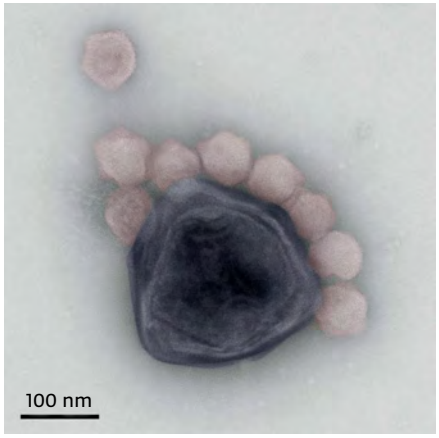
A view of the north pole: The colors show the elevation relationships on Ceres. The numbers indicate ten craters in which the framing cameras from the Max Planck Institute for Solar System Research in Göttingen detected water.

Photos and graphic: Mark A. Garlick (top); Nature Astronomy (bottom)

The Enemy of My Enemy Is My Friend

A single-cell organism protects itself from viruses with viruses

In humans, a viral infection is usually bad news. For a single-cell marine organism, however, it can mean salvation – when a parasite becomes a symbiotic partner. According to scientists at the Max Planck Institute for Medical Research in Heidelberg, however, the partnership doesn't benefit the cells that are infected first. They must die so that others may live. For the single-cell organism *Cafeteria roenbergensis*, a giant virus called CroV poses a mortal threat. After attaching itself to the cell surface, the virus causes the host cell to churn out giant viruses until it bursts. However, if a cell has previously been infected with the mavirus, it releases particles of both virus types. These maviruses save other single-cell organisms: if they reach new host cells at the same time as the giant viruses, they prevent the giant viruses from multiplying. A single-cell organism that is simultaneously infected by both viruses releases only mavirus particles but no CroV particles. Uninfected organisms are therefore protected from infection by giant viruses. The researchers are now looking for other single-cell organisms that use such unusual defense mechanisms.
(www.mpg.de/10851301)



Close relationship: Particles of the giant virus CroV (dark blue) and the mavirus (pink).

Looking Out for Others Means Longer Life

Elderly people who help and support others live longer. That is the finding of a study in which the Max Planck Institute for Human Development in Berlin participated. An international team compared survival data of more than 500 people between the ages of 70 and 103. Half the grandparents who cared for their grandchildren or actively assisted their children were still alive ten years after the initial survey. Among those who weren't actively dedicated to their offspring, by contrast, around half died within five years. The researchers also found that childless elderly people who care for friends or neighbors also benefit from the effect. However, Ralph Hertwig, Director at the Max Planck Institute for Human Development, doesn't believe that caring for others is a recipe for longevity. "Positive effects are likely only if the degree of commitment is moderate. Beyond that, it could lead to stress and have a negative impact."
(www.mpg.de/10873883)

The Fastest Fliers in the Animal Kingdom

The Brazilian free-tailed bat isn't just a skillful aviator, it also holds the current speed record

The flight characteristics of birds are unsurpassed and still serve as inspiration for aircraft engineers. Birds of the aptly named swift family, for example, hold the speed record for horizontal flight, darting across the sky at speeds of over 110 kilometers an hour. Bats, in contrast, have always been considered slow because of the greater air resistance resulting from their wing structure. This belief is mistaken, as researchers at the Max Planck Institute for Ornithology discovered. They have identified a new champion among the acrobats of the air: the Brazilian free-tailed bat, which zips through the night at speeds of over 160 kilometers per hour – and that without a tail wind. The bats, which weigh just 12 grams, reach such high speeds thanks to the aerodynamic shape of their body and – for bats – longer-than-average wings.
(www.mpg.de/10820081)

Animals with long, narrow wings usually fly faster than those with broad, stubby wings. The Brazilian free-tailed bat, which can reach speeds of 160 kilometers an hour, is a case in point.

Photos: MPI for Medical Research/U. Mersdorf and M. Fischer (top); MPI for Ornithology (bottom)