

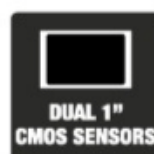
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*The massive meteor strike
that early humans survived*



69

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**Stunning photos show
INSIDE THE HUMAN EYE**

**How a fast train
BEAT THE NAZIS**

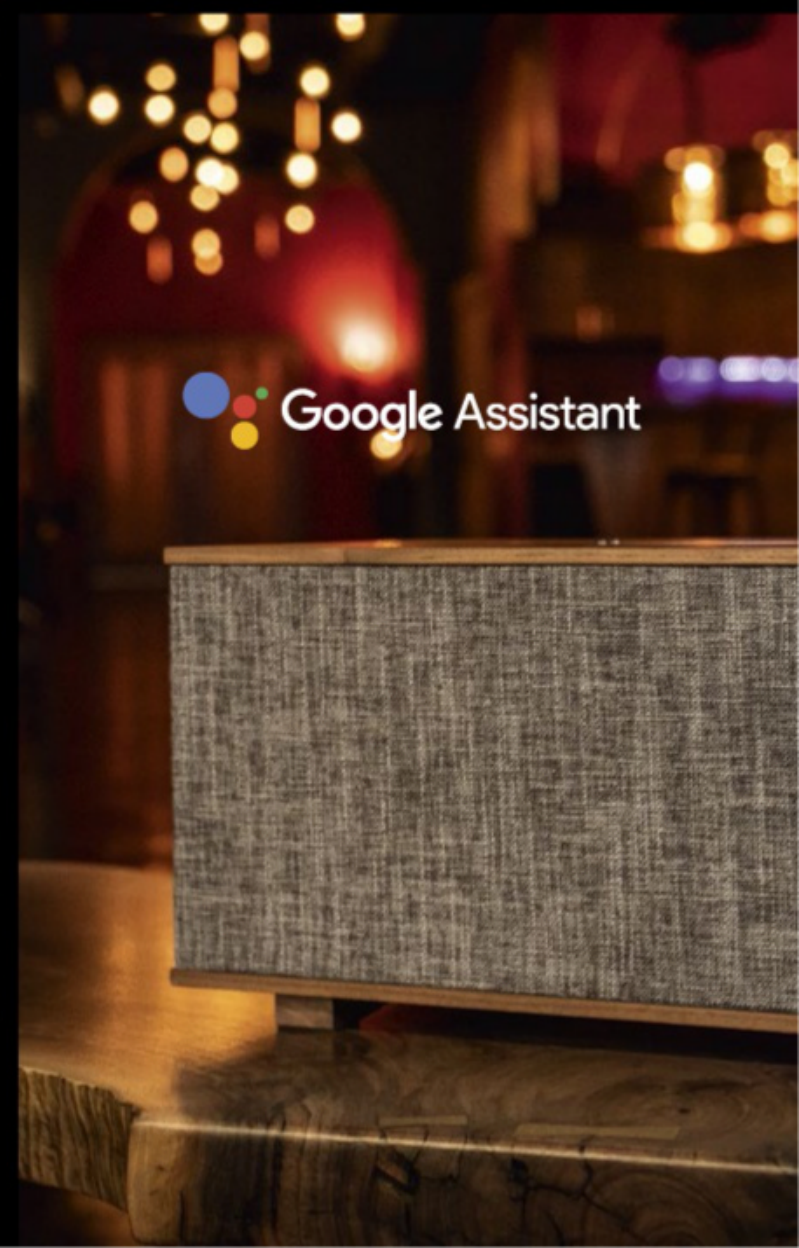
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COVER
STORY

32

BRACE FOR IMPACT!

Just as Stone Age humans started to relax out of an ice age 13,000 years ago, a meteor slammed into Greenland, bringing on another 1300 years of cold.

40

SPIDER MYTHS

Can they regrow legs and survive your vacuum cleaner? Are their webs really as strong as steel? And have you been eating them at night unawares for years? Our mythbusting experts separate fact from fiction...



44

THE HUMAN BRAIN PT. 2

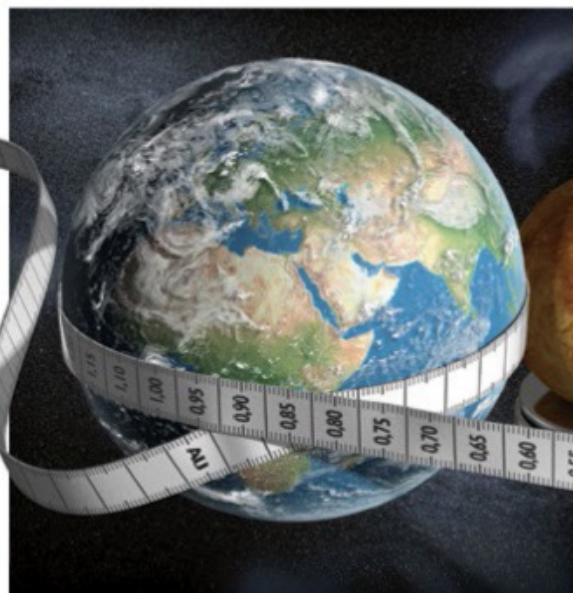
The second part of our Battle Of The Brain series examines some of the possible causes of depression and whether electromagnetism may offer help to some who don't respond to current treatments.



50

MEASURING THE SOLAR SYSTEM

How far to Ultima Thule, exactly? How fast is the Sun travelling? Scientists have been improving their measurements for hundreds of years...



60

ANIMALS IN LOW OXYGEN

Nothing else lives as high as the Himalayan jumping spider. So what is it jumping at?



66

PHOTODOC: THE HUMAN EYE

Get up close with amazing images of tear glands, rods, cones, and the whole complexity of the human eye.



64

SCIENTIFIC ARCHIVES: STEAM RECORD

Gresley's 'Mallard' was given every technological advantage in the race to beat the German steam locomotive speed record back in 1938.



REGULARS AND OTHER FEATURES

6

MEGAPIXELS

Amazing images of star-sharpening, parasitic wasp-eggs and more...



10

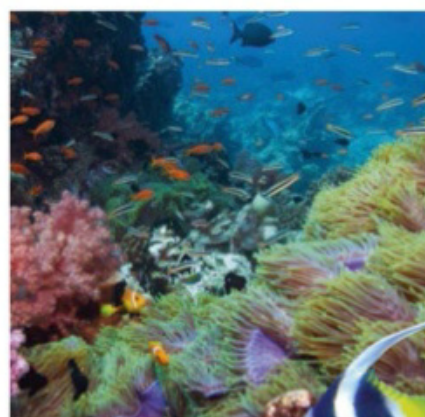
SCIENCE UPDATE

Good news! The Milky Way has an extra half a billion years to live before it crashes into the Andromeda galaxy.

18

ASK US

We all know about Absolute Zero. But is there also an absolute maximum?



78

INSTANT EXPERT: CORAL REEFS

How do they grow? Why so colourful? And what happens when the temperatures keep rising?

82

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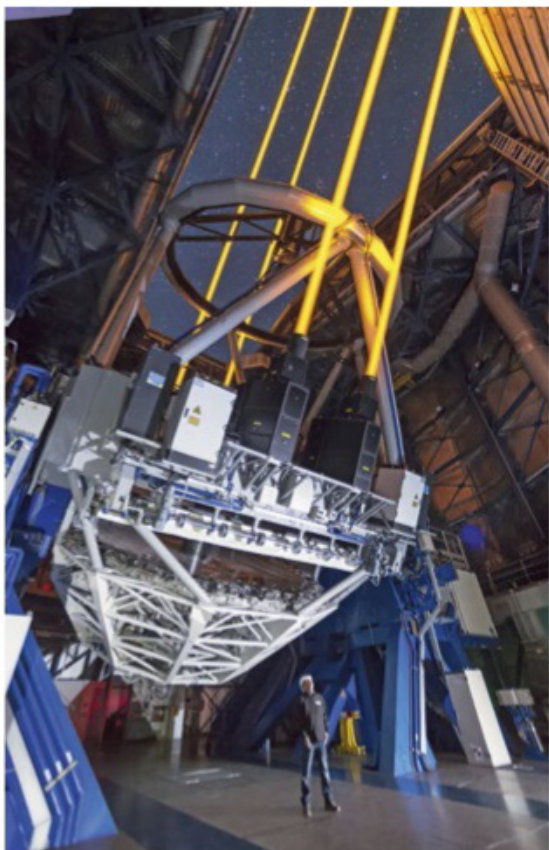
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We share with our readers a fascination with science, technology, nature, culture and archaeology, and believe that through education about our past, present and future, we can make the world a better place.



Beaming up: Lasers used to sharpen stars



The Atacama Desert in Chile is one of the driest places on Earth, and it is the location of the European Very Large Telescope (VLT), which offers a clear view of the sky on most nights. But although the conditions are ideal, the stars are blurred by Earth's atmosphere. To make its images sharper, the telescope is equipped with lasers that make sodium atoms in the atmosphere light up like artificial stars. Using the bright spots as guides, the telescope can be adjusted to compensate for the blur. The result: sharp photos of stars up to four billion times weaker than those which can be observed by the naked eye.

➤ Photo // P. Horálek





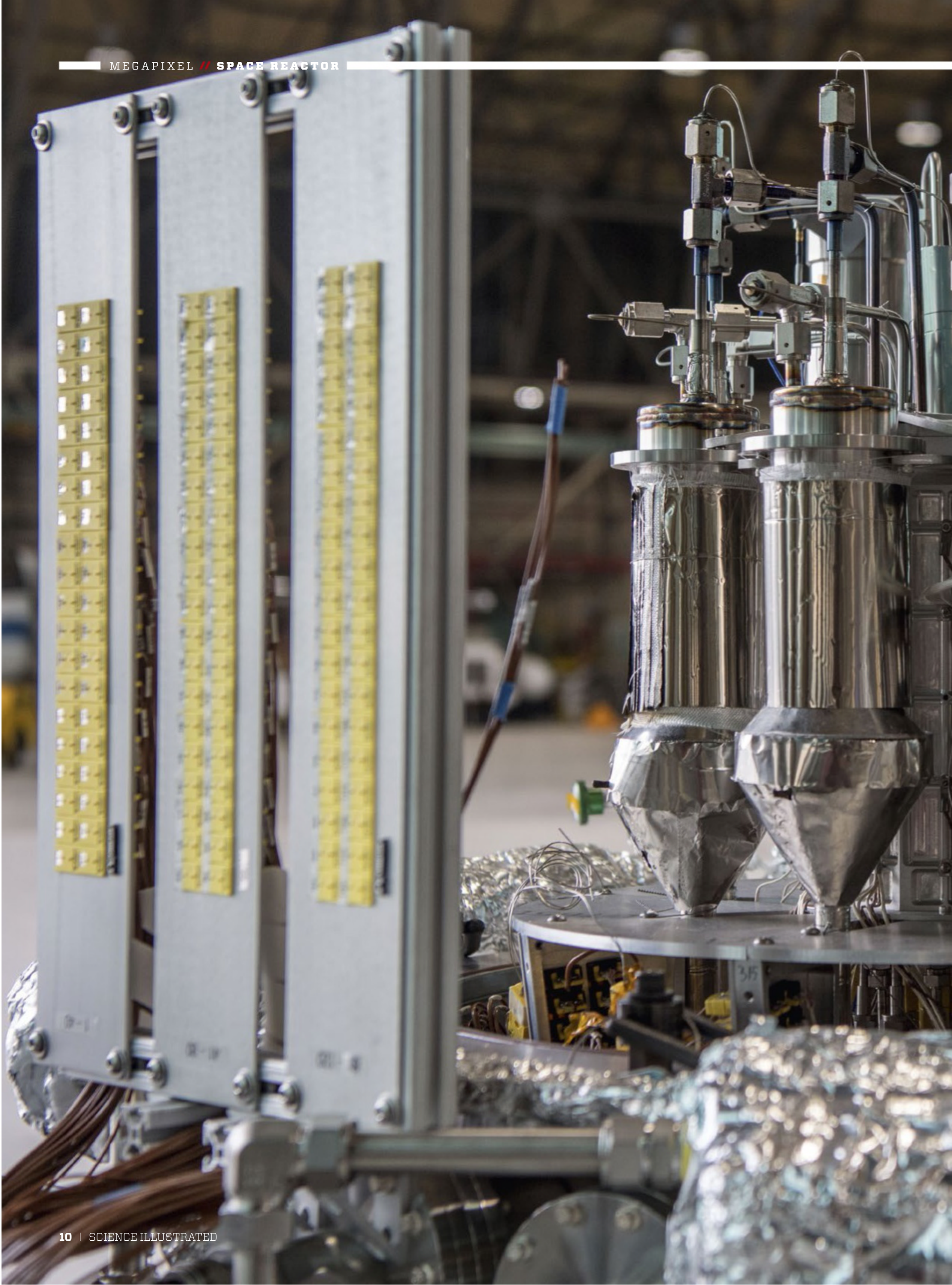
Dinner host: Caterpillar survives parasitic wasps



Parasitic wasps lay eggs in other insects' caterpillars by piercing them with their sharp ovipositor egg-laying organs, while simultaneously infecting the caterpillar with a virus that suppresses its immune system, so it will not attack the uninvited guests. As soon as the eggs hatch, the parasitic wasp larvae begin to eat their host from within. In this photo the larvae have exited the host and pupated in their silk-like cocoons after having used a butterfly caterpillar as a living incubator. In this case, the involuntary host survived, which is very unusual.


Photo // Lucas Bustamante




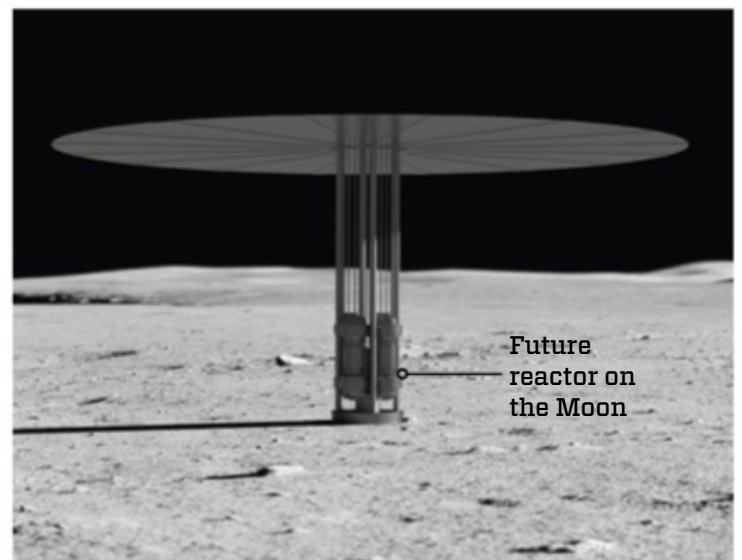




Remote power: NASA's mini reactor for the Moon & Mars

 The long nights on the Moon and the dust storms on Mars would make solar cells an unreliable energy source for future bases, so NASA is developing a small nuclear reactor that provides 10kW – corresponding to the consumption of several households – for more than 10 years. The reactor, KRUSTY, uses uranium-235 as fuel, converting the heat from the fission process into power. The 1kW prototype weighs only 134kg, though the more powerful final version will be about 100kg heavier.

 Photo // NASA



The Milky Way's life has been prolonged by 600 million years

Our galaxy will end its independent life when it collides with its large neighbour, the Andromeda galaxy – but this is now predicted to happen much later than astronomers had previously thought.

ASTRONOMY The Milky Way and the Andromeda galaxy are approaching each other and, at some point, they will merge into a new and huge galaxy named Milkomeda. Astronomers have predicted this for the past seven years, but new observations show that it will happen much later than previously believed. Until now the fusion has been predicted for about 3.9 billion years hence, but according to the new calculations it won't occur until 600 million years later – in 4.5 billion years.

Scientists from the Space Telescope Science Institute in the US have made their conclusion based on data from the Gaia satellite, which has mapped out the accurate positions and motions of one billion stars in the Milky Way. Gaia has also made measurements of stars in our neighbouring galaxies, such as Andromeda and the Triangulum galaxy. Using this data, scientists have been able to observe the motions of the galaxies themselves,

and to create a new model of their future courses. The model demonstrates that the Triangulum galaxy will influence both the Milky Way and Andromeda as they approach each other, and it will end up orbiting the result of the collision.

When the Milky Way and Andromeda merge, it will not necessarily mean that the stars of the galaxies collide. The distances between the stars of the galaxies are so great that the likelihood of a collision is small. On the other hand, the stars will influence each other significantly with their gravity, and that will change the structure of the merged galaxy. According to astronomers, the two spiral galaxies will become one elliptical galaxy, and the two supermassive black holes at the centres of the galaxies may possibly merge into one. This could mean that the galaxy becomes a quasar, in which the light from the centre outshines all radiation from the stars around it.

Dramatic Milky Way demise

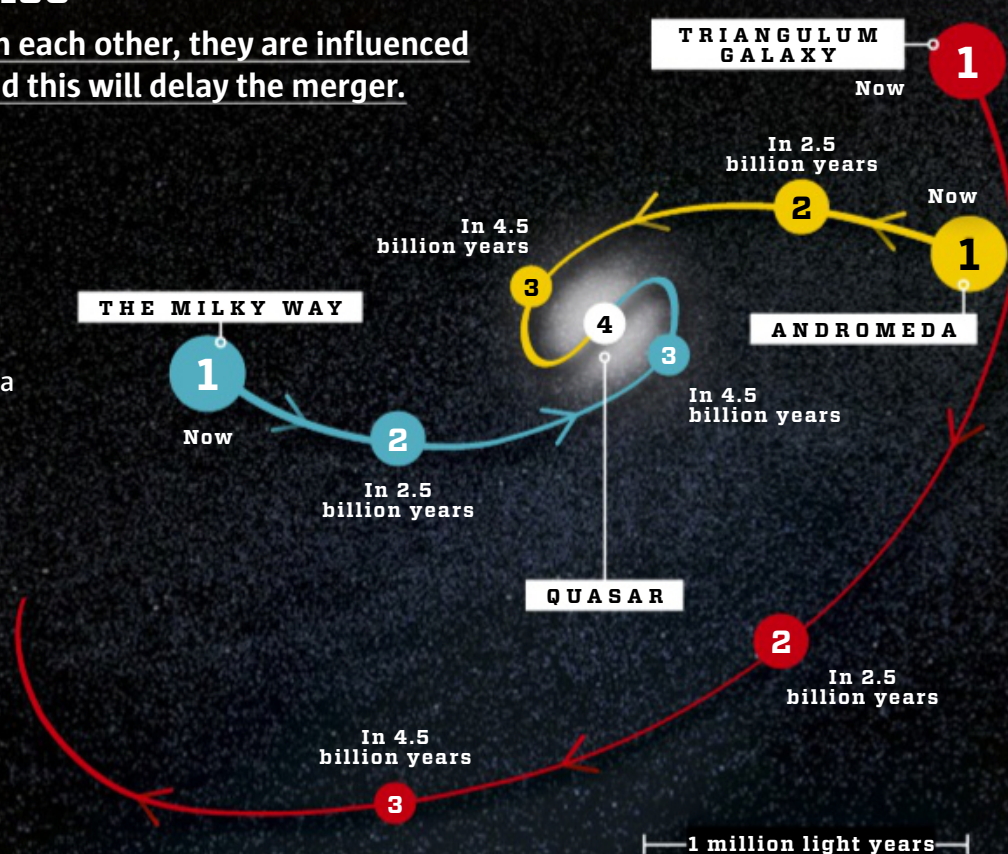
As the Milky Way and Andromeda approach each other, they are influenced by the gravity of the Triangulum galaxy, and this will delay the merger.

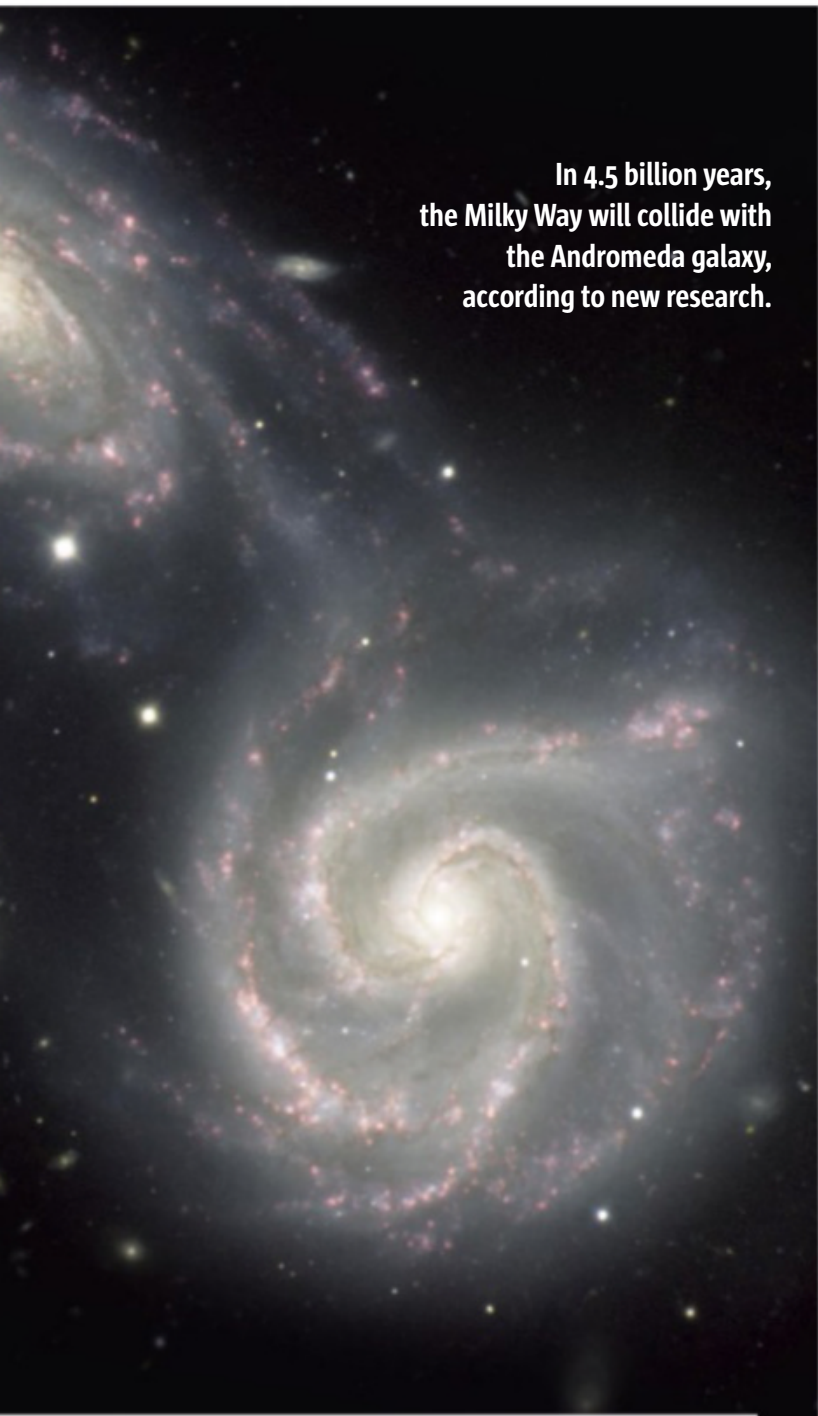
1 Right now, the distance from the Milky Way to the Andromeda galaxy is 2.5 to 3 million light years. They are heading towards each other.

2 In 2.5 billion years, the Milky Way and Andromeda will be 1 million light years closer to each other. The Triangulum galaxy has influenced both their courses.

3 In 4.5 billion years, the Milky Way and Andromeda collide and begin to rotate closely around each other, until they finally merge into one huge galaxy.

4 The result of the collision might be a quasar, a galaxy with a highly active supermassive black hole at its centre.





In 4.5 billion years, the Milky Way will collide with the Andromeda galaxy, according to new research.



● **TRIANGULUM**
Type: Spiral galaxy
Stars: 40 billion
Diameter: 60,000 light years
Mass: 50 billion solar masses

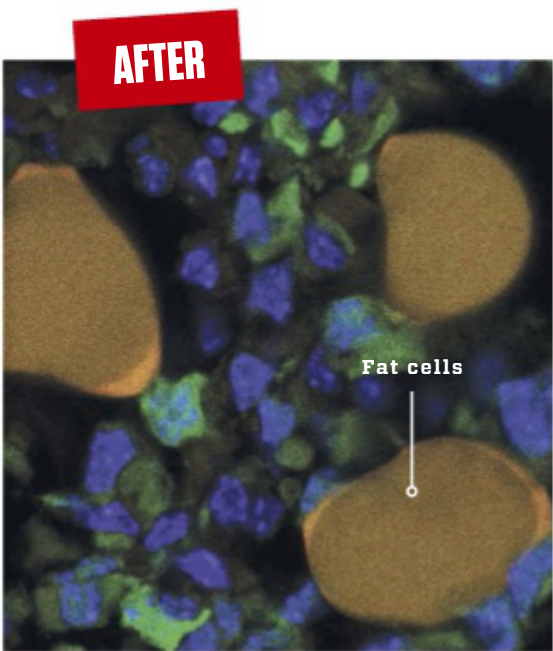
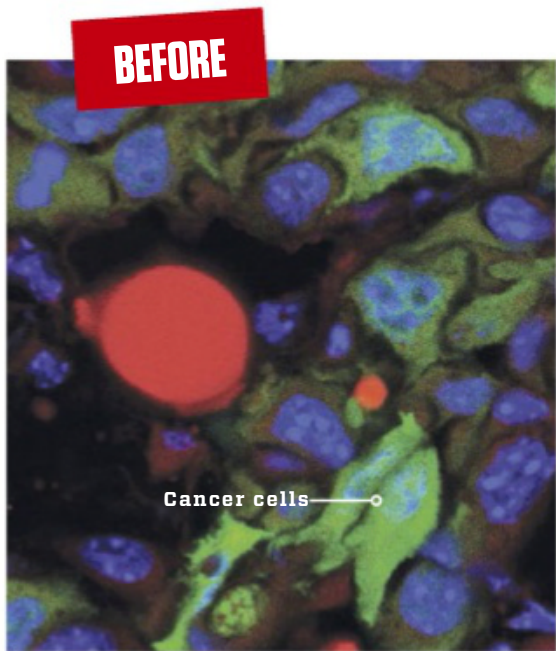


● **ANDROMEDA**
Type: Spiral galaxy
Stars: 1,000 billion
Diameter: 220,000 light years
Mass: 1,700 billion solar masses



● **MILKY WAY**
Type: Barred spiral galaxy
Stars: 200+ billion
Diameter: 100,000 light years
Mass: 1,000 billion solar masses

GEMINI OBSERVATORY & NASA/JPL-CALTECH/R. HURT & LORENZO CONOLI & GIOVANNI BENNITTE



DEPARTMENT OF BIOMEDICINE/UNIVERSITY OF BASEL

The combination of two known drugs ensures that cancer tumours do not produce metastases. Instead, new cancer cells develop into fat cells.

New treatment converts cancer into fat

MEDICINE A combination of two approved drugs could convert cancer cells into harmless fat cells, according to a new study made by scientists from the University of Basel, Switzerland. One drug, rosiglitazone, is used to treat type 2 diabetes, boosting insulin sensitivity. The drug binds to receptors in fat tissue and contributes to maturing fat cells. The other drug, trametinib, is used for cancer treatment, curbing the growth of cancer cells. Scientists tested the combination on mice that had human breast cancer tumours implanted into their breast fat. A cancer tumour spreads to other parts of the body by releasing cells that can flow through the blood stream and form new tumours – also known as metastases. Before these “breakaway cells” can leave the original tumour, they

change – rejuvenating, to put it in simple terms, by reverting back to an earlier cell stage. This is where the new treatment has its effect. In their early stage, the cells are more sensitive and can develop in several directions. The combination of the drugs makes them develop into fat cells instead of cancer cells, thereby curbing the spread of the cancer. In the mice, the treatment prevented the cancer spreading to other parts of the body. What's more, the experiments demonstrated that the treatment could also have the effect of shrinking the original tumour. Scientists now aim to find out whether the treatment is also efficient against types of cancer other than breast cancer, and to investigate the effects of combining the new treatment with chemotherapy.

Test yourself Answers to p82. No peeking!

LOGIC

PROBLEM 5: 4 minus A. The square between the centres of the circles has an area of $2 \times 2 = 4$. Deduct the area of four quarters of a circle = A.

PROBLEM 6: On day 7. On day the plant was one metre tall, and on day 8, it was 50cm.

SCIENTIST IN FOCUS

7B: A Beautiful Mind.

8C: The Insider. Crowe received Oscar nominations for 'The Insider' in 2000 and 'Gladiator' in 2001, and won for 'A Beautiful Mind' in 2002.

9D: A car crash. Nash and his wife, Alicia Nash, both died in a taxi crash in 2015.

10A: Game theory. The theory is based on studies of choices and optimum behaviour when the costs and profits of different options depend on the choices of other individuals.

VISUAL INTELLIGENCE

PROBLEM 1: 10 other ways! 1-6-12-15, 1-7-12-14, 1-7-10-16, 1-8-10-15, 1-8-11-14, 2-5-11-16, 2-5-12-15, 2-7-9-16, 2-8-9-15 or 2-8-11-13.

PROBLEM 2:

NUMERACY

PROBLEM 3: 37. The figures increase by the odd numbers of 1, 3, 5, 7, and 9, so the next number is $26 + 11 = 37$.

PROBLEM 4:



BY THE WAY

PLATYPUS MILK PROVIDES A NEW WEAPON AGAINST BACTERIA

Australian scientists have mapped out the structure of a protein in platypus milk that can be used in the fight against resistant bacteria. The protein folds and curls in a way that scientists have never observed before, likely a key to the bacterium-killing effect.

SHUTTERSTOCK



AND TALKING OF THE PLATYPUS ...

NOBODY KNOWS THE NUMBER OF PLATYPUSES

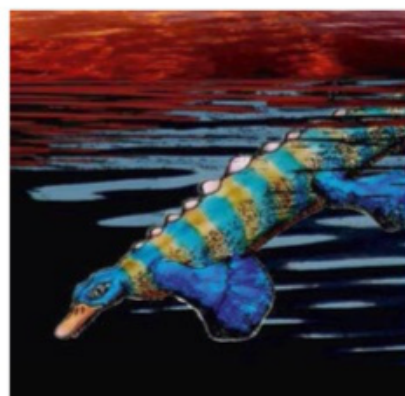
➤ Biologists know the habitats of platypuses, but nobody knows how many animals there are – maybe 100,000, but perhaps only 20,000. Scientists from independent Victoria-based research company cesar will count the animals based on the unique DNA traces each platypus leaves in the water of its habitat.



SHUTTERSTOCK

PLATYPUS DESIGN IS 250 MILLION YEARS OLD

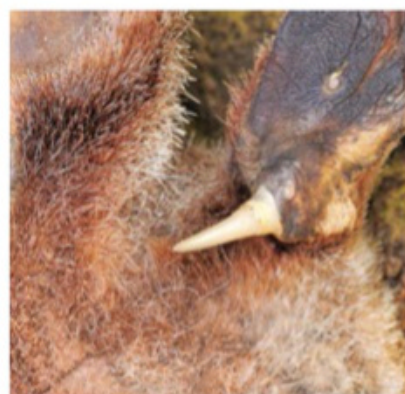
➤ Chinese palaeontologists have discovered the fossil of an animal that lived 250 million years ago, before the first dinosaurs. It had a small head and a beak. The eye sockets were so small that scientists think the creature was almost blind, hunting by means of its sensitive beak, just as platypuses do today.



GIANLUCA DANINI

MALE VENOM COULD BE EFFICIENT AGAINST DIABETES

➤ Platypuses are among the few mammals that produce venom. Scientists have discovered that the toxin includes a version of the GLP-1 hormone, which is important in the treatment of diabetes. The platypus variant can remain active much longer than the variant in humans, so it might lead to improved drugs.



DAVE WATTS/ALAMY/IMAGESELECT



NASA

When astronauts visited the Moon in 1971, they brought back small stones. One of them turns out to have been formed on Earth.

Earth's oldest stones were discovered on the Moon

GEOLOGY In 1971, astronauts from the Apollo 14 mission collected stones on the Moon and brought them back to Earth. Ever since, the lunar stones have been carefully stored, visited only by scientists examining them to learn more about the Moon's geology. For one of the stones, however, they needn't have bothered. New studies indicate that it was formed not on the Moon, but on Earth. Indeed it may be Earth's very oldest stone, as it was preserved on the Moon, protected there against the geological forces that exist on our world.

This surprise discovery has been made after examination by an international team of scientists. The stone consists of the minerals quartz, feldspar, and zircon, which are rare on the

Moon but common on Earth, where quartz and zircon are formed in oxygen-rich environments at high temperatures and pressure. Geologists have dated the rock to between 4 and 4.1 billion years of age, and also determined that the rock was formed about 20km below Earth's surface. A major asteroid impact on Earth flung it into space, after which it landed on the Moon, then orbiting Earth at a third of the distance it does today. On the Moon it fell victim to further asteroid strikes, which partly melted it some 3.9 billion years ago and buried it deep below the surface. There it remained until a new impact brought it back to the surface some 26 million years ago in a strike which produced the Cone crater, where the astronauts discovered the stone.

128,000 km

– is how far the stone travelled to get from Earth to the Moon. The trip back to Earth was at least three times longer, as the Moon is now further away.



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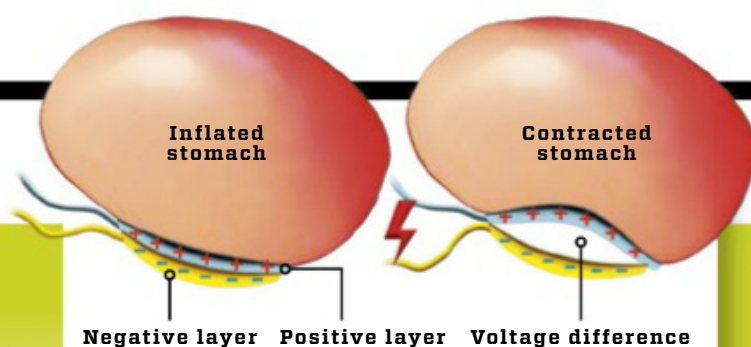


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**POPULAR
SCIENCE**

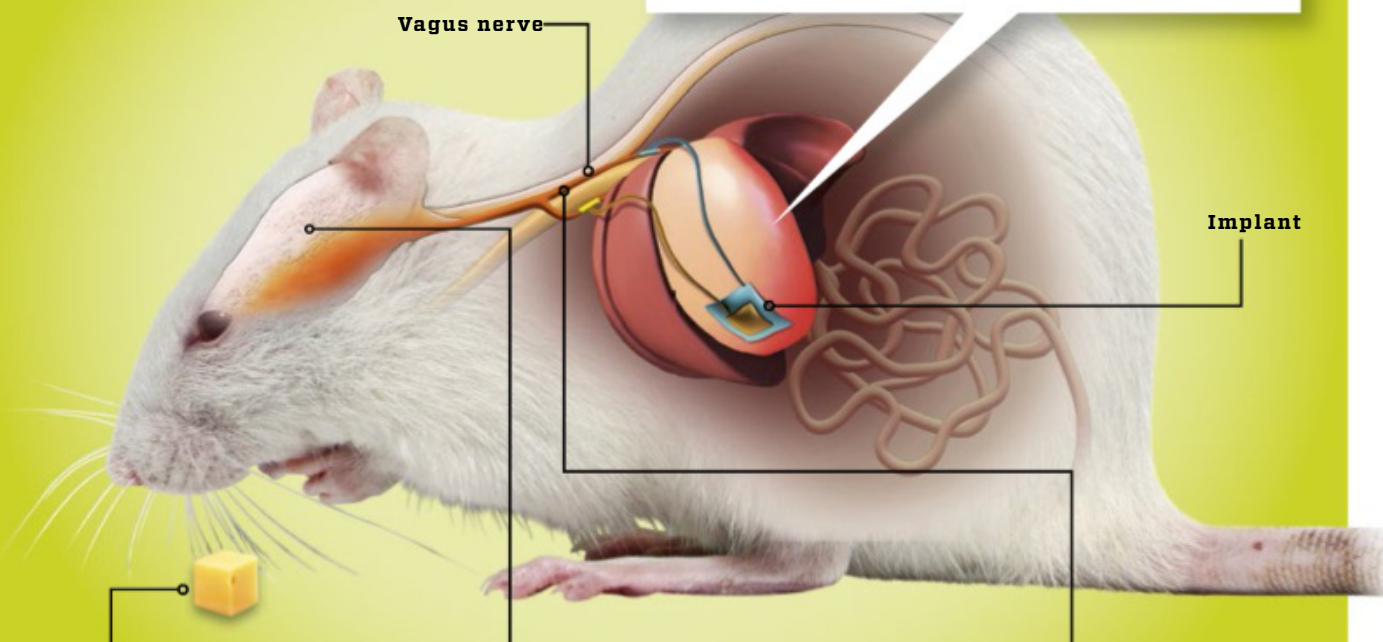
Implant uses the stomach as a battery

The implant consists of two electrically charged layers. The stomach's motions trigger the electrical signal that allows the brain a false sensation of fullness.



The stomach produces voltage in the implant

2 The motions of the stomach makes the implant layers come together and apart. As they part, a voltage difference is produced between them.



The rat eats

1 Just a small bite is enough to make the stomach set to work.

The brain is full

4 The brain receives the signal and considers it to be a sign of fullness. The rat immediately stops eating.

Vagus nerve gets shock

3 Via electrodes, the voltage difference produces an electric shock in the vagus nerve that sends a signal on to the brain.

Electric shocks – diet of the future?

By means of slight electric shocks, a new implant can fool your brain into believing that you are full, making it easier to lose weight.

MEDICINE Obesity has become a global epidemic, with some 650m people considered severely obese. But a small implant that curbs the craving to eat might help change that.

The implant, which was developed by scientists from the University of Wisconsin-Madison in the US, is a square approximately 1 x 1cm with a thickness of 1mm. In simple surgery, it is placed on the outside of the stomach and linked with the vagus nerve, which is the body's main road for signals between the digestive system and the brain. The implant uses the fact that the stomach moves as soon as it receives food, alternately contracting and expanding to knead the food. The motion is sufficient to generate an electrical current in the implant of 0.1-0.5 volts, producing a small shock in the vagus nerve. The

signal continues to the brain and is interpreted as a sign of fullness. The scientists implanted the device into obese rats, which lost 38% of their body weight in 100 days.

The surgery is much more gentle than gastric bypass surgery, by which surgeons make the stomach smaller in order to make the patient feel full earlier. The new implant can also be removed, returning the patient to normal eating rhythms once sufficient weight has been lost.

The scientists now aim to test the implant on pigs, more similar to humans in anatomy and body weight than are rats.

The implant measures around 1 x 1cm, and is 1mm thick.



Two human species shared the same cave

ARCHAEOLOGY The two human species to which we are most closely related lived close to each other for thousands of years. This has been established by archaeologists from the University of Wollongong in NSW, who dated soil layers of the Denisova Cave in Siberia, in which many discoveries of both Denisovans and Neanderthals have been made. The studies show that the Denisovans used the cave 287,000 to 55,000 years ago. The Neanderthals seem to have moved in 193,000 years ago, staying until 97,000 years ago.

While archaeologists are not certain that the two human species lived in the cave at the same time, proof of socialisation was found in August 2018, when genetic studies of a bone from a young girl showed that her father was a Denisovan, her mother a Neanderthal. The bone is about 100,000 years old.

More recent discoveries have also been made in the cave of processed animal bones, mammoth ivory and ostrich egg shells left by humans. These finds are 49,000-43,000 years old. According to some archaeologists, they were left by Denisovans, because no bones from modern men have been found in the cave. Others think that they originate with modern men who arrived at the cave shortly after the Denisovans disappeared.



Archaeologists have found bones from both Neanderthals and Denisovans in the Siberian cave.

MIKKEL JUUL JENSEN & XUDONG WANG/UNIVERSITY OF WISCONSIN-MADISON

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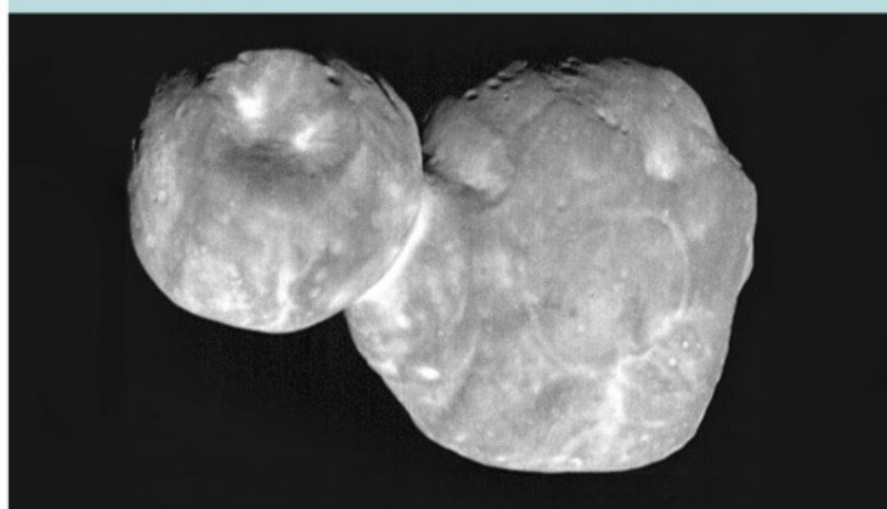
Mysterious object surprises astronomers

ASTRONOMY NASA scientists are taken aback by images coming from the New Horizons space probe during its encounter with the Ultima Thule object. This enigmatic Kuiper Belt object does not have the shape that scientists expected. When the probe approached Ultima Thule, it seemed that the object was shaped rather like a snowman, with roughly spherical “body” and “head”. Now close-ups taken against the light show that Ultima Thule is flatter than expected. This raises several questions, as scientists have never before observed an object of this shape orbiting the Sun. According to astronomers, Ultima Thule and other objects on the outskirts of the Solar System are the oldest we can find today, and they can show how planetary building blocks were formed.

Astronomers are also surprised that Ultima Thule has an almost

smooth surface, with only a few craters. This might mean that the Kuiper Belt does not include as many small objects as astronomers used to think. In this Ultima Thule confirms the impression gained when New Horizons flew by Pluto and its moons, finding that those surfaces also displayed very few craters. In the case of Pluto, it's possible that geological forces erased all such evidence, but that idea can't be applied to its moons, which are geologically inactive. The new knowledge may indicate that processes went faster than thought as dust and pebbles combined to form the first worlds, leaving much less material than scientist have expected.

ULTIMA THULE AS PHOTOGRAPHED BY NEW HORIZONS



The New Horizons space probe's latest images reveal that Ultima Thule is much flatter than scientists used to think.

Scientists' theory:



The real thing:

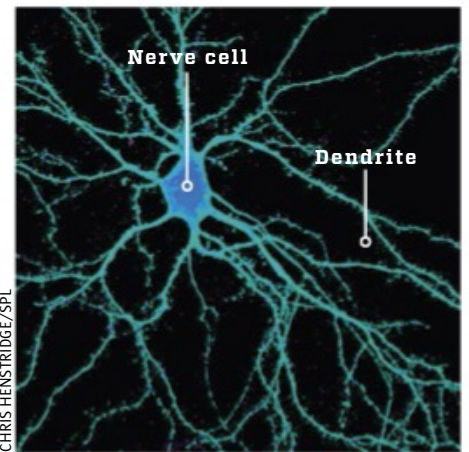


AROUND THE WORLD • Bolivia



Romeo and Juliet to save dying frog species

Biologists have discovered a population of *Telmatobius yuracare* frogs in the mountains of Bolivia. It's the first wild observation since 2008, during which time scientists have held only one individual in captivity, a male named Romeo. Now joined by a female, Juliet, it is hoped that together they can lay the foundations of a new population (with a happier ending than that of their literary counterparts).



The volume of nerve cell dendrites influences how intelligent we are.

Longer thicker brain-cell arms determine your IQ score

HUMAN BRAIN The length and width of brain cell extensions, also known as dendrites, seem to determine our IQ, according to new studies by the Dutch Vrije University in Amsterdam.

Dendrites are the extensions that allow individual nerve cells contact with other nerve cells. Scientists studied the nerve cell dendrites of 46 patients who were subjected to surgery as part of epilepsy or brain cancer treatment. The surgery aimed to remove sick brain tissue, but surgeons also removed a bit of healthy tissue which the scientists were allowed to study.

Before the surgery, the patients took an IQ test, allowing the scientists to compare their scores to measurements of their brain cells. The patients with the highest IQ also had the largest dendrites. The scientists emphasise that although there is only a slight difference in dendrite size from one person to the next, this may have a major effect on the brain's total capacity given that the brain includes billions of nerve cells and even more dendrites. The scientists also make the link with other new studies demonstrating that brain signals are not produced only in brain cells, but also in the dendrites.



The 3D figure is printed from the bottom using a light-sensitive gel.

New method makes 3D printing 100 times faster

Scientists can now shape 3D figures at speed, using light frequencies to harden a liquid gel.

TECHNOLOGY Chemists from the University of Michigan in the US have invented a new way of creating 3D printed structures, and it is 100 times faster than the ordinary method. Normally, 3D printers work by printing many layers of a material on top of each other, gradually producing a 3D structure. Using the new technology, the structure takes shape in thick gel that hardens when it is subjected to light of specific wavelengths.

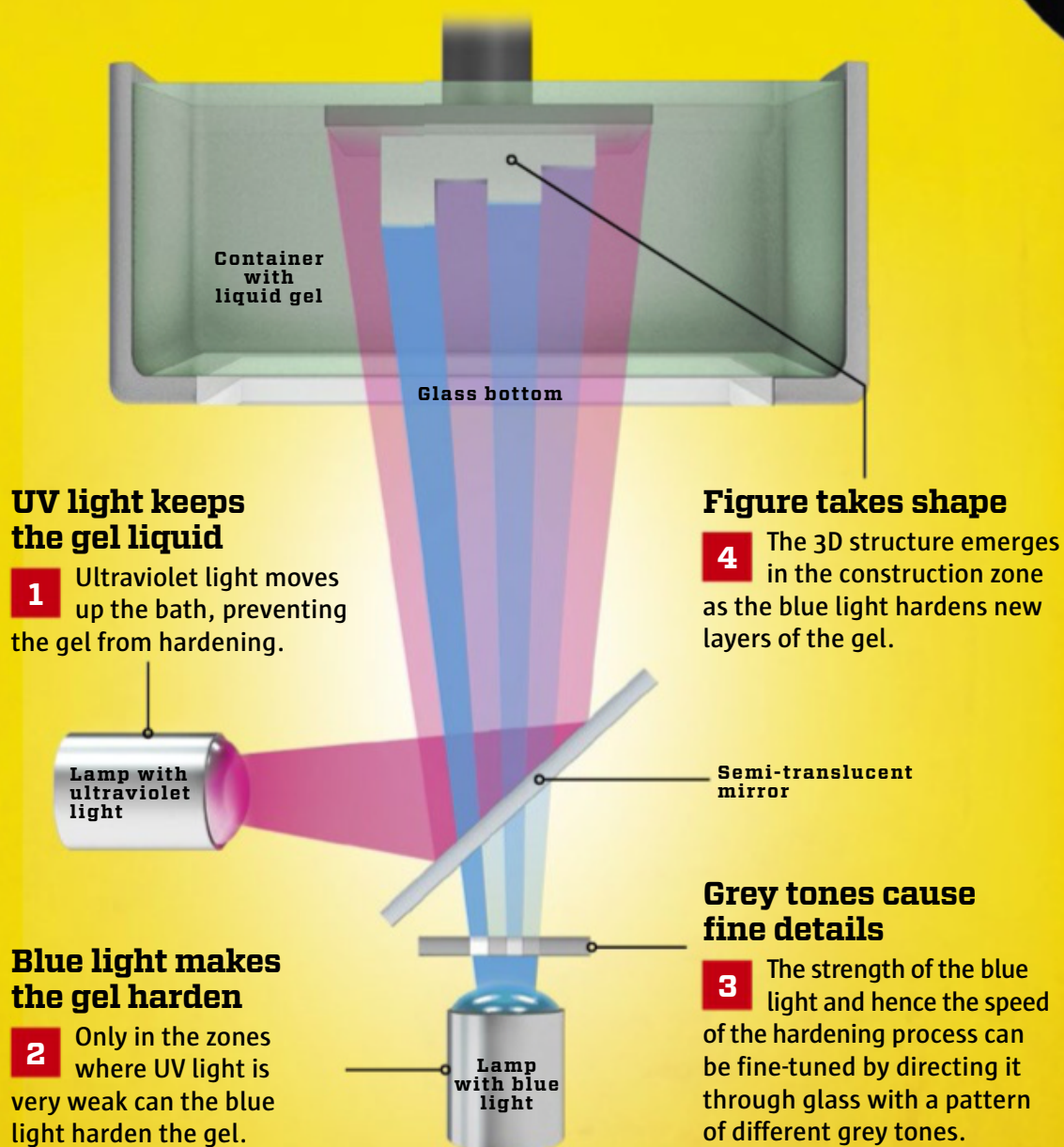
In the scientists' experiments they used a resin-like gel that hardens when blue light of specific wavelengths is applied. The gel cannot harden when it is subjected to ultraviolet light, allowing the scientists to control the places in which the gel hardens and turns into a 3D figure.

Both types of light are aimed at the gel from below and up through the container, which has a bottom made of glass. First, the scientists activate the UV light, selecting a specific intensity which passes up into the gel to some defined distance within which the gel can harden. Subsequently, the blue light is activated, divided into beams of different intensities which can thereby govern the speed at which the gel hardens in different place. As the figure takes shape, the construction platform is raised up through the gel, so the light beams work to add new layers to the 3D structure.

The technology is known as stereolithography, and the US scientists are not the first to work with it, but the ground-breaking factor is the use of the restrictive UV radiation, speeding up the process. The scientists were able to print a 2-metre structure in one hour, compared with 23mm per hour from other stereolithography printers.

3D figure is created in a shower of light

The new 3D print emerges as specific areas in a container with liquid gel are allowed to harden. The scientists control the process via a fine balance between UV and blue light sent through the container.



Fish virgin birth amazes scientists

EVOLUTION In an aquarium at the University of Nottingham, England, a small fish has surprised biologists. The fish, a female stickleback, became pregnant with her eggs developing embryos while they were still inside her, something totally contrary to sticklebacks' normal way of reproducing. Like almost all other fish, the female should lay her eggs and the male then fertilise them with his sperm.

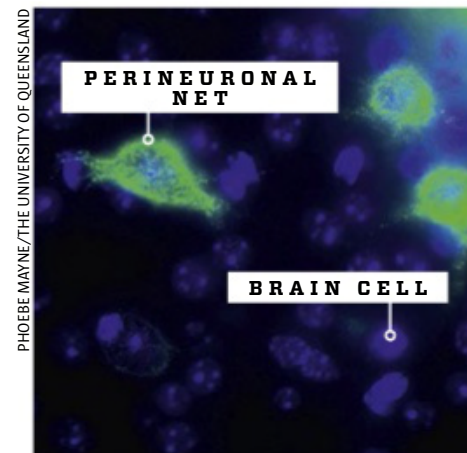
The scientists discovered the fish's extraordinary condition in connection with another research project, in which they studied stickleback eggs. Whereas the embryos in the eggs were healthy and viable, their mother, nicknamed Maria, was swollen and close to death. The scientists put her to sleep, subsequently extracting the eggs with the embryos, of which

56 survived until adulthood. The scientists initially believed that Maria had cloned herself, but DNA studies showed that the offspring had two parents, so the eggs must have been fertilised. One explanation could be that Maria passed through a place where another female's eggs had already been fertilised, with some of that male's sperm ending up in Maria's oviducts.

The scientists are now looking for the same condition in other fish. If it exists, it is important to our understanding of evolutionary history. Perhaps this was what happened when the first species began to give birth to live offspring.



Scientists have discovered eggs with living embryos in the stomach of a stickleback. 56 of them survived into adulthood (left).



Vitamin D improves the brain's perineuronal nets (green), which encapsulate brain cells.

Vitamin D improves your memory

HUMAN BRAIN Vitamin D improves the absorption of important substances in the intestines, regulates the immune system, and keeps track of the blood sugar. According to a new research project, the vitamin is also very important in the brain, where it helps cells build new connections.

Scientists from the University of Queensland studied the brains of mice which suffered from vitamin D deficiency, and discovered that a structure surrounding nerve cells, the perineuronal net, was missing in the mice. The net encapsulates specific nerve cells and stabilises the cells' links. The mice lost much of their perineuronal nets in the hippocampus brain area, which is involved in memory. The scientists tested the mice's ability to learn and remember, and the mice with vitamin D deficiency performed more poorly than other mice.

According to the scientists, vitamin D protects the perineuronal nets in the hippocampus from being destroyed by enzymes. The perineuronal nets are not evenly distributed throughout the brain. People with Alzheimer's can improve when the net is removed in specific brain areas. So more research is now required to determine why the nets might play a particular role in the hippocampus.



AROUND THE WORLD · Peru



140 children sacrificed to please the gods

Close to Peru's northern coast, archaeologists have discovered the skeletons of 140 children of the Chimú culture which dominated the region from the 11th to 15th century. The skeletons have marks indicating their hearts were cut out. They were sacrificed to pacify the gods after intense rain.

Implant stops the bladder lying to the brain

By means of light, scientists can control the activity of selected cells. This is used by a new implant which obstructs the nerve cells of the bladder if they send incorrect signals about the bladder being full.

FLEXIBLE BAND MEASURES BLADDER

1 A flexible band around the urinary bladder registers how often the rat urinates.

LIGHT DIODE KEEPS TRACK OF NERVES

4 When the rat's need to urinate is to be curbed, the implant's light diode is activated. The light prevents the bladder's nerve cells from sending "full bladder" signals to the brain.

CHIP COLLECTS DATA

2 The data from the flexible band is sent through a chip on the rat's stomach to a connected computer.

COMPUTER ANALYSES RHYTHM

3 The signals from the chip are sent via Bluetooth, and the computer reacts if the rat urinates too often.

Implant controls the urge to pee

Scientists can correct a communication error between the urinary bladder and the brain which makes many people go to the bathroom more than is actually necessary.

MEDICINE A new implant could become a great help to people who are troubled by the urge to pee too often. Studies have shown that in the US alone, some 33 million people are bothered by the need to urinate – even when it is not necessary. This is because nerve cells around the urinary bladder send incorrect signals to the brain, indicating that the bladder is full.

The new implant works by connecting to an external computer or mobile phone to register how often a person urinates. If it happens too often, a light diode in the implant lights up, and this light influences particular light-sensitive proteins in the nerves around the bladder.

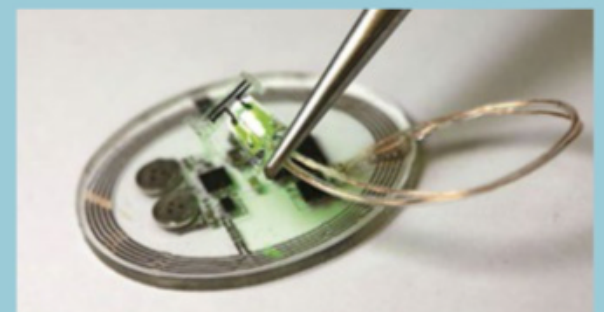
These nerve cells around the bladder have been programmed in advance to produce the light-sensitive proteins;

scientists sneak genetic information into the cells by means of a harmless virus. When the light activates the proteins, it has a restrictive effect on the nerves, so they send fewer 'full bladder' signals to the brain.

The implant was developed by scientists from Northwestern University in the US, who have tested it on rats that had been medicated to pee too often. With the implant, they returned to a normal rhythm.

The method of controlling the nerves by means of light is inspired by optogenetics, as used by brain researchers when they want to change the activity of specific brain cells. The method is highly accurate, and the light affects only selected nerve cells. Existing implants send electric impulses to the nerves, but it's unavoidable that the

nerves of other organs are also influenced. If a number of studies demonstrate that the new method is safe and does not involve any side effects, it could be used further to control nerves around several organs including the heart and the lungs, and to remedy other conditions.



The new implant measures how often the rat urinates. If it is too often, a light diode is activated, restricting the nerve cells around the bladder.

Celtic soil bacterium may save lives

MEDICINE Multiresistant bacteria are among the world's major health threats, and calculations show that they will claim 1.3 million lives by 2050 in Europe alone. Scientists are now getting unexpected help in their struggle, with an international team of scientists discovering an unknown bacterium type in the ground of Northern Ireland which is proving able to combat multi-resistant bacteria.

The scientists were inspired by local writings and oral tradition which describe how Celtic priests treated different conditions such as toothache or infection by holding soil wrapped in cotton against the affected area. The scientists examined soil types from the area including acid peat and alkaline soil from grazing land, and in the alkaline soil they found the bacterium. Subjected in the lab to a series of other bacteria, it stopped the growth of several multiresistant species. It was efficient against four of the six bacteria at the top of the hazardous list, one of them being MRSA, a major problem in hospitals and nursing homes where it can be lethal to people who are already weak or have an impaired immune system.

The scientists still do not know how the bacterium kills the hazardous bacteria, but when they discover the substances that do the trick, the way will be paved for crucial new antibiotics.



Experiments show that the new bacterium produces toxins, which eliminate MRSA bacteria.

Satellites show the world becoming greener

Extensive tree planting projects and increased farmland have grown the world's green areas by 5% since 2000.

GEOGRAPHY Our world has become greener in the past 20 years. Tree planting and new farmland have increased the vegetation of large regions so that the green patches of the world map have grown by about 5% since 2000, corresponding to an area the size of the entire Amazon rainforest.

The optimistic new outlook comes from scientists who studied data collected by the NASA satellites Terra and Aqua. The satellites are equipped with spectro-radiometers by the name of MODIS. Over the past two decades the 2330km-wide viewing swathe of MODIS has allowed scanning of every point on our world for vegetation every 1-2 days.

Perhaps surprisingly it is the world's two most densely-populated nations, China and India, which have contributed the most to a greener world. Both have increased their farmland and their forests. China in particular has carried out major tree planting projects, so almost 22% of the big country is now

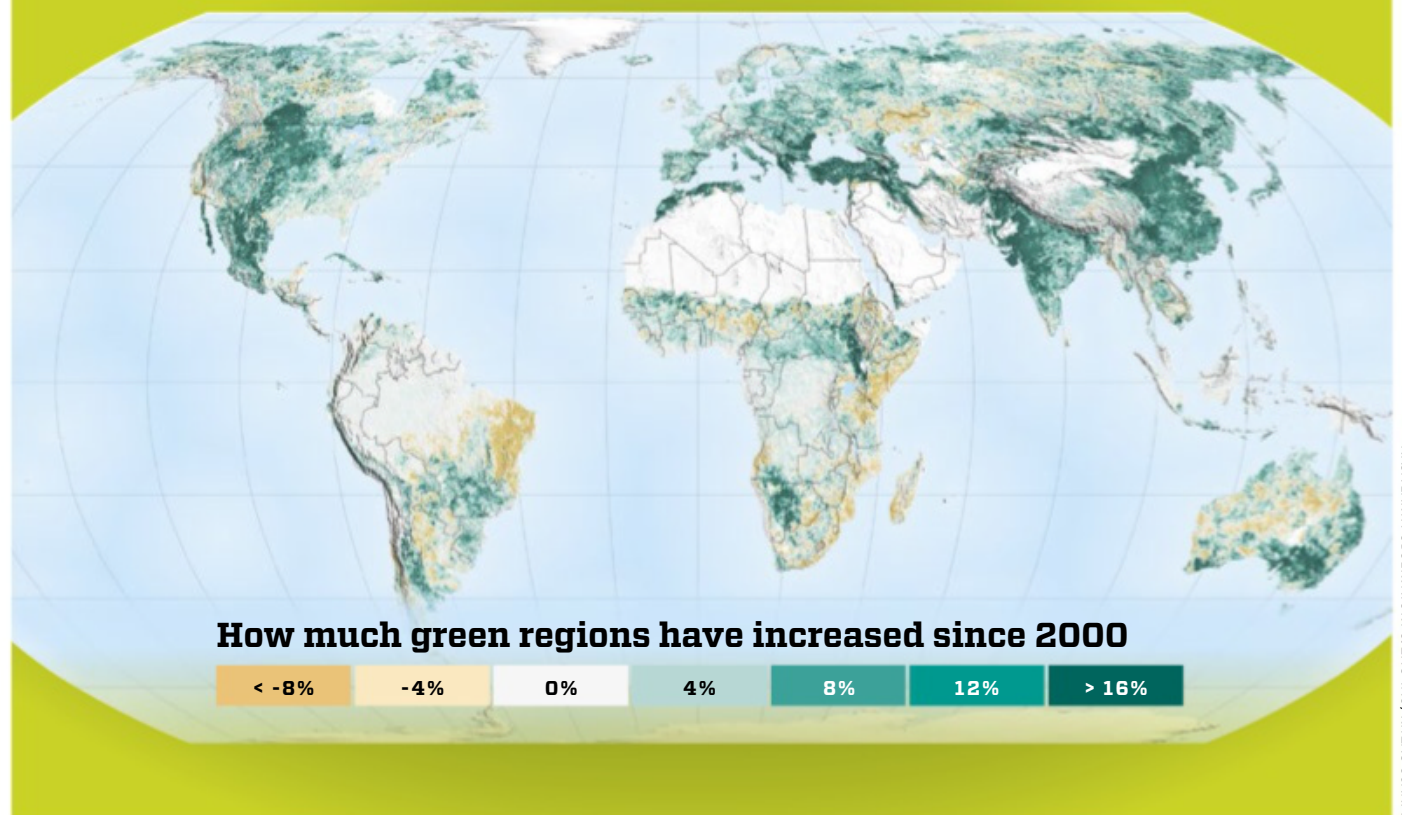


Large-scale tree planting projects have increased China's forests, so they now take up 22% of the country's area.

covered in forest. According to the scientists, the increasing vegetation should be considered in climate models, as it contributes to storing large quantities of CO₂, which would otherwise end up in the atmosphere, worsening the greenhouse effect.

The northern hemisphere is in the lead

While the rainforests of South America and Southern Africa are reduced, things are getting ever greener north of the Equator. China and India have added the most green land.





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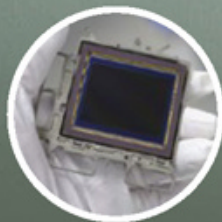
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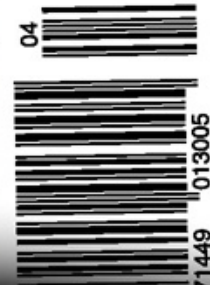
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Where does the energy from sunlight go?

If Earth receives energy from the Sun all the time, shouldn't our planet warm up? Where does the energy go?

PHYSICS Sunlight supplies Earth with constant energy, but instead of just becoming ever warmer, our planet manages to shed exactly the same quantity of energy as it receives.

When sunlight hits the planet, it is either deposited as heat or reflected back into space. The ability to reflect light is called the surface reflection coefficient, or albedo. The light that a surface reflects is what we see as the colour of the surface. If a surface reflects all visible wavelengths of light, we see the surface as white, and we say that the surface has an albedo of

close to 1. If the surface does not reflect any light, we see it as black: an albedo of 0. Earth's atmosphere, clouds, and surface reflect some 30% of all sunlight, so the planet's albedo is 0.30.

The remaining 70% of the sunlight is absorbed into the atmosphere and the top soil layers, raising their temperature. According to the first law of thermodynamics, energy can never disappear, only change into different forms. The heated molecules of the atmosphere and soil will themselves shed the energy over time in the form of long-wave infrared radiation.

The Sun sends 342 watts per square metre towards Earth, but over time it is all given back to space again.

Do artificial sweeteners cause cancer?

MEDICINE Artificial sweeteners can be synthetic or natural substances. They make things much sweeter than the corresponding calorific value of ordinary sugar, so that very small doses can make products sweet while adding very few calories.

In 1996, American neurologist John Olney claimed that the Aspartame artificial sweetener caused cancer. His argument was

Aspartame is an artificial sweetener as high-calorie as sugar – some 400kcal/100g – but 200 times sweeter.

based on data showing that since the approval of Aspartame in 1981, the number of brain cancer cases had increased. This caused

heated debate, but since then, basically all studies have found that Aspartame does not cause cancer, and 100+ health

authorities throughout the world allow the sweetener in food today. Yet many scientists also agree that its long-term health effects have not yet been sufficiently clarified.



SHUTTERSTOCK

Coca-Cola Light and Zero include the Aspartame sweetener. According to several studies, it is harmless in moderate quantities.

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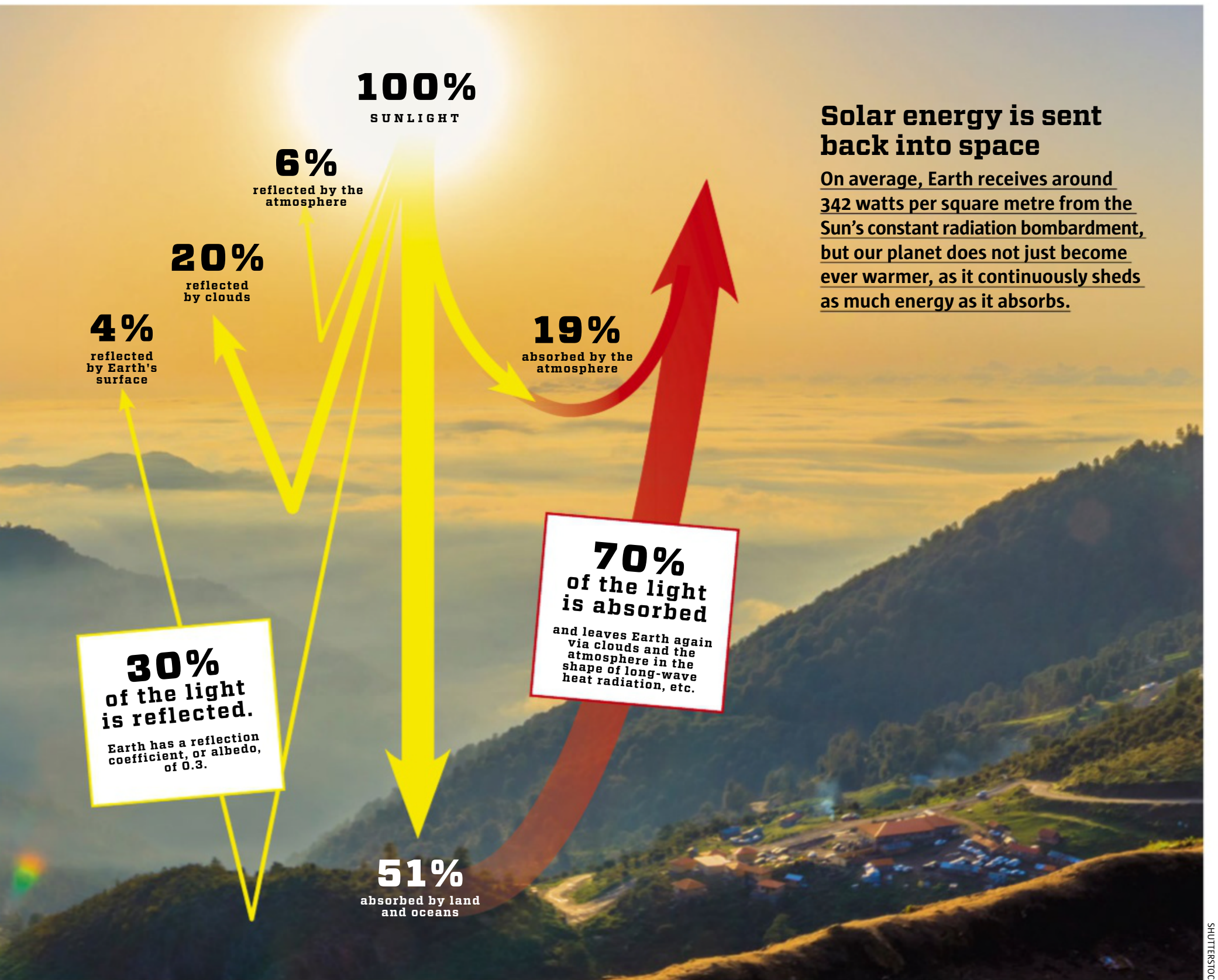
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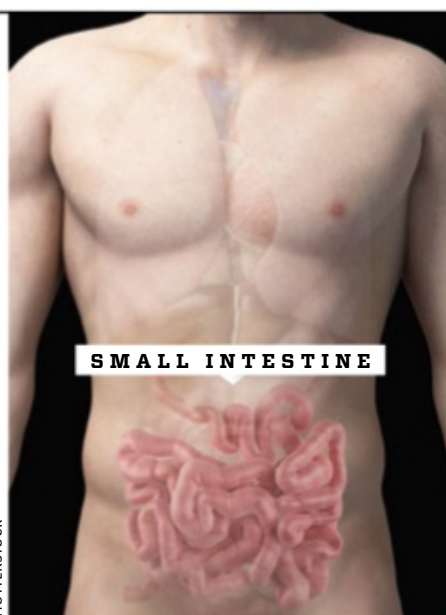
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SCALE · Which has the greater surface area?

Small intestine

The first 6 metres of the intestines are the small intestine, which links the stomach and the colon. The vast majority of the nutrition we get from food is absorbed in the small intestine through the intestinal wall, which is dotted with tiny projections known as villi. The many projections increase the small intestine's total surface area, which is around 30m² in adults.



SMALL INTESTINE

The surface area of the small intestine can be

15

times the surface area of the skin.



SKIN

Skin

The human body's heaviest organ is the skin, weighing typically 3.6kg in an adult. The skin protects the body's internal organs from the surroundings and keeps the internal environment stable. The thickness of the skin varies: it is 1mm on the eyelids, but up to 3mm on the back. The total area of the skin of an adult person is around 2m².

Can plants get cancer?

BIOLOGY Plants often get diseases and defects that resemble cancer, but there are three major differences. Firstly, plant cancer often develops due to infection or damage caused by insects, rather than through cell mutations, as in animals and humans. The second important difference is that plant cancer does not produce metastases. Metastases are new cancer tumours that develop

elsewhere in the body because cancer cells are able to spread via the lymph system or the blood stream to settle in other places of the organism. In plants, the cells remain where they are.

Finally, cancer only rarely kills the plant, because plants do not have any crucial organs that can be destroyed. In animals and humans, cancer can prevent specific organs from functioning, causing death.



An infection with the *Rhizobium radiobacter* soil bacterium has developed into a cancer-like tumour on a beech tree.

+ HOW THINGS WORK · How does a blood glucose meter work?

Most blood glucose meters work by measuring an electrochemical reaction between the sugar of the blood – glucose – and a special enzyme, using a test strip.

BLOOD SAMPLE IS TAKEN

- 1 The patient pricks a finger to produce a drop of blood.

THE BLOOD IS PLACED ON A TEST STRIP

- 2 The drop of blood is placed on a test strip consisting of two electrodes. One of them contains the glucose oxidase enzyme.

TEST STRIP

BLOOD GLUCOSE METER

ELECTRODE

GLUCOSE OXIDASE

ELECTRODE

AMPERAGE INDICATES GLUCOSE LEVEL

- 4 When the strip is inserted into the blood glucose meter, the electrical current is measured. The more glucose in the blood, the more gluconic acid is produced in the reaction, so the current level can be converted into the blood glucose level.

REACTION GENERATES A CURRENT

- 3 The glucose of the blood reacts with the glucose oxidase to produce gluconic acid. The reaction releases a flow of electrons that passes through the lower electrode's circuit.

WORLD RECORDS

How deep can the sand of a desert become?

The vast majority of deserts have a firm base of rock, stone or gravel, but in an erg – the Arabic word for a sand desert or sand sea – the sand can be several metres deep. An erg is often located in a hollow in a desert area, such as a dry lake, in which sand collects over time. Large sand dunes often develop in the erg, and can reach hundreds of metres high. The Duna Federico Kirbus in Argentina is the world's highest sand dune, with a sand depth of more than a kilometre.



SHUTTERSTOCK

1,230
metres



Argentina

WHERE: The Catamarca province in North-Western Argentina.

WHAT: Huge sand dunes develop when the wind blows in the same direction for a long time.



A tiger beetle is a biting insect with mandibles that have been adapted for cutting and crushing food.

Do insects have beaks?

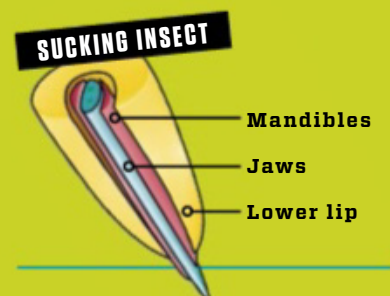
Many insects have large jaws that protrude from their heads. Can these be classified as beaks?

ZOOLOGY All insects' mouth parts protrude from their heads in the same way as a bird beak, but they are not real beaks – even though there is an entire order known as “beak-mouth insects”, equipped with a long, powerful proboscis. The order includes more than 80,000 species, including ticks, cicadas and aphids. The proboscis has evolved to prick holes in skin surfaces and to suck up plant juice or animal blood.

Although all insect mouth parts comprise the same basic structures, they come in a wealth of shapes depending on dietary habits. But generally, insect mouths can be divided into biting or sucking. Biting insects such as beetles and larvae have scissor-like structures known as mandibles which are used to crush the food, whereas the mandibles of sucking insects have developed into needle-like structures.

ALL INSECTS HAVE THE SAME MOUTH

The probosces of sucking insects consist of the same structures as those of biting insects – but adapted for sucking instead of biting.



SHUTTERSTOCK & CLAUUS LUNAU

What is the risk of being struck by an asteroid?

ASTRONOMY Thousands of asteroids have orbits that bring them sometimes close to Earth, and about once a year an asteroid the size of a car comes close to us. The result is a meteor that burns up in the atmosphere. If the asteroid is bigger, it might shatter on its way through the

ASTEROID COULD STRIKE MARS OR EARTH

- **Name:** 53319 (1999 JM8)
- **Diameter:** 7000m
- **Orbit:** Orbits the Sun every 4.5 years in about the same plane as Mars and Earth
- **Closest passage:** 11.5 million kilometres from Earth in 2137

atmosphere, so that only small fragments reach the surface. That happened near the Russian city of Chelyabinsk on 15 February 2013, when a 17m asteroid with a weight of about 12,000 tonnes exploded 23km above the city. The authorities go to great lengths to spot the potentially hazardous asteroids of diameters 150+m that come closer to Earth than 7,500,000km. As of 1 January 2018, NASA has recorded 1885 such asteroids – 157 of which had diameters largely than a kilometre.

Every year, meteor strikes bring 37,000-78,000 tonnes of extra material to Earth.



THINKSTOCK

WHAT IS THIS? · Luminous algae in the surf



Special alga types make the waves on this Mexican beach light up at night thanks to the phenomenon of bioluminescence.

1 The luminous algae belong to the group of dinoflagellates, which secrete the light-emitting compound luciferin. They often belong to the *Noctiluca* “shining at night” genus.

2 Scientists do not know exactly why *Noctiluca* secretes the material. It might be a defence against predators such as water fleas, since the light attracts fish which consume water fleas.

3 Bioluminescence occurs by many shores throughout the world – including Australia, where notable displays are seen in Lauderdale, Tasmania, and Jervis Bay, south of Sydney.

DOUG PERKINS/GETTY IMAGES

... there is no upper temperature limit?

Absolute zero is the lowest limit of the thermodynamic temperature scale. But is there a similar upper limit for the temperature scale?

PHYSICS Just as there is an absolute zero of zero Kelvin or -273.15°C , there is – according to existing physics theories – also an upper temperature limit of some 1.42×10^{32} , or 142 million million million million $^{\circ}\text{C}$. The temperature is known as the Planck temperature – named after German physicist Max Planck, who was the first to predict it.

The temperature of a substance is an expression of the vibrations of the particles of which it consists. The warmer the substance, the faster its particles are vibrating. At absolute zero, no particles move, so no substance can become any colder. Planck realised that there is also an upper limit to how fast particles can

vibrate. The speed of the vibrations determines the wavelength and thus the colour of the light emitted by a warm body – red-hot metal becomes ever more white-hot as it gets warmer. The wavelength becomes shorter as the temperature rises, but according to quantum mechanics the wavelengths reach their absolute minimum at the Planck temperature. So, there is an upper limit on how hot matter can become. As far as scientists know, nothing has ever reached the Planck temperature – even when the universe had just formed and all matter and energy were united at one point, the temperature is believed to have been 'only' 10^{27}°C .

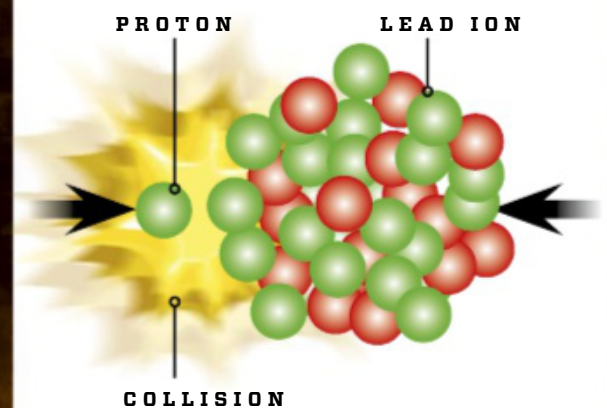
CERN's ALICE detector has measured the highest temperature in the universe known to scientists.



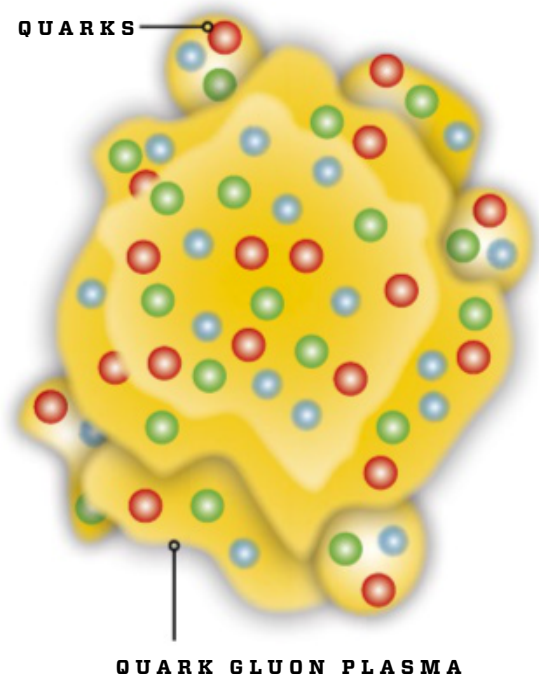
The hottest point in the universe is here on Earth

During experiments in CERN's LHC particle accelerator, scientists have measured the highest temperature ever, when protons collided with lead ions to recreate the primordial soup of the universe.

1 Two bundles of lead ions and protons were accelerated in different directions to 99% of the speed of light. When the two bundles collided, almost all their kinetic energy was converted into heat.



2 The temperature in the collision was measured to be $5.5 \times 10^{12}^{\circ}\text{C}$ – the highest temperature in the known universe. The result of the collision was quark gluon plasma, the primordial soup produced after the Big Bang.

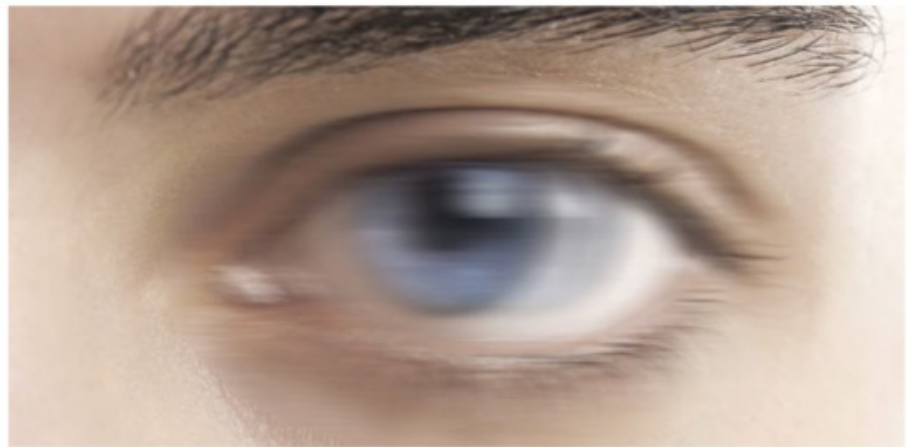


Why can some people make their eyes ‘shake’?

HUMAN BODY Muscles around the eyeball keep our eyes in almost constant motion, allowing us to focus on an object while the head moves, or to follow an object with our eyes without turning the head. The motions are automatic and instinctive, and we rarely notice them, as they serve a natural purpose. However, some people can produce them

intentionally, so it seems as if their eyes are ‘dancing’ in their heads.

An American study from 1978 indicates that approximately 8% of the population has this ability, which is probably genetic. In other cases, a series of diseases, either congenital or developed later, can cause involuntary, jerky eye motion. Known as nystagmus, the condition impedes vision.

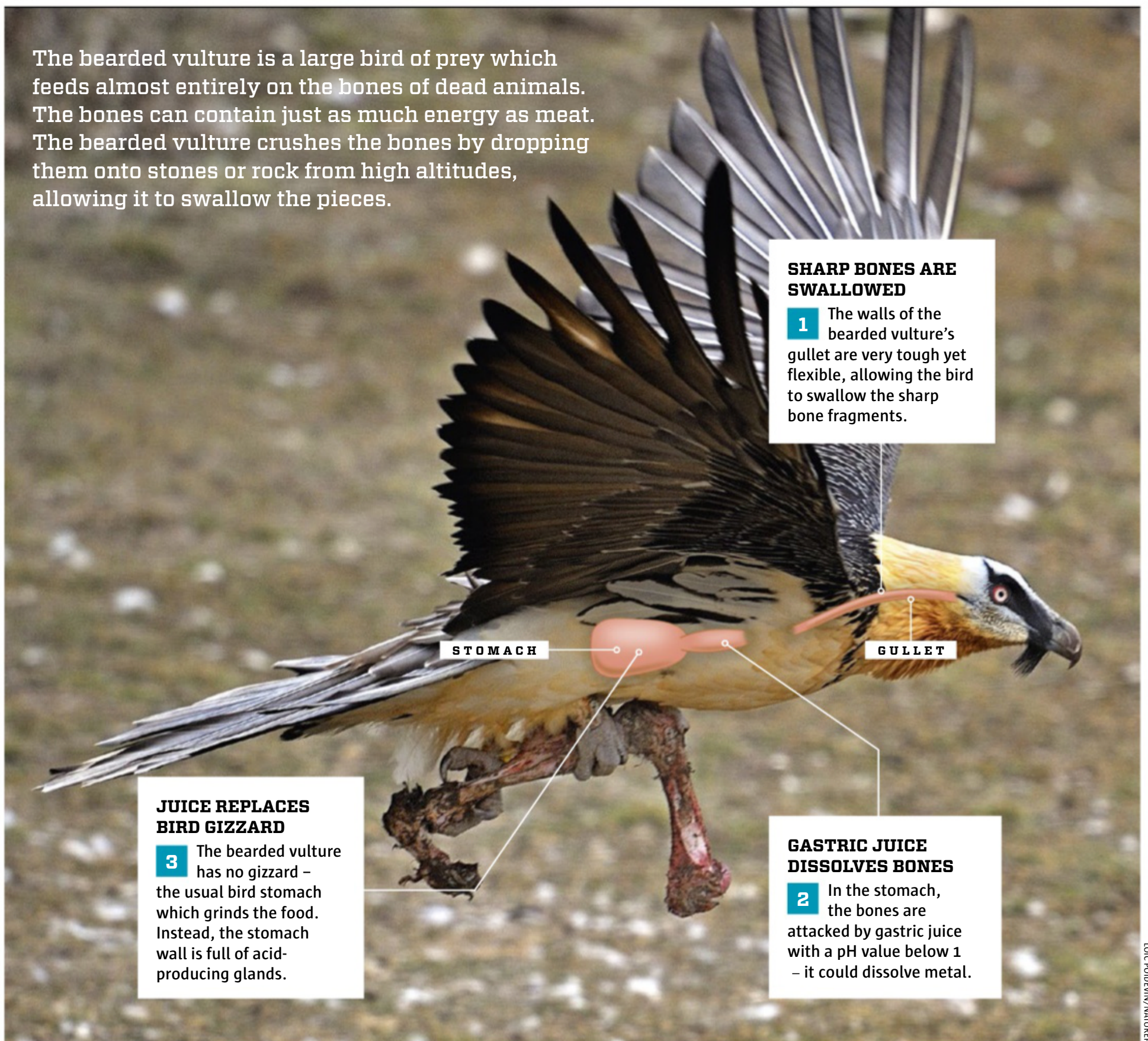


SHUTTERSTOCK

Nystagmus causes involuntary eye motion, but about 8% of people can voluntarily cause the motion.

+ HOW THINGS WORK · How can a bearded vulture feed on bones?

The bearded vulture is a large bird of prey which feeds almost entirely on the bones of dead animals. The bones can contain just as much energy as meat. The bearded vulture crushes the bones by dropping them onto stones or rock from high altitudes, allowing it to swallow the pieces.



SHARP BONES ARE SWALLOWED

1 The walls of the bearded vulture’s gullet are very tough yet flexible, allowing the bird to swallow the sharp bone fragments.

JUICE REPLACES BIRD GIZZARD

3 The bearded vulture has no gizzard – the usual bird stomach which grinds the food. Instead, the stomach wall is full of acid-producing glands.

GASTRIC JUICE DISSOLVES BONES

2 In the stomach, the bones are attacked by gastric juice with a pH value below 1 – it could dissolve metal.

LOIC POIDEVIN/NATUREPL

WHY DOES A FREEZER SEAL WHEN THE DOOR CLOSES?

When you close a freezer, a low pressure zone is produced in the cold space, sealing the door. The low pressure develops because warm air enters when the door is open, then is cooled when the door closes. Since cold air takes up less space than warm air, under-pressure is produced. After about a minute, new air will have entered along the edges of the rubber strip, and the pressure becomes equalised again.



When the door closes, the air of the fridge is cooled, and temporary underpressure develops.

SHUTTERSTOCK



The huge Uluru, once known as Ayers Rock, is covered in a rust layer that makes it red.

How did Uluru become so large and so red?

Is Uluru a part of a mountain range that existed long ago? And what is the large rock made of that makes it red?

GEOLOGY The geological story of Uluru – once known as Ayer's Rock – began some 550 million years ago. Rivers carried the sand that later became Uluru from the Petermann Ranges to a plain. Then 50 million years later, rising ocean levels flooded the plain, and the pressure from the ocean and its sediments turned the Uluru sand into sandstone. Later tectonic motions 400-300 million years ago lifted the entire Uluru area above sea level and

folded it, producing mountains and valleys. Uluru rotated and ended in an upright position. Since then, the elements have worn down the entire area, but because Uluru's sandstone is harder than other layers in the area, it now rises 348m above the surrounding Simpson Desert. Sandstone is really greyish, but in contact with air and moisture its iron minerals oxidise into the characteristic red colour, which is why Uluru is rusty red.



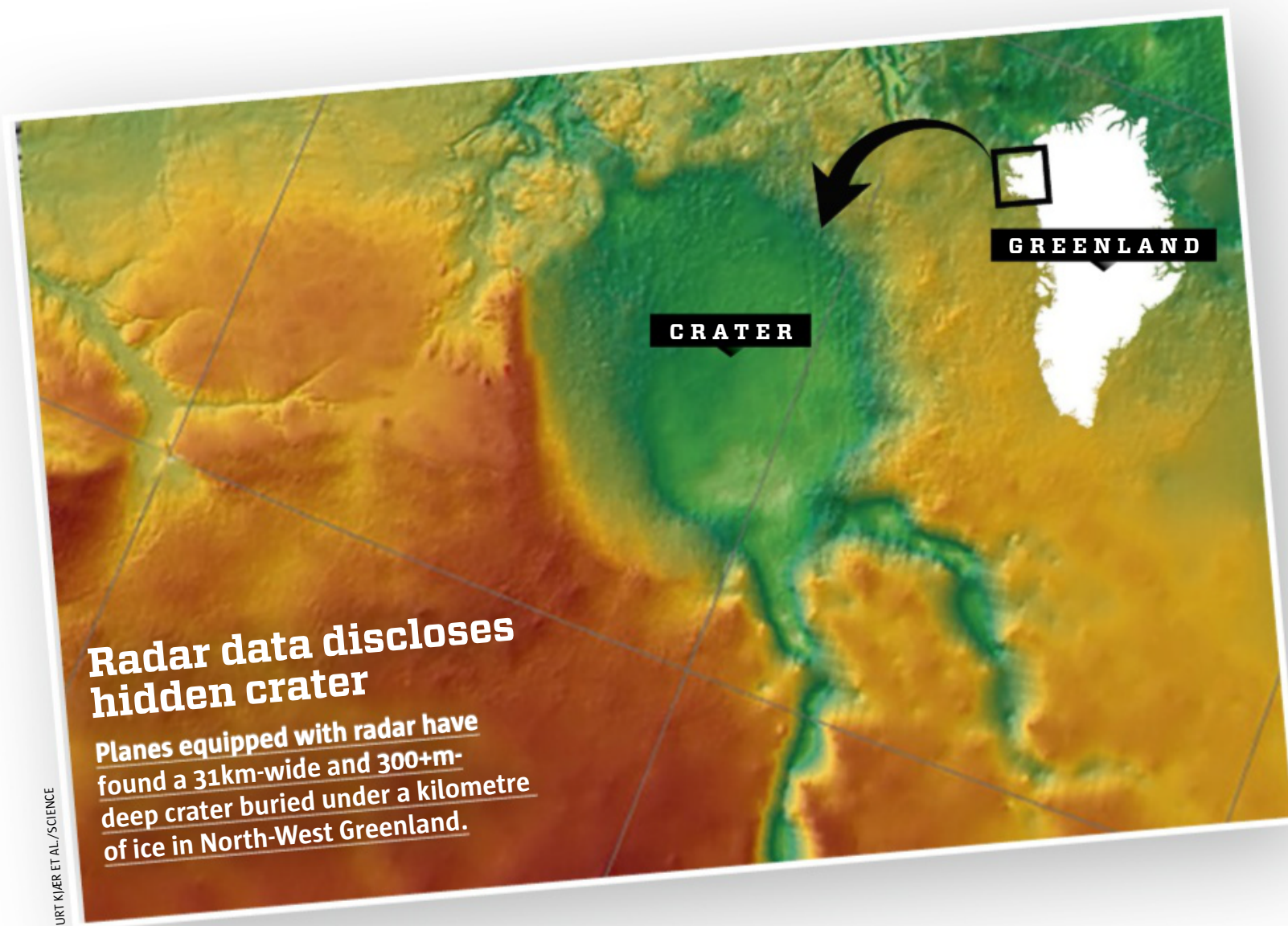
LARGE ROCKS EXIST ALL OVER THE WORLD

Huge rocks (named monoliths by geologists) like Uluru exist throughout the world. Outside Nigeria's capital, Abuja, you will find the Zuma rock, which rises 745m above the surroundings, twice as high as Uluru.

SHUTTERSTOCK

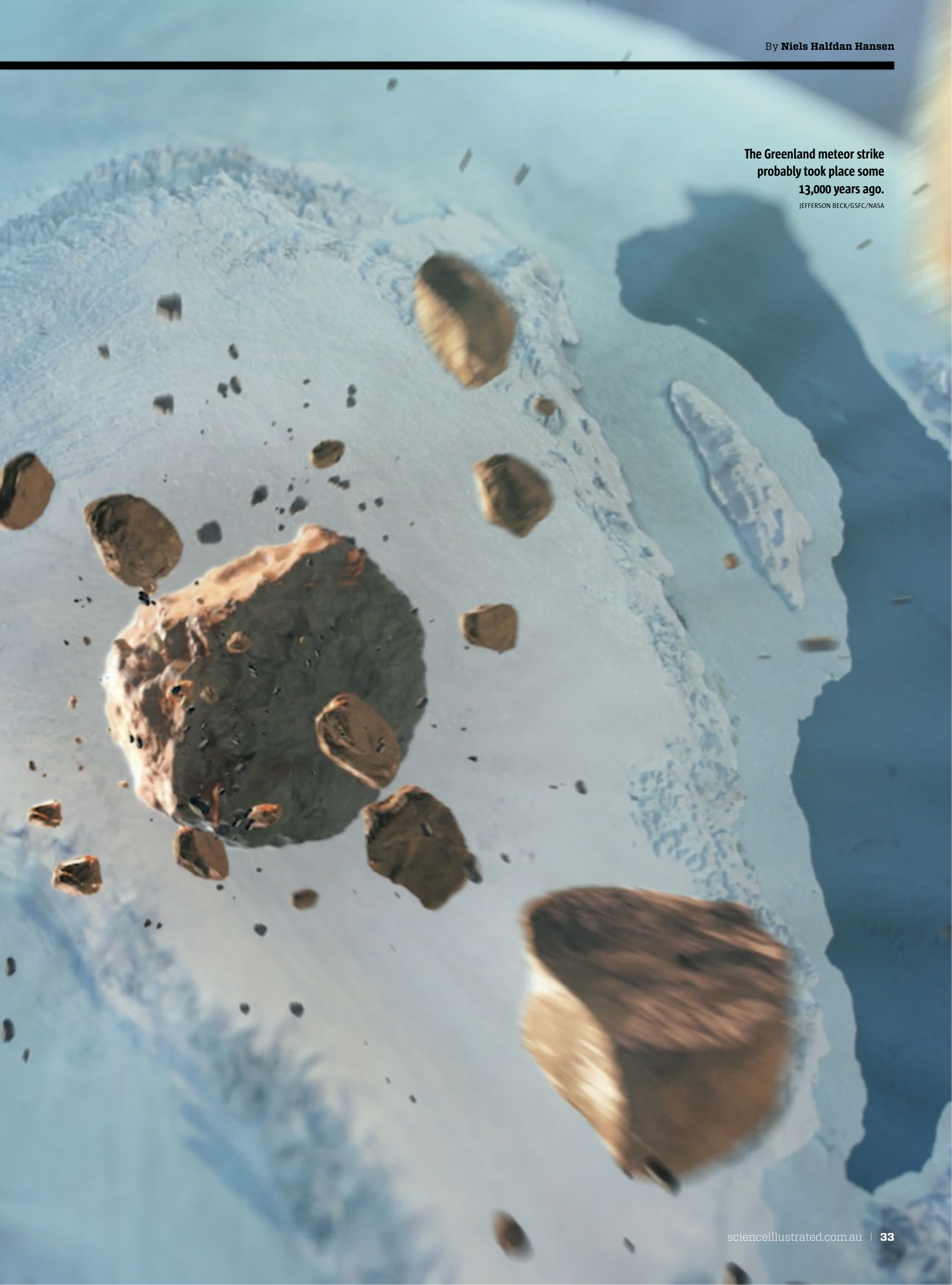
The giant meteor strike that humans (mostly) survived...

A meteor with a diameter of 1.5km strikes Greenland with the force of 700 nuclear bombs. The discovery of a huge crater reveals that this meteor strike may have delivered a millennium of cold temperatures for late Stone Age humans.



The Greenland meteor strike
probably took place some
13,000 years ago.

JEFFERSON BECK/GSFC/NASA



A colossal rock travels silently through space, far away from its birthplace between Mars and Jupiter. The first contact with Earth's atmosphere slows it down, and gravity slowly forces the meteor onto a direct collision course with our blue-green planet. Ahead of this uninvited cosmic guest, pressure and temperature rise fast until the rock is shrouded in a mantle of glowing plasma as it speeds towards the planet's ice-covered north pole at a speed of 60,000km/h. The collision between the two heavenly bodies causes an explosion equivalent to 47,000 Hiroshima bombs. Everything within a 20km radius of the impact point is pulverised and converted into hot dust and gas.

The scenario sounds like the beginning – or the end – of a disaster film. But it is very real, and our ancestors witnessed it only 13,000 years ago, according to the new discovery of a huge meteor crater under the Greenlandic ice sheet. Scientific studies indicate that the meteor didn't only destroy the ice sheet and Earth's crust, it caused dramatic climate change – 1000 years of cold – which wiped out entire peoples, ultimately changing the history of mankind.

Radar reveals huge depression

Scientists know the existence of some 180 meteor craters on Earth. These are of many different sizes, and are located on all continents. The most impressive one is the Vredefort Crater that was formed when a heavenly body with a diameter of 12km struck Earth in what is now South Africa, two billion years ago. Some 14,000

cubic kilometres of rock melted, and material was flung 2500km away, landing as far afield as Scandinavia. At that time, Earth was inhabited only by monocellular organisms, and the simple ecosystems probably made it through the disaster without any dramatic losses. A similar event now would kill most life on Earth, as the atmosphere would be filled with dust that would block out the sunlight for decades, making global temperatures fall from a global average of 15 degrees to below zero.

700

one-megatonne nuclear bombs would be the energy equivalent of the impact.

Luckily, no meteors of those dimensions have struck Earth since the 10km-wide rock that made the dinosaurs 'disappear' about 65 million years ago. But the risk of disastrous strikes is always there, and it is important for geologists to find and study as many craters as possible. Only in this way can they discover the exact effects of an impact – and how often they occur.

So scientists were thrilled in 2015 when they came to suspect the existence of a large,

unknown crater under the 1km-thick ice sheet in the north-western corner of Greenland. They found the bowl-shaped depression of the bedrock, its diameter no less than 31km, by comparing several sets of radar data collected mainly by NASA over a period of 20 years. Radar equipment can see through the ice to reveal the landscape underneath it.

But before the scientists, headed by Danish geologist and professor Kurt Kjær, could be sure that the depression was a crater, further studies were required. So in 2016 they went to Greenland to find evidence on the coast near the depression, while a plane with new and more powerful radar equipment, the Alfred Wegener Institute's Polar 6 research aircraft, collected data of an even higher resolution.

Gold and cracks indicate a meteor

In the large meltwater plain at the foot of the Greenland ice sheet, the scientists searched for more evidence of the hidden crater – known as the Hiawatha Crater after the adjacent glacier. And they found exactly what they had been looking for. In samples of the sand and pebbles that the melting ice carries out from the glacier, geologists discovered clear evidence of a meteor. Small sand grains of quartz demonstrated obvious evidence of extreme pressure. Using a microscope, the scientists could see small cracks inside the minerals, and by comparing them to samples from other craters, it was clear that a meteor was the most likely explanation.

Higher presence of rare elements such as gold, nickel, and cobalt in the mineral samples also betrayed the existence of a meteor crater

Crushed sand grains disclose strike

Radar waves gave scientists clues to find a huge crater. Slanting rock, gold, and cracked sand grains provided them with the final evidence of a tremendous meteor strike.



FILELAX - J. KÄSSBOHNER & SHUTTERSTOCK

Radar maps out the landscape beneath the ice

1 Radar waves emitted from a plane travel through the ice but are reflected by the rock beneath it. By recording the time passed before the waves return to the plane, scientists can map out level differences below the ice.

under the ice, also indicating that it was an iron meteor. Iron meteors consist almost solely of iron and iron-nickel alloys, and they manage the trip through the atmosphere much more successfully than rock meteors, which typically explode and burn up. Hence iron meteorites constitute 90% of all the large meteorites that have been discovered on Earth, even though iron meteors strike Earth quite rarely.

The discovery that the Hiawatha meteor was of the iron type perhaps solves the mystery of two very large and several smaller iron meteorites which have been discovered in North-West Greenland in recent centuries, some 300km south of Hiawatha. The biggest one is the 30+-tonne Ahnighito, discovered in 1894. It can be seen at the American Museum of Natural History in New York, and it is the world's third biggest iron meteorite. The other large specimen is the 20-tonne Agpalilik, which was discovered in 1963 and can now be admired in the square in front of Denmark's Copenhagen Geological Museum. The two meteorites are of the same iron type, and now scientists are wondering if they are both remains of the Hiawatha meteor, estimating that any other explanation would be statistically unlikely.

Finding the time

With the overwhelming proof of radar data, minerals, and other studies – and perhaps even remains of the meteor itself – it is of all the more interest to establish when it all happened. Yet this represents a major challenge, as there is no way of determining the age directly. But radar data shows that the crater is well-preserved, ►



Geologist Kurt Kjær took samples of the soil close to the crater to find more evidence of the impact.

KURT KJÆR/UNIVERSITY OF COPENHAGEN



KURT KJÆR/UNIVERSITY OF COPENHAGEN

Sloping rock revealed impact

2 The scientists measured the rock's incline along the western edge of the crater, and the data show that the rock is pointing towards the centre of the major depression, indicating that the crater formed via a violent event, not slow erosion.



KURT KJÆR/UNIVERSITY OF COPENHAGEN

Rare elements are remains of meteor

3 Gravel samples from the area were crushed and analysed. Material that had been carried out from beneath the glacier contained high levels of elements such as gold, nickel, and cobalt, which exist in iron meteors, but not in the other rock of the area.



ADAM A. GARDE/KU

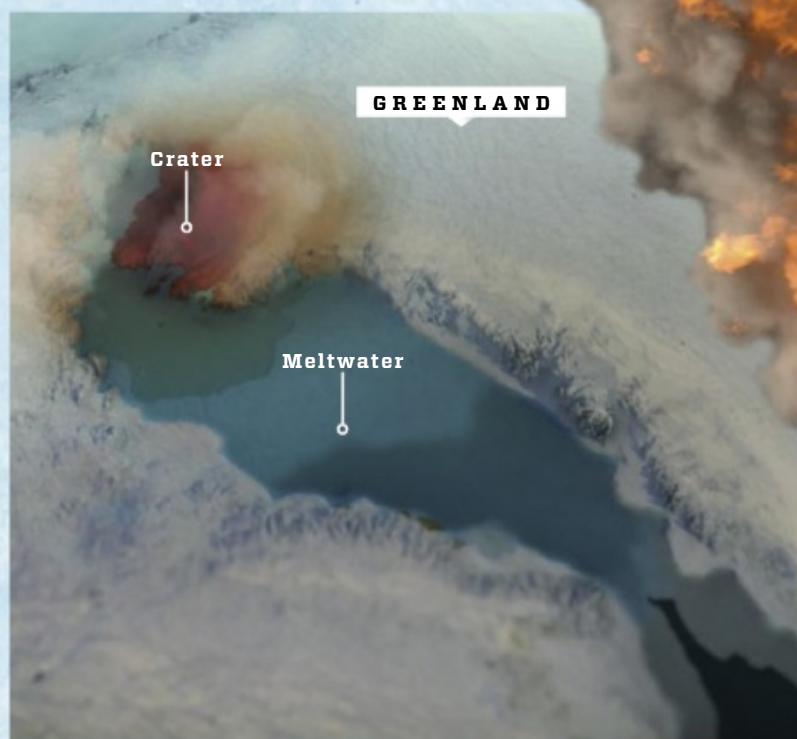
Cracks in sand grains indicate a forceful explosion

4 The scientists discovered small cracks in sand grains that meltwater had carried out from the crater. The cracks are signs of the kind of brief, intense application of pressure that is known only from meteor strikes and nuclear bomb explosions.

Meteor interrupted global defrosting

The ice age was about to end, and temperatures were approaching those of today. But then disaster struck. A huge meteor melted hundreds of cubic kilometres of ice, blocked warm ocean currents, and threw Earth back into the cold.

JEFFERSON BECK/GSFC/NASA

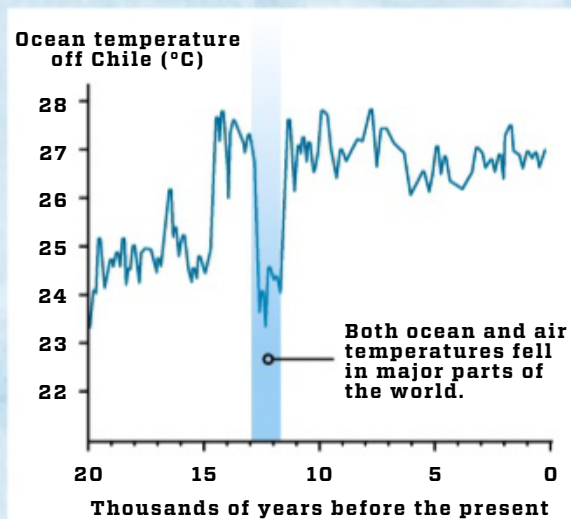


The meteor strikes Greenland

1 An 11-billion-tonne iron meteor with a diameter of about 1.5km knocks a 7km-deep hole in Earth's crust in North-West Greenland. The hole subsequently collapses into what is now the Hiawatha Crater.

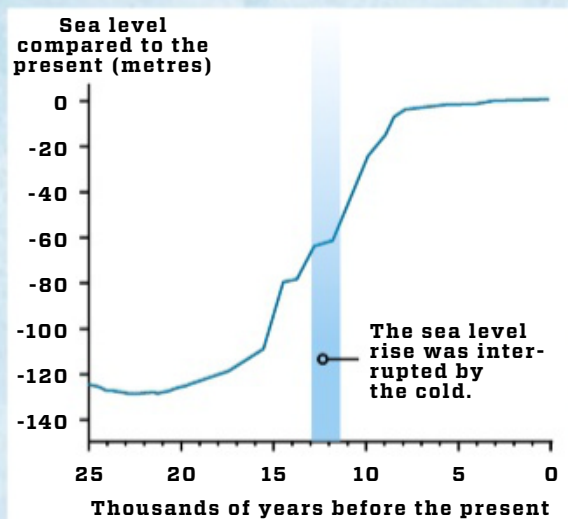
The ice melts, and dust blocks out light

2 The impact pulverizes 20km³ of rock and melts hundreds of km³ of ice. The dust blocks out the sunlight, and the meltwater fills the waters off Greenland, so that ocean currents from the Equator can no longer send warmth to the north.



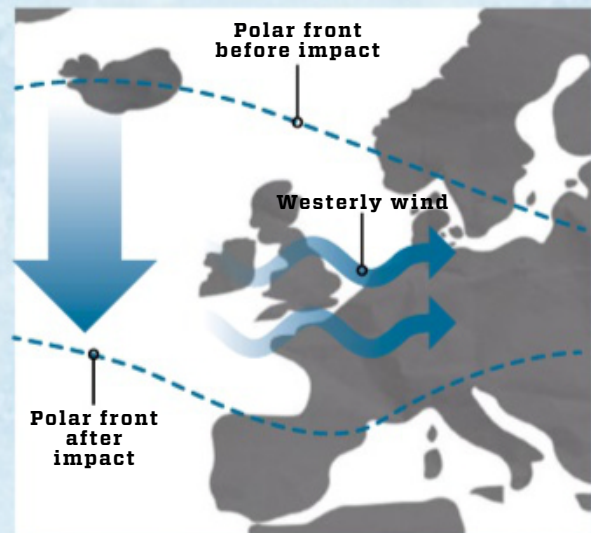
Temperatures fall

3A The strike causes cooling everywhere on Earth, even in the tropical ocean north of Chile, where water temperatures fall 3-4 degrees. The cooling remains for 1300 years.



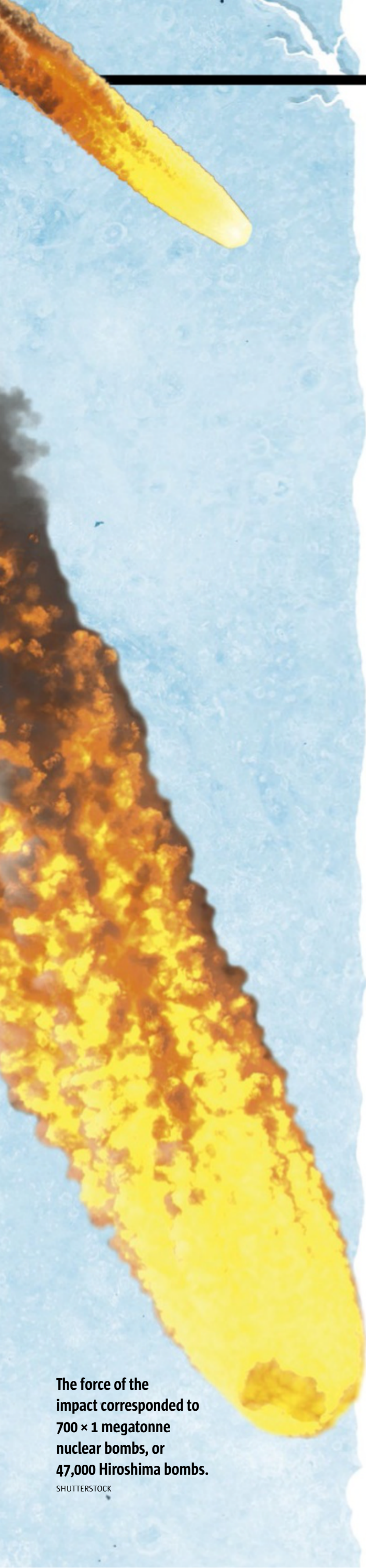
Sea-level rise is curbed

3B The major northern ice caps were about to melt after the ice age, and so ocean levels rose. The rise was suddenly halted when temperatures fell.



Polar front moves

3C The polar front, which makes up the boundary between polar and temperate air masses, moved thousands of kilometres south, so that cold, moist air affected much of Europe and beyond.



► with steep slopes and the central elevation that is characteristic of a young crater. And as ice quickly smooths down irregularities, the crater is probably no more than three million years old, and most likely less than one million.

In addition, radar data showed the oldest ice in the crater to be young compared with ice in other areas of Greenland, and that the ice was subjected to an immense impact shortly before the end of the most recent ice age some 11,500 years ago. In combination, the results indicate that the crater could prove to provide an answer to one of the biggest mysteries of climate research.

Impact explains extreme cold

Some 12,850 years ago, Earth seemed about to escape its most recent ice age.

But then temperatures fell again, heralding 1300 years of cold. Oceans ceased established circulations, the great glaciers of North America, Scandinavia and Siberia halted their retreat from the poles, even growing slightly, and newly-formed forest in areas such as southern Scandinavia was turned back into tundra.

The cause of the dramatic shift has always been unknown, but now the scientists behind the discovery of the Hiawatha Crater think that their huge meteor is the culprit. The effects of the impact are exactly what is required to trigger

a chain reaction that might end up cooling major parts of our planet in this way.

Previously, scientists have demonstrated that the cooling – known as the Younger Dryas cold effect – materialised at unprecedented speed. In 2009, Canadian geologist William Patterson and his colleagues studied drill cores from an Irish lake floor, discovering that the ecosystem of the area collapsed in a few months when the Younger Dryas cold event struck.

The speed of the climate change also supports the idea that the cause of the Younger Dryas was not a natural phenomenon, as these would be likely to require a long time to make such a significant change to climate, compared with a disastrous event that threw the planet back into the

freezer in record time. Studies of drilling into the Greenlandic ice sheet also indicate that the climate change happened over a period of no more than three years.

So a major meteor strike is an obvious explanation of the sudden cooling, for several different reasons. An impact of such dimensions in this geographical location would fill the atmosphere with dust, ash, and microscopic muddy droplets which could block out sunlight and heat for up to 10 years. That would make temperatures fall, as for a period of time more ►

1500

gigatonnes of ice melted as a result of the Greenlandic impact, scientists estimate.

Scientists might already have found remains of the large meteor – such as the Agpalilik, which is exhibited in Copenhagen.

CARSTEN BRANDT/GETTY IMAGES

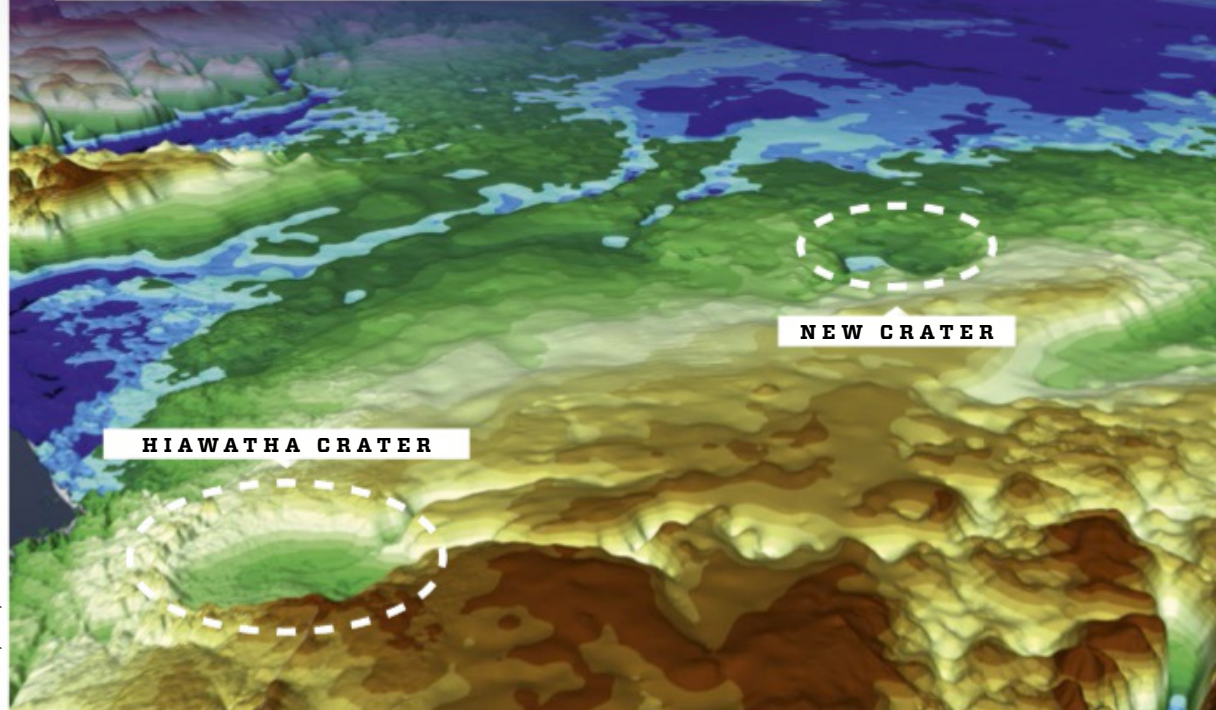


The force of the impact corresponded to 700 × 1 megatonne nuclear bombs, or 47,000 Hiroshima bombs.

SHUTTERSTOCK

Geologists find another crater under the ice

A few months after the publication of the discovery of the Hiawatha Crater, another group of scientists spotted another possible meteor crater some 180km south-east of Hiawatha. The new crater is probably older than the Hiawatha.



SVS/GSFC/NASA

► energy would escape Earth into space than the other way around.

Secondly, the heating from the strike would have produced vast levels of meltwater, which would have flowed from the ice sheet into the Atlantic to produce a light lid of fresh water that would sit atop of the heavier salt water. The lid of fresh water would slow down ocean circulation and thereby stop the transportation of luke-warm water from the Equator towards the north, which today we know as the Gulf Stream. All in all, global temperatures fell by 3-4 degrees during the Younger Dryas – and this had a severe effect on the human populations of Europe and North America.

Cold caused culture collapse

When the Younger Dryas finally ended after 1300 years, the present warm period, the Holocene, finally made its impact. The climate quite quickly became much more stable, allowing people to cultivate the land. The result was the first meagre farming efforts and permanent settlements occurring almost simultaneously some 11,500 years ago in areas

Drilling to reveal age of crater

New studies of the crater and detailed computer simulations of the impact are to reveal if the meteor was the cause of the 1300-year-long cold period.



KEN IKEDA MADSEN & SHUTTERSTOCK

Computer simulation reconstructs disaster

■ **HOW IT WORKS:** All knowledge about the strike is fed into a computer model, which simulates several possible versions of the impact.

■ **STATUS:** Completed.

■ **PRICE:** approx. A\$22,000.

■ **WHAT SCIENTISTS LEARNED:** The simulation shows that the ice did not curb the strike itself, but the ice determined where the remains of the meteor ended up. So scientists now know where to look.



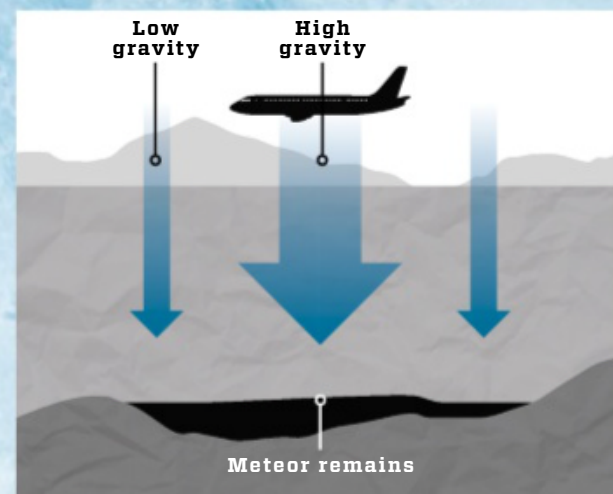
Combing of the coast reveals remains

■ **HOW IT WORKS:** Scientists search the area in front of the Hiawatha Glacier looking for material that was ejected in the impact, and perhaps remains of the meteor itself.

■ **STATUS:** Nearing completion.

■ **PRICE:** approx. A\$220,000.

■ **WHAT SCIENTISTS WILL LEARN:** Meteor remains may reveal their age, and analyses could show if known remains are from the same meteor.



Gravity data maps out strike

■ **HOW IT WORKS:** A plane with a gravimeter that measures the strength of Earth's field of gravity passes above the crater from many directions.

■ **STATUS:** Nearing completion.

■ **PRICE:** approx. A\$220,000.

■ **WHAT SCIENTISTS WILL LEARN:** An iron meteorite causes a markedly more intense field of gravity than ice and ordinary bedrock, allowing scientists to map any material from the impact below the ice.

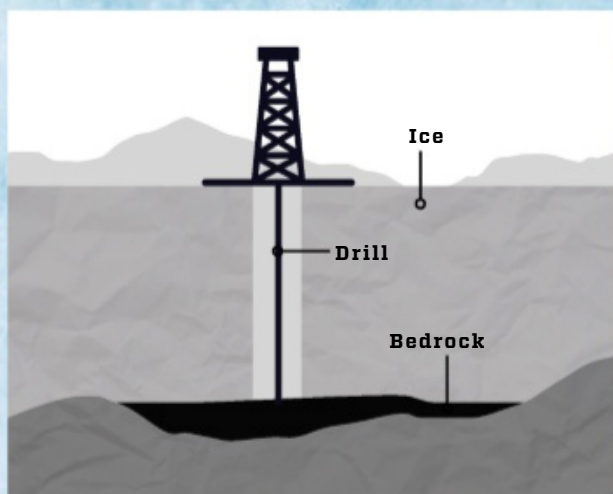
including the Middle East, China, Mexico and Peru. Without the Younger Dryas cold event, farming might have developed 1000 years earlier or more, and our civilisations today would be more technologically sophisticated than they are.

The sudden cold period had even more tangible consequences. The beginning of the Younger Dryas coincides with the collapse of the Clovis Culture in North America – possibly because the cold killed many of the animals on which the Clovis depended for food.

The discovery of the Hiawatha Crater and its link to the Younger Dryas provide scientists with an unprecedented insight into a meteor strike affecting mankind – it reminds us of the potential consequences of the present melting of the Arctic. And the young age of the crater has made scientists estimate that major meteor strikes might happen more often than previously thought. Studies that are currently under way should provide the necessary answers to solve the last mystery of the crater. **SCI**

Scientists would like to drill down to the crater. Here a similar drilling method is tested in Antarctica.

JAY JOHNSON/NSF



Deep drilling gives away the exact age of the crater

■ **HOW IT WORKS:** An ice drill is used to drill all the way down to the bedrock. Samples of ice and bedrock are taken – including meteor evidence, if any.

■ **STATUS:** Not yet planned.

■ **PRICE:** approx. A\$2.2 million.

■ **WHAT SCIENTISTS WOULD LEARN:** Ice samples could date the impact, whereas rock samples could provide more direct and detailed information about the meteor and the strike.



5

MYTHS ABOUT
SPIDERS

TRUE
OR
FALSE

“Spiders can
survive in a
vacuum cleaner”



➤ Many Australians are rather proud of our legendary spider populations, but others find them less alluring, and around the world many tall tales are spun. Are these true, or false?

MYTH

1

PARTLY TRUE

The vacuum cleaner seems like an easy solution to the problem of unwelcome guests in the corners of ceilings, but in principle spiders can survive the turbulent rollercoaster ride into the dust bag, and crawl back out.

To do so, first the spider must resist the artificially low pressure required by the vacuum cleaner to suck dirt up through its hose. Spiders can do that. NASA has sent spiders on repeated expeditions to the low pressure existing outside Earth's atmosphere. In 2011, two golden orb spiders thrived so much on a 45-day space mission that they successfully made webs similar to those they construct on Earth.

The next problem could be limbs lost and/or destroyed from the dangerous slide down the hose. But there is a solution to this difficulty too. Thanks to a special healing process, the arachnid can lose any damaged legs and grow new ones later.

The spider sheds a leg by switching off the blood supply using special muscles. When the leg is dead and has fallen off, the spider waits for the next moult. Unlike humans, spiders have exoskeletons, and they must shed their entire external skeletons and produce new ones as they grow.

If a spider survives the trip to the bag, it can reduce its metabolism and manage without food for up to 200 days.

Spiders are true survivors that can resist low pressure and regrow lost limbs.

SHUTTERSTOCK

"All spiders make their own webs"

Spiders are famous for their webs, but a few species use different methods to capture their prey.

Not all spiders make complex webs to capture their prey.

One example is the Himalayan jumping spider, which lives at altitudes above 6km (see also p61). When insects are captured by the wind and carried up the mountain, the spider is ready to jump from the mountain side to capture them in mid-air – safeguarded only by one single silk thread. The daring leap can be up to 50 times the spider's own body length. Another example is wolf spiders which, instead of making a web, actively hunt and capture their prey on the forest floor.

MYTH

2

FALSE

The jumping spider captures its prey without a web.

SHUTTERSTOCK



A spider can make webs in 7 different ways

Thanks to different glands, a spider is able to produce up to seven different silk threads for different purposes.

Cylindrical:

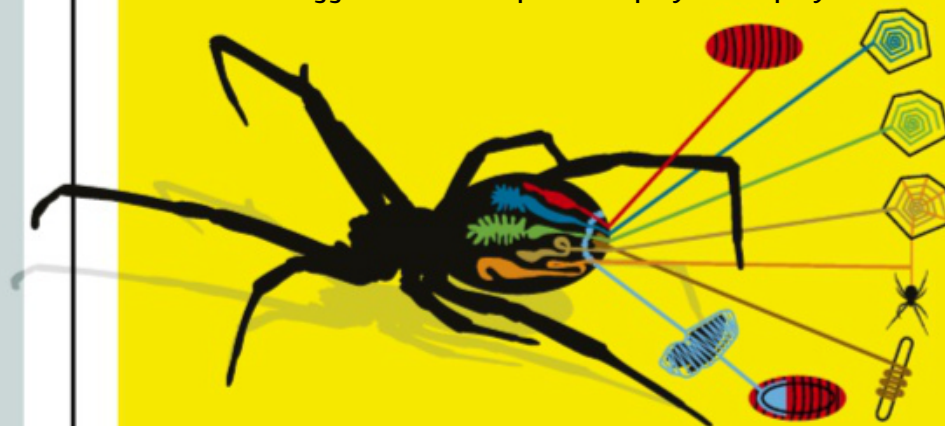
■ Produces robust silk that is used as a protective sac around the eggs.

Flagelliform:

■ Produces the innermost and most flexible silk threads that capture the prey.

Aggregate:

■ Produces extremely sticky silk that retains the prey.



Minor ampullate:

■ Produces stable silk that makes up the load-bearing web threads.

Major ampullate:

■ Produces a safety line that the spider uses for moving up and down.

Piriform:

■ Produces the silk that holds the web in position between branches, etc.

Aciniform:

■ Produces the silk used to wrap prey like a packed lunch.

“Spiders are aggressive”

Torn-off sex organs, long fangs and fatal love bites – spiders’ bizarre sex acts and cannibalistic behaviour have earned the eight-legged creatures a reputation of being unkind and aggressive. But recent studies also include examples of the very opposite. American scientists from Cornell University in New York have taken a close look at two types of whip spiders, which are characterised by walking on only six of their eight legs. The two last legs have evolved into a type of antenna, which the arachnids can also use to caress each other and express love. Other scientists have discovered examples of the fact that a specific spider species of the *Eresus cinna-berinus* family can live in complex family relations with up to 100 members in one nest. The family members help each other capture food and bring up offspring.



Specific spider species live in large families that help each other capture food.

GEORGETTE DOUWMA/NATUREPL

MYTH
3

PARTLY
FALSE

MYTH
4
FALSE

“You swallow eight a year”

“While you are sleeping, spiders and other creepy-crawlies move into your mouth.” Or do they? One of the most diehard myths about spiders is that you swallow at least eight a year. Nobody knows the origin of the myth, but from a scientific point of view, it doesn't make sense. Spiders normally remain in their webs, or in quiet places where they can peacefully hunt their prey. Moreover, the size difference between humans and spiders is so marked that we just form part of the landscape to them; they do not actively seek us out.

If a spider were to come close to a sleeping human accidentally, there is still a long way to go before it is actually swallowed. Sleeping noises and motions will probably scare off the eight-legged creatures, and a tingling sensation in the face is sufficient to wake up most people. All things considered, the risk of swallowing a spider is very slight.

Sleeping sounds and motions will often scare off spiders.

SHUTTERSTOCK





MYTH
5
PARTLY TRUE

“Their web is as strong as steel”

Both steel and Kevlar are stronger than a cobweb, but the combination of flexibility and strength makes the web difficult to imitate.

In spite of its delicate nature, a cobweb is very strong – but not stronger than materials such as steel and Kevlar. A cobweb has a tensile strength of 1 gigapascal, whereas steel and Kevlar have strengths of 1.6 and 3.6 gigapascals respectively. On the other hand, cobwebs are much more flexible, and that is one of the reasons why scientists throughout the world are struggling to copy the

strong fibre threads in the lab. If they are successful, they hope to replace everything from car bumpers to bullet-proof vests with the artificial spider silk, as the combination of flexibility and strength makes it perfect for absorbing energy and halting objects.

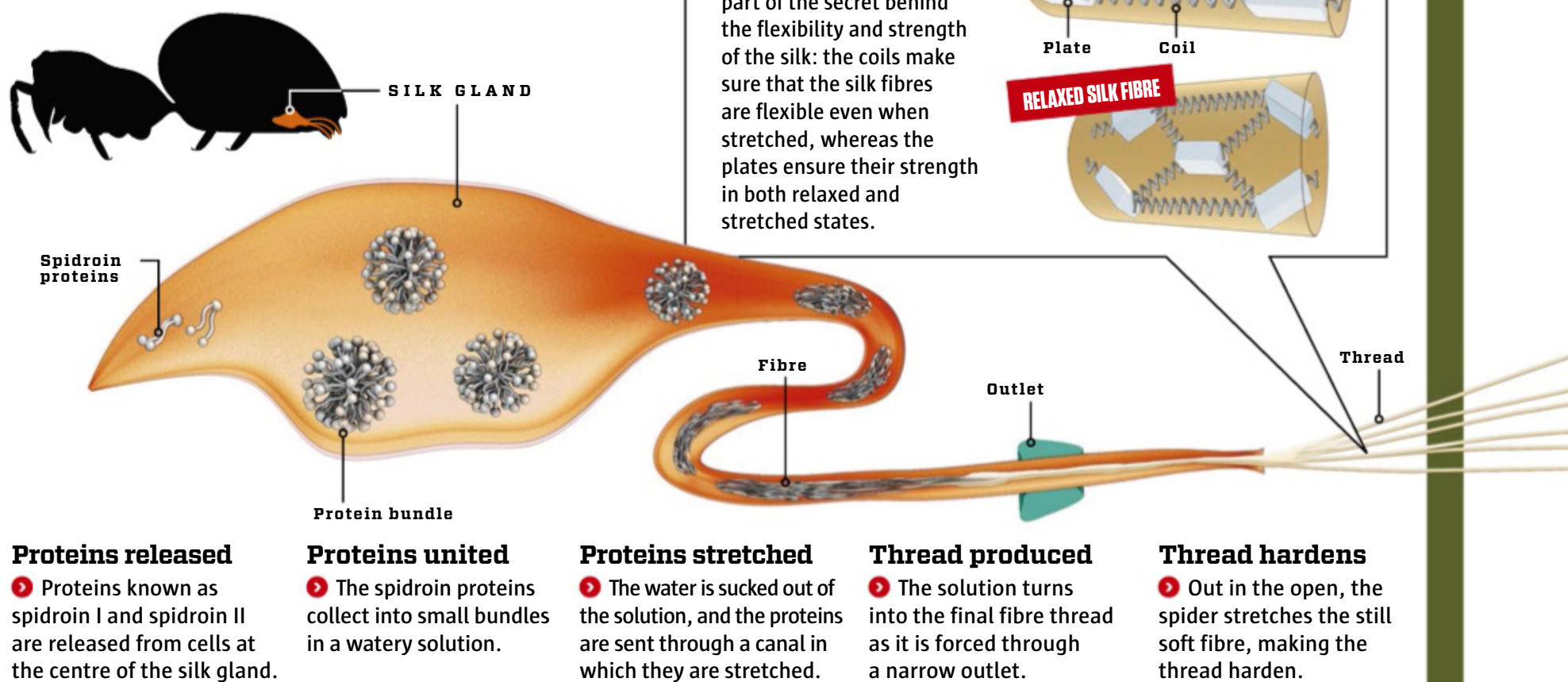
Scientists also hope that the artificial silk can be used as a more environmentally-friendly and degradable alternative to oil-based plastic.

Silk glands on the hind part of the spider produce the fibre threads that make up the strong web.

STEPHEN DALTON/NATUREPL

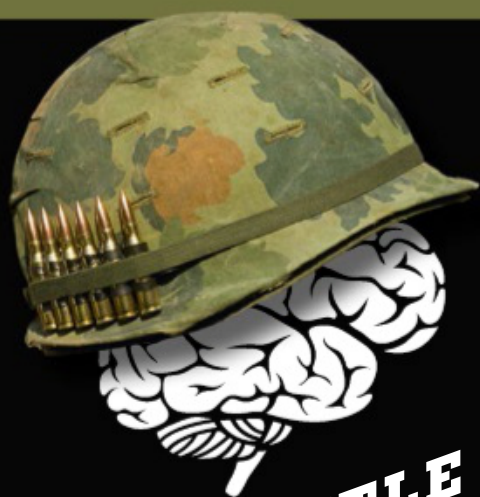
Soft thread hardens in the air

The spider's silk gland is a sophisticated chemical factory that converts water-soluble proteins into strong thread.



MIKKEL JUUL-JENSEN

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OF THE BRAIN**

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Immune cells vs
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Antidote vs
Alzheimer's



350 million people suffer from depression, and antidepressants can have no effect for many.

ELECTROMAGNETISM AND DEPRESSION

► Put on an electromagnetic helmet to make yourself happier? A ground-breaking therapy aims to increase nerve-cell activity to help those whose depression doesn't respond to current treatments.

Millions of positively-charged sodium ions flow into the nerve cell through a microscopic gate of protein in the cell's exterior shell, the cell membrane. The intense flow of electrically-charged ions makes an adjacent gate open as well. More ions flow in. A new gate opens, and then another one. A chain reaction of open gates and electric current spreads down through the nerve cell's long projection, finally reaching the end, where the flow makes the cell release a multitude of neurotransmitters. The substances bind to another nerve cell, where gates open to trigger another chain reaction. The electrical impulse flows through your brain from nerve cell to nerve cell, causing a pleasant feeling to spread.

That's how the brain normally works. But the system can be thrown off balance, sometimes resulting in depression. Some 350 million people are estimated to suffer from depression, which can cause a lack of joy and of energy. In many patients, medication or talk therapy (psychotherapy) can cause improvement, but some do not react to the traditional treatments. Electromagnetism is now bringing new hope to these people.

Medication scrutinised

For decades, scientists have struggled to understand how depression originates. In the 1960s, they discovered one of the first scientific explanations of the phenomenon. It was proposed that a lack of specific neurotransmitters in the brain – particularly serotonin – is the primary cause of depression. The theory led to a simple solution: by increasing the quantity of serotonin available to nerve cells, depression could be remedied. ►

Chain reaction extends signals

In healthy brains, nerve cells are experts on producing electrical signals and passing them on to the adjacent cells.

CLAUS LUNAU

Ions flow into the nerve cell

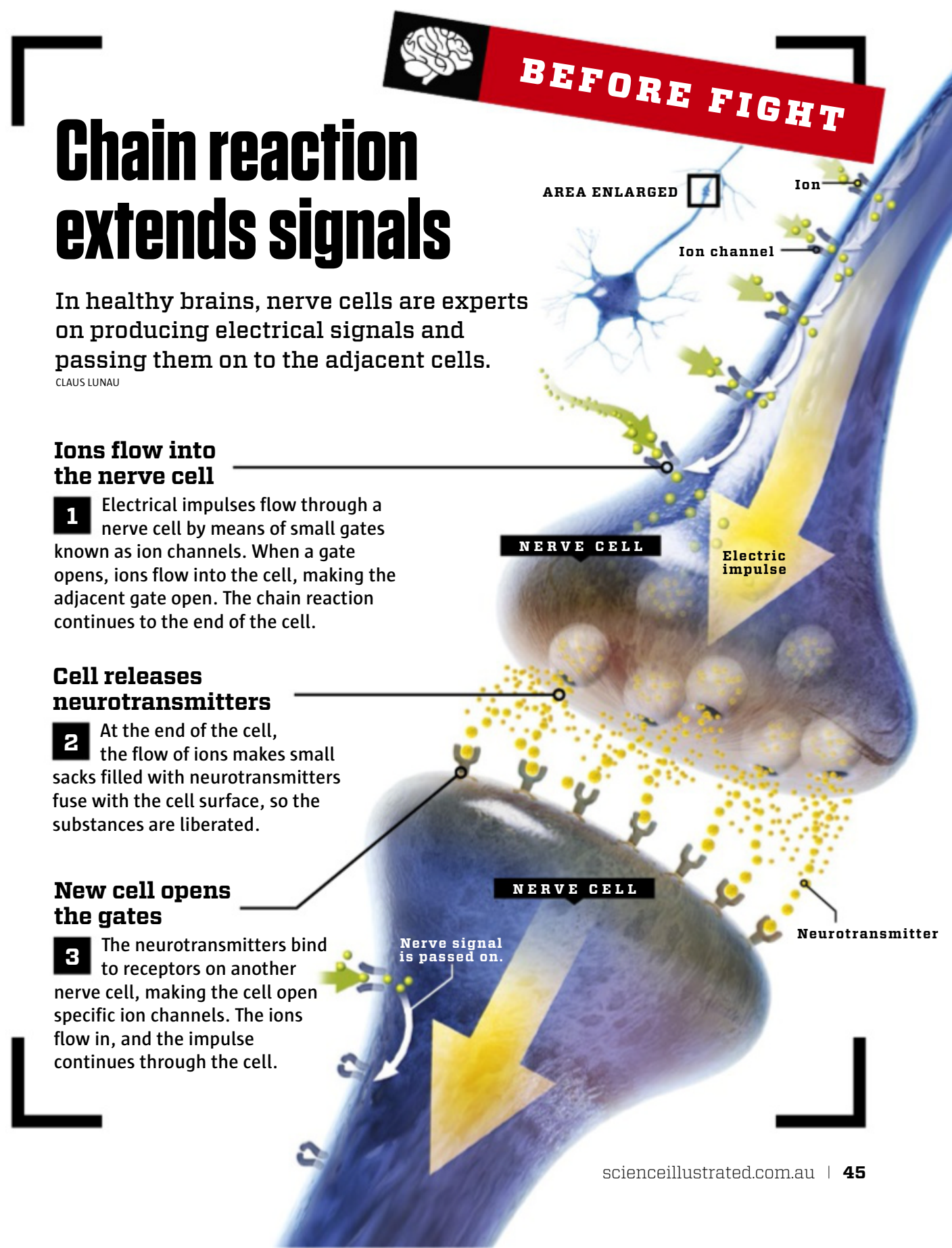
1 Electrical impulses flow through a nerve cell by means of small gates known as ion channels. When a gate opens, ions flow into the cell, making the adjacent gate open. The chain reaction continues to the end of the cell.

Cell releases neurotransmitters

2 At the end of the cell, the flow of ions makes small sacks filled with neurotransmitters fuse with the cell surface, so the substances are liberated.

New cell opens the gates

3 The neurotransmitters bind to receptors on another nerve cell, making the cell open specific ion channels. The ions flow in, and the impulse continues through the cell.



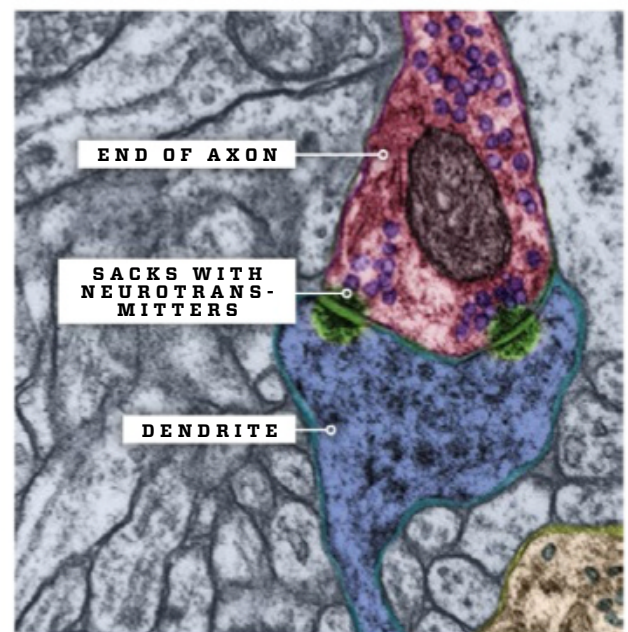
► Shortly after this a new group of drugs was marketed: SSRIs or Selective Serotonin Reuptake Inhibitors. They curb the mechanism that normally removes serotonin from the brain's synapses – the links between the nerve cells. So they increase the quantity of the neurotransmitter in the synapses.

Together with several similar substances, SSRIs have become one of the preferred types of treatment in the Western world. But they have also caused plenty of scepticism. They can have a number of side-effects, such as nausea, poor sleep, reduced sex drive, and impotence. Moreover, some experiments show that SSRIs are no better at relieving depression than harmless placebo pills.

In order to come closer to the truth regarding SSRIs, an international team of scientists in 2018 carried out a major analysis of

all the experiments that have tested the effect of the drugs on depression. The analysis is the most extensive of its kind so far, and the result was clear: the SSRIs are better than a placebo – but they are not as efficient as some scientists have claimed.

The analysis is a milestone in the treatment of depression, but it is not the definitive answer for individual patients. There might be a major difference between the drugs' efficiency on individual patients. This means that some will benefit more from one specific product than the average, whereas others do not experience any improvement. And the fact that the popular SSRIs do not always have significant effect on the disease has made scientists realise that depression is a much more complex disease than previously believed, and a long series of new theories are emerging.

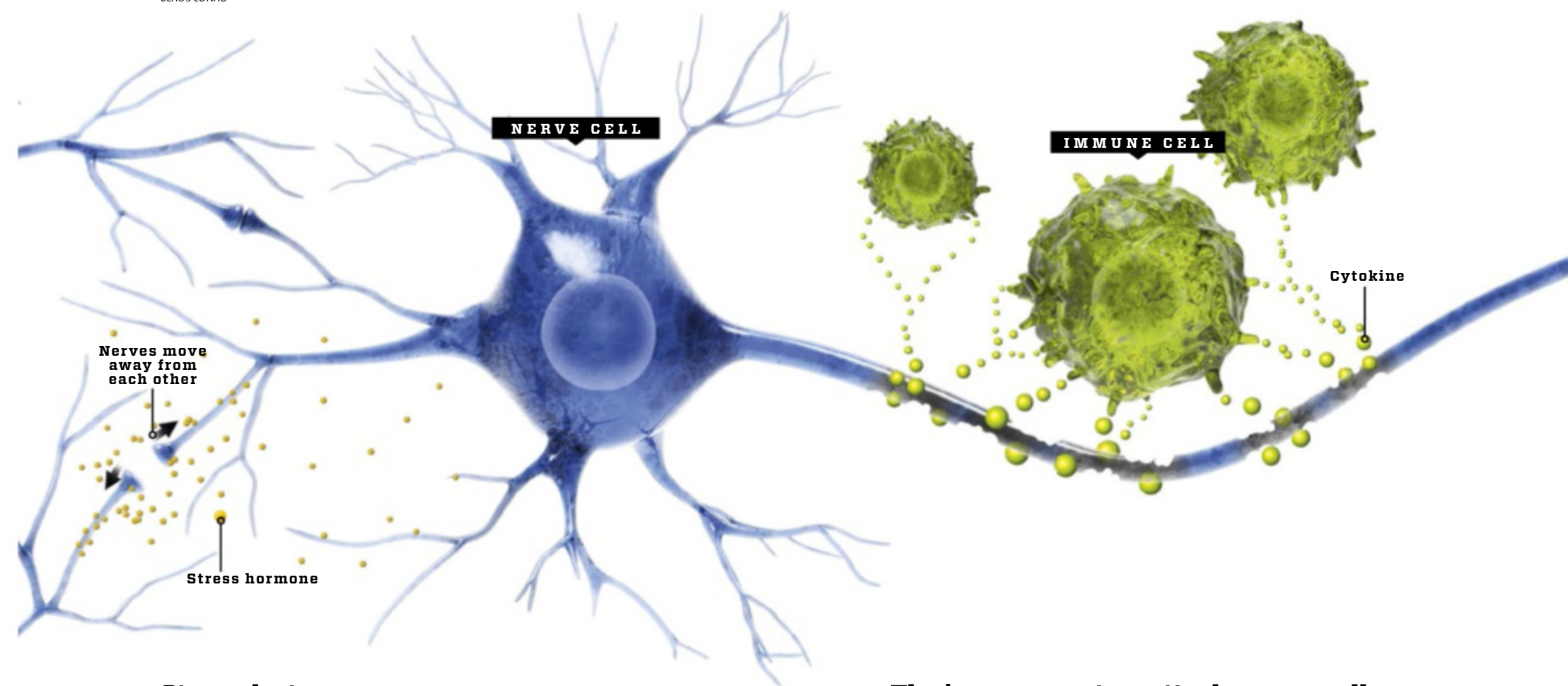


In a synapse, one nerve cell's projection, also known as an axon, releases neurotransmitters to another nerve cell's dendrite.

Stress destroys links

Infection, stress, and sleep rhythm imbalances are some of the things that could cause trouble with signal-sending in the brains of depressed people.

CLAUS LUNAU



Stress destroys synapses

1

THEORY 1: In the case of prolonged stress, brain cells are showered in stress hormones such as cortisol. The hormones curb the production of a series of important proteins in nerve cell synapses. The synapses shrink, and some of them disappear, so the cells cannot send signals to each other.

The immune system attacks nerve cells

2

THEORY 2: A chronic, mild infection in the body increases the risk of depression. During the infection, the immune cells are hyperactive, and they liberate substances known as cytokines. The cytokines prevent the nerve cells from producing new synapses, and at their worst they can kill the nerve cells.

Infection poisons the brain

SSRIs immediately increase the quantity of serotonin in the brain, but it typically takes several weeks before the depressed person feels any marked improvement from the medication. So scientists now agree that the drugs' efficiency in treating depression is down to more than a simple increase in the quantity of serotonin. The drugs influence other parts of the body, such as the immune system, and that might explain their effect.

A lot of research indicates that a series of different systems are affected during depression – there might be fewer synapses, a lack of specific proteins, and other possibilities. And according to some scientists, the changes have a common, more deeply-rooted cause: infection. Several experiments have shown that depressed people have higher levels of

infection in their bodies than would usually be expected. Infection is normally the body's way of combating harmful organisms such as bacteria – but it can also be caused by stress.

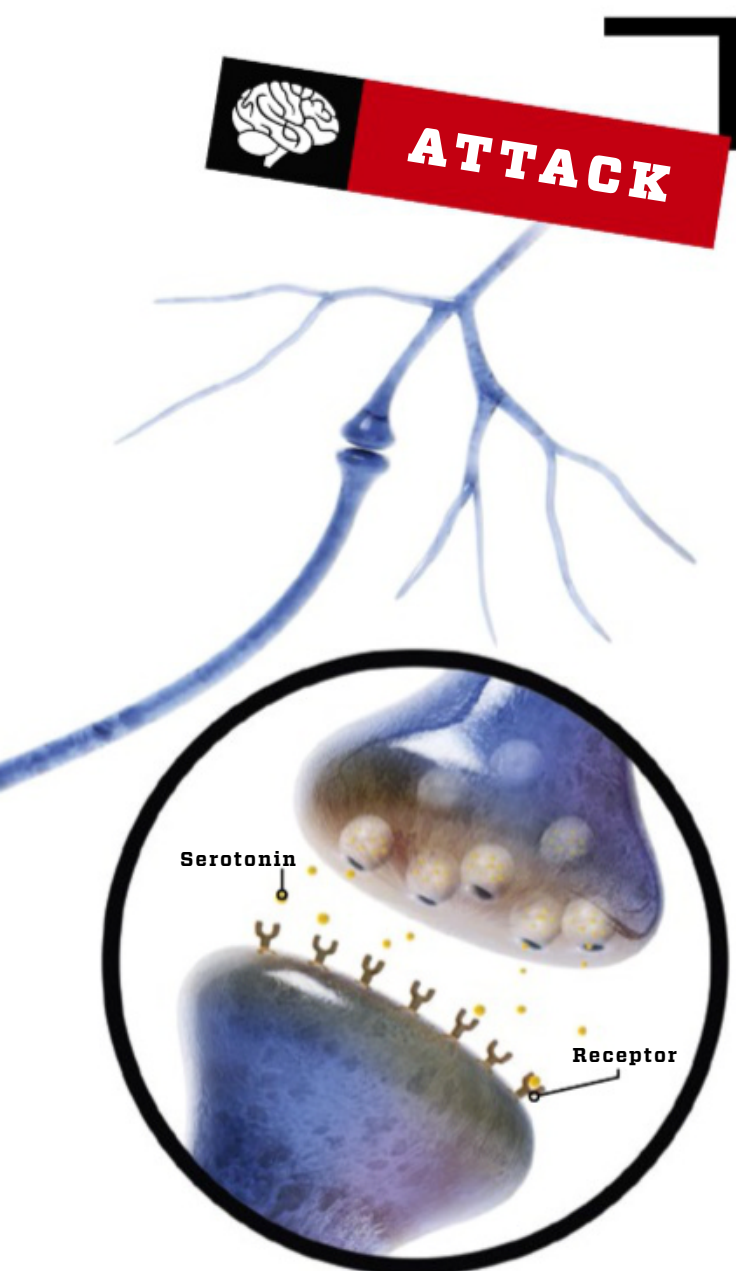
One consequence of the infection could be that the body converts some of the otherwise beneficial tryptophan (a substance that is used to produce serotonin) into substances that are toxic to brain cells. The toxin settles on special receptors on the nerve cells, making them hyperactive, until they are so 'worn out' that they are no longer able to liberate important neurotransmitters. The result is that the brain's pleasure systems then do not function optimally. Some experiments indicate that measures counteracting the effect of infection also relieve symptoms of depression. This can include activities such as working out and exercise. When we work out,

we activate the muscle cells, making them absorb tryptophan, so that less of it is likely to develop into toxins.

The brain is bad at adapting

The brain's ability to adapt (plasticity) also plays a central role in depression. High plasticity means that the brain is able to produce new brain cells, blood vessels, and links between nerve cells. But the plasticity of depressed people is highly reduced.

Our brains must adapt constantly, and can be put to their most serious trials during major changes such as losing a job, or a family member. Experiments have shown that some people are genetically predisposed to develop depression following major upheaval in their lives. This might be due to genes that deny them sufficient brain plasticity. ▶



Poor sleep curbs signals

3

THEORY 3: Too little or too much sleep might cause changes of the nerve cells' ability to liberate or react to the serotonin neurotransmitter. So signalling between the cells is reduced.

Millions never treated

Hundreds of millions of people suffer from depression, and elderly women are the most badly affected. Yet fewer than half of them are ever treated.



350,000,000
people suffer depression worldwide

5.1%



3.6%



Some 4.4% of a population develop the condition. Women are the most badly affected, particularly those aged 55-74.

35.7%

of patients diagnosed with depression receive treatment, according to an American study.

SHUTTERSTOCK

► Some types of antidepressants seem to work by improving the brain's ability to produce new links between the nerve cells of the brain. This happens particularly in the hippocampus brain centre, which is typically smaller in depressed people. Animal experiments demonstrate that the medication makes the hippocampus grow to its normal size.

In recent years, scientists have tried to improve the plasticity of depressed brains without the use of medication, focusing on techniques including electric stimulation of brain cells. One method involves surgical implantation of small electrodes into the brain, but this has caused very little effect, and the procedure is risky, given the brain surgery.

The transcranial magnetic stimulation method, by which powerful electrical pulses are sent into the brain via a device located outside the head, is a bit more sophisticated. Test of the


treatment show it to have some, if not an overwhelming, effect on depression. However, the method involves a major problem: the patient must come to the hospital every time he or she is treated – and that is relatively often. A new treatment is now solving this issue. It can take place in the patient's own home, and the results of the first tests of the treatment are very promising.

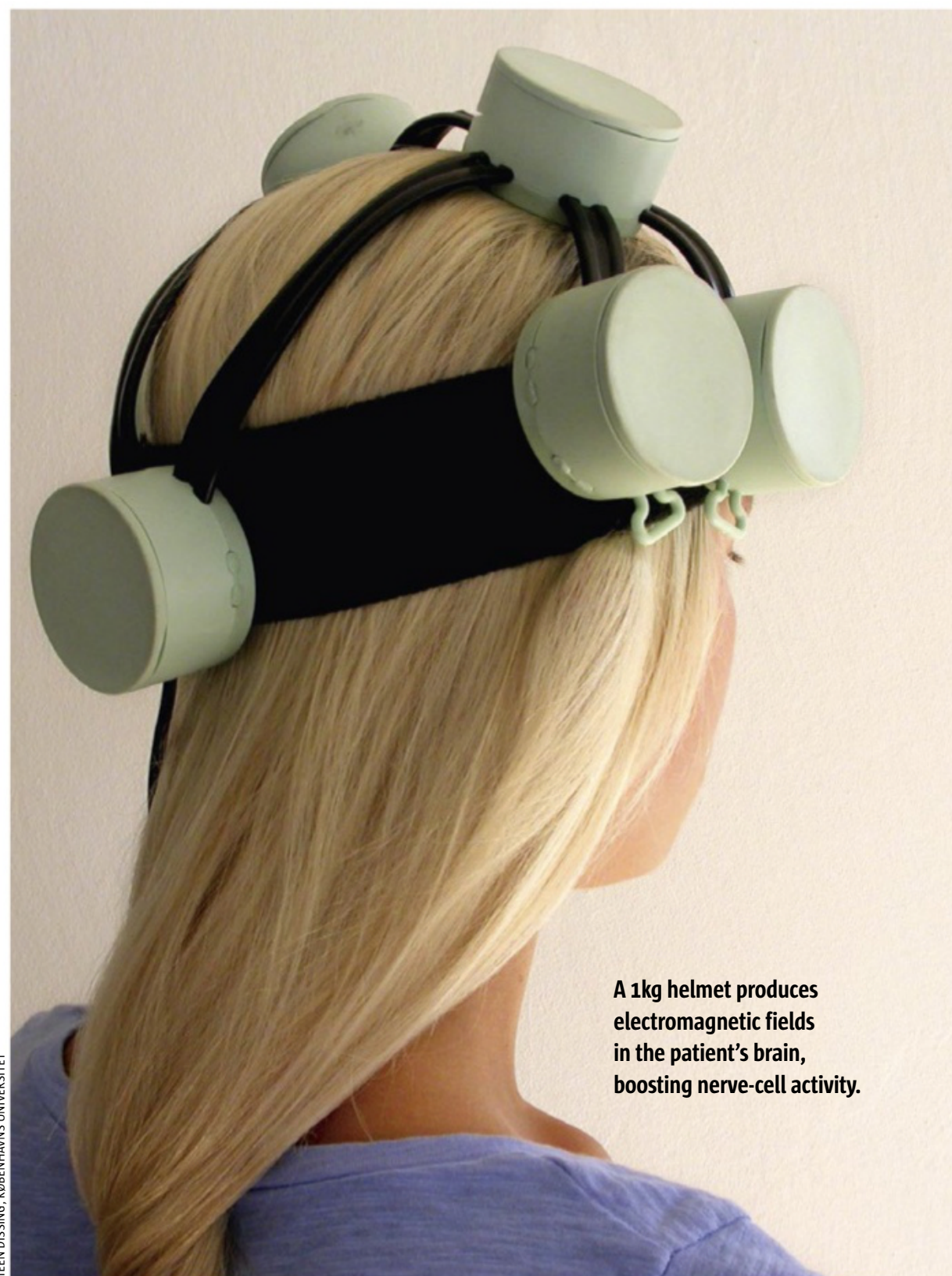
Helmet revitalises cells

Put on your electromagnetic helmet and let it remain there for 30 minutes. Do this every day, and after a few months, you are no longer depressed. That is what happened to about half of the chronically-depressed people who participated in experiments with the T-PEMF treatment – Transcranial Pulsating Electromagnetic Fields. In one half of the test subjects, the majority experienced marked improvement

of their symptoms. The treatment was approved in Europe in 2015, but so far few doctors have felt convinced by the experiments in which T-PEMF has been tested. Now a new extensive study might change doctors' opinion. T-PEMF has been tested in six Danish hospitals, and the results, which will be published this year, seem to confirm that the treatment is efficient against depression.

The treatment involves a helmet with seven copper coils that produce weak, pulsating, electromagnetic fields in the brain. The fields' strength is about the same as the electrical fields that occur naturally when nerve cells send signals. The electromagnetic fields probably stimulate a series of growth factors in the brain, making the nerve cells produce new synapses and causing blood vessels to develop more branches that can supply the brain cells with oxygen and nutrition. The result is an improvement of nerve cell activity – and hence reduced depression.

T-PEMF is potentially great news for the depressed people who do not benefit from existing treatments, but the method might also prove to benefit people with other brain diseases caused by reduced brain activity. The results from 2018 indicate that T-PEMF also reduces the symptoms in patients who suffer from Parkinson's disease – and scientists now hope that the treatment can also prove effective against dementia. 



A 1kg helmet produces electromagnetic fields in the patient's brain, boosting nerve-cell activity.

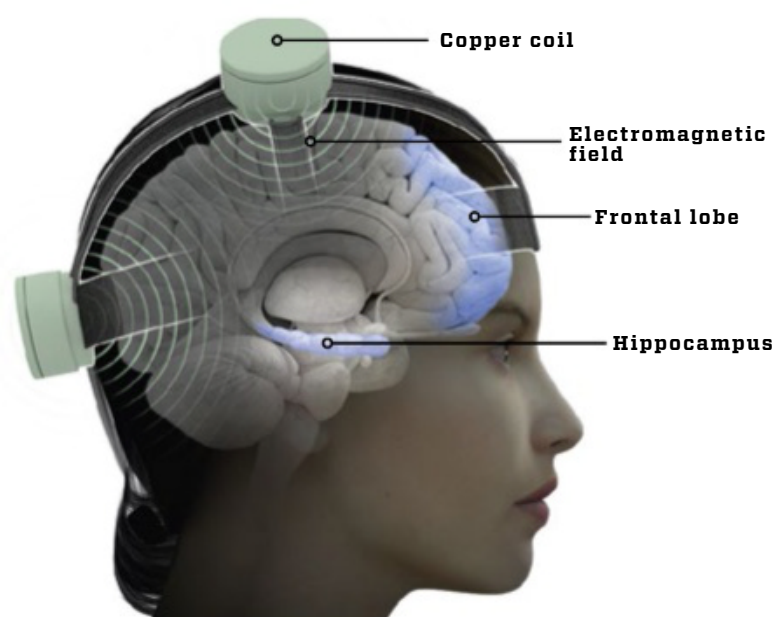
STEEN DISSING, KØBENHAVNS UNIVERSITET



Helmet makes nerve cells grow

A helmet made of electromagnetic coils sends impulses into the brain, influencing brain cell enzymes. The result is an increase in links between nerve cells, and more nutrition to power high activity in the cells.

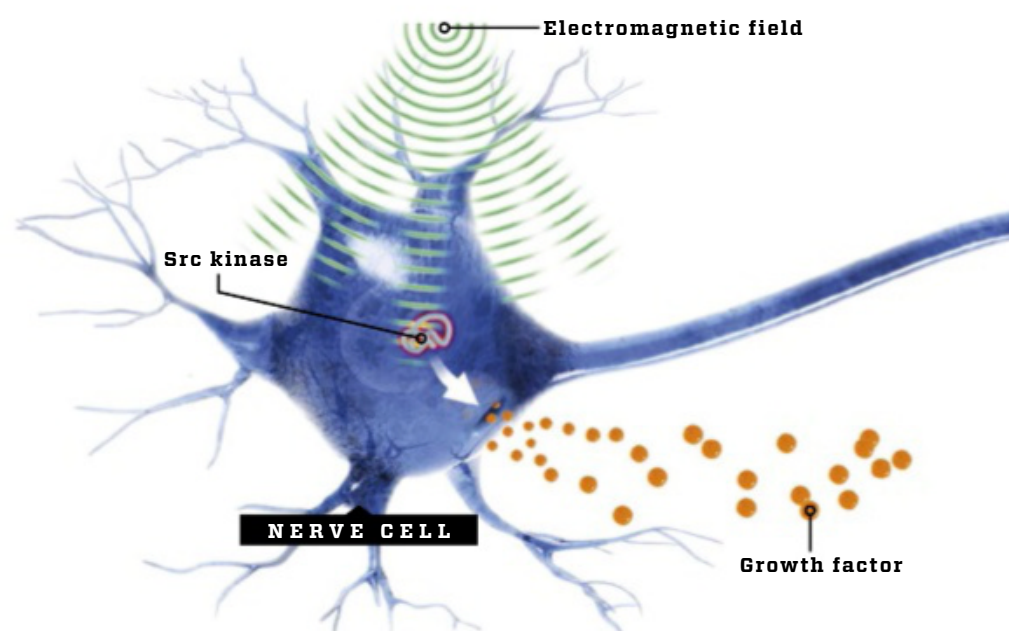
CLAUS LUNAU



Coils send impulses deep into the brain

1

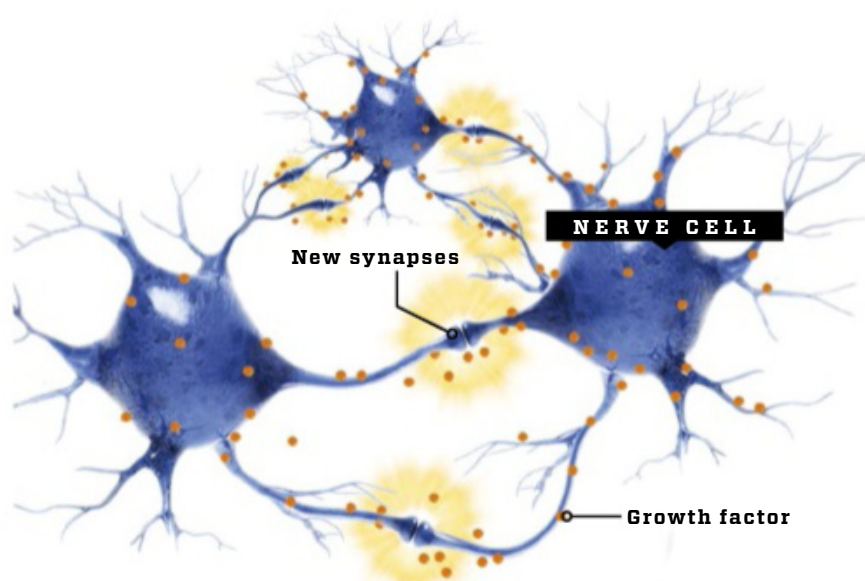
The patient activates seven coils located on his or her head. The coils produce pulsating electromagnetic fields that spread deep into the brain. The fields are particularly aimed at the hippocampus brain centre and the frontal lobe, which are often unusually small or suffer reduced activity in depressed people.



Pulses activate enzyme

2

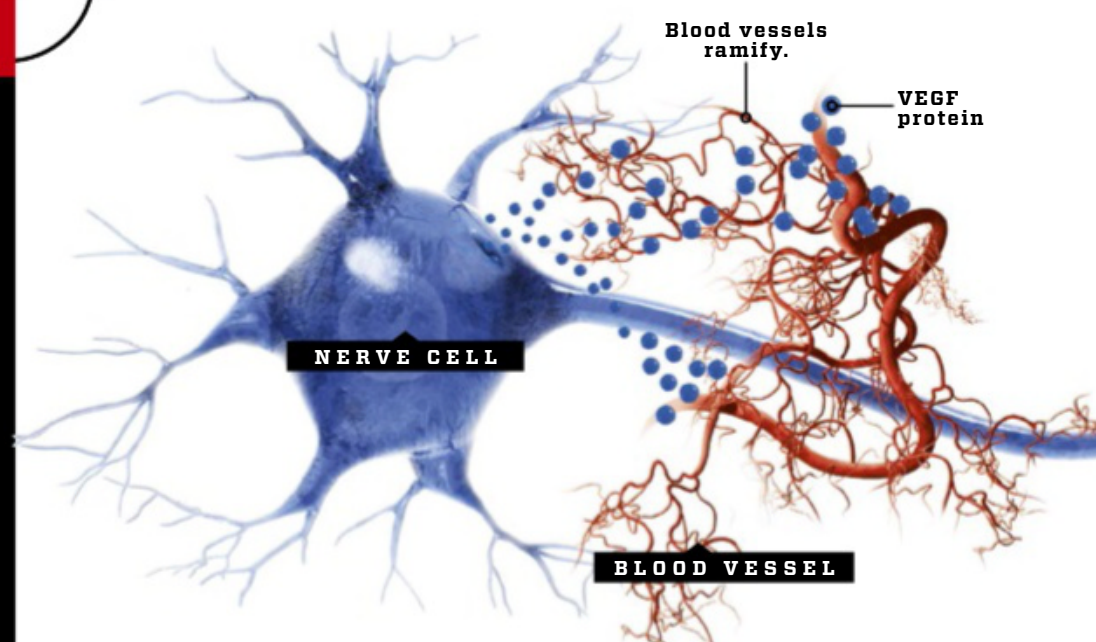
The electromagnetic pulses influence electrically charged parts of the Src kinase enzyme, which is located inside nerve cells. The Src kinase is thereby activated and sends a signal into the cell, causing the cell to begin liberating large levels of 'growth factors' to its surroundings.



Growth factors make cells grow

3

The growth factors bind to receptors on the nerve cell and on adjacent cells. The receptors send signals into the cells, making them produce new synapses. The extra links between nerve cells result in markedly increased signalling in the affected brain area.



Nerve cells attract new blood vessels

4

The increased activity makes the nerve cells release more growth factors, including the VEGF protein, which binds to the blood vessels of the brain, making them branch towards the nerve cells. The new blood vessels supply more oxygen and nutrition to the nerve cells, so they can maintain their higher activity levels.

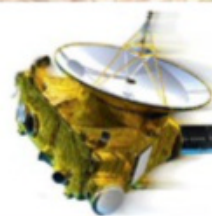
WILL PUNTER



250

1769-2019

James Cook went to Tahiti to time the transit of Venus 250 years ago. The rare astronomical phenomenon was the key to calculating the distance between the planets of the Solar System.



DISTANCE

Space probes allow us to measure the distance to the smallest of worlds, and rare ice comets grant us a peek at the outskirts of the Solar System.

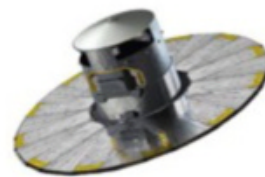
ASTRONOMERS MEASURE AND WEIGH THE SOLAR SYSTEM

➤ When Venus passed in front of the Sun in 1769, astronomers were able to measure the distance from Earth to the Sun accurately for the first time. Now, scientists are mapping out the Solar System by means of probes and space telescopes, enabling them to measure and weigh the tiniest of objects.



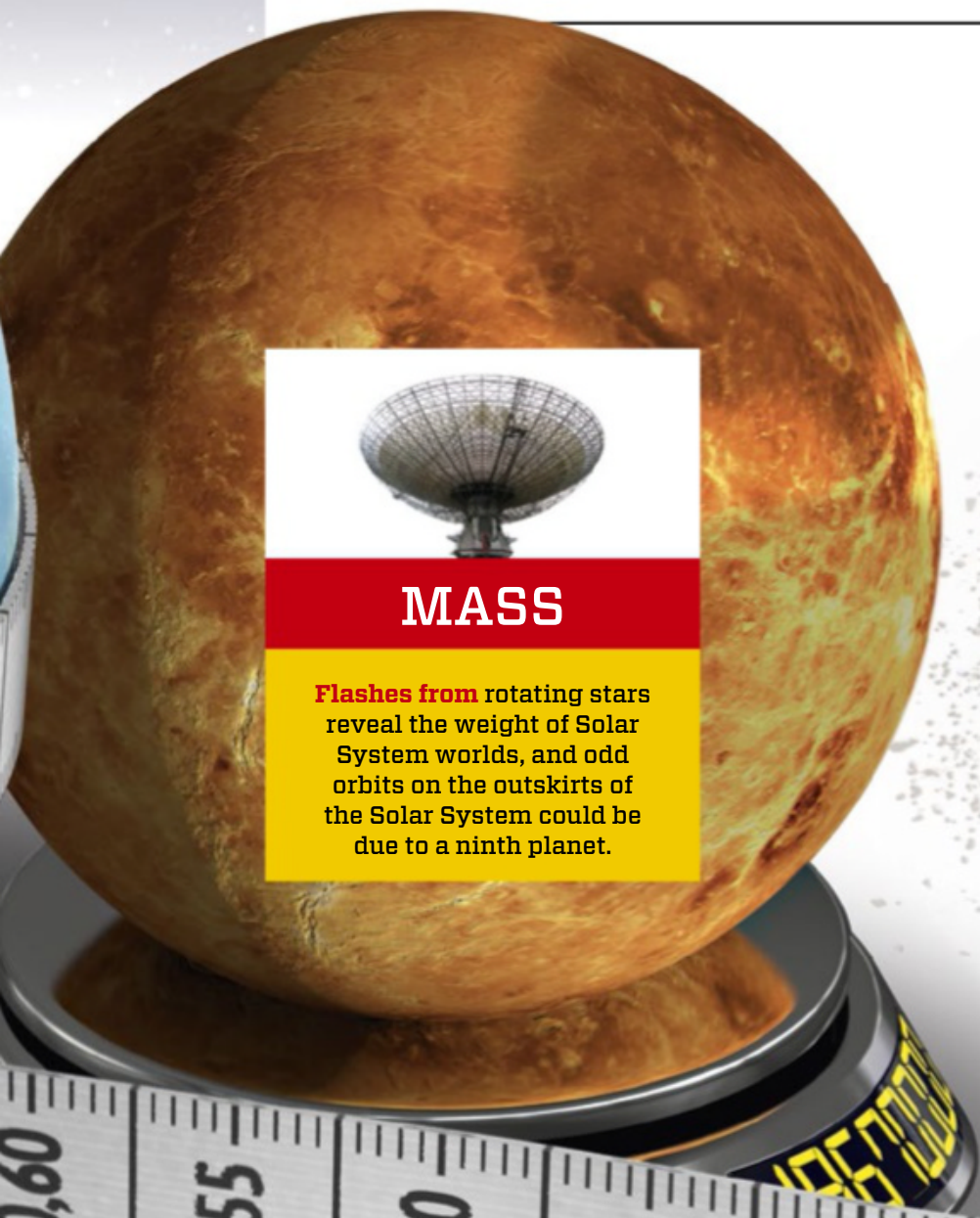
MASS

Flashes from rotating stars reveal the weight of Solar System worlds, and odd orbits on the outskirts of the Solar System could be due to a ninth planet.



SPEED

A space telescope measures, how quickly the Solar System rotates, and a new theory explains why one of the planets is rotating out of step with its atmosphere.



DISTANCE

THE **NEW HORIZONS** PROBE WAS LAUNCHED IN 2006, AND IN 2015 IT PASSED BY THE DWARF PLANET OF PLUTO. THE PROBE IS NOW EXPLORING OTHER OBJECTS IN THE KUIPER BELT.

NEW METHOD OF MEASUREMENT

Probe measures the outskirts of the Solar System

Radio signals between a space probe and telescopes on Earth measure the distance to a remote ice world.

Based on orbit times, astronomers have calculated the planets' distances to the Sun, and by launching space probes they can now also determine the distances even to small objects on the remote outskirts of the Solar System. Earlier this year, the New Horizons space probe passed the so-far-remotest object of the Solar System, the frozen ice world of Ultima Thule. By sending radio signals between the probe and Earth, scientists could calculate that Ultima Thule is 6.47 billion km away. Knowledge about heavenly bodies' locations is key to being able to navigate accurately in space and so travel to places such as Mars.

NASA

Space probe replies

2 About six hours later, New Horizons picks up the signal with its 2.1m-wide antenna. With a delay of only a few hundred nanoseconds, New Horizons replies.

Telescopes send a signal

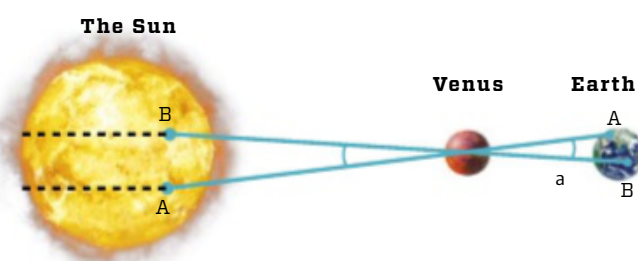
1 Radio telescopes located in Australia, Spain and the US – the Deep Space Network – communicate with the New Horizons probe shortly before it passes the Ultima Thule object on the outskirts of the Solar System. To measure the distance, the telescopes send a special coded radio signal to the probe.

When Captain James Cook set sail, heading for Tahiti in August 1768, he was really on his way towards another planet. Not only did he carry neither dependable maps nor a reliable means of communication, his real destination was the planet of Venus.

Cook's expedition was a race against time. He had to travel from England to the remote Pacific island before June 1769, or it would be too late to observe Earth's neighbouring planet pass across the Sun as a small, dark spot. Venus transits only

happen at intervals of some 120 years, so to astronomers the 1769 transit was a unique opportunity to calculate the distance between Earth and the Sun, and hence the distance to all other planets in the Solar System.

Since then, countless astronomical expeditions have followed in Cook's footsteps. Driven by the same curiosity to explore the unknown, scientists have aimed telescopes at all corners of our astronomical neighbourhood. They have sent probes to the outskirts of the Solar System and have travelled into space themselves. Their measurements have revealed



TRANSIT OF VENUS. Observers in the northern and southern hemispheres observe Venus' transit across the Sun differently. The distance between the observers and the angle of the lines of sight make it possible to calculate the distance to Venus.

NASA

Ultima Thule is the most remote Solar System object ever visited. The distance to the frozen rock has now been measured using radio waves. See also 'Science Update' on page 16.

Signal's travel time reveals distance

3 The radio telescopes on Earth pick up the weak signal. As the waves travel at the speed of light, the distance to Ultima Thule can be calculated based on the time passing before the signal returns to Earth.



Astronomers in Australia prepare to observe the Venus transit in 1874.

BIGGEST MISTAKE

POOR IMAGES BLURRED THE TRANSIT OF VENUS

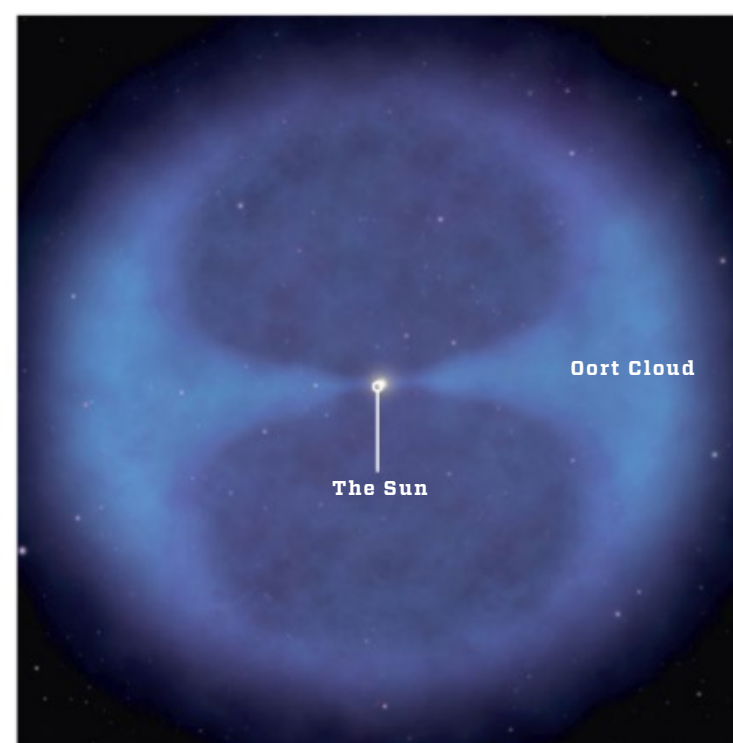
German astronomer Johann Franz Encke calculated the distance between Earth and the Sun (AU) to be 153,340,000km based on observations from the 1700s – 3.5+ million km longer than the present result. Before the Venus transit in 1874, he challenged his colleagues to come up with a better result. The astronomers practised measuring the transit using primitive simulators, but although photography had been invented and several observatories did take photos during the transit, the quality was so poor that nobody managed to measure the distance accurately.

BIGGEST MYSTERY

Where does the Solar System end?

According to many astronomers, the Solar System is located in a ball-shaped shell in which billions of frozen comets and ice worlds orbit the Sun. Nobody has ever observed the Oort Cloud, but ice comets with extremely long orbits of 200+ years indicate that it exists. The comets can only come from regions outside the Kuiper Belt, and the hypothesis is that they were once forced out of the Oort Cloud's no-man's-land far away from the Sun. Encounters with other interstellar objects sent them towards the centre of the Solar System.

The cloud is believed to be located 1000-100,000 AU from the Sun – much further than the Kuiper Belt, which is 'only' 30-50 AU away. The Voyager 1 probe launched in 1977 is expected to reach the Oort Cloud in 300 years, exiting it again in 30,000 years.



a complex relationship between Solar System distances, speeds and mass, finally allowing us to find our own spot in the universe.

However, Captain Cook and his crew of 94 knew nothing about all this as they struggled against scurvy, storm and the risk of madness aboard the Endeavour.

Venus as a thumb

Two major realisations of the 1600s and 1700s made the Venus transit of 1769 extremely important. In 1619, the German astronomer Johannes Kepler calculated the relative distances

to the six known planets (Uranus and Neptune had not then been discovered). By using Tycho Brahe's thorough recordings of the planets' locations on specific days, Kepler also found their accurate orbit times. The discovery revealed a mathematical relation between the planets' orbit times and their distances to the Sun: the square of the orbit time divided by the cube of the distance always produces the same number.

The principle is known as Kepler's third law, and it states the relationships between the planets' distances to the Sun in relative numbers. If the distance between Earth and the Sun is

determined as the astronomical unit AU, the distance to Venus was, according to Kepler, 0.724 AU, which is only a few decimals different to the result of modern calculations. But the astronomers of the time did not have the tools to convert their relative values into absolute numbers.

Then in 1716, English astronomer Edmund Halley developed a method for calculating the distance to the Sun by timing Venus' transit across the Sun's disc. Halley's method uses a phenomenon known as parallax, which is based on a simple concept: by holding your thumb at ►

MASS

NEW METHOD OF MEASUREMENT

Remote pulsars weigh Solar System miniatures

The light from remote rotating stars reveals the mass of small Solar System objects.

Normally, astronomers must send a probe to an object to measure its mass. When the spacecraft passes by a planet, moon or asteroid, that object influences the craft slightly, revealing the object's mass. However, scientists can now use flashes from pulsars (small rotating stars) to weigh even small asteroids without leaving Earth. Over the next seven years, measurements of the light from 20 pulsars will provide us with more accurate mass indications than probes allow.

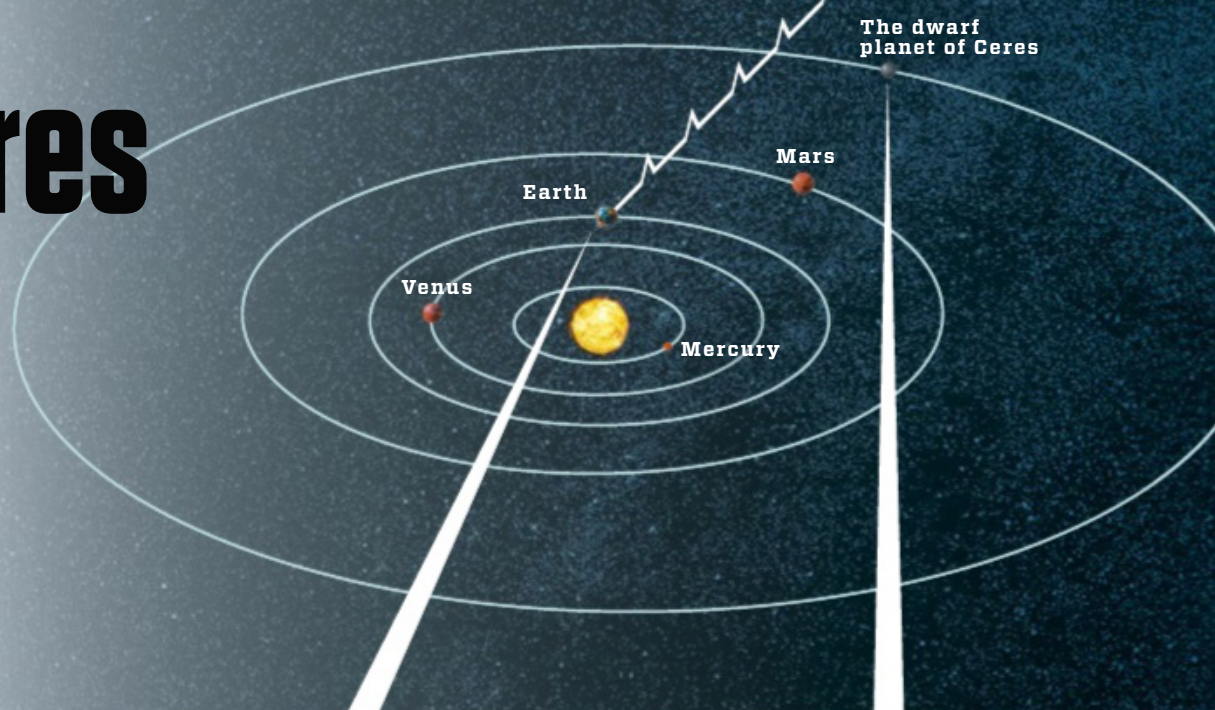
SHUTTERSTOCK

A NETWORK OF TELESCOPES, THE INTERNATIONAL PULSAR TIMING ARRAY, PICK UP THE ULTRA-WEAK SIGNALS FROM REMOTE PULSARS.



Pulsar emits flashes

1 Pulsars are small rotating stars which emit beams of radio waves, just like the light from a lighthouse. The waves travel through space as extremely regular flashes.



Planets influence pulsar flashes

2 A telescope on Earth spots a pulsar flash, and scientists use it to calculate when a future flash will arrive. They allow for the time of arrival being influenced by all planets' masses.



Irregularity indicates mass errors

3 If the arrival of the flash differs from the calculated one, a world must have been registered with a slightly faulty mass – such as Ceres. Astronomers adjust the object's mass until the arrival time is correct.



► arm's length and observing it with first your right eye closed and subsequently your left eye, you will see a shift of the finger as compared to the background. Based on the shift and the distance between the eyes, it is possible to calculate the distance to the thumb. In a transit of Venus, during which Venus passes between the Sun and Earth, Venus functions as the thumb, with observations from different places on Earth being the two eyes.

An observer in the Northern Hemisphere will see Venus pass in an orbit that is slightly more to the south on the Sun than an observer in

the Southern Hemisphere. By timing Venus' four contact points with the edge of the Sun accurately, astronomers can draw the two paths across the Sun and measure the distance between the upper and lower one.

When the distances between the two observers and between the two paths on the Sun are known, the cross field between the observers' lines of sight will reveal the location of Venus. The location produces an angle which, together with the distance between the two observers, makes it possible to calculate the distance to Venus by means of simple

trigonometry. Parallax calculations are still used today according to the same principles, such as when the Gaia telescope calculates the distances to stars. In this case, remote stars are used as a reference point, and Earth's location at six-month intervals are used as the distance.

Clouds/equipment tease scientists

Venus transits occur in pairs with eight years between them, followed by long periods of 121.5 and 105.5 years. Halley did not manage to test his Venus transit method during his lifetime. So when Cook left, he knew that the transit of



BETTMANN/GETTY IMAGES

American astronomer Clyde Tombaugh discovered the dwarf planet of Pluto in 1930.

BIGGEST MISTAKE

WRONG MASS STARTED PLANET SEARCH

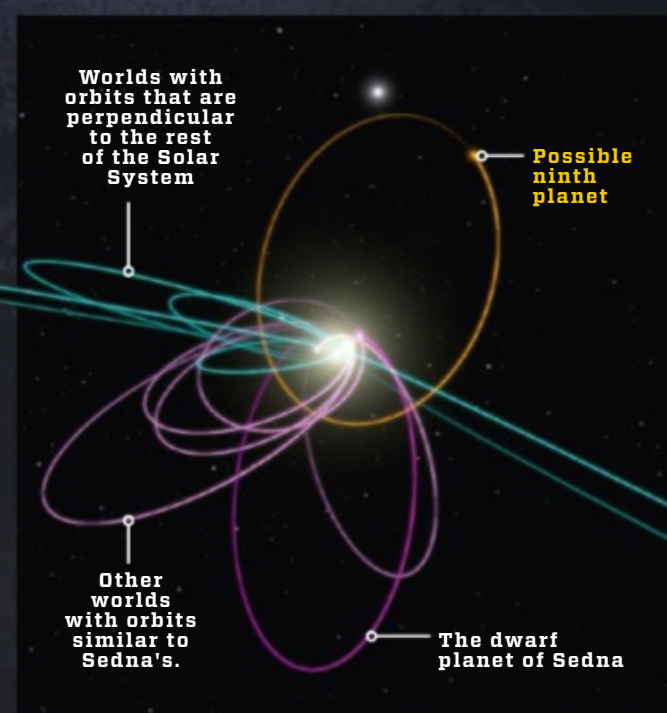
An irregularity of Neptune's orbit triggered an intense search for an undetected Solar System planet in the early 1900s. In 1930, when astronomer Clyde Tombaugh observed an object orbiting deeper in space than Neptune, scientists concluded that it had to be a planet, naming it Pluto. Not until 1992 did astronomers spot more objects in what is now known as the Kuiper Belt, and in 2006 Pluto was degraded to dwarf planet status. After the Voyager probe passed by Neptune in 1989, it turned out that the ice giant's mass had been calculated incorrectly. No unknown planet had influenced Neptune's orbit.

The planet that might influence the worlds in the remote Solar System is an ice giant of 10 times Earth's mass.

BIGGEST MYSTERY

Does the Solar System include one more planet?

Eleven small worlds deeper in space than Neptune have odd orbits. According to some scientists, this could be explained by the existence of a huge, undiscovered planet. The dwarf planet of Sedna has a long, elliptical orbit that meets five other small world's orbits at the point where they come closest to the Sun. Other worlds' orbits are almost perpendicular to the eight known planets' planes. The theoretical ninth planet that might influence the orbits of the small worlds has a huge, elliptical orbit reaching 700 AU, and an orbit time of 10-20,000 years.

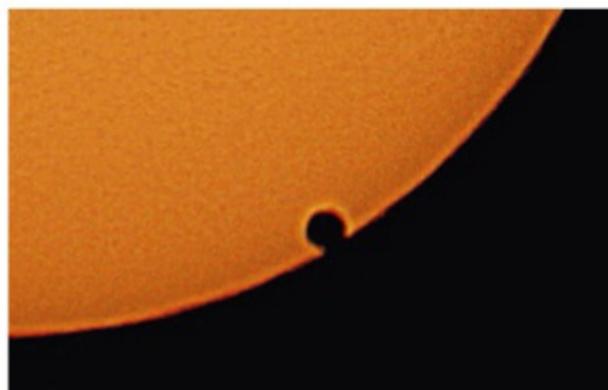


MARK GARLICK/SPL

Worlds on the outskirts of the Solar System have odd orbits that could be explained by an unknown planet.

Venus was the key to calculating all other distances in the Solar System. If Cook could find the distance to Venus, he could – by means of Kepler's third law – also find the distance to the Sun, and hence calculate the distance to all the planets. The Venus transit in 1761 did not produce any results, so astronomers were in a hurry to make important observations before the opportunity passed by until 1874.

Halley's method required observations to be made throughout the world, so on 3 June 1769, astronomers aimed their telescopes at the Sun in 77 different locations, including India, Siberia,



RITZAU SCANPIX

An optical illusion caused Venus to cast a shadow and appear drop-shaped, making it difficult to measure the transit in 1769.

Norway and Madagascar. James Cook had reached Tahiti and enjoyed a completely cloudless sky all day. Others didn't see as much of the approximately six-hour transit. Yet as it turned out, clouds were not the only source of error in these complex measurements.

The observations were hampered by a phenomenon known as the black drop effect, which portrays Venus with a drop shape as the planet lets go of the Sun's outer edge and again as it approaches it again on the opposite side. The effect is believed to be an optical illusion that occurs due to the light's refraction in Earth's

THE SOLAR SYSTEM BY THE NUMBERS

DISTANCE

The distance between the planets grows exponentially. The outermost ones are further from each other than the innermost ones.

Astronomers use the distance between Earth and the Sun as a measuring unit (AU) in the Solar System:
150 million km
= 1 AU

MERCURY: 0.387 AU
VENUS: 0.722 AU
EARTH: 1 AU
MARS: 1.52 AU

JUPITER: 5.20 AU

SATURN: 9.58 AU

Saturn is about twice as far from the Sun as is Jupiter.

URANUS: 19.2 AU

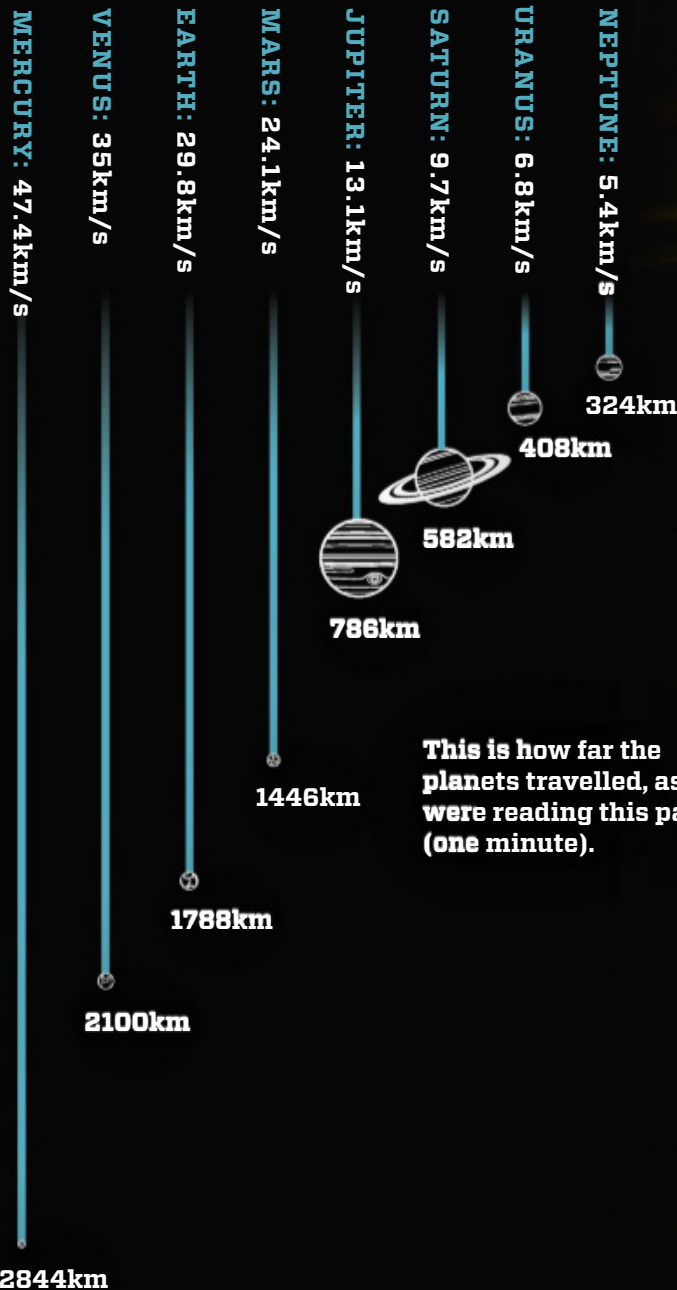
Uranus is about twice as far from the Sun as is Saturn.

From Neptune and beyond, the equation is not true.

NEPTUNE: 30.1 AU

SPEED

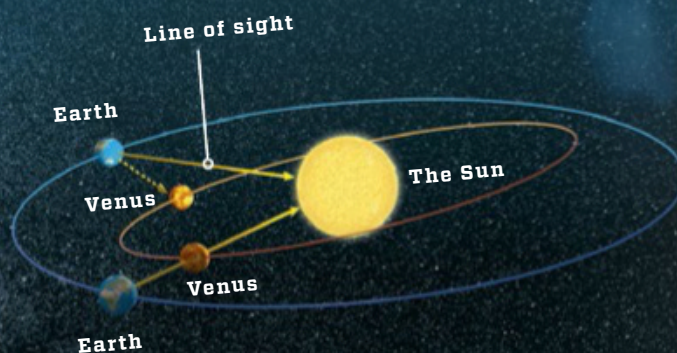
The closer a planet is to the Sun, the more it is influenced by the star's gravity, and the faster it travels in its orbit.



This is how far the planets travelled, as you were reading this page (one minute).

Why Venus transits are so rare

Venus overtakes Earth on the inside every 584 days, but its orbit tilts compared with that of Earth. So approximately every 120 years, Venus overtakes Earth while it is in direct line of sight between Earth and the Sun.



Earth is the fifth heaviest of the Solar System planets.



MASS

Mass is unevenly distributed in the Solar System. The Sun accounts for the vast majority, and Jupiter makes up much of the rest.

Earth weighs

5,974,000,000,000,000,000,000,000kg

- or 5.9 trillion trillion kg.

The Sun is

332,831

times as heavy as Earth, making up 99.86% of the total mass of the Solar System.

The R136a1 star in our neighbouring galaxy of the Large Magellanic Cloud is

315

times heavier than the Sun.

If you weigh 68kg on Earth, you would weigh ...

... 1598kg on the Sun - corresponding to a small orca

... 159kg on Jupiter - corresponding to a large female tiger

... 11kg on the Moon - corresponding to a medium, adult koala



Jupiter weighs some 2.5 times more than the seven other planets combined. But although the giant is more than 1300 times larger than Earth, it weighs only about 300 times more, because it consists mainly of low-density gas.

JUPITER

317.8
times
Earth's
mass

SATURN

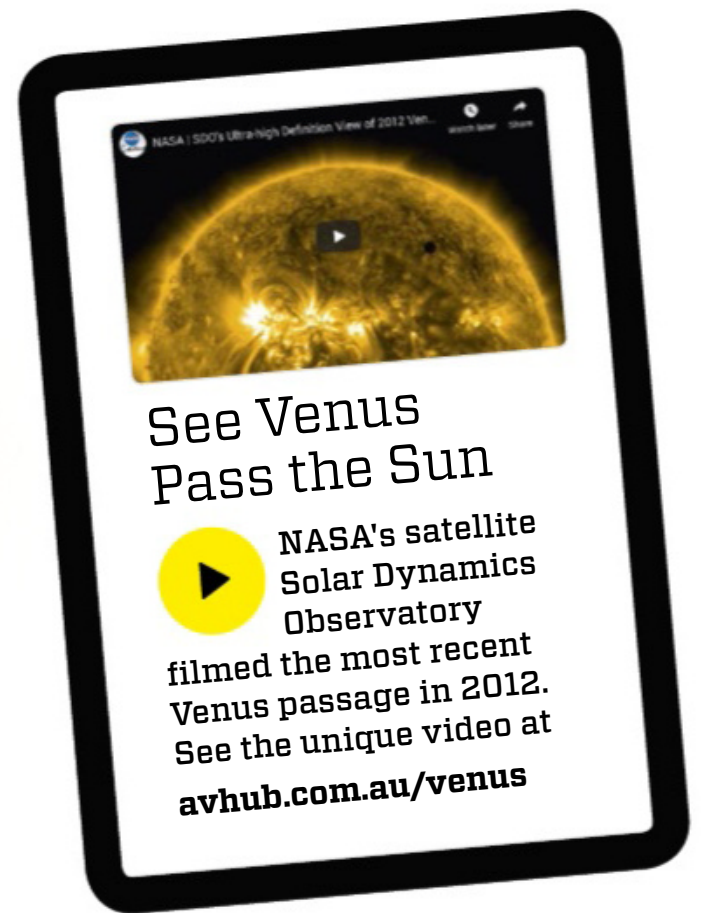
95.2
times
Earth's
mass

URANUS

14.5
times
Earth's
mass

NEPTUNE

17.1
times
Earth's
mass



► atmosphere and minor imperfections in telescope lenses. A similar effect can be caused by holding up two fingers against a light source. Right before the fingers touch each other, you will see a dark shadow between them. Venus' thick atmosphere also produces a gritty halo around the planet that makes its outline vague.

The atmosphere and the black drop effect makes it difficult to time the transit's critical initial and final stages entirely accurately, and things got even more complicated due to technical difficulties of the time. The stop-watch had not yet been invented, and portable clocks were very new. Astronomers had hoped to time the Venus transit with a deviation of less than two seconds, but Cook and his astronomer Charles Green measured the transit with a difference of 42 seconds - in spite of them observing it in almost exactly the same place.

Radar provides the correct answer

Even minor time differences can make a major difference in cosmic distance measurements, and when astronomers got the chance to compare the timing results in the years after the Venus transit, they varied by millions of miles.

British astronomer and mathematician Thomas Hornsby came closest to the real value of the astronomical unit with 150,838,824km thanks to Cook's observations, but he was still more than a million kilometres from the true value. As the expeditions of other nations delivered their results, the total scientific consensus was 153 million kilometres, plus or minus one million. The value was less accurate than scientists had hoped for, but far more accurate than previous estimates.

The measurements determined the distance to the Sun more accurately than astronomers are now able to measure the distance to the centre of the Milky Way. In the Venus transits of the ►

SPEED

NEW METHOD OF MEASUREMENT

Other stars' speeds reveal the Sun's speed

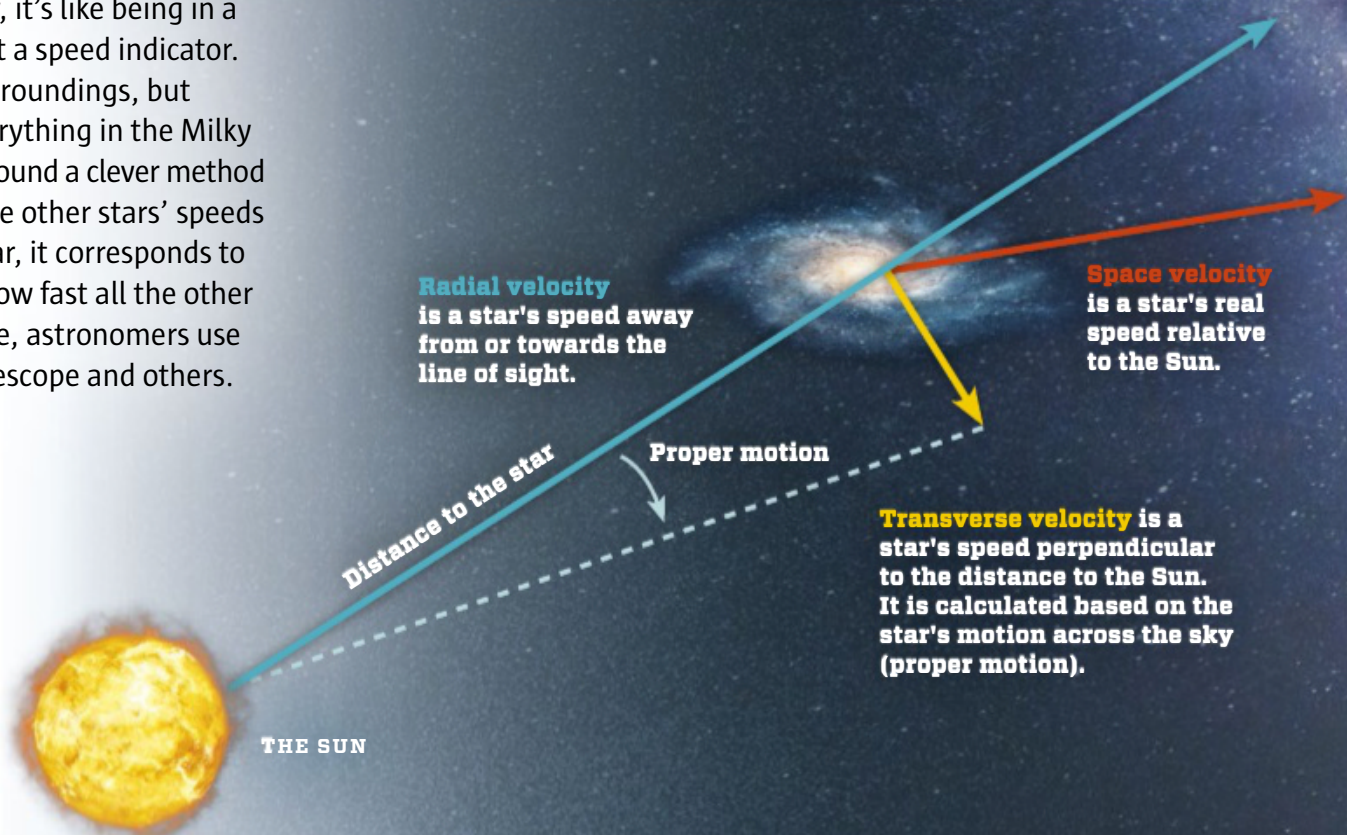
Scientists measure how fast the Solar System is travelling around the centre of the galaxy.

When astronomers are to measure the speed at which the Solar System is orbiting the centre of the Milky Way, it's like being in a car and trying to measure one's speed without a speed indicator. The car's speed is measured relative to the surroundings, but astronomers have no fixed point, because everything in the Milky Way is in motion. However, astronomers have found a clever method for deducing the speed of the Sun based on the other stars' speeds relative to the Sun. In the example with the car, it corresponds to determining one's own speed by measuring how fast all the other cars travel relative to yourself. For this purpose, astronomers use data for some 216,201 stars from the Gaia Telescope and others.

ESA & SHUTTERSTOCK

Three measurements reveal speed of stars

1 A star's average speed through space is calculated based on three factors: its distance to the Sun, and two types of speed: transverse velocity and radial velocity. Calculations of the three factors reveal a star's speed relative to the Sun, aka space velocity.



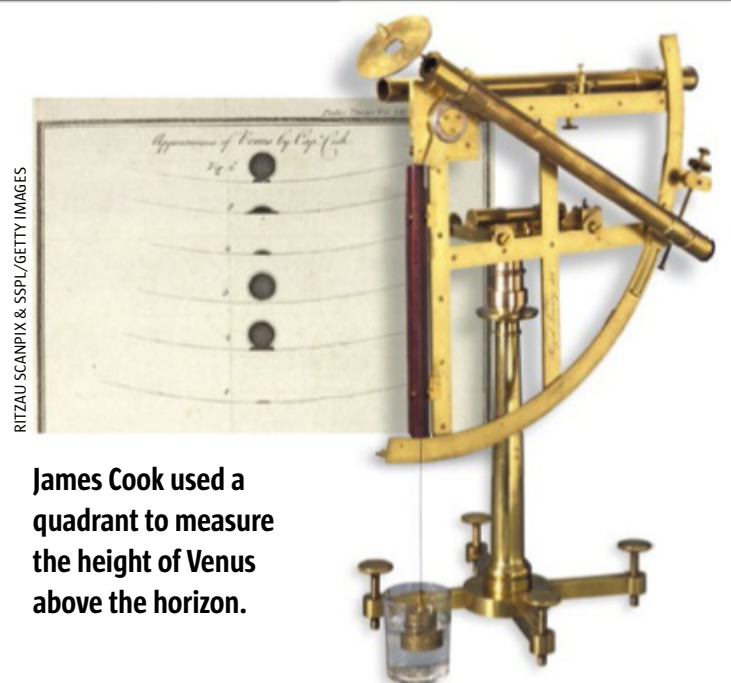
Stars with specific speed fail to appear

2 The stars travel at speeds that are either slower or faster than the Sun's, but almost no stars travel at one particular speed: 240km/s more slowly than the Sun. Scientists interpret this as stars that have not moved. The empty "spot" of the data causes a point zero in relation to the Sun, revealing the Sun's speed to be 240km/s.

► 1800s, the calculation ends up within 1% of the real value, and it was not until 1961 that NASA was able to use radar beams reflected by Venus' surface to measure the astronomical unit so accurately that the value can be used for navigation purposes. The signal returns to Earth after about 6.5 minutes, and as radar waves travel at the speed of light, the distance is 149,597,870,691m.

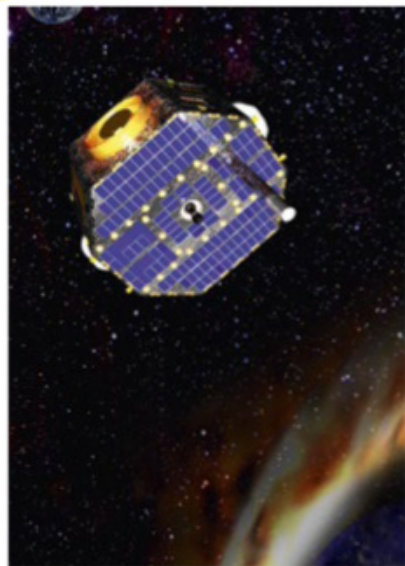
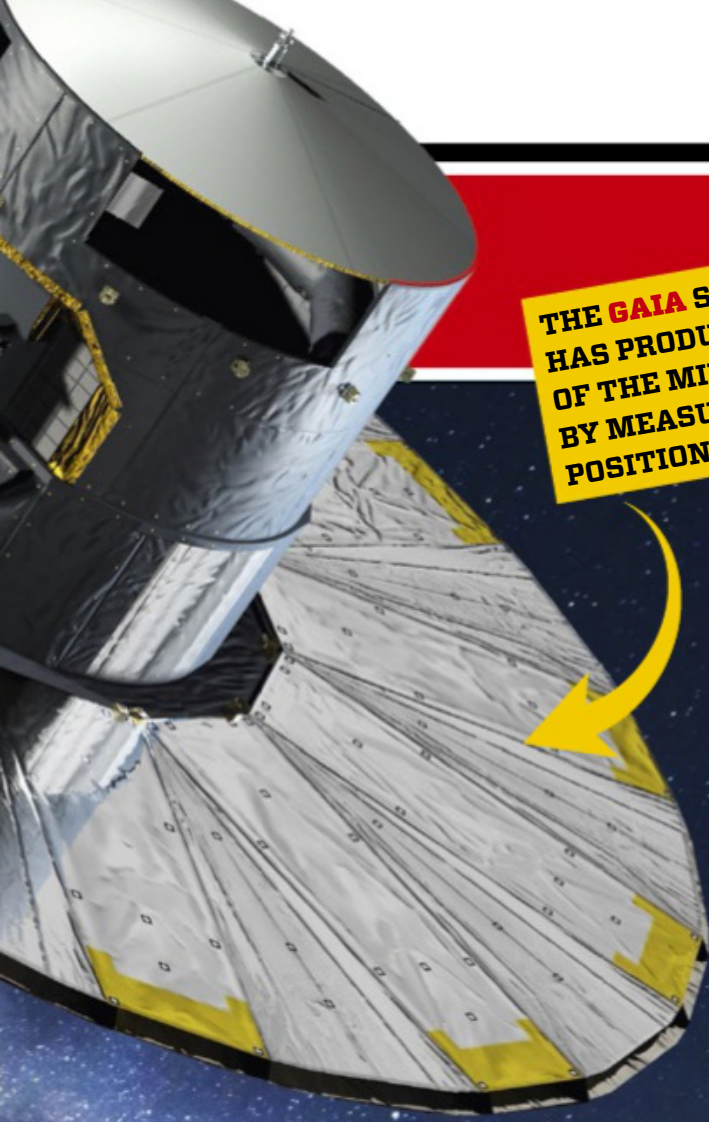
If scientists had continued to use the earlier estimates, Mariner 2 – the first probe to fly by another planet – would probably have missed Venus by 160,000+ kilometres.

The accurate AU value gave astronomers a valuable tool for a deeper understanding of the Solar System. Heavenly bodies' real sizes could be determined, and since then astronomers have also been able to estimate the masses of planets based on their influence on moons or passing probes, and to use Newton's laws of gravity to determine to what extent the attractive force speeds up other heavenly bodies. The measurements are used to improve the accuracy of tables of planetary positions – ephemerides – which are used to plan space missions. The ephemerides also form the basis



James Cook used a quadrant to measure the height of Venus above the horizon.

THE **GAIA** SPACE TELESCOPE HAS PRODUCED A 3D MAP OF THE MILKY WAY BY MEASURING STAR POSITIONS AND MOTION.



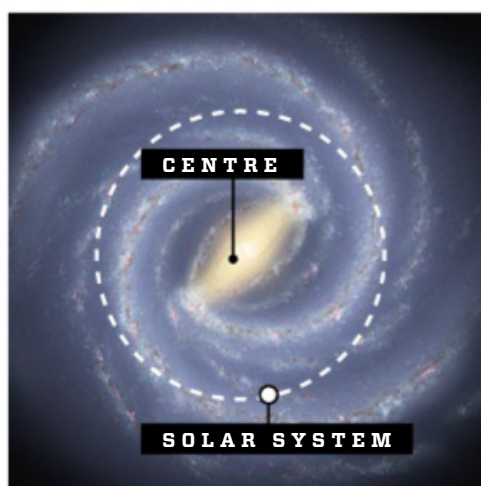
GSFC/NASA

The IBEX probe revealed that the Solar System is too slow to produce a pressure wave.

BIGGEST MISTAKE

MAJOR PRESSURE WAVE BECAME A SMALL RIPPLE

For decades, astronomers were searching for a pressure wave on the outskirts of the Solar System triggered by the solar wind's encounter with cosmic radiation from interstellar space. Such pressure waves have been observed around other star systems and are reminiscent of the wave in front of a fighter plane flying at supersonic speeds. In 2012, however, NASA's IBEX probe discovered that the speed of the Solar System is 11,000km/h slower than believed relative to interstellar space – and so the pressure wave will be no more than a ripple. Knowledge about the solar wind's encounter with space is important in order to understand how the Sun protects us against cosmic radiation.



NASA

The Sun's speed reveals the distance to the centre

3 Based on the speed of 240km/s, the scientists determine the distance between two points of the Sun's orbit, and that provides a basis for measuring the distance to the black hole at the centre of the Milky Way. Astronomers estimate that we are 25,766.5 light years from the centre of rotation.

BIGGEST MYSTERY

Why does Venus rotate irregularly?

The planet of Venus behaves oddly. Its rotation is extremely slow: one rotation takes some 243 Earth days. Yet the atmosphere of Venus rotates 60 times faster than the planet itself. In addition, the planet's rotation is not constant – the duration of one day on Venus varies by seven minutes, and Japanese scientists have discovered a phenomenon that may provide part of the answer.

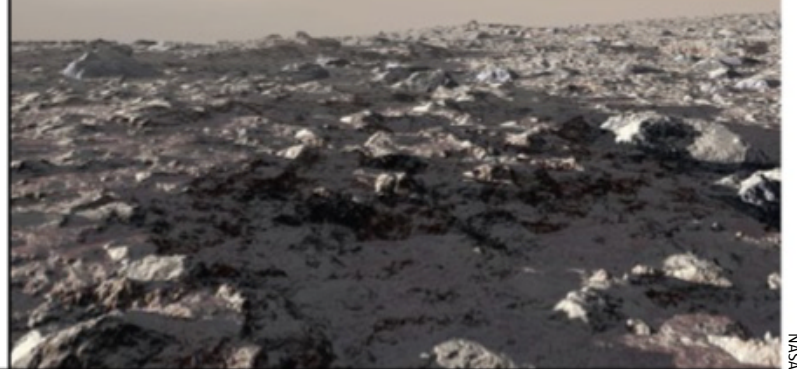
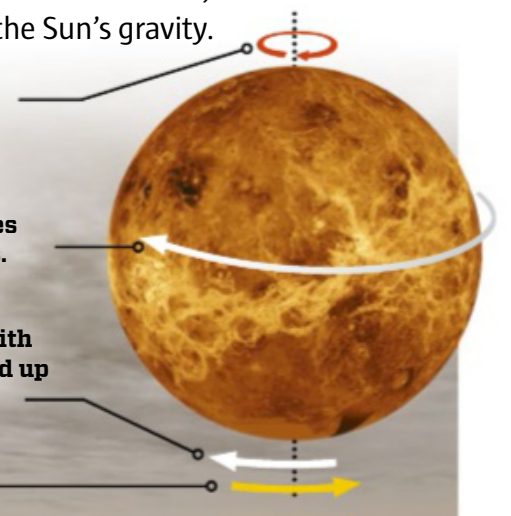
A galloping greenhouse effect has thickened the air and increased the friction between the atmosphere and the surface. Simulations show that the encounter between winds of speeds up to 400km/h and the planet's mountain ranges produces a pressure wave that propagates into the cloud cover. This increases the speed of the planet's rotation by up to two minutes in one Venus day. On the other hand, the rotation might be slowed by the Sun's gravity.

Venus rotates once in 243 Earth days.

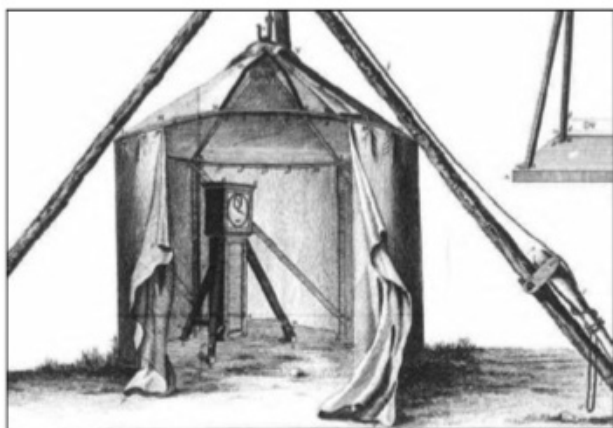
The atmosphere rotates the planet in four days.

High winds' friction with mountain ranges speed up the planet's rotation.

The Sun's gravity slows the rotation.



NASA



Cook's portable Observatory, in a tent made of wood and canvas with rotatable openings in the roof.

of the scientific field of celestial mechanics, which explains why the Solar System looks the way it does, and how we believe it is going to develop in the future.

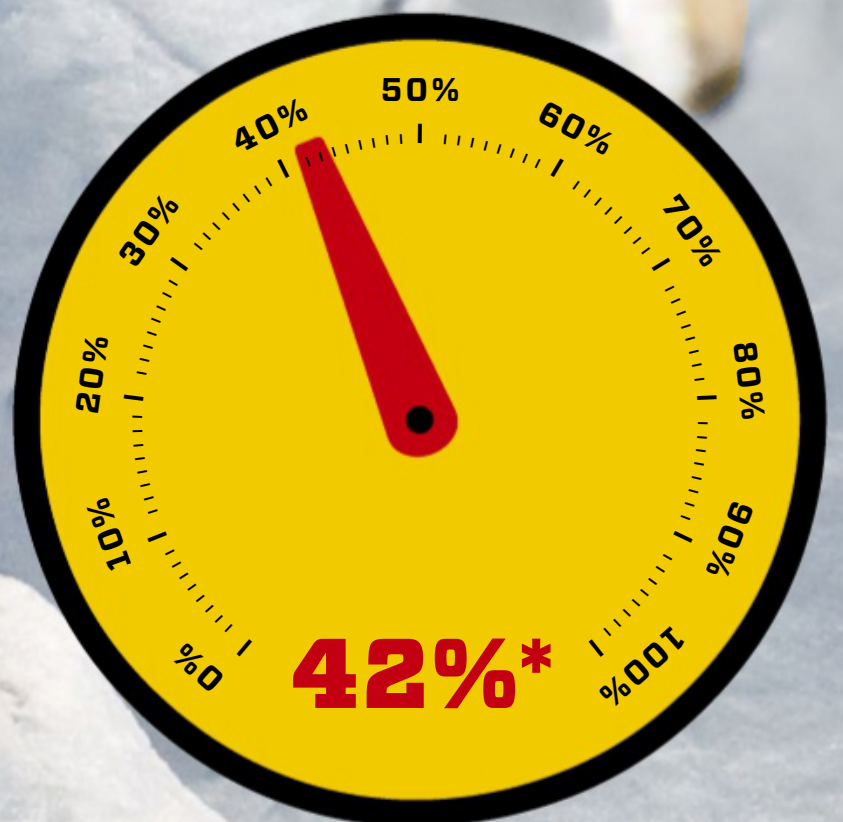
Today, astronomers measure the distances to remote galaxies in units that are much larger than AU, such as parsecs. But when a telescope is aimed at other solar systems, astronomers still use AU to describe how other worlds orbit in comparison to ours. So, the unit that allowed all distance measurements in the Solar System is used to assess the best 'Earth 2.0' theories.

The Venus transit of 1769 was the first time

that astronomers from all over the world participated in a scientific mission with a common objective. During James Cook's mission to Tahiti, the French government ordered the navy to allow the British expedition vessel complete freedom of movement, because its mission was "in the best interest of mankind". When NASA or other space agencies one day travel to Mars and elsewhere, it will likely again be an international mission, requiring the same courage and boldness as did sending ships in 1769 to the other side of Earth to watch Venus pass across the Sun. **SCI**

ANIMALS SURVIVING LOW-OXYGEN LIFESTYLES

➤ A spider in the thin air of the Himalaya. Geese with hidden genetic codes. Fish that function as alcohol factories. Thanks to their special anatomies, some animal species thrive even when oxygen levels become dangerously low...



*Percentage of the air's normal oxygen content at sea level (100%) which the animal requires.

No creature other than the Himalayan jumping spider exists at an altitude of 6500m.

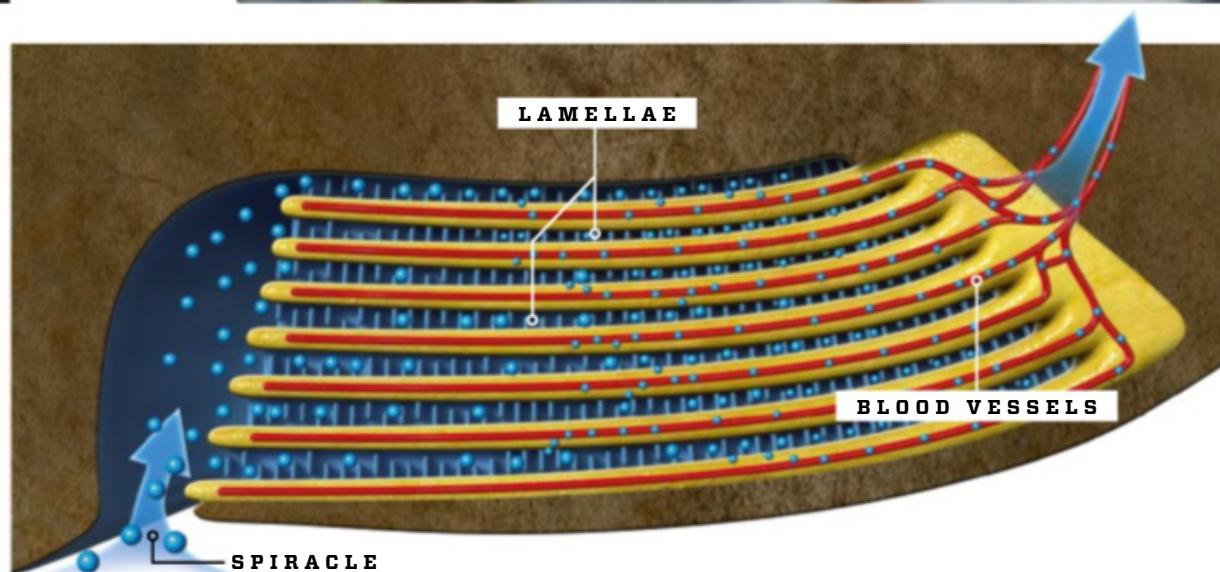
GAVIN MAXWELL/NATUREPL



Jumping spider is the world's highest-altitude animal

The *Euophrys omnisuperstes* jumping spider has used its special lungs to conquer the thin air of the Himalaya. The spider's lungs are made of layers designed like the pages of a book – hence the name 'book lungs'. The layers increase the lungs' surface area, so the surrounding blood vessels can efficiently absorb the scarce oxygen at an altitude of 6500m.

The spider feeds there on frozen insects that are carried to this altitude by the wind. The creature can jump more than 50 body lengths by diverting blood into its legs so the blood pressure rises, shooting the spider towards its frozen food.



The breathing hole is on the lower side

1 The spider breathes via a breathing hole known as a spiracle on the lower side of its body.

Cavities resemble book pages

2 In the lung, air is distributed into a series of small cavities, lamellae, that are layered like the pages of a book.

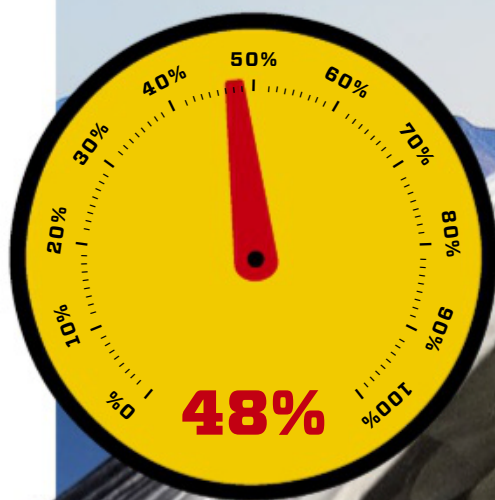
Fine blood vessels absorb the oxygen

3 Between the cavities, fine blood vessels transfer the scarce oxygen of the thin air to the blood.

CLAUS LUNAU

Minimum waste

Like all other birds, bar-headed geese breathe by means of air sacs. Together with genetic haemoglobin mutations, the air sacs ensure optimum use of the scarce oxygen molecules.



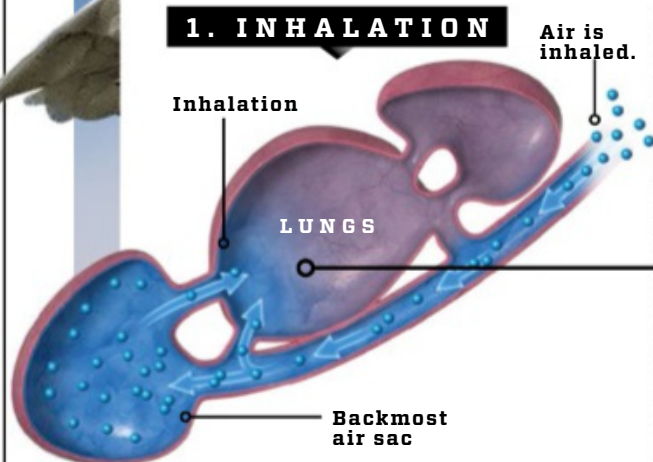
ENLARGED LUNGS

Air sacs improve lung function.

ENLARGED HEART

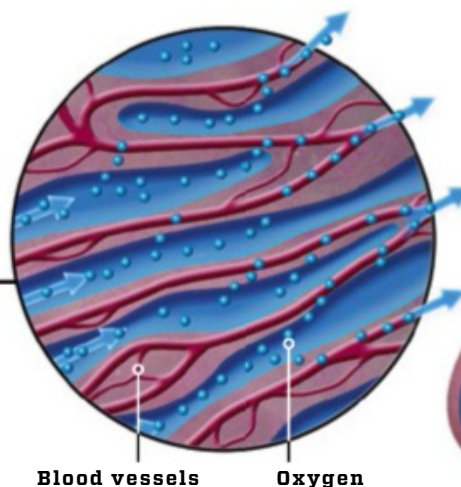
INHALATION AND EXHALATION OXIDISE THE BLOOD

1. INHALATION



Backmost air sac is filled

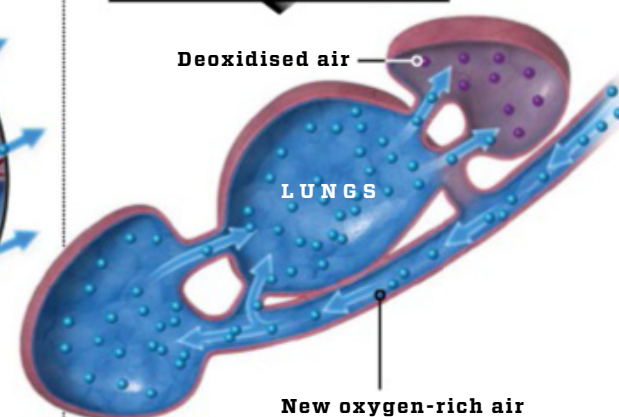
1 In the first inhalation, the bar-headed goose inhales air into the backmost air sac and lung. The lung wall is four times thinner than in mammals and can absorb oxygen more easily.



Haemoglobin binds oxygen

2 The oxygen passes across the lung membrane, binding to haemoglobin. Four genetic mutations in the haemoglobin ensure that the oxygen binding is highly efficient.

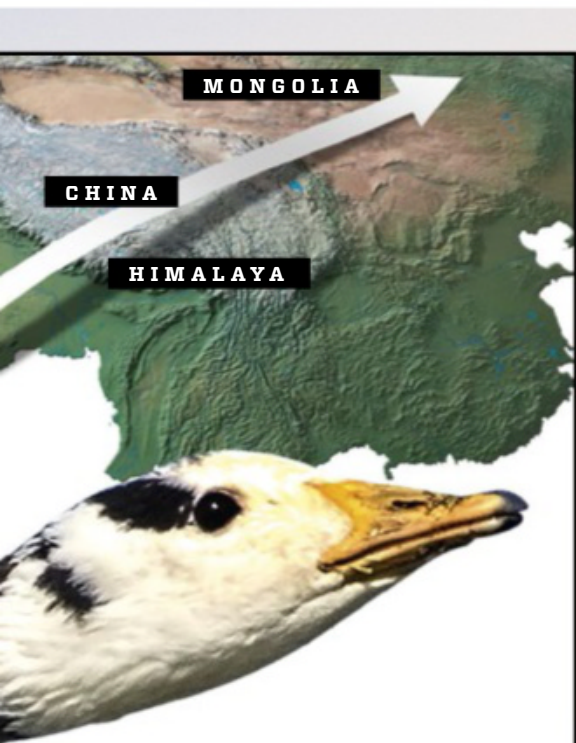
2. INHALATION



Deoxidised air parked

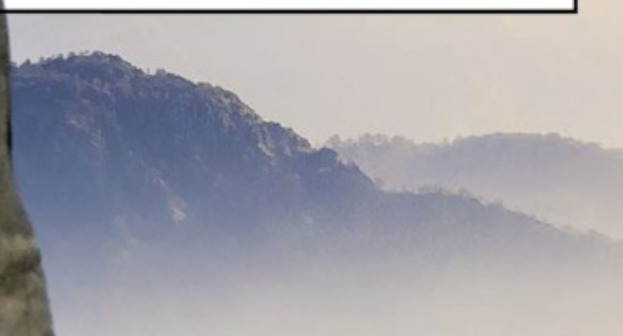
3 In the next inhalation, the deoxidised air is sent from the lungs to the front-end air sac. At the same time, new oxygen-rich air is inhaled into the backmost air sac.





GEESE FOLLOW COLD AIR ACROSS THE HIMALAYA

The bar-headed goose flies from Southern India to Mongolia – across the Himalaya – at altitudes above 6000m. The goose flies with cold winds, if possible, as they contain more oxygen than warm winds.



Air is exhaled

4 Exhalation involves the deoxidised air being blown out, whereas previously inhaled oxygen-rich air is pushed from the backmost air sac into the lungs.

CLAUS LUNAU & SHUTTERSTOCK

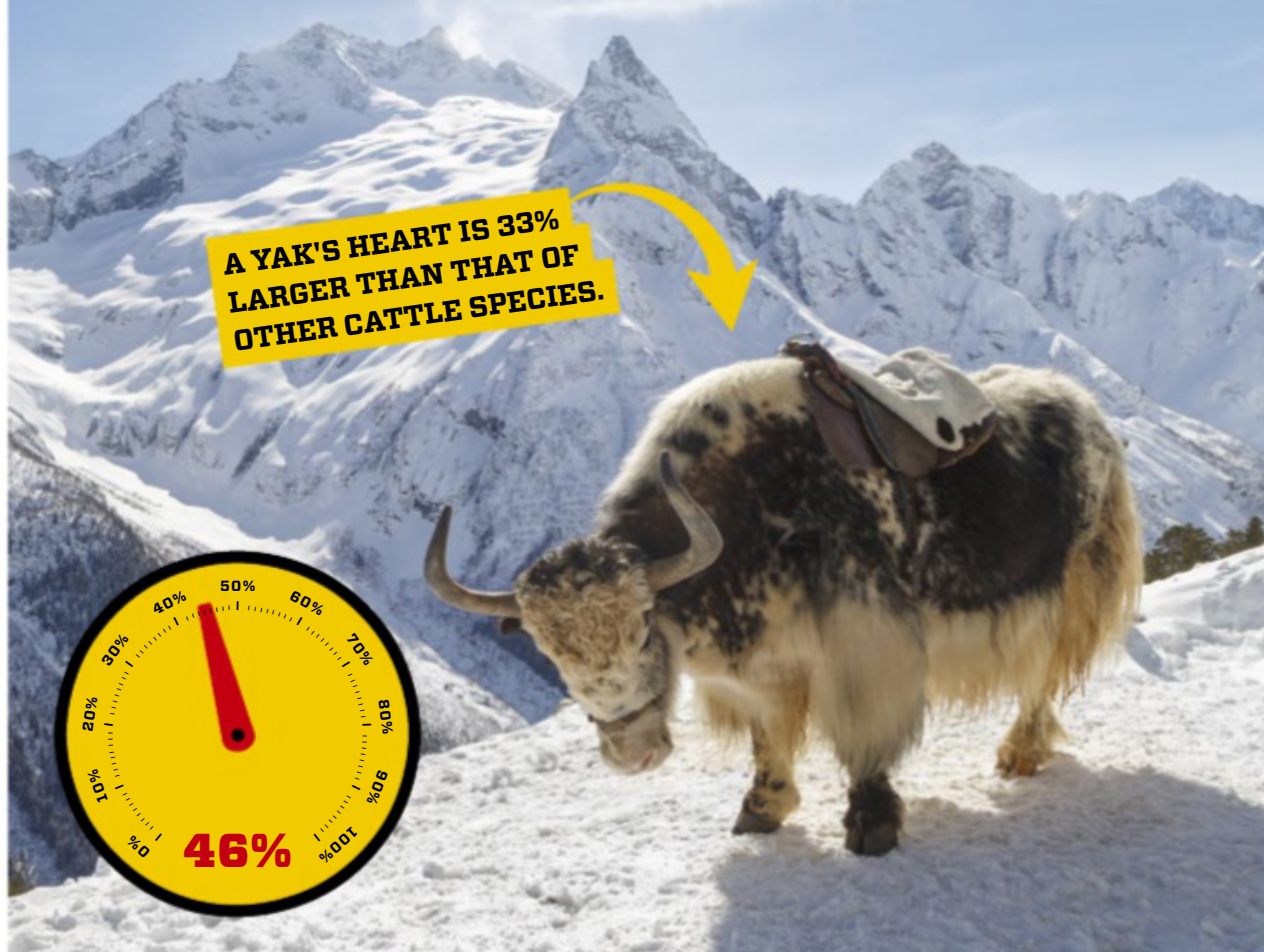
The big-hearted yak

Yaks can live at altitudes of up to 6100m. Both physiologically and anatomically, the yak differs from the ordinary cattle from which it originated 4.9 million years ago.

Whereas the low oxygen level of high altitudes causes lethally high blood pressure in ordinary cattle, genetic mutations help the yak regulate its blood. Oxygen-poor environments normally boost the production of red blood cells and so raise the blood

pressure, but scientists have found three mutated yak genes that counteract the process, keeping blood pressure stable. In addition, the yak's haemoglobin binds oxygen more efficiently, while mutations in five other genes optimise the utilisation of nutrients, so the yak can survive on limited food.

The yak has also developed several anatomical advantages. It has two sets of extra ribs, increasing its lung capacity considerably compared with other cattle, and its heart is larger, weighing up to 1.5kg.



SHUTTERSTOCK

ALL CANADA/IMAGESELECT



Mouse molecule is hypermutated

The deer mouse lives in the Rocky Mountains of NW America. Around 10cm long, the rodent can survive at altitudes of some 4000m thanks to mutations in the genes that code for haemoglobin. In haemoglobin, four iron molecules are located in special heme pockets in which the oxygen molecules get stuck. Deer mice have no fewer than 12 different mutations in their heme pockets, making oxygen stick more efficiently and improving the efficiency of the haemoglobin.

Alcohol helps fish through the winter

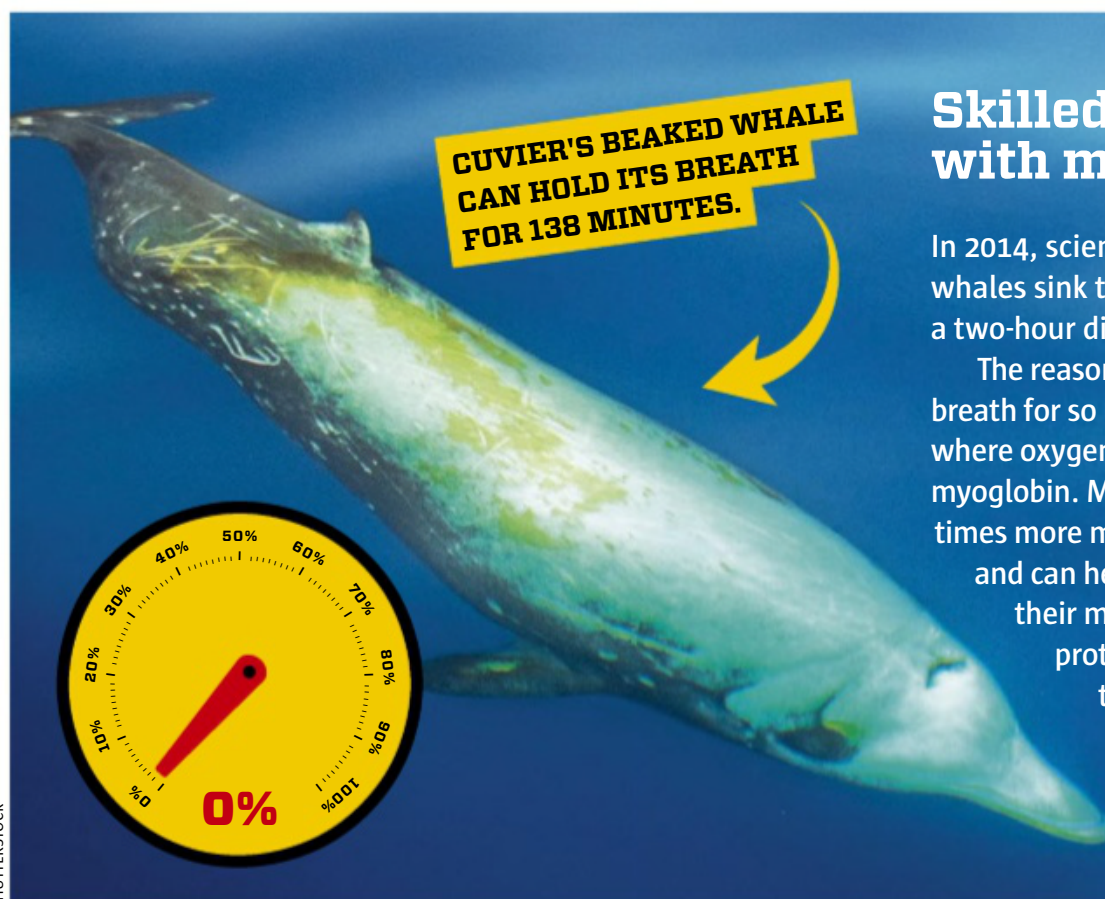
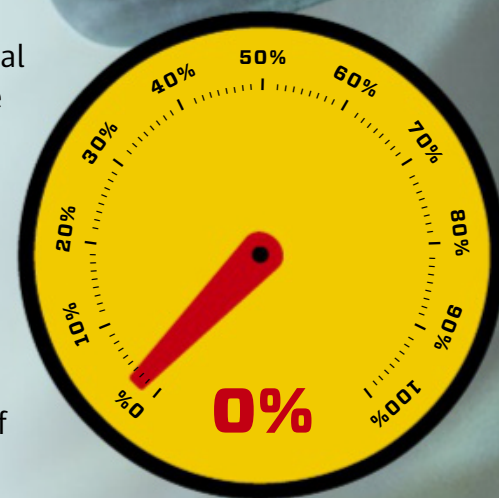
Five months stuck on the floor of a frozen lake is no problem for the crucian carp. Thanks to a special enzyme, the fish can exist without oxygen.

The crucian carp has developed one of the most extreme ways of surviving, enabling it to spend up to five winter months in frozen oxygen-free lakes. The freshwater fish is equipped with a special type of enzyme in its mitochondria, which helps it live without oxygen. In the cells, glucose (sugar) is broken down (via a process known as glycolysis) into pyruvate, which is one of the mitochondrion's primary fuels.

Normally, the cells have access to oxygen, and via the PDHc enzyme, pyruvate is broken down into substances that drive the normal energy cycle, producing energy for the body. Without oxygen, the cells will instead convert pyruvate into lactic acid – the effect we know from intensive running. But if the

lactic acid accumulates over long periods of time, it can be hazardous for cells, and lethal if the accumulation takes place over several hours.

The crucian carp can survive for months without oxygen because its enzyme has mutated. Instead of producing lactic acid, the enzyme breaks down pyruvate into ethanal, which is an initial stage of ethanol (alcohol). The enzyme is very similar to those that exist in beer yeast and produce alcohol in the beer. In the case of the crucian carp, the alcohol is transferred to the gills and liberated into the water. With sufficient glucose in liver and muscles, the fish can make it through an oxygen-free winter without dying of lactic acid poisoning.



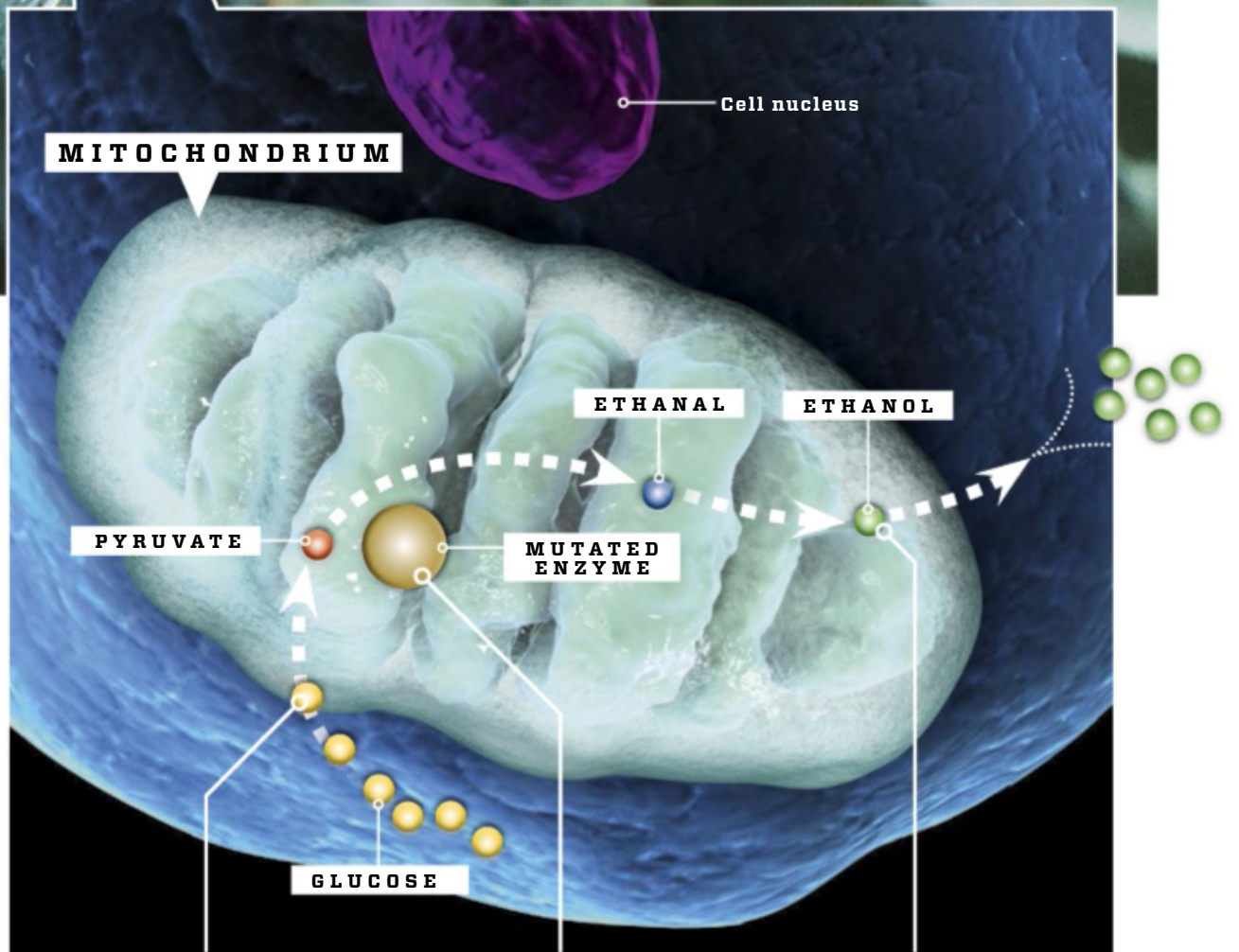
Skilled diver charged with myoglobin

In 2014, scientists observed Cuvier's beaked whales sink to a depth of 2992.2 metres during a two-hour dive.

The reason the beaked whales can hold their breath for so long is found in their muscles, where oxygen binds to proteins known as myoglobin. Marine mammals have some 10 times more myoglobin than terrestrial mammals and can hence store much more oxygen in their muscles. High concentrations of proteins are normally hazardous, as they can huddle together, but the whale's myoglobin molecules are positively charged and hence repel each other.



Glucose stores and a special enzyme ensure that the crucian carp can live without oxygen.



Sugar is converted into pyruvate

1 Under oxygen-free conditions, the crucian carp converts glucose into pyruvate in a process known as glycolysis, which takes place in cell fluid.

Enzyme prevents poisoning

2 Normally, pyruvate will produce lactic acid, which is lethal in high concentrations, but a mutated enzyme prevents lactic acid poisoning in the fish.

Fish exhales alcohol

3 The enzyme converts pyruvate into ethanal and then ethanol (alcohol), which is liberated to the gills. The process can go on until all glucose has been consumed.

CYRIL RUOSO/NATUREPL



Wood frogs are full of antifreeze

The *Rana sylvatica* wood frog can endure -16 degrees Celsius, halting both breath and cardiac rhythm when it hibernates. The frog's cells are full of antifreeze proteins that settle as a mantle around the ice crystals, while sugar molecules in the cells ensure that the body's freezing point is lowered – just as we use salt on roads in the winter.

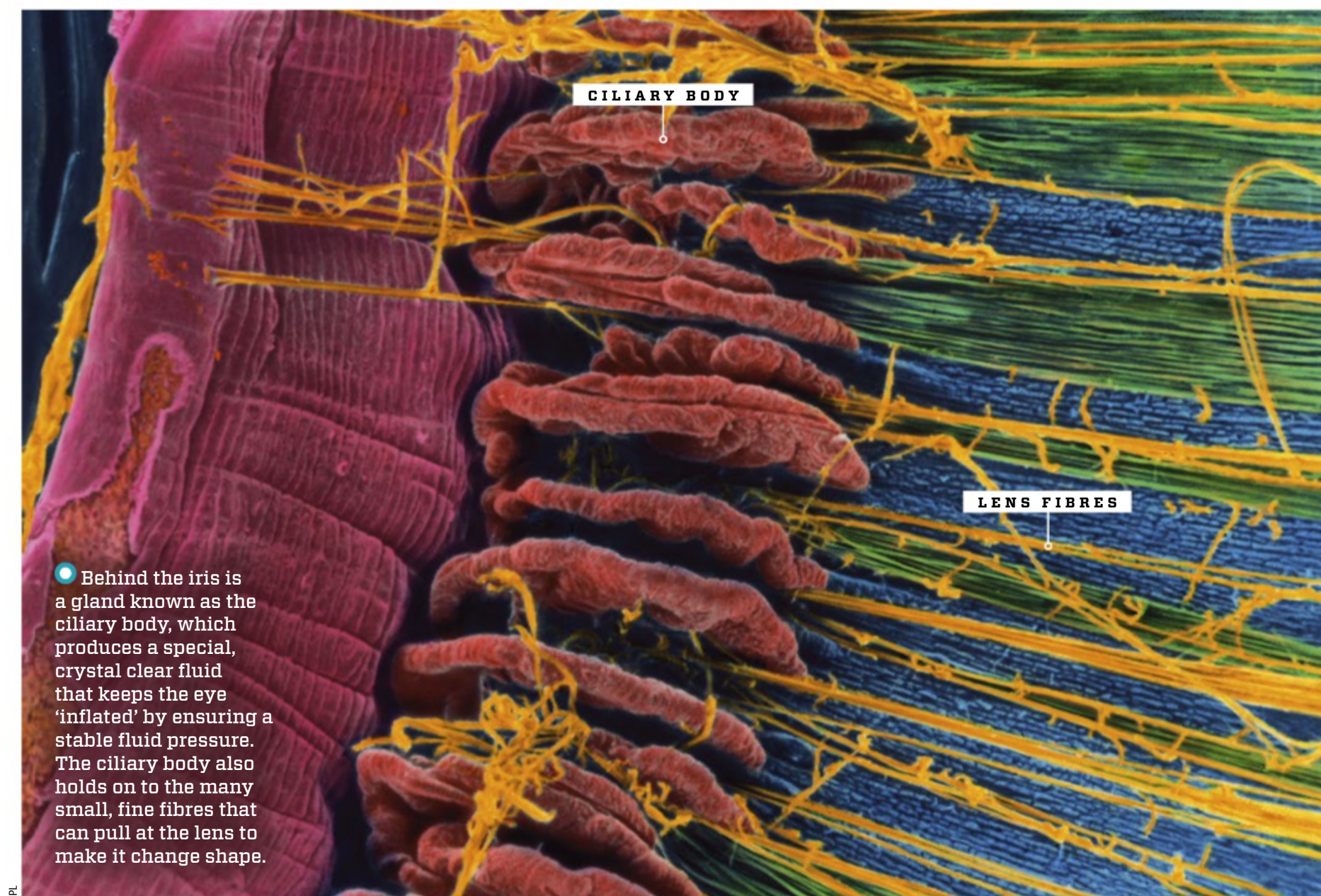
● The iris stretches like a rolling landscape around the black pupil. It regulates the quantity of light that reaches the interior of the eye, and it consists of two different muscle layers to expand and reduce the size of the pupil.



Scientists focus on the eye's interior

With 130 million light-sensitive cells, high-protein fluids, and electrical signals, your eye is one of your body's most complex and hard-working organs.

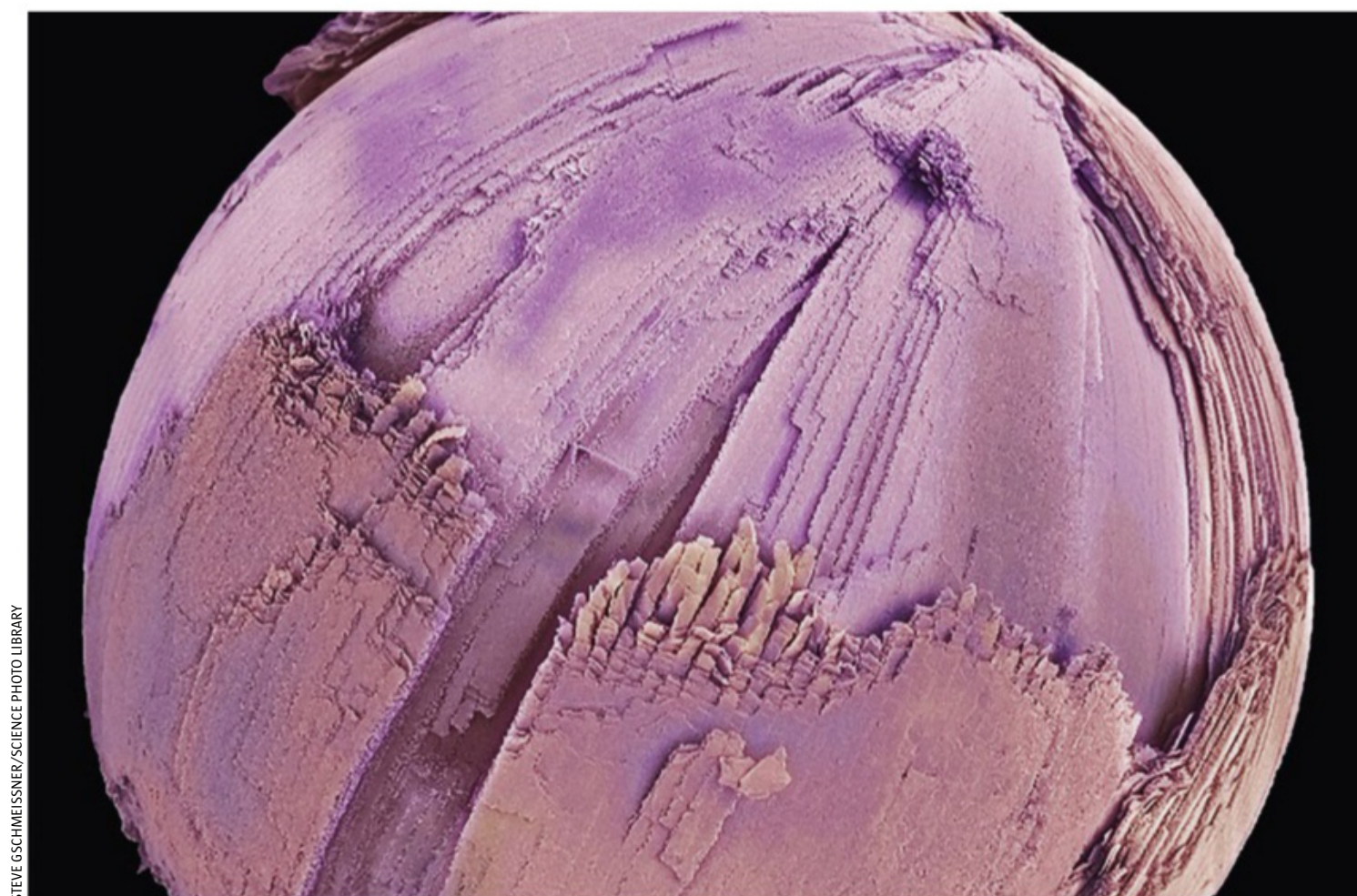
| **IRIS** | Muscles allow light to enter.



● Behind the iris is a gland known as the ciliary body, which produces a special, crystal clear fluid that keeps the eye 'inflated' by ensuring a stable fluid pressure. The ciliary body also holds on to the many small, fine fibres that can pull at the lens to make it change shape.

SPL

| **CILIARY BODY** | Fluid 'inflates' the eye.



STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY

● Behind the iris is the lens. The 4mm-wide, flexible disc directs the light passing through the pupil onto the retina, so you can see clearly. The lens consists of one type of cell - lens fibres - which exist in lots of development stages and are organised in several layers.

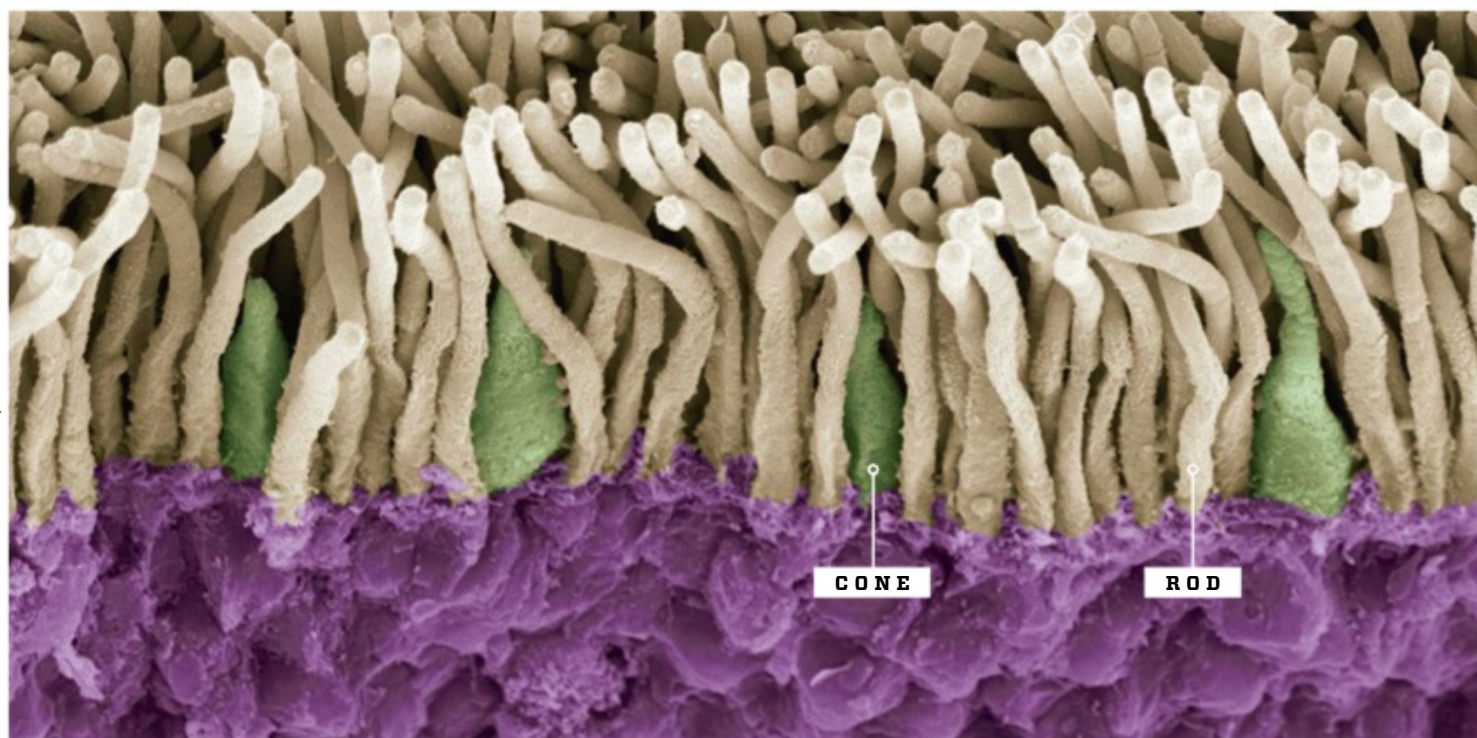
| **LENS** | This image of the lens reveals oblong fibres.

Under the upper eyelid, you will find the eye's largest tear gland, the job of which is to produce lachrymal fluid. The gland is divided into large clusters of gland cells that produce a mixture of water, proteins and salts. The fluid that protects the cornea surface exits via the corner of the eye when you cry.



SUSUMU NISHINAGA/SPL

TEAR GLAND | A gland produces a potent cocktail of proteins, salts, and water.

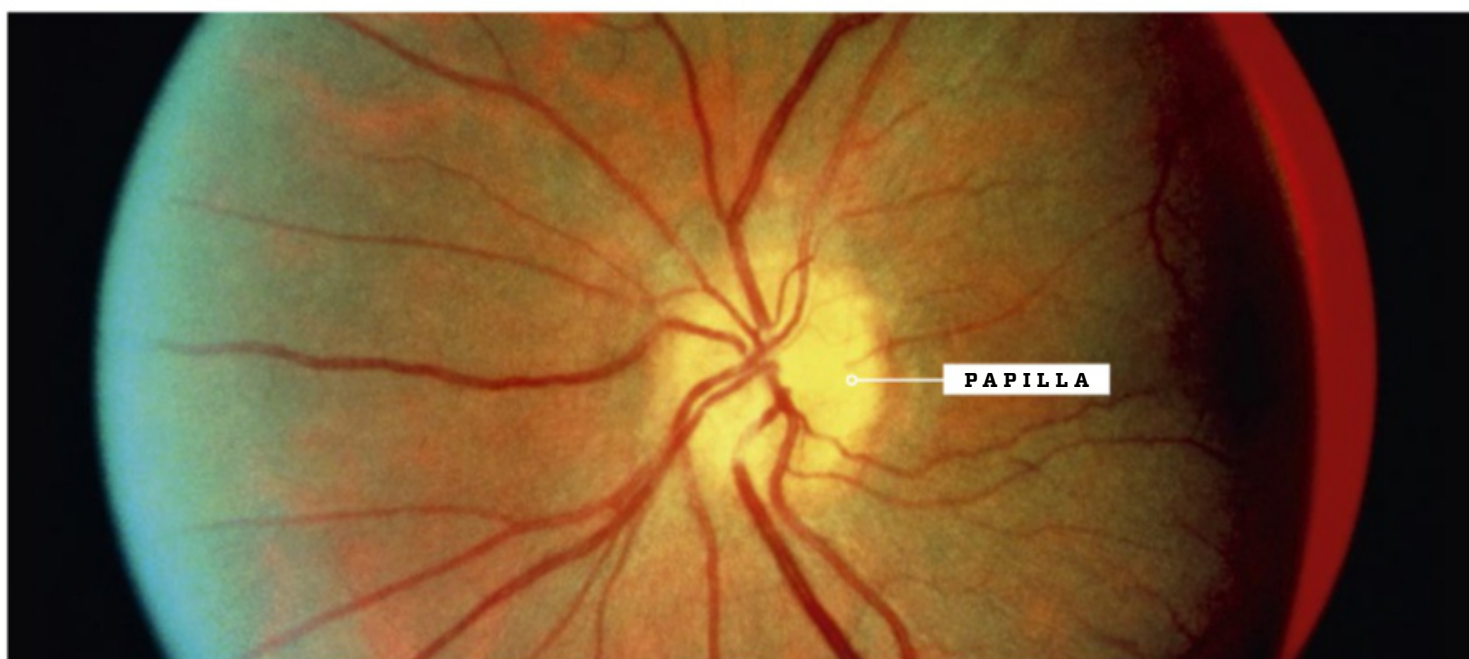


DR. NICOLÁS CUENCA & ISABEL ORTUÑO-LIZARÁN/NIKON SMALL WORLD 2018

On the back wall of the eye is the retina, which includes more than 130 million nerve cells or photoreceptors that process the light impressions entering from the pupil. The photoreceptors primarily come in two types: “rods”, which are light-sensitive and used in night vision, and “cones”, used under excellent light conditions, producing our colour vision.

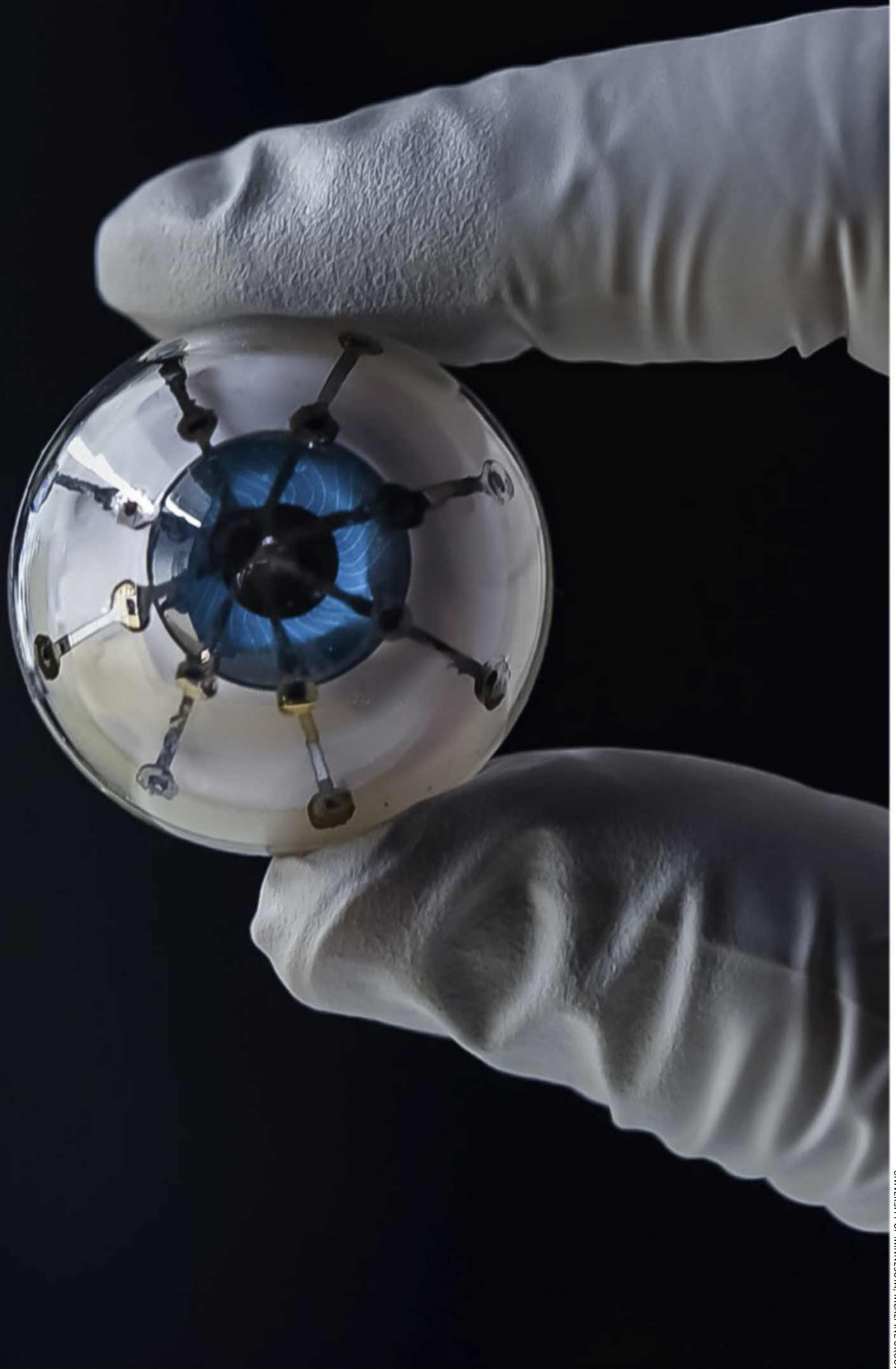
RETINA | Millions of nerve cells produce colour vision.

In the retina, you will find the optic nerve, which uses electrical signals to transfer visual impressions from the retina to the brain. The beginning of the optic nerve can be observed as a clearly demarcated area known as the papilla, including a central part where the eye blood vessels meet.



SPL

OPTIC NERVE | Electrical signals send images to the brain.



● The millions of individual components of the eye and its immense complexity make it difficult to copy, but scientists recently managed to 3D print a series of image-viewing sensors on a hemisphere-shaped glass surface - they have created a bionic eye. The next major step is to find a method to print the light receptors on a soft surface.

UNIVERSITY OF MINNESOTA, MCALPINE GROUP

| **ARTIFICIAL EYE** | 3D printer produces light receptors on a glass surface.

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**FROM THE
SCIENTIFIC
ARCHIVES**

PRESENT STATUS

SUPER TRAIN TO TRAVEL 1200KM/H

From Helsinki to Stockholm in 28 minutes: that's the mission of the Hyperloop, which aims to compete with air travel by promising speeds up to 1200km/h. The principle behind the amazing transport system is to eliminate friction and air drag by means of powerful magnets and tunnels void of air. The first stretches are hoped to be completed in 2021.



The idea behind Hyperloop was introduced by Tesla CEO Elon Musk in 2012.

The world's fastest
steam locomotive

SPEED KING: Gresley's Mallard

➤ In the 1930s, an English engineer decided to build the world's fastest steam locomotive. A new speed record would improve the nation's self-confidence in the struggle against poverty and the aggressive Germans.

COULD HAVE BEEN EVEN FASTER

The world speed record was set on a track between Grantham and Peterborough. Track works at Grantham and a curve at Essendine meant Mallard only had about 24km to reach its top speed. On a longer stretch without obstacles, the train would have travelled even faster, according to experts.



Fireman Tommy Bray (left) and driver Joseph Duddington inspect the instruments that recorded Mallard's world speed record.

Nobody could know anything in advance. The attempt was planned in secrecy, so that when the 'Mallard' steam locomotive left London for Barkston in central England on the morning of 3 July 1938, most people were told that its brakes needed another round of testing. The engine driver, Joseph Duddington, and fireman, Tommy Bray, had been ordered to keep the real aim of the trip secret.

There was one glitch. Not knowing the importance of the day, one of the country's most respected inspectors cancelled his attendance, saying he didn't work on Sundays. A replacement was quickly found, and he was to be informed shortly before departure, along with all parties involved, that this morning Mallard was aiming to win back the steam engine speed record from

Germany. While previous British attempts had failed, today Mallard aimed to bolster the nation's self-confidence by showing that Britain was not about to be overshadowed by Nazi Germany.

Troubled times

The years leading up to World War II were bleak for the United Kingdom. In 1935 it was smitten by major riots, the economy was in recession following the Wall Street stock market crash in 1929, and many workers were short of food, with soup kitchens feeding the hungry in big British cities. Politics were polarising; fascist protesters struggled against rival political and ethnic groups, while in Wales the Communist-led labour movement recruited 300,000 people for one demonstration. Meanwhile, the German economy thrived. Two years previously, ►



AOP/GETTY IMAGES

Mallard's record was to spur optimism in the UK at a time characterised by unrest, strikes, and hunger.



AOP/GETTY IMAGES

Gresley also designed the Flying Scotsman

Nigel Gresley's most famous locomotive is arguably the Flying Scotsman, the express between London and Edinburgh.

In 1938, when Mallard set its steam locomotive speed record, Nigel Gresley was too ill to participate. Shortly after the triumph, his health problems deteriorated, and he died on 5 April 1941.

In 2001, Gresley was honoured with a memorial plaque in the central train station of Edinburgh. The plaque was dedicated not only to the record-breaking Mallard, but to all his efforts in developing steam engines, including the trend-setting Silver Jubilee (1935) and perhaps his most famous train engine, the Flying Scotsman (1923).

The Flying Scotsman was built for the London and North Eastern Railway, where Gresley was the Chief Mechanical Engineer from 1923 until his death. The train performed a

regular express service between London and Edinburgh, Scotland, hence the name. In the beginning, the train ride took almost eight hours, but technical improvement of the engine reduced travel time to 5 hours and 50 minutes. The name is still used today for the fastest trains (four hours) on the same route.

The Flying Scotsman locomotive was the pride of the company, but it was phased out in 1963 and replaced by modern diesel engines. The engine later visited railway enthusiasts throughout the world – travelling to the US and Canada in 1969-73, and to Australia for the

Bicentennial in 1988.

Sir Nigel Gresley with a stop watch in one of his efficient trains.

► Adolf Hitler had taken power, and in 1936, Nazi Germany achieved one of those noteworthy records that made the country seem even more mighty and threatening: on 11 May 1936, a German Borsig steam engine gained a top speed of 200.4km/h west of Berlin, a world speed record for steam engines.

One of the passengers was Heinrich Himmler, head of the SS, who knew well that the record was a major propaganda victory for Nazi Germany and its proponents.

For almost 150 years, Britain had been the leading developer of steam engines. It was a British mine engineer, Richard Trevithick, who invented the steam engine in 1804, and in the second half of the 1800s two different private transport companies had competed on rival routes from London to Scotland, the West Coast and East Coast Main Lines, to develop the fastest and most powerful engines for the transportation of passengers and goods between London and Edinburgh.

But with its failing economy, marked unemployment and social unrest, Britain in the 1930s was no longer the leading world power that the nation had once been.

To save England's honour

The man who was to save the nation's honour by designing the world's fastest steam engine was Nigel Gresley. Born in Edinburgh in 1876, Gresley was supposed to follow in his father's safe footsteps and become a rector. He wanted to become a mechanical engineer, however, and at the age of 17 became an apprentice at a railway factory.

After finishing his training, he was employed by a design office which developed railway engines, and his obvious engineering talent earned him the job of chief engineer at just 35. One of the many technological



One of many train engines is the iconic Silver Jubilee (1935) designed by Sir Nigel Gresley.

ENGLISH RECORD
202.7km/h 1938



Nigel Gresley was knighted for his work improving train services.



GERMAN RECORD
200.4km/h 1936

In May 1936, the German Borsig DRG 05 set a steam locomotive speed record. Aboard the train was Heinrich Himmler, head of the SS, and the record was a propaganda victory for Nazi Germany.

advances introduced by Nigel Gresley was the removal of the raised and windowed central section of many train passenger cars of the 1800s, introducing instead elliptical roofs which reduced wind resistance.

In order to gain more engine power, he designed a locomotive with three cylinders instead of the standard two of the time (one for each set of wheels). Engines with two cylinders caused a rocking motion in the train as the weight of the pistons was pushed back and forth and from side to side. Gresley's small stroke of genius consisted in placing an extra cylinder between the wheels, which contributed to balancing the three pistons' motions, and producing more power. Not only did he thereby supply the engine with more horsepower, he also reduced the wear on the tracks caused by the rocking motion.

Since the early 1920s, Nigel Gresley had been trying to develop and improve a specific type of locomotive, known as Pacifics. The Pacific locomotives were characterised by their two small sets of control wheels at the front, three large sets of driving wheels at the centre, and a small set of wheels at the back, which supported the driver's cab.

Gresley developed first an A1 Pacific, and subsequently an improved A3 Pacific, both of which were powerful engines. But both models still physically resembled the steam locomotives of the 1800s with their oblong cylindrical boilers and fairly flat fronts. A radically new design was needed if the

engine was to obtain a higher speed and optimise fuel consumption.

Inspired by race car

The inspiration for the development of the A4 Pacific model, the Mallard, came from the world of race cars. In 1923, Italian car designer and developer Ettore Bugatti introduced a completely new, streamlined type of race car, and Nigel Gresley took note, using a similarly streamlined design for his A4 locomotive. He was one of the first to test miniature locomotive models in wind tunnels, and by designing the Mallard with a streamlined wedge shape, he reduced the aerodynamic resistance along the sides of traditional steam engines when at high speed.

Propaganda as fuel

The A4 model was completed in 1935, about one year before the Deutsche Reichsbahn beat the speed record with its Borsig train. The German propaganda victory caused headlines in Britain, and calls were made from several sides for the nation to win back the record. That sparked a new speed race among different British train companies competing to travel ever faster. But still the fastest train reached only a speed of some 183km/h, a long way from the German record of 200.4km/h.

Beating the speed record became an obsession for Nigel Gresley, and he ensured that one of the A4 Pacific-class locomotives

entering service in 1938, 'Mallard', was equipped with all the newest technologies. Steam pressure in the boiler and cylinders was increased, and even the steam pipes were streamlined so that steam could be forced through the pipes with less resistance.

Make it happen before Sunday!

One day in late June 1938, Nigel Gresley asked his leading technical advisor to step into his office, to go through the most recent results. Towards the end of the meeting, Gresley leaned back in his chair and asked whether Mallard could go any faster than it had done previously. The advisor suggested some possible technical improvements.

"Would you please make it happen before Sunday?" Nigel Gresley replied.

When the Mallard was ready to be tested on 3 July 1938, it had been in operation for exactly four months, fully broken in and running freely, but before any chance of significant wear to affect performance. Mallard was in top shape.

The trip began in Barkston in central England, north of Grantham, on the East Coast main line. Apart from the speed recording car, the train included several passenger carriages. At 4.15pm, the train left Barkston, heading for Peterborough. Driver Joseph Duddington had to slow down for track work at Grantham, but after that he could pick up speed. The train quickly accelerated to 137km/h, its coal consumed ►



PT.W. REMNANT

Fireman Tommy Bray, driver Joseph Duddington, and inspector Sid Jenkins after the record ride. Jenkins was invited at the last minute, because the original inspector didn't want to work on a Sunday.

» by the flames as quickly as the fireman could feed it into the furnace. In the speed-recording car, the speed reached 187km/h, beating the British record, but below the German record, and Mallard was approaching Essendine, where the driver would have to brake to avoid the train being derailed.


As the train sped through the town of Little Bytham, it reached a speed of 198km/h, and increasing. "Come on girl," the driver, Joseph Duddington, later remembered himself thinking. "We can easily do better."

And then, only for a brief moment, the Mallard reached a speed of 202.77km/h (126 miles per hour), setting a record that beat the Germans and indeed has never since been broken by any steam engine in the world.

The news attracted great attention, but experts were soon wondering whether

Mallard could have travelled even faster. The track work at Grantham gave the locomotive only some 24km to reach its top speed before it was forced to slow down at Essendine. If Mallard had been allowed to pass Grantham Station at a speed above 100km/h, the engine's final speed might have been even more impressive.

Graceful retirement

Mallard operated in the British railway system until 1963, completing some 2.4 million kilometres. Today the locomotive holds pride of place in the UK's National Railway Museum in York. 

Innovation led to record

With its streamlined shape and innovative engine technology, Mallard represented the final word in steam engine technology. The locomotive's record has never been beaten.

AERODYNAMIC SHAPE

6

As on Bugatti's race car, air drag was reduced by making the air pass over the engine instead of along its sides.

DOUBLE KYLCHAP EXHAUST SYSTEM

5

This system could take advantage of both combustion exhaust gases and the steam from the cylinders. Mallard was the first to employ two of these.

THREE CYLINDERS

3

More engine power than the traditional two cylinder engines and more stable operation, because the extra cylinder between the wheels balanced the sideward motion of the pistons. So the design delivered more horsepower and less load on the tracks.

STREAMLINED LIKE A FRENCH RACE CAR

French-Italian car designer and developer Ettore Bugatti, who founded the Bugatti car brand, was one of the first carmakers to experiment with wind tunnels to make his cars even faster. The wind tunnels provided useful information about air drag at high speeds, and in 1923 Ettore Bugatti

revealed a revolutionary new race car concept with his Bugatti Type 32 design. The car participated in only one race and was never a sporting success. However, it attracted attention due to its streamlined car body, which inspired Sir Nigel Gresley's designs for the A4 Pacific train engine.

The Bugatti Type 32 design attracted attention, but it was never successful.



PO/FOTO/TOPEOTO

IMPROVED BOILER PRESSURE

1

The boiler pressure was increased from 220 to 250psi to force the steam faster through the pipes.

STREAMLINED AIR PIPES

2

The inside of the pipes through which the steam was to pass was streamlined, so the steam could pass more easily.

THE COAL CAR

7

The coal tender and passenger cars had elliptical roofs, reducing their air drag.

THREE SETS OF WHEELS

4

The train was equipped with three sets of driving wheels, allowing for a larger boiler and more horsepower.



MALLARD (Type: A4 Pacific)

Ready for operation: 3 March 1938
In operation: 25 years (1938-1963)
Crew: 2 (driver and fireman)
Length (without tender): . 21.34 m
Capacity: some 3000 hp
Driving wheel diameter: . 203.2 cm
Engine weight: 104.6 t
Coal tender weight:..... 63 t
Coal tender capacity: 8 t of coal, 18.5 t of water
Number of A4 locomotives built: 35

AOP/GETTY IMAGES

Instant Expert: Coral reefs

The colour explosion of huge coral colonies

➤ **Coral reefs are primarily associated with tropical waters, but in fact the small star-shaped corals also exist in other places of the world. However, those locations don't gather as many species as do tropical coral reefs, where thousands of different species of fish, sharks, clams and sea urchins can share a reef system.**

Tropical coral reefs are some of the highest-diversity areas in the world, ranking second only to tropical rain forests on dry land. Around reefs, you may primarily encounter thousands of colourful fish, but the ecosystem also includes members of most other marine animal groups – crustaceans, molluscs, worms, tunicates, echinoderms and many others.

The reason why so many thousands of different animal species live so close to each other is the coral reef itself, which has been produced over thousands of years of coral activity. By liberating calcium, which settles and builds in thin layers one on top of the next, corals have slowly built a varied, underwater landscape of tall calcium 'tubers' with holes and cavities inside and between, providing countless habitats.

The corals themselves are small, star-shaped creatures that resemble miniature sea anemones. They live in large, unbroken colonies that might be flat, ramified, circular, or ball-shaped – and they can be soft or hard. It is, however, only the hard species that produce coral reefs. Many corals have special colours, but

these are not the creatures' own pigments, rather they come from microscopic algae – zooxanthellae – that live in the tissue of the corals. The corals and algae live in a symbiotic relationship from which both parties benefit. The corals can capture small, edible particles in the water with their tentacles, but photosynthesis by the algae provides them with an additional energy boost of carbohydrates, etc. Meanwhile the algae enjoy a safe life inside the corals' tissues.

The coral reefs function as habitats for many different animals, but species exist that have adapted to feed directly on the coral colonies. The large crown-of-thorns starfish is one, forcing its stomach out of its mouth and placing it across a coral 'tuber', subsequently digesting all the corals with which it comes into contact, until only the naked calcium skeleton remains. Other eager coral eaters are parrotfish, whose teeth have merged into a large beaklike structure that enables them to gnaw coral branches into smaller sections, which they then swallow. The corals are digested, and the calcium segments are liberated in the shape of powder.

IMPORTANT COLOURS

■ Scientists have wondered about the purpose of the colour explosion among coral reefs. They have come up with two likely functions. First, the colours are a required differentiation for the huge number of species that live on a coral reef; without the patterns and colours, members of an individual animal species might have to spend a lot of time finding each other, risking time-consuming and at worst lethal mistakes. Secondly the colours serve as camouflage. Seen from a predator's point of view, the constant flicker of colours makes it harder to follow and focus attention on a single individual.

Life on a coral reef

Life on a coral reef is varied and colourful. The corals which make up the reef can appear in many different shapes and colours.

Soft corals

➤ Soft corals are common in places where the water is a little more stagnant. Unlike hard corals, soft corals live on a reef but don't contribute to a growing structure.

Clownfish

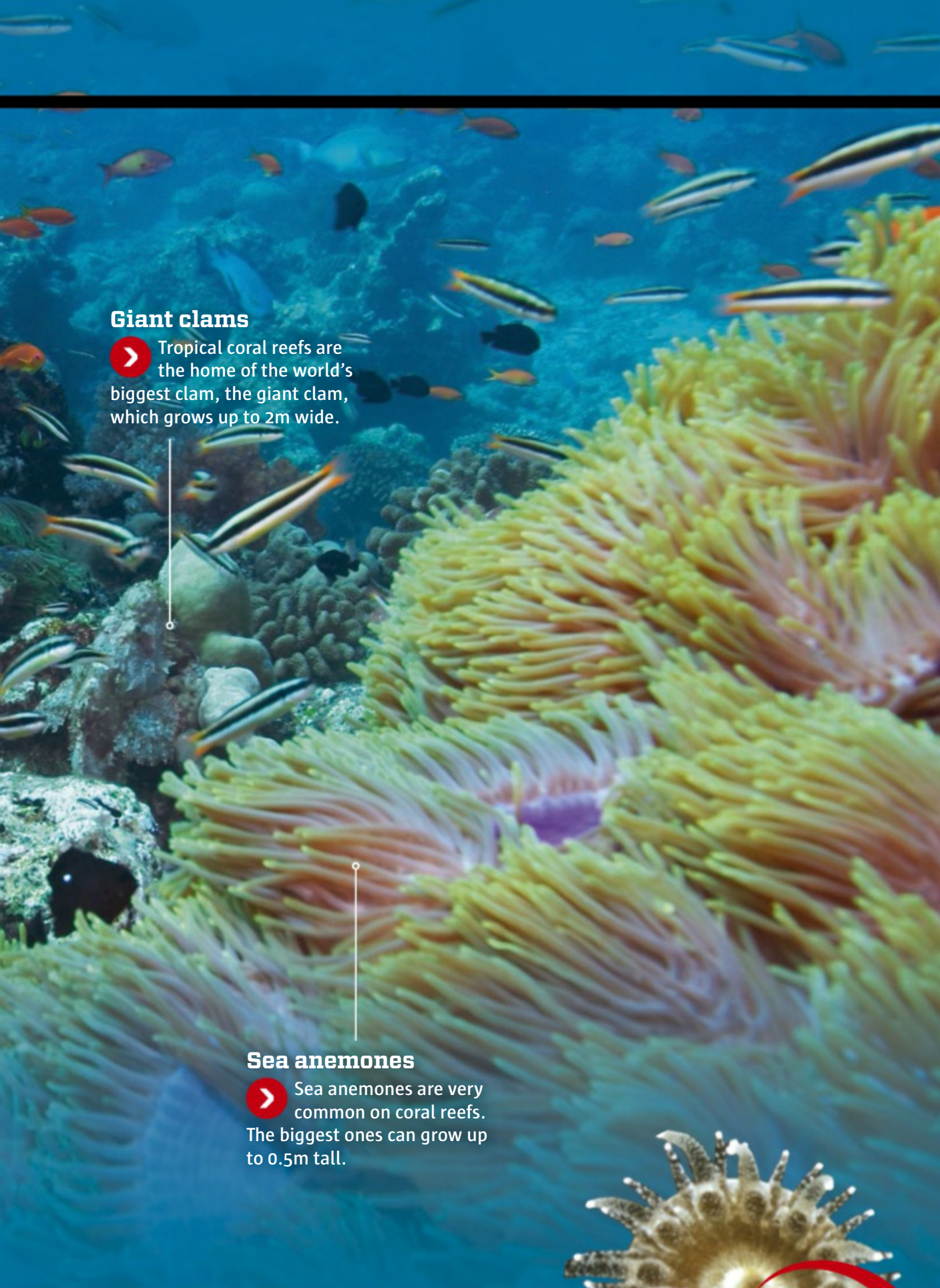
➤ Several species of clownfish exist, known for their close relations with sea anemones.

Coral reefs are highly endangered

Successive heat records are bad news for the coral reefs of the world. When ocean temperatures rise, corals get stressed and react by spitting out their co-habiting algae. As these algae supply 90% of the energy available to corals, the corals will starve if the temperature does not fall again. This is what we see as coral bleaching and subsequently coral death. In 2016, 29% of the Great Barrier Reef's corals died in shallow waters, and the alarming development continued in 2017. Scientists cannot yet estimate to what extent the coral reef will recover. Adding to the dangers of climate are over-fishing, pollution, and the plans to expand coal production and traffic near and through the area.

Warmer ocean water can bleach and destroy coral reefs. New coral reefs can be made based on shipwrecks and other structures.

SHUTTERSTOCK



Giant clams

Tropical coral reefs are the home of the world's biggest clam, the giant clam, which grows up to 2m wide.

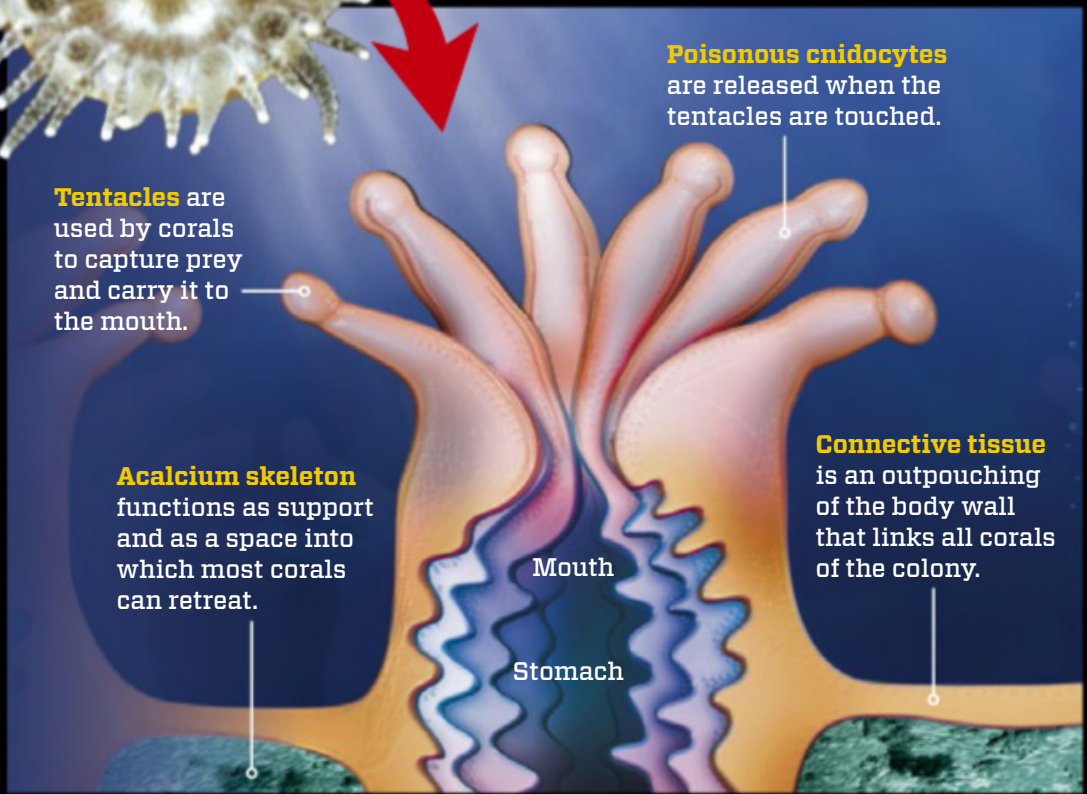
Sea anemones

Sea anemones are very common on coral reefs. The biggest ones can grow up to 0.5m tall.



Corals

Adult corals are simple tube-shaped organisms, whose 'tubes' are open at one end and closed at the other. A coral measures up to 3mm, but the creatures are linked via body wall outpouchings and can produce huge reefs such as the 2300km-long Great Barrier Reef. The adult corals are fixed in place, feeding on algae and small creatures that they capture with their tentacles.



Great Barrier Reef

The diversity around coral reefs is extreme. The mix varies from place to place, but there are always thousands of different species. The list below shows some numbers of species that are to be found on our Great Barrier Reef.

Sea turtles:
6 species

Sea urchins and starfish:
600 species

Sea snakes:
14 species

Sharks:
125 species

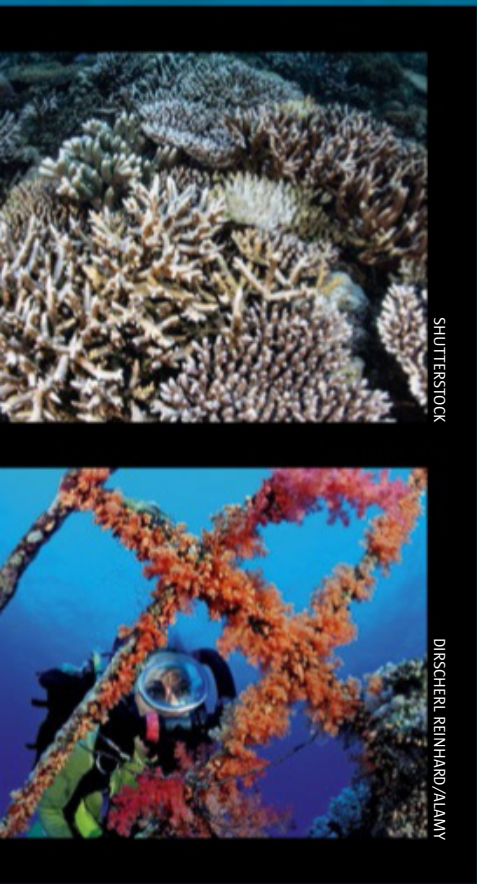
Snails and clams:
500 species

Fish:
1500 species

Corals:
400 species

SHUTTERSTOCK/JASON EDWARDS/GETTY/ JEFF HUNTER/GETTY

BOB EVANS/GETTY



SHUTTERSTOCK

DIRSCHERL REINHARD/ALAMY

Underwater ballet: the mating dance of humpbacks


 Two 30-tonne bodies are in motion through the water when humpback whales mate. This particular union of giants was captured off the Pacific island of Tonga, the female (top) swimming around the male in large circles with her flippers spread out. Before the mating began, males fought hard to get her. Typically, females are pursued by an entire group of males that parade themselves by leaping out of the water and beating their tails or flippers against the ocean surface. The female gives birth to one calf after 11-12 months of pregnancy.

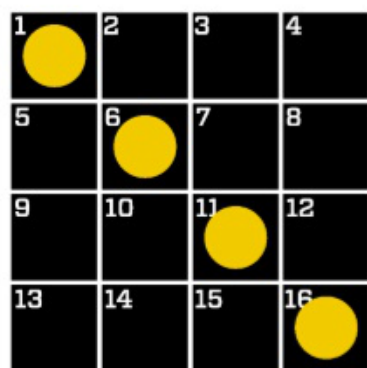
 Photo // Tony Wu



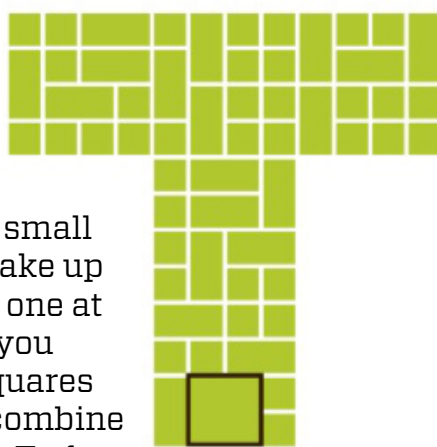
MIND BOMBS!

Solve problems designed for different types of intelligence, and find out in which you excel.

VISUAL INTELLIGENCE



1 Find at least five other ways to place the yellow circles while keeping only one circle in each horizontal row and vertical column. (Disregard inversions and rotations.)



2 In this T, the small tiles often make up a square like the one at the bottom. Can you find five other squares which together combine to form a smaller T of the same shape as the complete T?

NUMERACY

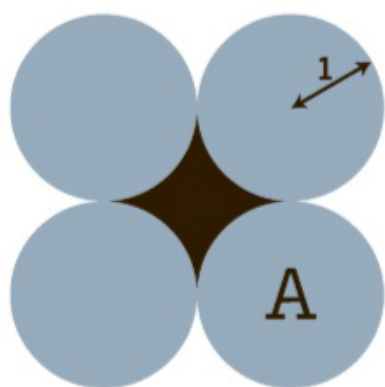


3 Which number belongs in the topmost balloon?

4 Divide the figure into six parts of the same shape and size in which the total is 15.

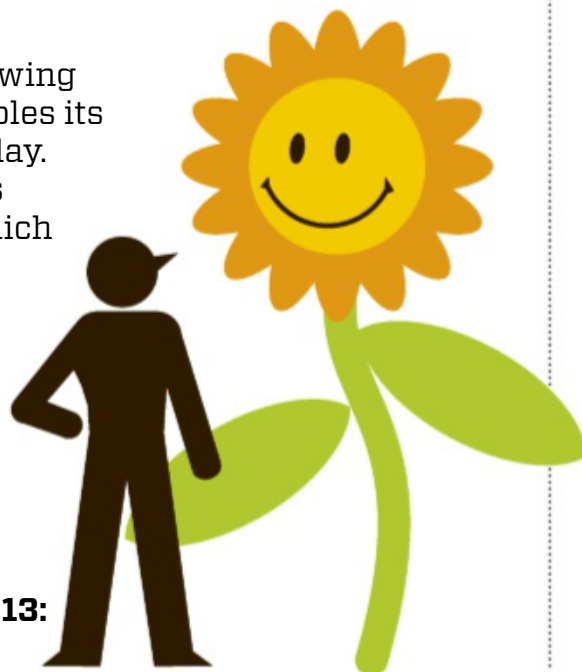
7	2	2	7	2	4
4	2	2	4	4	5
2	7	5	7	4	2
3	3	4	3	3	2

LOGIC



5 The circles each have a radius of 1 and area of 'A'. What is the area of the black star at the centre, expressed in terms of A?

6 A fast-growing plant doubles its height every day. On day 10, it is 2m tall. On which day was it 25cm tall?



Answers on p13:
no peeking!

Scientist in Focus

CREATIVE COMMONS



Name:
John Forbes Nash
Life-span:
1928-2015

Schizophrenic Nobel laureate

Few scientists' research is used for as many purposes as that of US mathematician and Nobel laureate John Forbes Nash, whose theories are employed in market economics, artificial intelligence, and politics. Nash is also known from a Hollywood film about his life and mental illness.

7 The film about John Nash's life opened in 2001. Its title was ...?

- A) A Beautiful Day**
- B) A Beautiful Mind**
- C) A Beautiful Life**
- D) A Beautiful View**

9 Nash died in May 2015 at the age of 86. What was the cause of death?

- A) Cancer**
- B) Pneumonia**
- C) A plane crash**
- D) A car crash**

8 The main character was played by Russell Crowe, who also starred in ...?

- A) Casablanca**
- B) Pelle the Conqueror**
- C) The Insider**
- D) Babette's Feast**

10 One of his most important contributions to scientific research concerns ...?

- A) Game theory**
- B) Insurance science**
- C) Information economics**
- D) Economic growth**

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