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Contents

ISSUE #70
AUSTRALIAN SCIENCE ILLUSTRATED
PUBLISHED 3 OCTOBER 2019

COVER STORY

26

CLIMATE CHOICES

If we keep on emitting greenhouse gases we face a horror scenario of rising global temperatures, drought and extreme weather events. We look at the choices to be made.

40

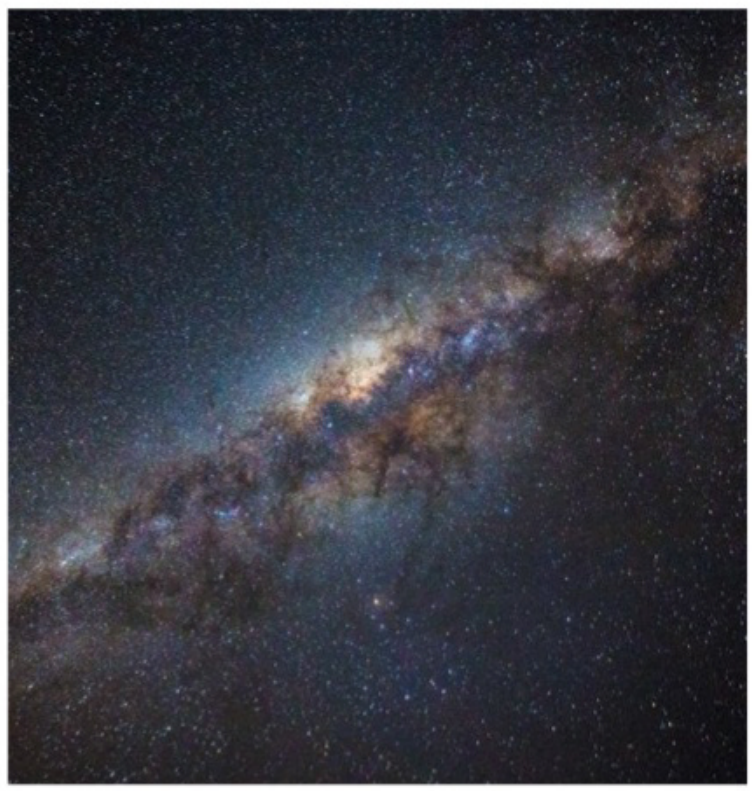
MILKY WAY FORMED FROM COSMIC CHAOS

The hub of the Milky Way turns out to be the oldest – not the newest – part of our galaxy, and indicates that 13.5 billion years ago it had a far more chaotic origin than was previously believed.

48

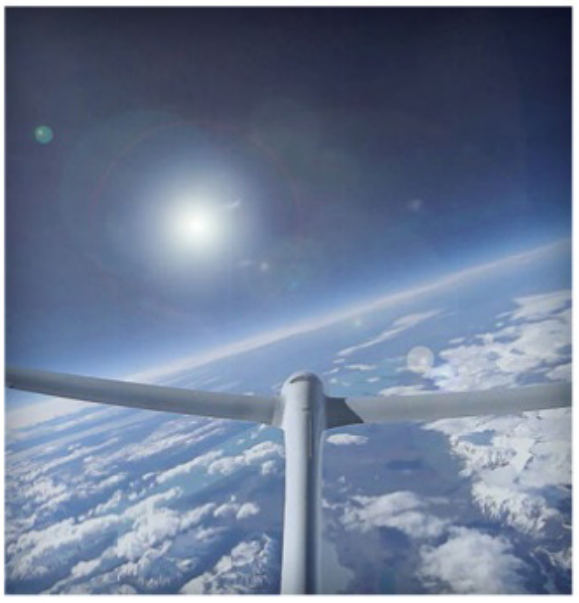
NEW WEAPONS AGAINST SNAKE BITES

With the race on to halve the number of deaths and disabilities caused each year by snake bites, scientists are working to replace 100+-year-old treatments with a new arsenal of antibodies and nanoparticles.



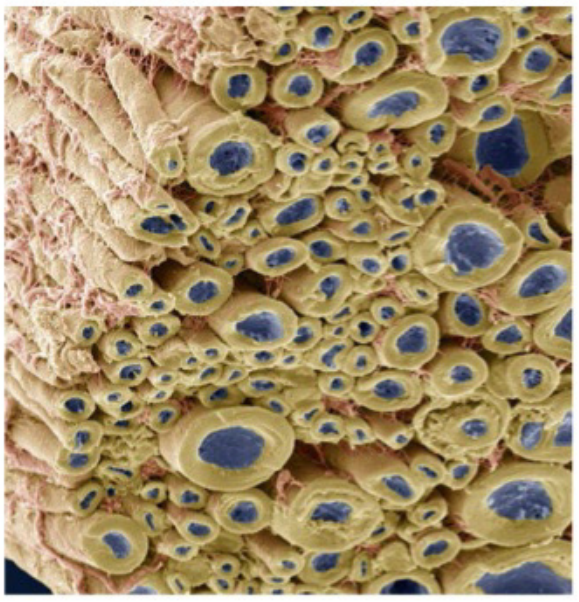
52
SPACE GLIDER

The Perlan II glider beat the world record, gliding without an engine 23km above the Earth. How did it get so high? And what secrets could be unlocked by its stratospheric flight?



56
HUMAN BRAIN PT.3

Scientists seek new ways to combat and even reverse the breakdown of myelin insulation in the brain's nerve cells and the debilitating effects of sclerosis that this can cause.



62
ELECTRIC ANIMALS

The hammerhead shark uses its head like a metal detector to spot signs of life in the blind spot below its head. Other animals also harness electricity to feed, navigate, and even climb walls.

68
HIGGS FIELD

They found the Higg's boson, but now they need to create pairs of them in order to explain how the Higg's field provides mass to particles every-where in the Universe at once...

REGULARS AND OTHER FEATURES

6
MEGAPIXELS
Sonic shocks and the biggest bee.

10
SCIENCE UPDATE
Putting a mammoth in a mouse egg, and hopping through the solar system in a steam-powered space probe.

16
ASK US
Can plants feel pain? Why is sea water salty? Our experts have the answers.

74
PHOTODOC: PRINTING BONES
3D printers can save sick skeletons by rapidly generating synthetic sections.

80
INSTANT EXPERT: SMELL & TASTE
The linked senses of smell and taste can sound alarms or evoke memories. And what is umami, exactly?

82
TEST YOURSELF!
Mind-bombs and teasers...

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EDITORIAL
Editor Jez Ford
jford@nextmedia.com.au

DESIGN
Art Director Malcolm Campbell

ADVERTISING ENQUIRIES
Advertising Manager
Di Preece
dpreece@nextmedia.com.au
ph: 02 9901 6151

Production Manager Peter Ryman
Circulation Director Carole Jones

INTERNATIONAL EDITION
Editor-in-Chief Sebastian Relster
International Editor Lotte Juul Nielsen

BONNIER INTERNATIONAL MAGAZINES
International Licensing Director
Julie Smartz
Art Director Hanne Bo
Picture Editors Allan Baggesø, Lisbeth Brünnich, Peter Eberhardt

nextmedia

NEXTMEDIA
Executive Chairman David Gardiner
Managing Director Hamish Bayliss

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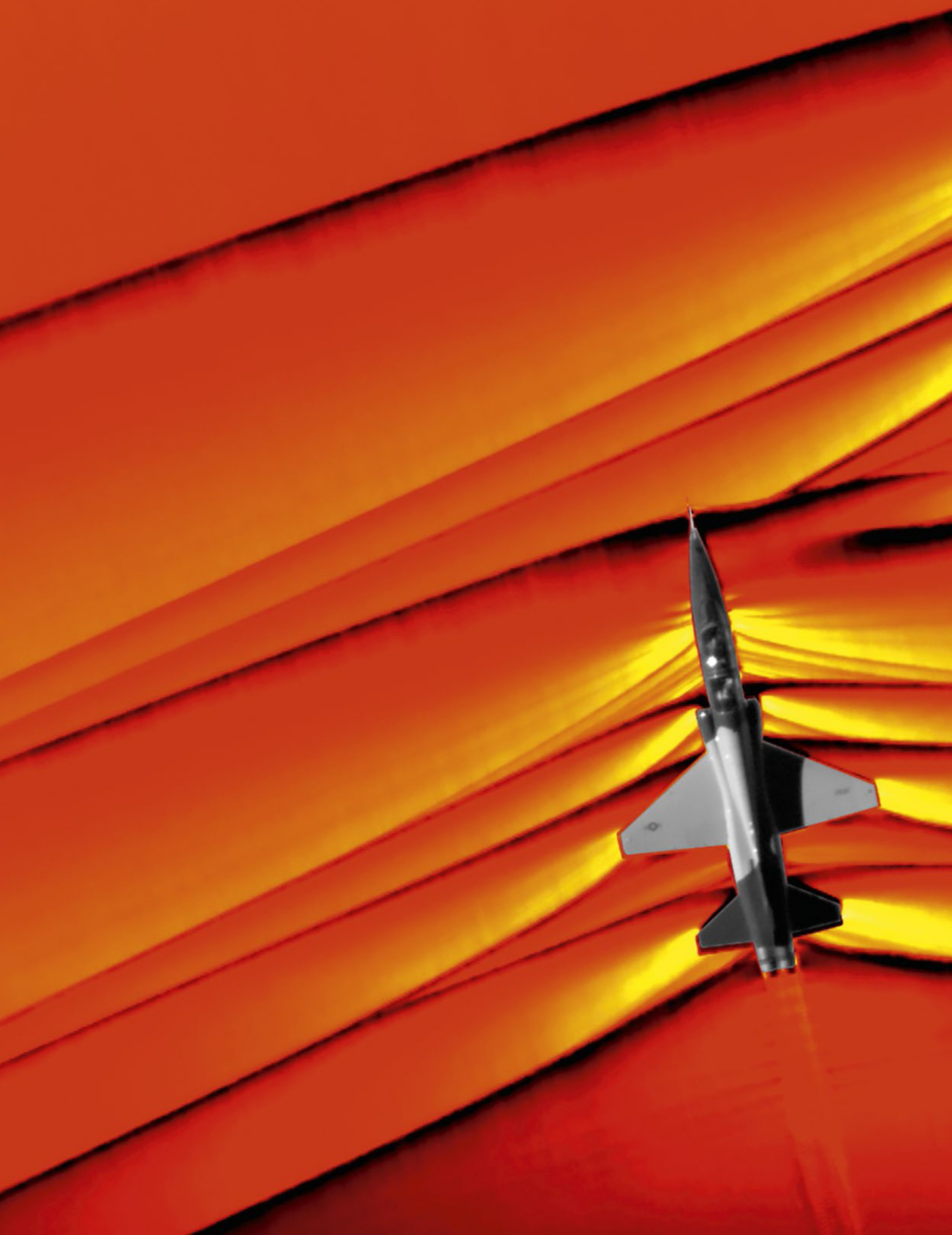


Compressed air: two sonic shock waves in collision

When a plane flies faster than the speed of sound, the pressure waves in front don't have time to flow around the aircraft and the air becomes compressed, eventually producing a shock wave, its energy discharge yielding the sonic 'boom' for which supersonic planes are famous. NASA has managed to capture this image of two such shock waves interfering like ripples on a pond, with the resulting variation of air density causing light to bend differently and so be observed as different colours.

Photo // NASA

NASA

Bee picture: World's biggest bee fights termites in trees

The biggest bee in the world is Wallace's giant bee, which lives in trees in Indonesia; it grows up to 4cm long and can have a wing span over 6cm. This year scientists managed to observe the bee for the first time since 1981. The giant insect flies through the tree-tops, moving into termite nests and collecting resin from the trees, which it uses to build protective barriers that then keep out the termites when they try to re-conquer their nests.

Photo // NaturePL

NATUREPL

Steam-powered space probe to jump through the Solar System

Scientists leverage old technology to make one of their major dreams come true: a space probe that might find fuel anywhere and so never exhaust its power supplies.

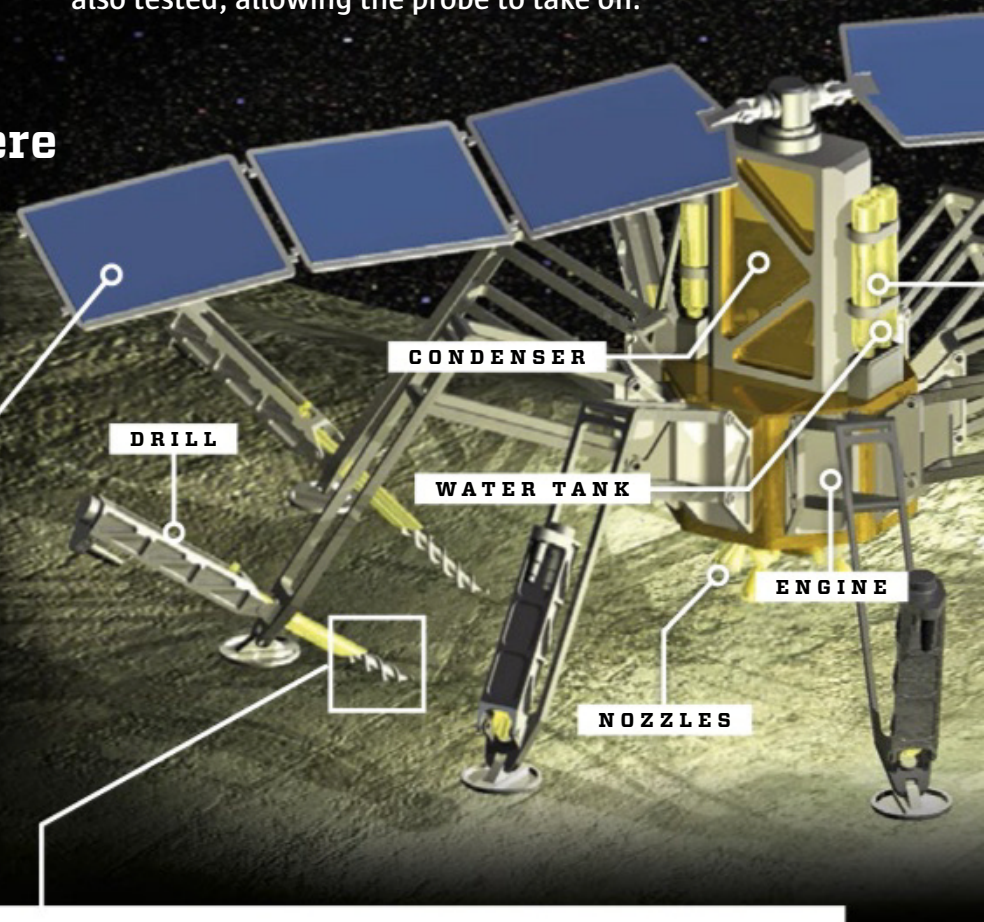
AEROSPACE A steam-powered rocket engine – it sounds like an idea from Jules Verne or H.G. Wells, but it is new, and real! Scientists from the University of Central Florida working with the private aerospace company Honeybee Robotics have developed the engine, which might allow a space probe to jump from world to world in the Solar System without ever running out of fuel.

The latest research indicates that water exists almost everywhere – not only on planets and moons, but also on small objects such as asteroids. In most places water exists in the form of ice, so the space probe must heat it. This happens by the probe drilling into the surface using hollow drills, the contents of which can then be heated by means of energy from the probe's solar panels. Once the water evaporates and enters the probe itself, it condenses again and is stored in the fuel tank. When the probe is ready to move on and leave the asteroid, the water is re-heated to create steam and deliver thrust through a rocket nozzle. In this way, the probe can fly from asteroid to asteroid, picking up fresh fuel as it goes.

On larger worlds such as the Earth and Mars, the higher gravity will require more thrust to achieve take off, but scientists expect that the steam engine can be made strong enough to escape asteroids and satellite bodies, even the Moon and Mercury. The scientists have successfully tested a prototype in a vacuum chamber, managing to drill into frozen soil, liberate water as vapour and condense it again. The steam engine was also tested, allowing the probe to take off.

Steam probe finds fuel anywhere

A new space probe takes off from asteroids by venting steam through its nozzles. It finds the 'fuel' in the form of water or ice on suitable asteroids or other bodies.

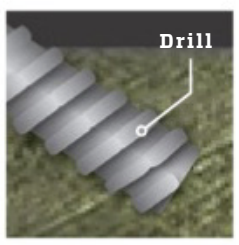


SOLAR CELLS GENERATE ENERGY

1 The probe needs energy to be able to drill for water, so it is equipped with solar panels.

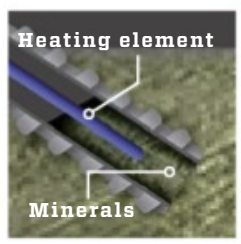
DRILL PENETRATES SURFACE

2 The probe's drill may only need to dig a few centimetres to find water – either in the shape of ice or bound in minerals.



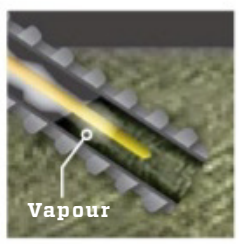
MINERALS FILL THE DRILL

3 The drill is hollow, so it becomes filled with the material located right beneath the surface.



WATER RELEASED AS VAPOUR

4 The probe heats the material with energy from its solar panels. The water evaporates, rising up through the drill.



VISUAL INTELLIGENCE

PROBLEM 1:
B and **D**.

PROBLEM 2:
E. Each circle moves in leaps of 45°, the innermost and outermost ones clockwise, the central one counter-clockwise.

NUMERACY

PROBLEM 3:
35. Two numbers are multiplied, and the third one is added: 3 x 9 + 8 = 35.

PROBLEM 4:
4. The totals of the two numbers in each radius alter between 6, 7, 8, 9 – 6, 7, 8, 9, etc.

LOGIC

PROBLEM 5:
Large barrel = 85 litres. Small barrel = 35 litres. We have two equations: L + S = 120 and L = 2S + 15. S, S + 2S + 15 = 120, and so S = 35.

PROBLEM 6:
The circle. All the yellow figures are located to the right of the hexagon.

SCIENTIST IN FOCUS

7: B) The phonograph, which was subsequently known as a gramophone.

8: D) The light bulb. Earlier patents existed, but Edison's was the first usable one.

9: C) 1093, including telegraphs, telephones, and moving pictures.

10: A) Deafness. Thomas Edison believed that it helped him focus.

Test yourself Answers to p82. No peeking!

HONEYBEE ROBOTICS SPACECRAFT MECHANISMS CORPORATION

The prototype was tested in a vacuum chamber, drilling into frozen soil to liberate water, then taking off with its steam-powered engine.

MARK STONE/UNIVERSITY OF WASHINGTON

A team of scientists has manipulated ivy genetically to break down chloroform and benzene into harmless substances which the ivy can use for growth.

Plants decontaminate indoor climate

BIOTECHNOLOGY Cancer-causing toxins can now be cleaned from the air of our homes by genetically-manipulated plants. Scientists from the University of Washington in the US have genetically manipulated ivy to be able to absorb microscopic chloroform and benzene particles which ordinary air filters cannot eliminate. Chloroform exists particularly in areas where chlorine is added to drinking water, while benzene is found mainly in houses with a garage from which vapour can escape cars and mowers.

The extra gene that gives the plant its new abilities is a synthetic imitation of a gene that exists in all mammals, including humans. In humans, the gene is active in the liver, responsible for the production of a protein that breaks down chloroform and benzene into harmless substances. But being active only in the liver, it doesn't protect us against these toxins when we breathe them.

Scientists tested the new cross-breed in the lab, where it was placed in an airtight glass tube and supplied with the two toxins. After three days the concentration of chloroform had been reduced by 82%, and after six days the substance was gone. The process was a bit slower with benzene, achieving a reduction of 75% after a week.

Scientists will now try to supply the plant with more genes, allowing it to break down other toxins such as formaldehyde, which is released to the indoor climate from tobacco smoke and laminated furniture and floors.

BY THE WAY

SCIENTISTS REVIVE MAMMOTH CELLS

Japanese scientists have extracted cell nuclei from the bone marrow of a 28,000-year-old mammoth and inserted them into mouse egg cells. Subsequently, they observed that the cell nuclei showed signs of division, but they were too damaged to complete the process. The result is a major step on the way to reviving mammoths.

KAZUHIRO NOGI/AFP/RITZAU SCANPIX

AND SPEAKING OF MAMMOTHS...

PRINTS SHOW COMPASSION AMONG PREHISTORIC GIANTS

A set of 117 footprints in the American state of Oregon demonstrate how a mammoth family crossed a dry lake bed 43,000 years ago. The prints show that one adult mammoth limped, and that the younger animals repeatedly sought it out and accompanied it – a behaviour that can also be observed among modern elephants.

GREG SHINE/BUREAU OF LAND MANAGEMENT

MAMMOTHS HAD TO RETREAT DUE TO HUMANS

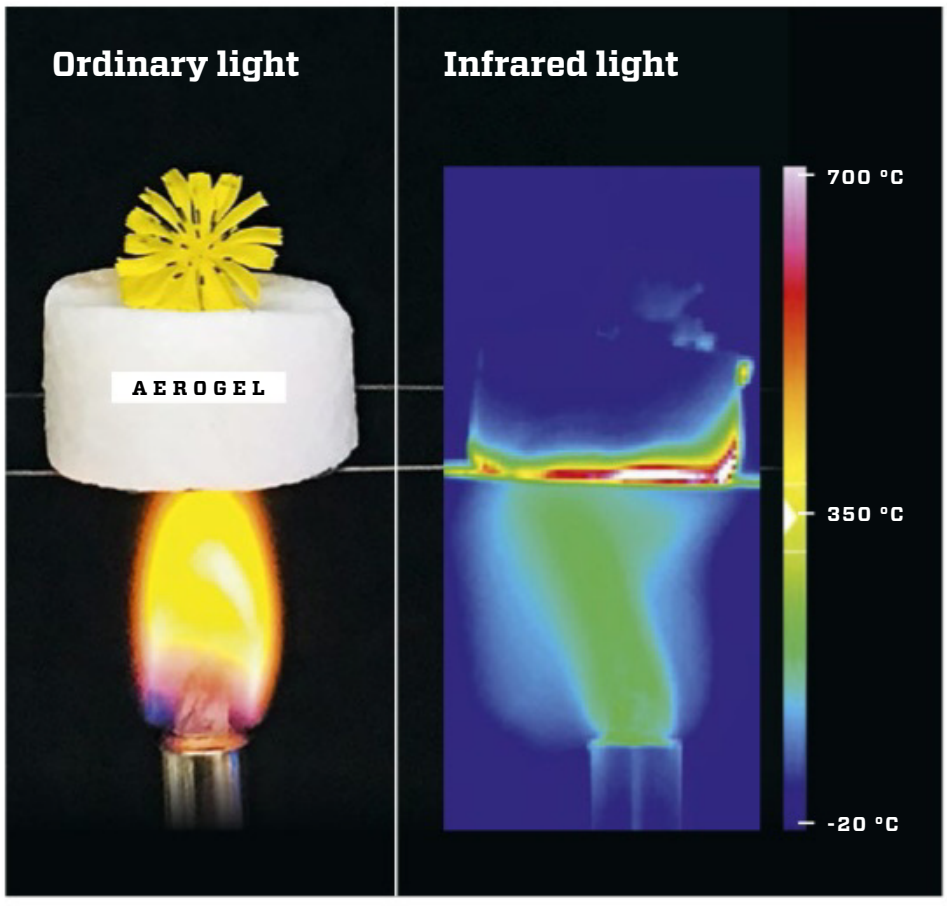
It has been unknown whether climate change or hunting led to the extinction of mammoths. Now palaeontologists have mapped out the range of mammoths and compared the data with the expansion of humans. According to the scientists, there is now every indication that hunting was decisive in the fate of the mammoths.

SHUTTERSTOCK

MAMMOTH GENES TO SAVE THE ELEPHANTS?

US scientists aim to create a cross-breed between an elephant and selected mammoth genes. The aim is to allow the elephant a better chance of surviving in nature, where it is now endangered. Scientists aim to provide the new animal with the mammoth's ability to survive in colder climates.

PIXABAY



XIANGFENG DUAN

Even a thin layer of aerogel can protect a flower from the heat of a flame. To the right, you can see the heat distribution in the material.

New material offers the world's best insulation

TECHNOLOGY Scientists from the University of California have developed a new super-light insulation material that tolerates both higher temperatures and faster temperature changes than any other known material.

The new material is an aerogel consisting of small air pockets divided by walls as thin as an atom. Aerogel is not a new invention, but here the insulating power has been very much improved. Each wall between the air pockets consists of two ceramic layers that work in the same way as the layers of glass in a double-glazed window, so less heat is conducted between pockets.

The scientists created the new aerogel based on experience with graphene's 2D structures of carbon atoms, where the plates of carbon are only one atom thick. The graphene plates can be united into a 3D structure, but the material does not tolerate high temperatures. So the scientists used the 3D graphene structure to build a skeleton to which they applied the ceramic material, subsequently burning the skeleton. The result was a new ceramic aerogel.

The scientists successfully tested the material through 500 cycles during which temperatures varied between -198 and +900 degrees Celsius. The aerogel also survived long-term heat exposure in which it was subjected to 1400°C degrees for a week.

The new insulation material could be particularly valuable in space, where probes and satellites require protection against the temperature changes that occur when parts of a spacecraft are directly exposed to solar radiation.

1400°C

for a week – and the new material still survived in laboratory conditions without melting.

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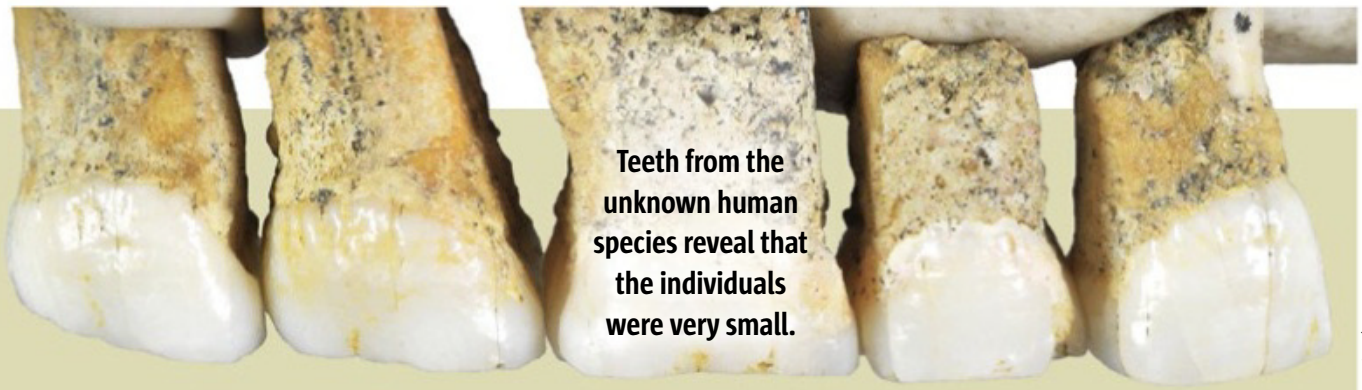


Teeth from the unknown human species reveal that the individuals were very small.

CALLAO CAVE ARCHAEOLOGY PROJECT/REUTERS/RITZAU SCANPIX

Mysterious old dwarf found in the Philippines

50,000-year-old bones and teeth could be from an unknown species that evolved in isolation over hundreds of thousands of years.

EVOLUTION Scientists from the Australian National University have discovered bones and teeth that could add a new chapter to human history. Although the finds from the Callao cave in the Philippines are scarce, there is every indication they come from an unknown human species living some 50,000 years ago.

The new discovery was made in the northern part of the island of Luzon, the scientists so far excavating the remains of at least two adults and one younger individual. The shapes of toe and finger bones show that they walked upright, but must have been good at climbing trees, too.

The scientists are comparing the discovery to that of *Homo floresiensis* in 2003. Based on the size of the teeth, the people were short, as was *Homo floresiensis*, perhaps due to the phenomenon of insular dwarfism, by which species isolated on islands can end up smaller.

The teeth are also interesting in combining a mixture of primitive and modern traits. They look generally like our own teeth, but with one important difference: the front molar has three roots and not just one like ours. This characteristic is known from Homo species that are much older, such as *Homo erectus*. Perhaps humans on Luzon were descendants of a group of *Homo erectus* which arrived from the mainland more than 700,000 years ago. Other discoveries indicate that this early Homo species was able to cross surprisingly large straits of water, while stone tools have also been found on Luzon dating to this time.

Two species of dwarfs discovered in South-East Asia

A newly-discovered Homo species from the Philippines might have evolved in complete isolation – like *Homo floresiensis* from the Indonesian island of Flores.

SHUTTERSTOCK

ISLANDER ANCESTOR CROSSED THE OCEAN

The newly-discovered dwarfs from the Callao cave in Luzon could be descendants of *Homo erectus* species that arrived from the mainland 700,000 years ago.

S. ENTRESSANGLE/E. DAYNES/SPL

ISOLATION MADE PEOPLE SHORTER

The skeleton of a *Homo floresiensis* woman shows she was only about a metre tall, the dwarfism due to the species evolving in isolation for thousands of years.

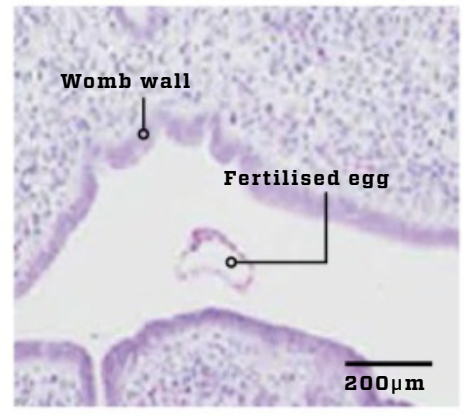
Important protein link to childlessness

MEDICINE Some 10% of all childbearing-aged women suffer from endometriosis. It is a condition that makes the tissue from the edge of the womb spread to other places of the body such as the ovaries, the pelvis and the intestines, and it can both be painful and reduce the chances of getting pregnant. Now, scientists from the University of California have found out why. In experiments with mice, they discovered that the condition is related to the lack of a specific protein known as HDAC3. The protein can be decisive in whether a fertilised egg sticks to the womb to develop into a baby.

In mice that had plenty of the protein, the egg easily stuck to the womb. But in mice that lacked the protein, the egg continued through the womb without making contact with the womb wall where it could get stuck. These mice could not get pregnant.

According to the scientists, the protein regulates the activity of a series of genes that combine to determine the womb's ability to receive a fertilised egg. The protein represses genes responsible for the formation of collagen, the fibres from which tendons, skin, and bones are made. Women who lack HDAC3 produce a lot of collagen in the womb, preventing it developing the changes that are normally caused by pregnancy.

The knowledge could spur new treatments of involuntarily childless women, and might lead to a cure for endometriosis.



T.H. KIM ET AL./SCIENCE TRANSLATIONAL MEDICINE 2019

Lack of HDAC3 prevents a fertilised egg from sticking to the womb wall.

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Ask Us

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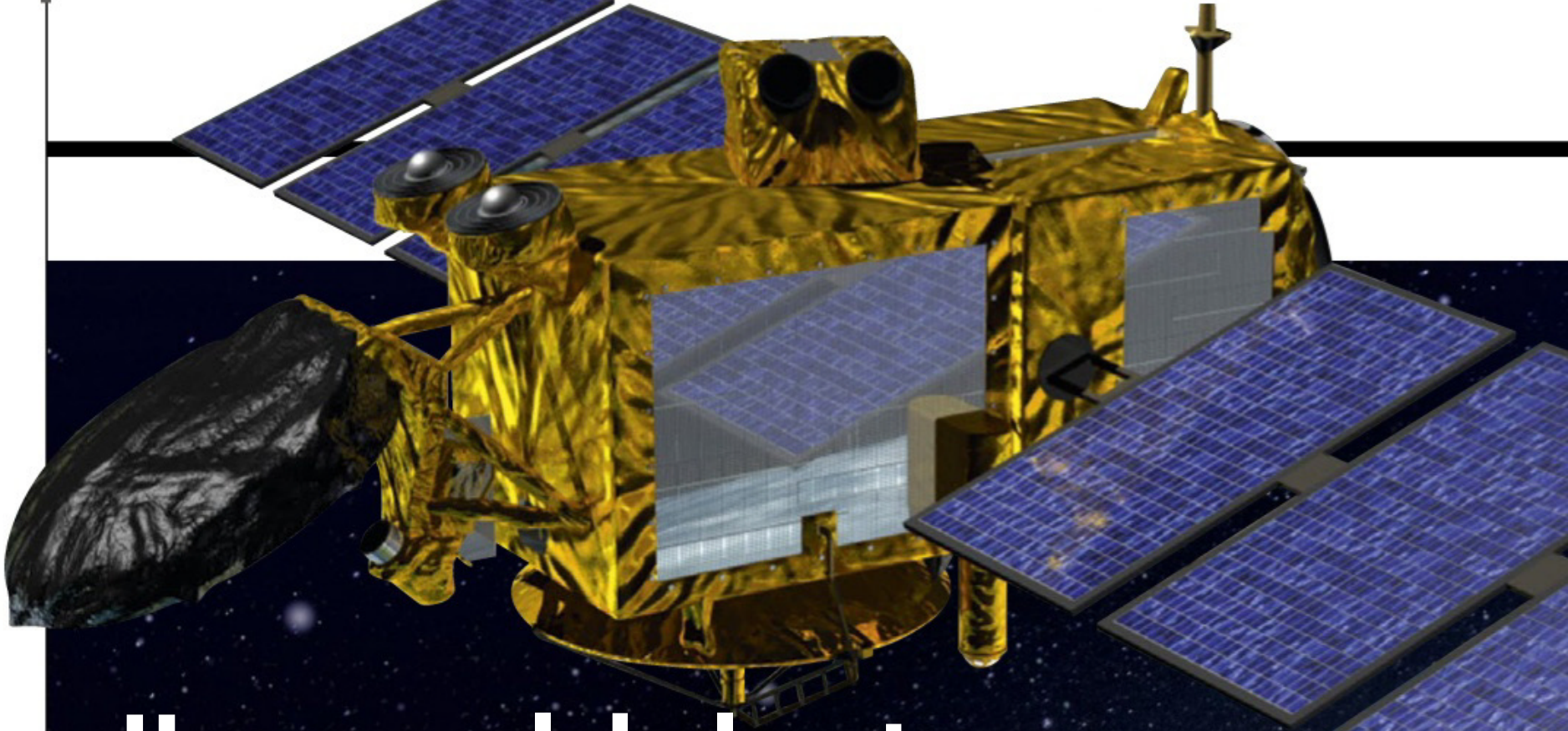


How are global water levels measured?

How are general changes in the world's ocean levels measured? It must be difficult given the need to take local factors such as tides and temperature differences into consideration.

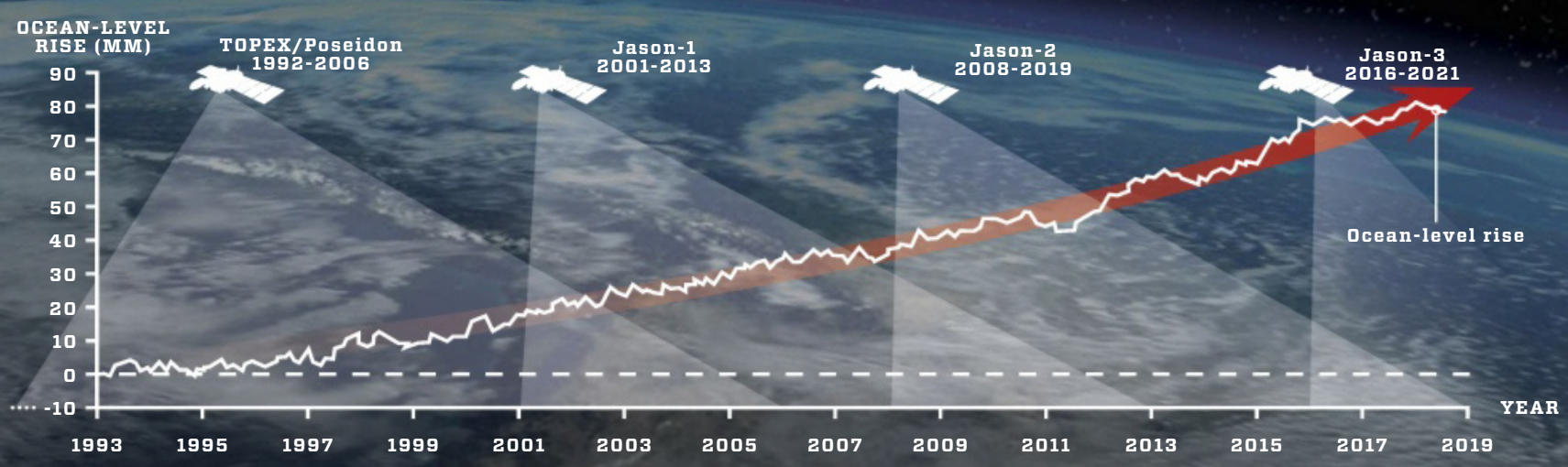
CLIMATE Scientists determine the global water level by means of satellites equipped with altimeters. Every second the altimeter emits some 1700 pulses of microwave energy towards Earth. By measuring the time passing before the reflected energy from the ocean surface returns to the satellite, it is possible to determine the level of the surface with impressive precision.

Before the first water-level satellite was launched in 1992 (the American-French TOPEX/Poseidon), harbour water-level markers were scientists' most important tools, but they provide only local data. The markers caused many sources of error, which satellites eliminate.

Satellites also have the advantage that they can cover the entire planet in about 10 days, providing an overall picture of water levels for all seas and oceans. By collecting all data from multiple overflights, scientists can calculate the average global water level over a calendar year, screening out the effects of wind, waves, ocean currents, tides and so on, all of which can influence individual data points. They can also dismiss

Satellites watch ocean levels rise

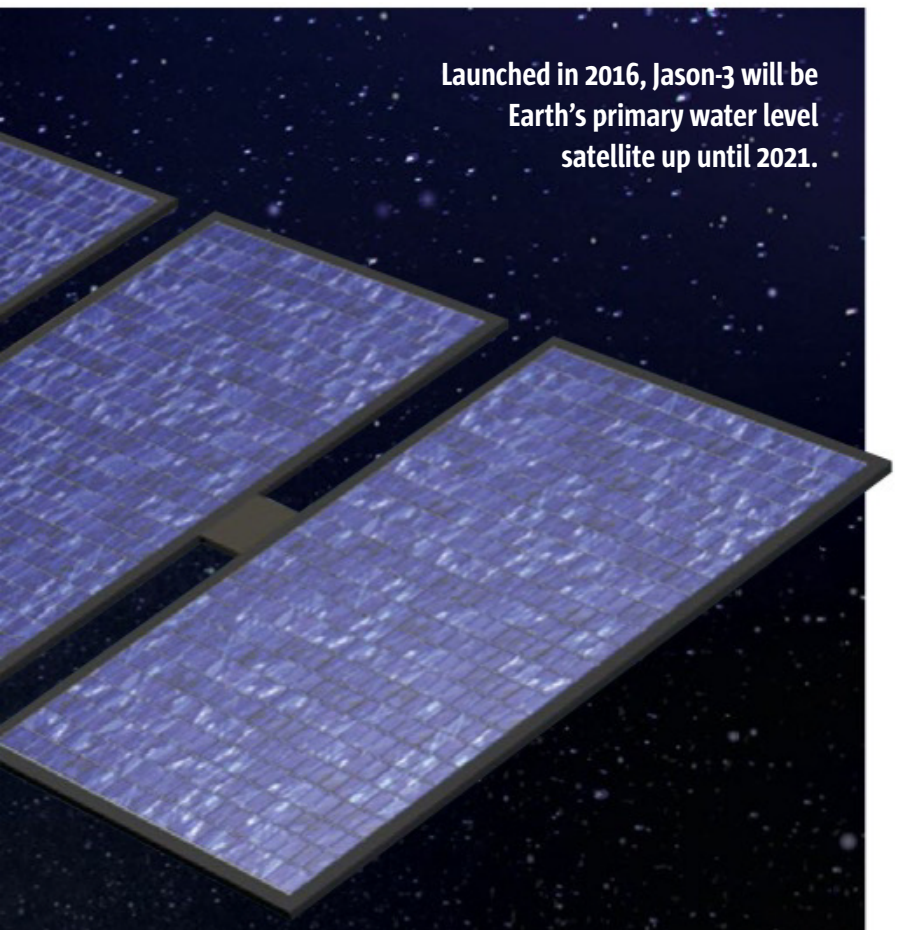
Measurements of global water levels have become increasingly important as the effects of global warming are assessed. When harbours and cities are to be protected against flooding caused by water level rises, ocean-level data from satellites becomes crucial.



› Since 1992, a water-level satellite has been orbiting Earth constantly. Currently it is Jason-3, which will be joined by Sentinel-6 in 2020.

› A few other satellites can also measure ocean water levels. Their data contribute to supporting measurements of the real water-level satellites.

› The data show that ocean-level rises are accelerating. Not only have water levels risen in the past 25 years, the rise is taking place ever faster.



Launched in 2016, Jason-3 will be Earth's primary water level satellite up until 2021.

local effects, such as in Scandinavia, where the land mass is rising compared with the rest of the world. The weight of ice masses during the most recent ice age had pushed it down, but since the glaciers melted approximately 20,000-15,000 years ago and their weight disappeared, the bedrock began to rise again. So a local water-level marker in a harbour in the Gulf of Bothnia – such as in Luleå in Sweden or Oulu in Finland – would indicate that water levels there are falling by about 1cm annually. However, satellite data can show that this is a local effect, with no relevance whatsoever to global water levels.

FLOATS REVEAL THE ORIGIN OF WATER-LEVEL RISES

Three thousand 'Argo' floats measure the temperature of the top 2000 metres of the oceans. The data can reveal how much of the ocean-level rise is caused by water being warmer (and so taking up more space), and how much is due to melting ice.

NASA & ARGO

TOP 5 · Where does lightning strike most frequently?

JORGE SILVA/REUTERS/RITZAU SCANPIX

1 Lake Maracaibo, Venezuela

233 annual lightning bolts/km² - For 260 days a year, Lake Maracaibo in Venezuela is tormented by a thunderstorm known as "the everlasting storm". The weather phenomenon is probably due to the high location and air humidity.

2 KABARE, DR CONGO
205 annual bolts/km²

Kabare on the western shore of Lake Kivu in the DR Congo was the world's lightning capital until 2016, when NASA published a new map.

3 KAMPENE, DR CONGO
177 annual bolts/km²

By Lake Kivu, solar heating causes intense air currents which mix with the moisture from the lake.

4 CÁCERES, COLOMBIA
172 annual bolts/km²

Moist winds from the wide Cauca River and the mountains surrounding the city make Cáceres Colombia's lightning capital.

5 SAKE, DR CONGO
143 annual bolts/km²

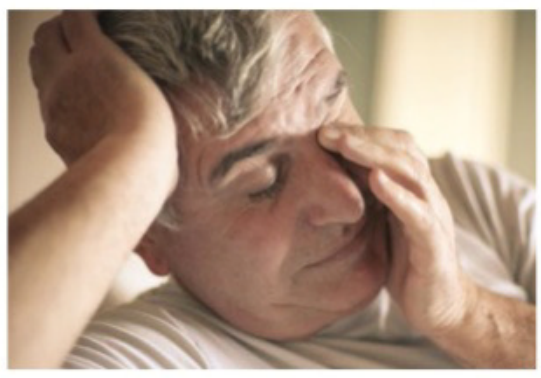
Intense thunderstorms close to the Equator place the DR Congo high on NASA's 'top 500' list of lightning locales.

What makes up grit in the eyes?

HUMANS That grit in the corner of the eye which many people experience when they wake up in the morning is a small, dried-up lump of dirt and dead cells. During the day, the tear film of the eye (consisting of water, oil-like lipids and hydrophilic mucins) removes the waste from the surface of the eye as we blink. But at night, the dirt is no longer carried away, collecting into a small lump at the corner of the eye.

A few people produce grit during the day, often due to the fact that their tear film is less efficient. The phenomenon can also occur if you are in a room with very dry air, making the tear fluid evaporate faster than the eye glands can produce new fluid.

Problems with extra grit in the eyes are also experienced by people with allergies, such as those connected with hay fever. Large quantities of grit might also be a sign of eye disease, so if in doubt, consult your doctor.



SHUTTERSTOCK

Eye grit consists of dirt and dead cells which have not been removed.

Do the Maldives have fresh water?

GEOLOGY The Maldives' capital and main island, Malé, gets its water from different places. The island, which is nearly entirely covered with buildings, has a little ground water that is bound in fresh water lenses under the atolls. But excessive use of ground water means that salty ocean water has entered the lenses, and the natural water resources are now almost dry. Instead, the city collects rainwater, imports bottled mineral water, and desalinates ocean water, which now makes up the majority of the water in the taps.

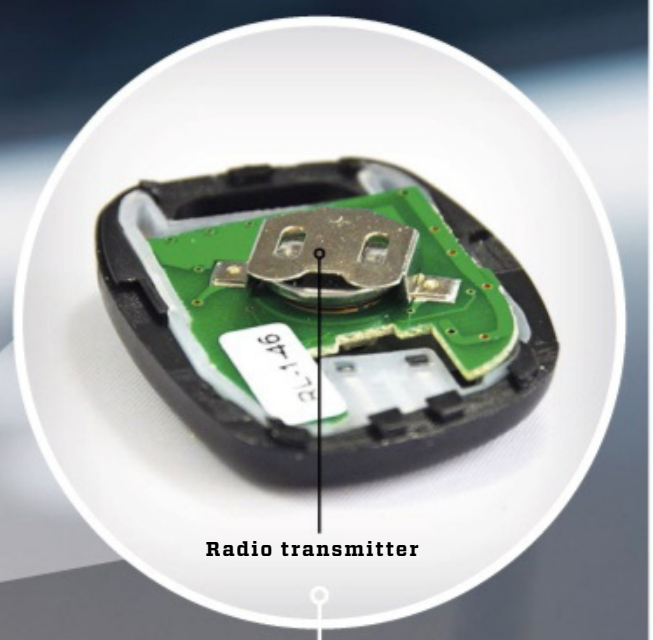
In 2014, Malé experienced a drinking water crisis when a fire rendered the desalination plant useless. For a period of several weeks, water in plastic jars and bottles had to be flown in as emergency aid from India, Sri Lanka and China.

WANG MINGLIANG XINHUA/EYEVINE/RITZAU SCANPIX

The capital of the Maldives, Malé, only has a limited quantity of ground water. Instead, ocean water is desalinated into drinking water.

HOW THINGS WORK · How does remote central locking work?

A remote door lock includes a radio transmitter with a reach of 5-20 metres. A chip in the remote control uses a random generator to produce a code of 40 numbers – either zeros or ones. The signal is synchronised with the car computer, which carries out the action required.



Radio transmitter

Signal

Remote control

1 A radio transmitter in the key uses the same number generator as the car's receiver, so transmitter and receiver are always synchronised. When one code is sent off, the number generator produces a new code, which is saved. The car does the same thing.

2 When you use the remote control, the radio transmitter sends the code to the car together with a function code which tells the car to lock or unlock the doors or to open the boot.

3 The car computer checks if it has arrived at the same code as is received from the remote control. If the codes match, the action is carried out. Otherwise, nothing happens.

SHUTTERSTOCK & ARCHIVE

WHAT MAKES BREASTS LARGE OR SMALL?

In 2012, American scientists showed that at least seven genes contribute to determining breast size. But twin studies indicate that genes can only explain 56% of differences in breast size. Another important factor is weight. If a woman puts on weight, some of the extra kilos will materialise in the breast tissue, giving her bigger breasts. Moreover, hormones such as oestrogen play an important role in breast size.

THINKSTOCK

At least seven genes contribute to determining the size of a woman's breasts, alongside other factors.

A

The *Gynaephora groenlandica* (the Arctic woolly bear moth) caterpillar can tolerate temperatures down to -70°C.

LOUISE MURRAY/VISUALS UNLIMITED/GETTY IMAGES

B

K. WATERS/UNIVERSITY OF NOTRE DAME

C

SCOTT CAMAZINE/PHOTO RESEARCHERS/RITZAU SCANPIX

How can insects survive freezing?

Why can insects tolerate extreme cold without frost injury and death?

ZOOLOGY Severe frost is a challenge to living organisms, as cold makes enzymes and cell membranes function more poorly, whereas ice crystals might harm cell structure. Insects are characterised by low heat production and poor insulation, so in cold regions they have developed enzymes and cell membranes which can function at low temperatures.

A few insects produce anti-freeze proteins that reduce the freezing point of bodily fluids, whereas some insects from the Arctic deliberately produce ice in body cavities outside cells to protect the cell's vital parts from ice that takes up much more space than water.

But the ice-free environment inside the cell makes the water leave the cell, causing it to shrink. To avoid shrinking damage, insects have developed cryoprotectants that support the cell structure. A common cryoprotectant is glycerol, which accumulates in cells and prevents them from becoming emptied of liquid.

BEETLES AND CATERPILLARS CAN TOLERATE SEVERE FROST

A Some moth caterpillars can spend the winter in a frozen state, tolerating body temperatures down to -70°C.

B The Alaskan beetle contains anti-freeze molecules of sugar and fatty acids, which help it tolerate temperatures of -60°C.

C Gall midge larvae grow inside goldenrod aster stems and survive temperatures of -55°C by means of special anti-freeze proteins.

Why does CO_2 heat the Earth?

CLIMATE Carbon dioxide is a greenhouse gas because it retains heat within our atmosphere. When sunlight hits the Earth, our world emits thermal energy back into space in the form of infrared electromagnetic radiation with a lower frequency than the incoming light. Greenhouse gases absorb a major part of the radiation energy in these lower frequencies, and the thermal energy is thereby sent back to Earth. Normally, there is an equilibrium between the incoming heat radiation and the amount that is emitted again, but as greenhouse gases absorb more energy, temperatures rise. Some greenhouse gases, such as methane, are even better at absorbing radiation energy in the infrared spectrum than is carbon dioxide. See also p29.

CO_2 makes global temperatures rise because the gas absorbs heat which would otherwise be released back into space.

CO_2 IS NOT THE WORST GREENHOUSE GAS

- **CO_2** = 1 GWP (Global Warming Potential)
- **Methane** = 86 GWP
- **Laughing gas** = 268 GWP
- **Carbon tetrafluoride** = 4950 GWP

SHUTTERSTOCK

WHAT IS THIS? · Sun dogs or mock suns

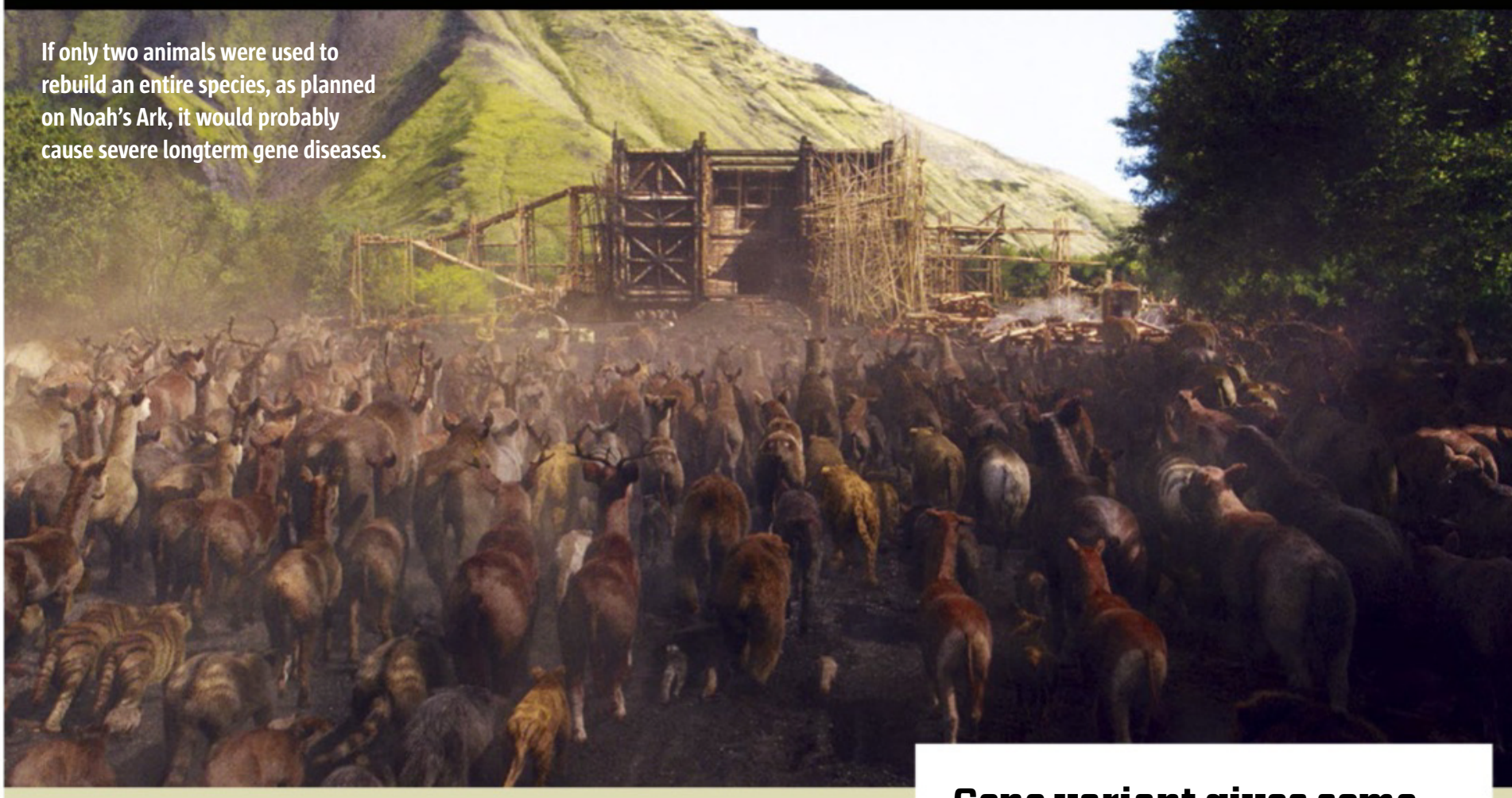
Bright dots flanking the Sun are known as 'sun dogs' or 'mock suns'. The phenomenon is due to light being refracted in ice crystals.

1 'Sun dogs' occur when sunlight passes through thin clouds of hexagonal ice crystals deep inside Earth's atmosphere. The crystals work as prisms that refract the light.

2 If the ice crystals are haphazardly orientated, all you will see is a bright circle around the Sun – a halo. The most common halo has a diameter of 22 degrees.

3 If the crystals lie more horizontally, the larger hexagonal plate-like ice crystals will refract light on this plane. If the Sun is on the same horizontal plane as the viewer, as at sunset, the result can be two very bright spots ('sun dogs'), one on each side of the Sun.

SHUTTERSTOCK



If only two animals were used to rebuild an entire species, as planned on Noah's Ark, it would probably cause severe longterm gene diseases.

Two animals: enough to save a species?

In the movie 'Noah' and the biblical story of Noah's ark, two of each animal are brought aboard the ark. But could a population be rebuilt realistically from just two animals?

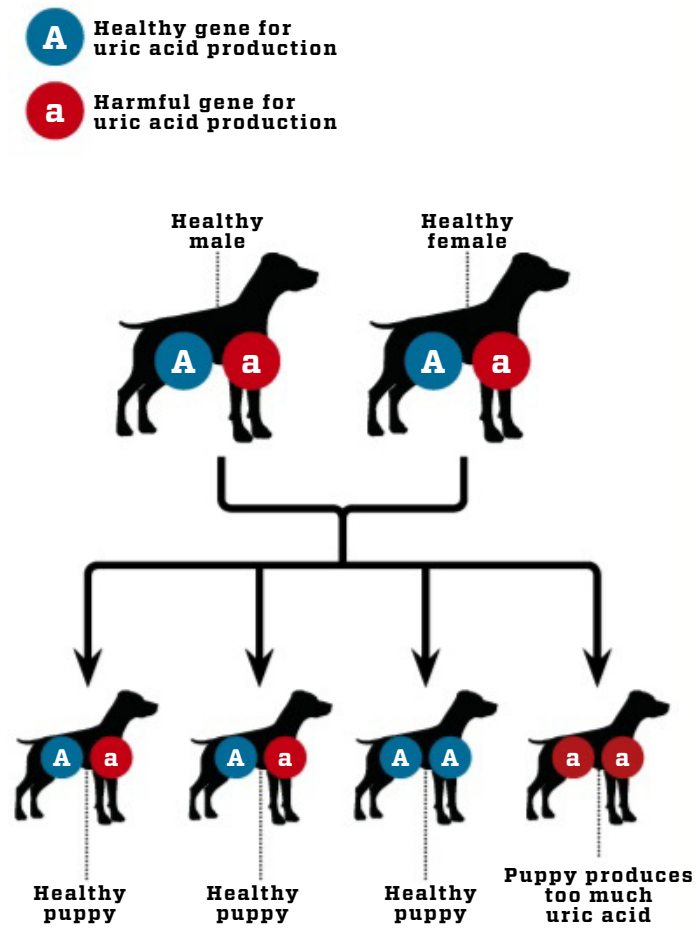
BIOLOGY If an animal species is reduced to only one male and one female, such an extreme bottleneck event would make future generations highly inbred. Mating between brother and sister or parents and offspring could not be avoided, likely causing poor fertility and viability. Inbreeding is harmful because it reduces the genetic variation of the animal group, so harmful gene variants accumulate, with potentially fatal consequences.

Most genes come in two variants, of which one might be harmful. If the other gene variant is functional, it will normally outcompete the harmful one, and the animal will be heterozygous for the gene in question. But when two heterozygous animals mate, their genes are mixed, with the harmful gene variants ending up in the same embryo in 25% of cases, making those offspring homozygous for the gene in question and so less viable. In a small population in which inbreeding cannot be avoided, the risk rises of heterozygous animals mating.

Biologists are highly aware of the consequences of inbreeding in zoos and dog breeding, where new breeds are produced based on very few individuals. Nevertheless, some dog breeds still struggle with inbreeding symptoms. Dalmatians, for example, are susceptible to kidney stones because of a harmful gene variant which, if it occurs in a double version, releases excessive levels of uric acid into their urine.

Gene variant gives some Dalmatians kidney stones

A harmful gene variant can make Dalmatians release too much uric acid, causing kidney stones. Though the parents are not themselves ill, they carry the harmful gene, which will be expressed in 25% of puppies.

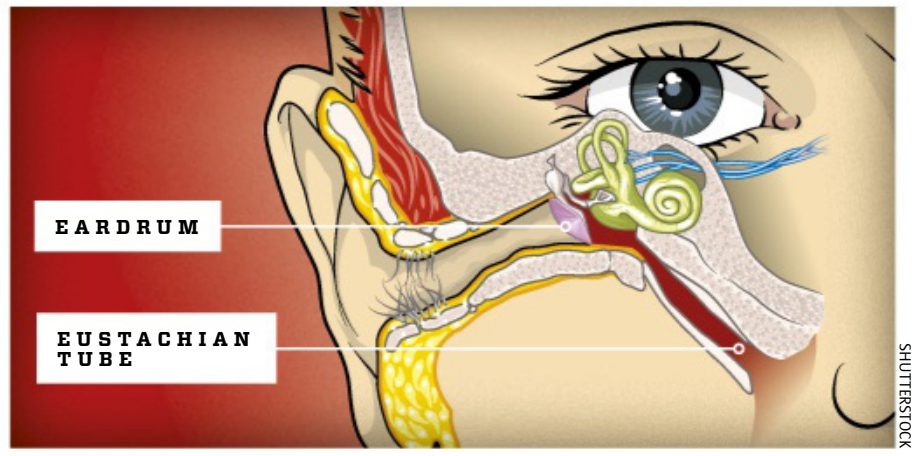


ILM/RITZAU SCANPIX

Why do my ears 'pop'?

HUMANS The 'pop' of the ears experienced in a plane during ascent and descent comes as the eardrum falls back into place.

The middle ear and the pharynx are connected via the eustachian tube, which is shut most of the time. But when you swallow or yawn, the tube opens to equalise the pressure on either side of the eardrum. During a flight, the pressure changes in the cabin of the aircraft – and so affects the external sections of the ear. By yawning or swallowing, you can bring the areas behind the eardrum to the same pressure, making the drum fall back into place. But the pop of a yawn doesn't always come from the auditory canal; a small buffer disc of cartilage in the jaw joint can also 'pop' when the mouth opens.



SHUTTERSTOCK

When the pressure in the eustachian tube is equalised with the pressure in the outer ear, the eardrum falls back into place with a 'pop'.

⊕ PHYSICS IN PRACTICE · Do stones fall more slowly on a high mountain or in a low valley?

A stone falls faster when dropped at the top of a mountain than when dropped in a low valley, because the air is thinner on the mountain, and the friction from air drag is therefore lower.
If the differing air drags were not a factor, the stone would actually fall more slowly on the mountain, because it is further away from the Earth's centre, so the gravitational acceleration is lower.

EARTH'S SURFACE

GRAVITATIONAL ACCELERATION: At the Earth's surface, it is approximately 9.81 m/s^2.

AIR DRAG: At the Earth's surface the air offers higher resistance, so the stone falls more slowly than on a mountain.

MOUNT HUASCARÁN

GRAVITATIONAL ACCELERATION: On Mount Huascarán in Peru, it is 9.76392 m/s^2, slightly weaker than at the Earth's surface.

AIR DRAG: The air is thinner, so the stone falls faster.

SUIZAPERUANA

SCALE

How lethal is Australia's inland taipan's venom compared to a viper's?

Inland taipan

The world's most poisonous snake lives in remote regions of arid central Australia. One single bite from the inland taipan delivers sufficient potent neurotoxin to kill more than 100 people. Thankfully, bites are rare.

SHUTTERSTOCK

50,000

times more lethal

SHUTTERSTOCK

Viper

The viper is common in Europe except in the northernmost regions of Sweden, Norway, and Finland. Viper bites are also relatively common, with 1000+ recorded annually in Sweden. Bites rarely require hospitalisation, and only 0.2% are lethal.

ANTIVENOM FROM NANOPARTICLES? see p48

T. FRAZIER M./GETTY IMAGES

Plants can smell, see, and feel

Plants do not feel pain in the same way as animals, but they do react strongly to their surroundings.

SOUNDS Plants grow either towards or away from sources of sound, depending on the frequency.

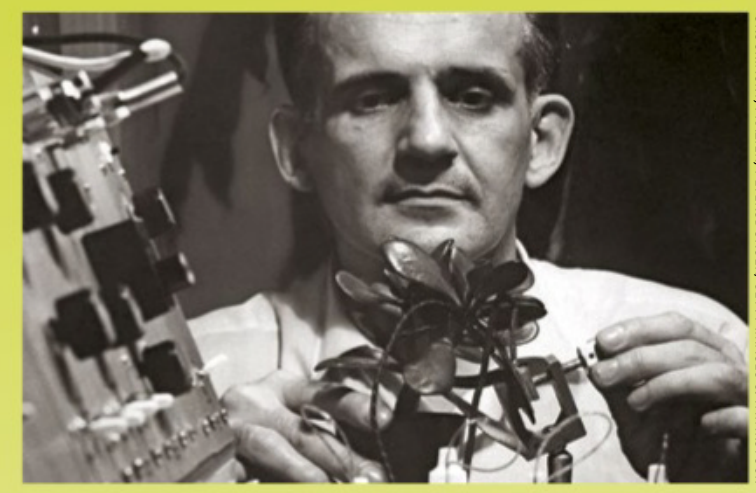
LIGHT Plant shoots grow in the direction of light, while their roots do the opposite.

SMELLS Parasitic plants use smells to find their preferred host plants.

Can plants feel pain?

BIOLOGY In the 1960s, CIA agent Cleve Backster hooked plants up to a lie detector as he held a match under a leaf or cut the leaf off. The plant reacted like a person under high stress. Just as interestingly the plant also reacted when he tortured other plants in front of it. He concluded that plants must be able to communicate with each other.

Scientists today are pretty sure that plants cannot feel pain in the ordinary sense of the word, as they have no central nervous system. But plants certainly react to light, sound, smells and touch. And they also communicate with other plants, one example being when they liberate warning chemicals if attacked by herbivores.



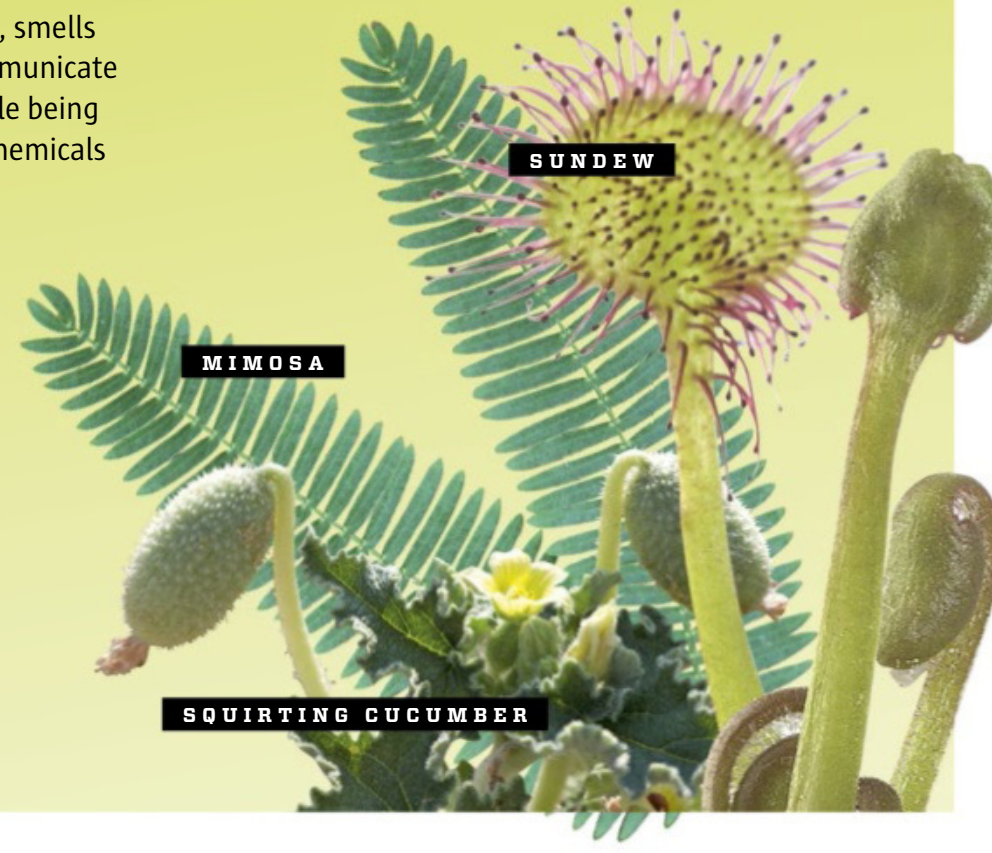
GROSKINSKY, FRAZIER, PETERSBURGER/GETTY IMAGES & THINKSTOCK

In the 1960s, interrogation specialist Cleve Backster used a lie detector to show that plants react to 'torture'.

SUNDEW – This carvinorous plant captures small insects, using an entire leaf to curl up around the prey.

MIMOSA – When people or animals touch the leaves, these collapse after a few seconds, hanging slack.

SQUIRTING CUCUMBER – The mature fruit of this plant disperses seeds by squirting a seed-filled liquid several metres through the air.



Why is sea water salty?

GEOLOGY Sea water is salty through substances that have been supplied by rivers very slowly throughout Earth's lifetime. The substances are liberated from the land via a process known as weathering, a slow chemical breakdown of rock which dissolves the rock into ions such as sodium and chlorine. These then combine to produce the minerals in sea salt.

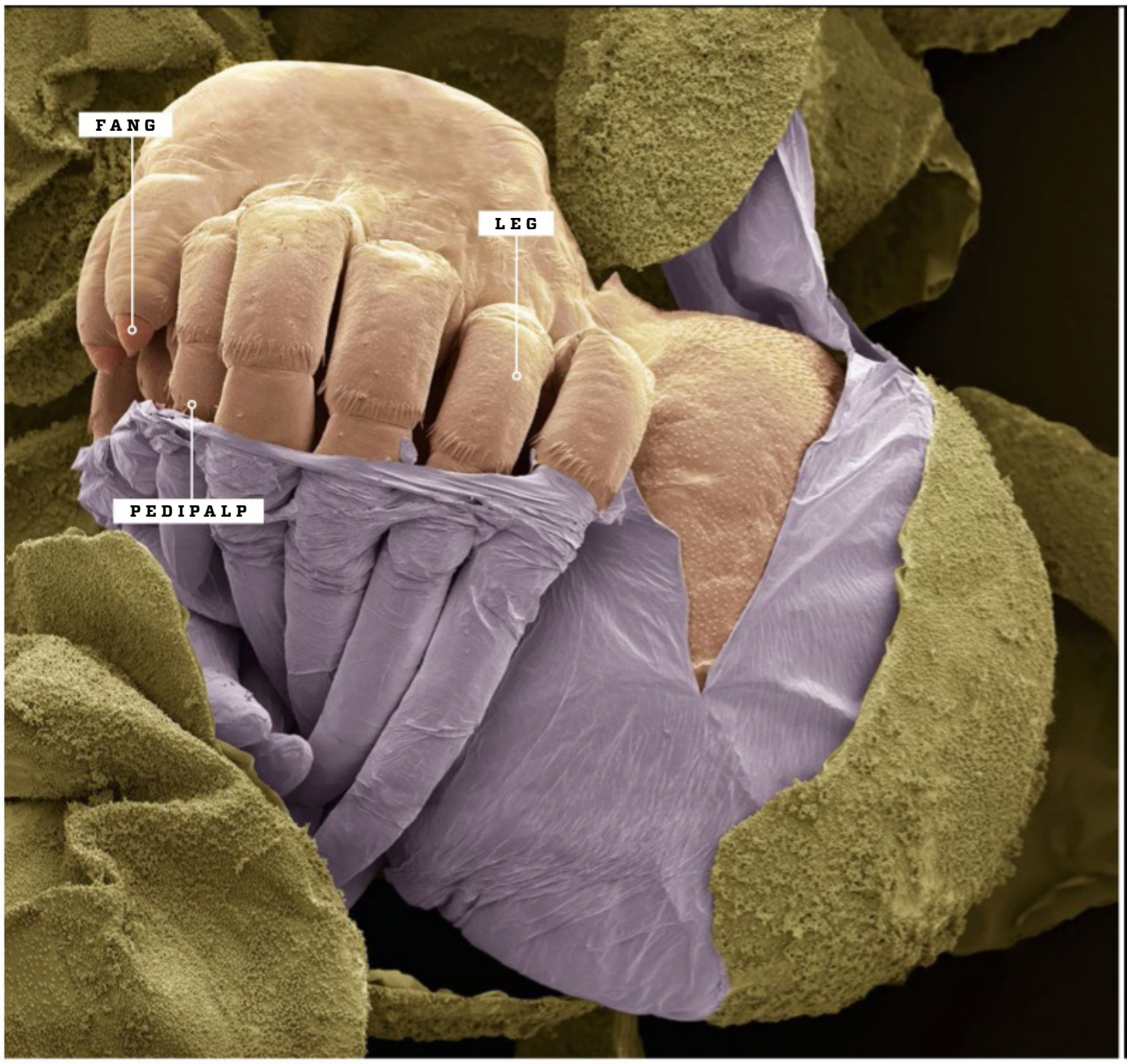
Relatively shortly after its formation, before the oceans existed, the Earth had areas of water collected in huge lakes located in meteor craters and other depressions. The water in the first oceans fell as rain and was hence fresh, but it slowly became more salty over time from the weathering described above. Today, the oceans include an average of 3.5% salt.

SALTIEST WATER

- **Don Juan salt lake (Antarctica):** 40% salt
- **Kara-Bogaz-Gol lagoon (Turkmenistan):** 35% salt
- **Assal salt lake (Djibouti):** 34.8% salt
- **Dead Sea (Israel and Jordan):** 33.7% salt

The high levels of salt in the water of the Dead Sea provide such buoyancy that it is almost impossible to dive underwater.

CLOSE-UP · Newly-hatched spider



An artificially-coloured photo from a scanning electron microscope shows a baby spider leaving the egg.

› To the right you can see the abdomen, to the left the forepart with four pairs of legs, a pedipalp that functions as the sex organ for males, and the jaws with their toxic fangs.

› Until the egg hatches, it is located in a sac of silk – an egg sac. The females of some spider species watch over the egg sac or carry it about with them.

› Spiders have hard exoskeletons that do not grow, so a newly-hatched spider must change its skin 5-10 times before it is fully grown and able to reproduce.

STEVE GSCHMEISSNER/SPL

... stars are twinkling?

From Earth, almost all stars look as if they twinkle or flash. Is this due to solar eruptions on the surface of the stars?

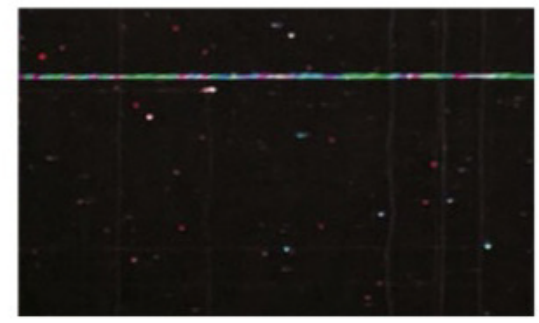
ASTRONOMY Astronomers only know of a few stars that actually flash: these are called variable stars. The reason that almost all stars seem to twinkle as we observe them from Earth is to be found in the atmosphere. The air above us is never really at rest; it includes countless small whirls and bubbles caused by slight temperature differences, or disruption from objects in motion including birds, planes, and the wind itself. These all combine to cause microscopic differences in the air's mass which function as tiny lenses that refract light on its way through the atmosphere. We see a more extreme version of this phenomenon over a hot sunlit asphalt road, where the light's refraction becomes more apparent.

Observed from Earth, stars are just tiny, pinhead-sized light sources, so even these tiny lenses in the atmosphere can efficiently refract their light. The refraction means that different colours of the stars' light reach us at different times, and this continuously changing colour from individual stars is what we register as flashes or twinkling. The brighter the star, the less the refraction affects its light, so the less it flashes. The same is true for planets such as Venus and Mars, which deliver light beams so wide that the lenses do not interrupt them at all.

Capture the colour change of starlight

By means of a mirror reflex camera with a powerful zoom lens, you can prove that the star's flashing is due to colour change.

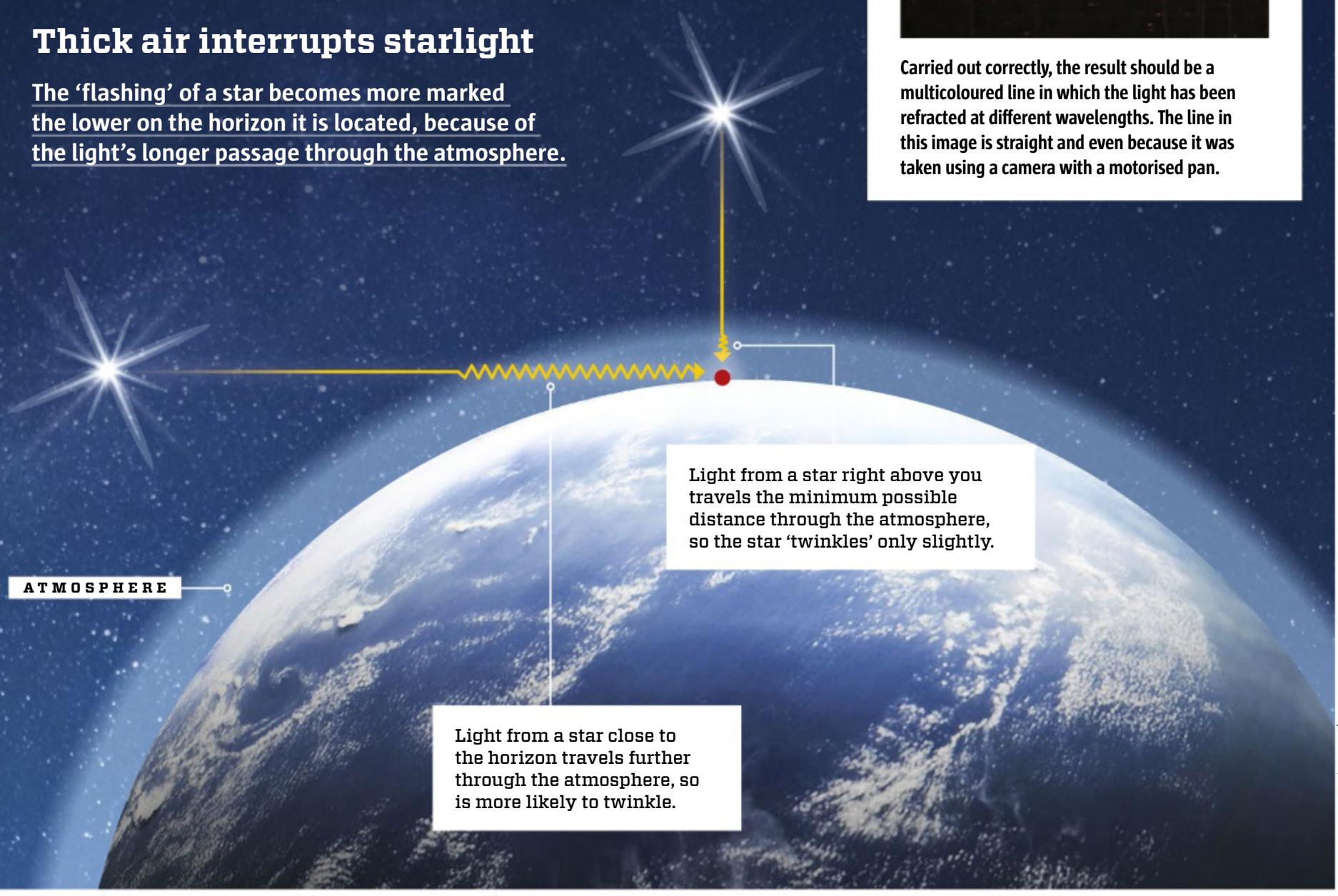
1. Place the camera on a tripod mount or a flat smooth surface. Point it at a star close to the horizon.
2. Use maximum zoom and a shutter speed of 10 to 20 seconds. Press the release button.
3. Turn the camera very slowly, so the star moves from one side of the image field to the other during the period in which the shutter is open.



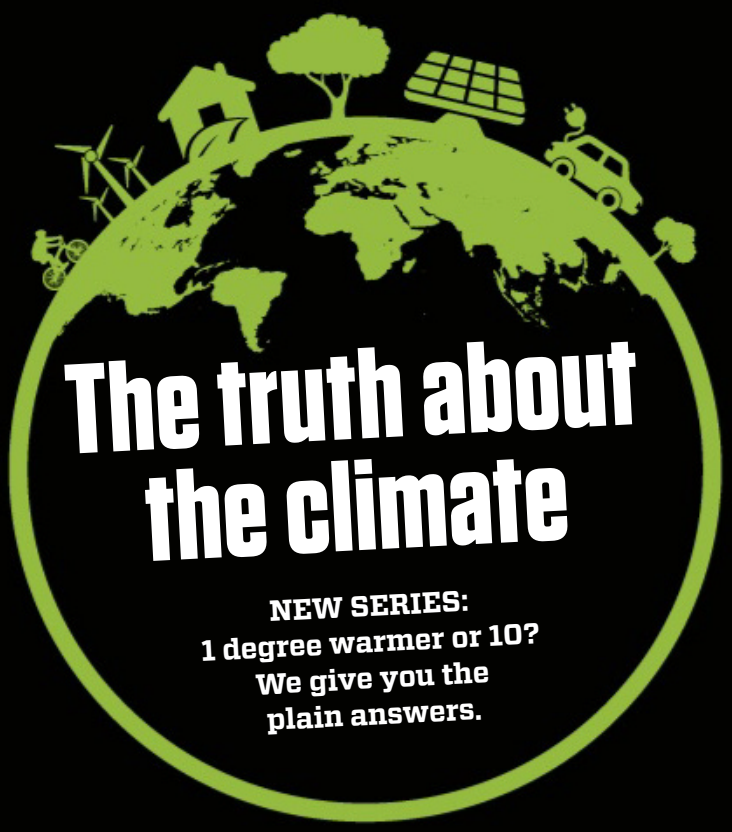
Carried out correctly, the result should be a multicoloured line in which the light has been refracted at different wavelengths. The line in this image is straight and even because it was taken using a camera with a motorised pan.

Thick air interrupts starlight

The 'flashing' of a star becomes more marked the lower on the horizon it is located, because of the light's longer passage through the atmosphere.



JESPER GRØNNE & SHUTTERSTOCK



The truth about the climate

NEW SERIES:
1 degree warmer or 10? We give you the plain answers.

We can still make it!

LAST CHANCE BEFORE THE INFERNO

- 200 million people fleeing from drought and extreme weather – it could be a future scenario, but the crisis can still be avoided if we grow our food on rooftops, add vegetables to our burgers, and power cars by surplus energy.

→ LIFE TOWARDS 2099: p26
→ A GUIDE TO CURBING CARBON: p36

HORROR SCENARIO

- We keep on emitting more carbon dioxide.
- Global temperatures rise by five degrees.
- Flooding and drought destroy cities and agriculture.

DREAM SCENARIO

- We curb our carbon dioxide emissions.
- We actively remove carbon dioxide from the atmosphere.
- The world will become only 0.5 degree warmer.

By **Niels Halfdan Hansen**

SHUTTERSTOCK & LOTTE FREDSLUND

HORROR SCENARIO

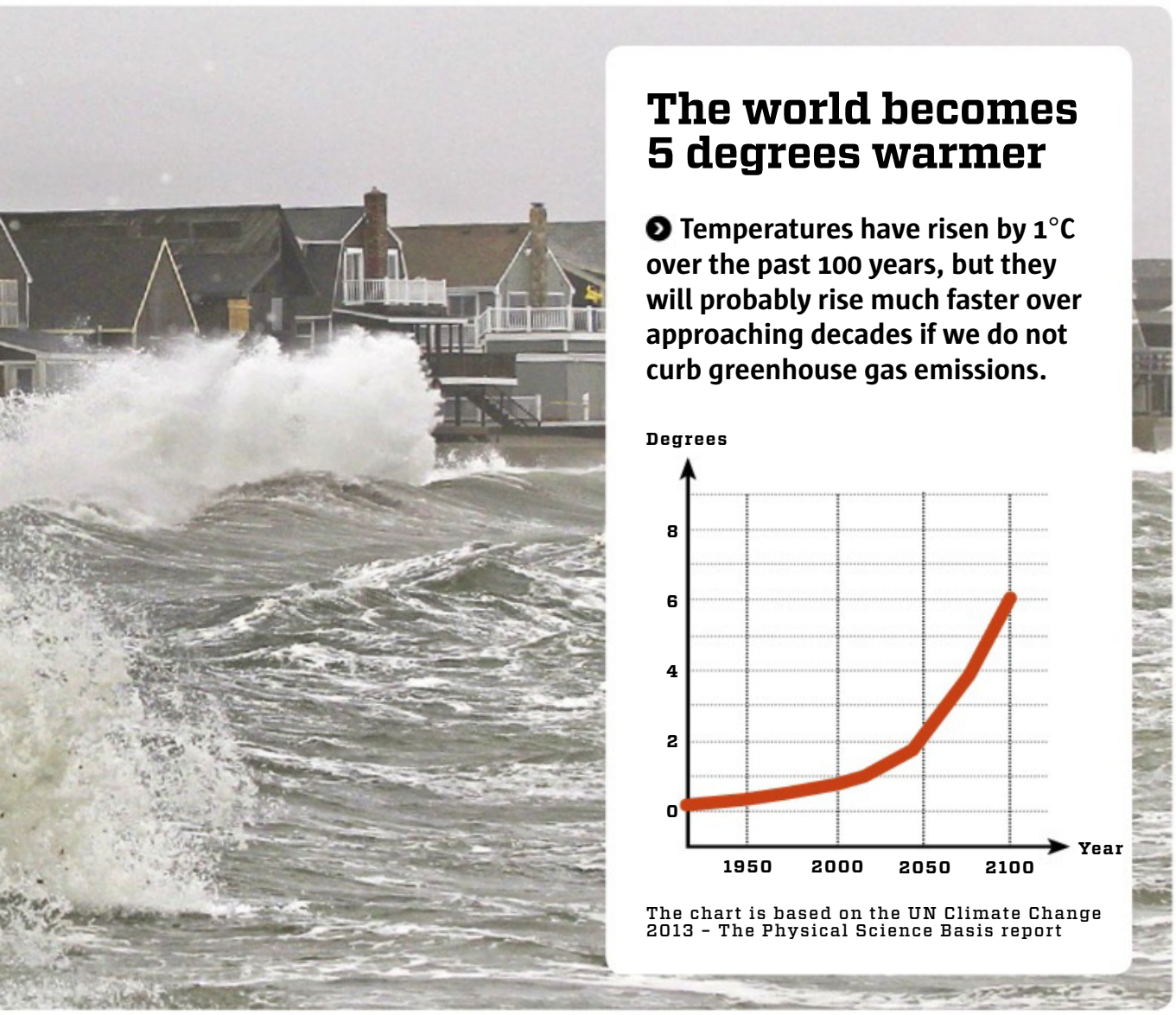
In a world five degrees warmer, violent weather phenomena will affect Earth much more often.

DAVID L. RYAN/BOSTON GLOBE/GETTY IMAGES

DREAM SCENARIO

In order to curb global warming, we must plant more trees and perhaps bring farming to the cities.

VINCENT CALLEBAUT



The world becomes 5 degrees warmer

Temperatures have risen by 1°C over the past 100 years, but they will probably rise much faster over approaching decades if we do not curb greenhouse gas emissions.

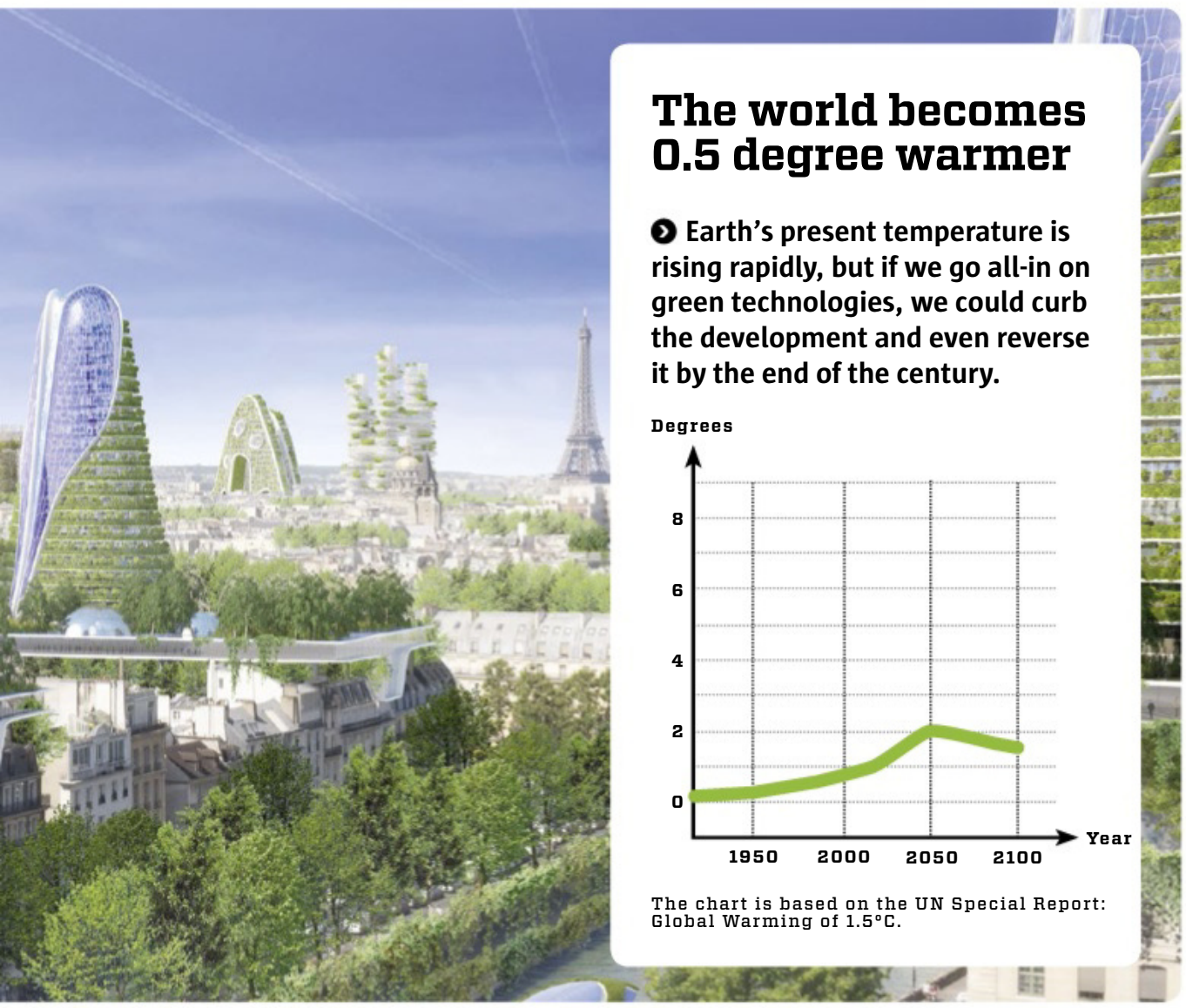
The chart is based on the UN Climate Change 2013 – The Physical Science Basis report

It is 2099. The Arctic sea ice is long gone, and the world's major glaciers in Greenland and Antarctica are bleeding billions of cubic metres of meltwater. Huge regions in Africa, Asia and South America are scorching lifeless deserts, while rises in ocean levels force the 11 billion people of the world to live in densely populated areas in the temperate zones. Every year extreme rainfall, tornadoes, hurricanes and flooding destroy ever more of the quickly disappearing agricultural regions, and food is scarce.

That is what the future for you and the planet might be like if atmospheric carbon dioxide levels keep rising the way they are now. At worst, global temperatures could increase by more than five degrees before the end of this century, resulting in major food challenges, massive refugee flows, and a constant struggle to protect ourselves against disasters caused by the weather.

Emissions are still increasing

1 or 10 degrees warmer? Scientists' climate models have been greatly improved over recent decades, but they are still having ▶



The world becomes 0.5 degree warmer

Earth's present temperature is rising rapidly, but if we go all-in on green technologies, we could curb the development and even reverse it by the end of the century.

The chart is based on the UN Special Report: Global Warming of 1.5°C.

It is 2099, and temperatures have fallen slightly again this year. In South America, the rainforest is gaining ground again, farmers are reclaiming farmland back from deserts throughout the world, and in the Arctic a small area with sea ice survives the summers. In a joint effort, the nations of the world have forced temperatures down to a level that is only 1.5 degrees above the level before global industrialisation.

That is what our future could be like, if we act now. In 2015, the nations of the world agreed to keep temperature rises to a maximum of 1.5 degrees. The world has already become one degree warmer since industrialisation, leaving a margin of only 0.5 degree. To fulfil our ambition, we must curb our carbon-dioxide emissions – but other initiatives are also required, since even if we stopped our emissions today, the carbon dioxide already in the atmosphere would keep on heating the world.

More warming

The cause of the global warming that we experience right now is the emission of ▶

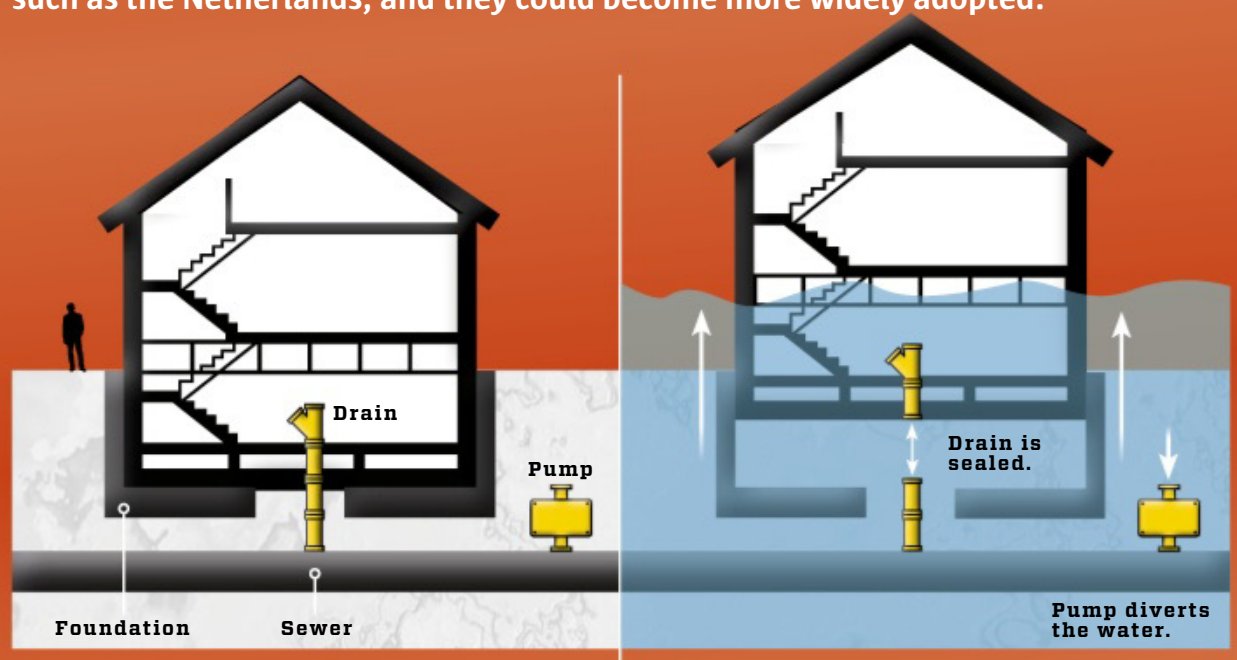
CHALLENGE

The world is under water

In a world five degrees warmer, flooding will be markedly more frequent than today. The heat will cause more extreme rainfall, and when ocean levels rise by several metres, major areas will flood in storm surges. Some scientists even think that the number of geological natural disasters such as tsunamis will be more frequent.

House floats on water

Floating homes are already built in areas threatened by flooding, such as the Netherlands, and they could become more widely adopted.



SHUTTERSTOCK

HOUSE SUPPORTED BY FOUNDATION

1 The house rests on its foundation. The basement without doors and windows is made of a waterproof material. The house's drain hooks up with the sewer with self-sealing nozzles.

BASEMENT LIFTS HOUSE

2 In case of flooding, the house floats due to the lift of its air-filled basement, and the drain is sealed. A pump removes the water, and the house sinks back into position.

greenhouse gases, including carbon dioxide and methane from energy generation, transport, and farming. The gases capture some of the heat radiation from Earth and reflect it back again. When the level of these gases increases, more radiation is held back, and Earth's surface becomes warmer. Over the past few hundred years, the quantity of carbon dioxide has increased by 45%, whereas the quantity of methane has increased by 150%.

Since the global climate agreement of 2015, which included the aim of a maximum temperature rise of 1.5 degrees, scientists have warned that it might already be too late to fulfil the ambition. The atmosphere's content of carbon dioxide has risen from 280 millionths to over 410 millionths, meaning that temperatures would keep on rising even with the quantity of carbon dioxide maintained at the present level. So we can no longer realistically aim to prevent temperatures from rising more than 1.5 degrees – that line will probably be crossed within a few decades. Instead, the ambition must be to have temperatures fall back to the agreed 1.5 degrees before 2100, and to make sure that they remain stable after that. This can probably be achieved if we reduce our emissions of carbon dioxide considerably, and try to actively remove greenhouse gases from the atmosphere.

Costa Rica is the role model

Scientists estimate that our emissions of carbon dioxide must be no more than 2.1 tonne per capita per year if temperatures are to be stabilised by 2100. Some countries in Africa and South America presently emit less than that, whereas others emit far more. In Western Europe, the number is 3-6 times higher. In Australia, and in North America, it is about 8 times higher. The global average is currently some 5 tonnes per capita per year.

In order to reduce emissions, we must switch to energy sources that do not emit greenhouse gases. We are already doing that, but the speed must be increased. Some nations, such as Iceland, Norway, and Costa Rica, are close to getting 100% of their energy from green sources, and American scientists estimate that the rest of the world could do the same before 2050. If we act quickly and go 'all in' on green energy now, we can create a global network before the end of the century that will stably supply climate-

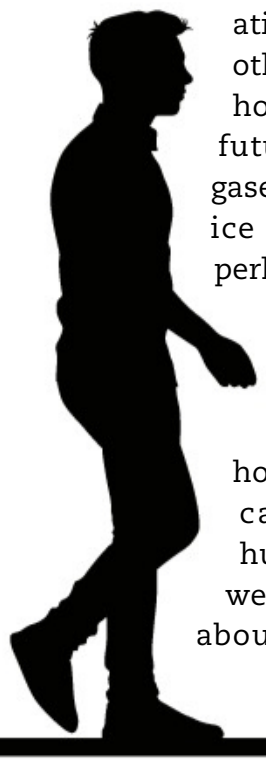
HOMES

CHALLENGE

Houses cannot consume energy

In the western world, buildings consume 40% of energy, so development of new housing types is crucial. In the EU, all new homes from 2020 must be much more energy efficient, and future homes must be completely independent of external energy sources. In Australia, only in the Australian Capital Territory is it even mandatory currently to disclose the energy-efficiency ratings of all new dwellings.

difficulties handling a future in which we keep on emitting huge quantities of greenhouse gases. Even if we somehow knew exactly how much carbon dioxide we would emit, the uncertainty about the future climate would still be considerable. Such uncertainty is due to still-imperfect climate models. These can very accurately simulate the climate of the past century when scientists feed them atmospheric data about greenhouse gases, the rate of major volcanic emissions, and the variation of solar radiation. On the other hand, we still cannot say how well the models handle a future with more greenhouse gases and significant variation of ice volumes, vegetation, and perhaps other factors still unrecognised or unknown.



The possibility of these unknown factors makes it difficult to calculate exactly how sensitive the climate is to carbon dioxide. In spite of hundreds of thorough studies, we still have only a rough idea about how much temperatures will rise if the quantity of carbon dioxide in the atmosphere is doubled. Some estimate that the rise will be as modest as 1.5 degrees Celsius, whereas others estimate it to rise by 4.5 degrees.

The date when carbon dioxide levels in the atmosphere will double (compared with levels in the era before industrialisation) depends on our actions now and in the future. If we continue our existing emissions of carbon dioxide, the doubling will be a fact in 2080. And if the world's 9.7 billion inhabitants of 2050 would all like to live the way we do now in the western world, the doubling will be reached before 2060.

Many nations of the world have begun to join the struggle to save the climate, but there is still a long way to go. According to data from the International Energy Agency, the world's energy consumption increased by 2.3% in 2018 as compared to 2017. The data also shows that the fossil fuels of coal, oil, and gas were responsible for the majority of the increase, and so our greenhouse gas emissions rose by 1.7% in 2018 as compared to 2017. So things are still going in the wrong direction. The consequences will affect everyone in the world.

200 million people flee

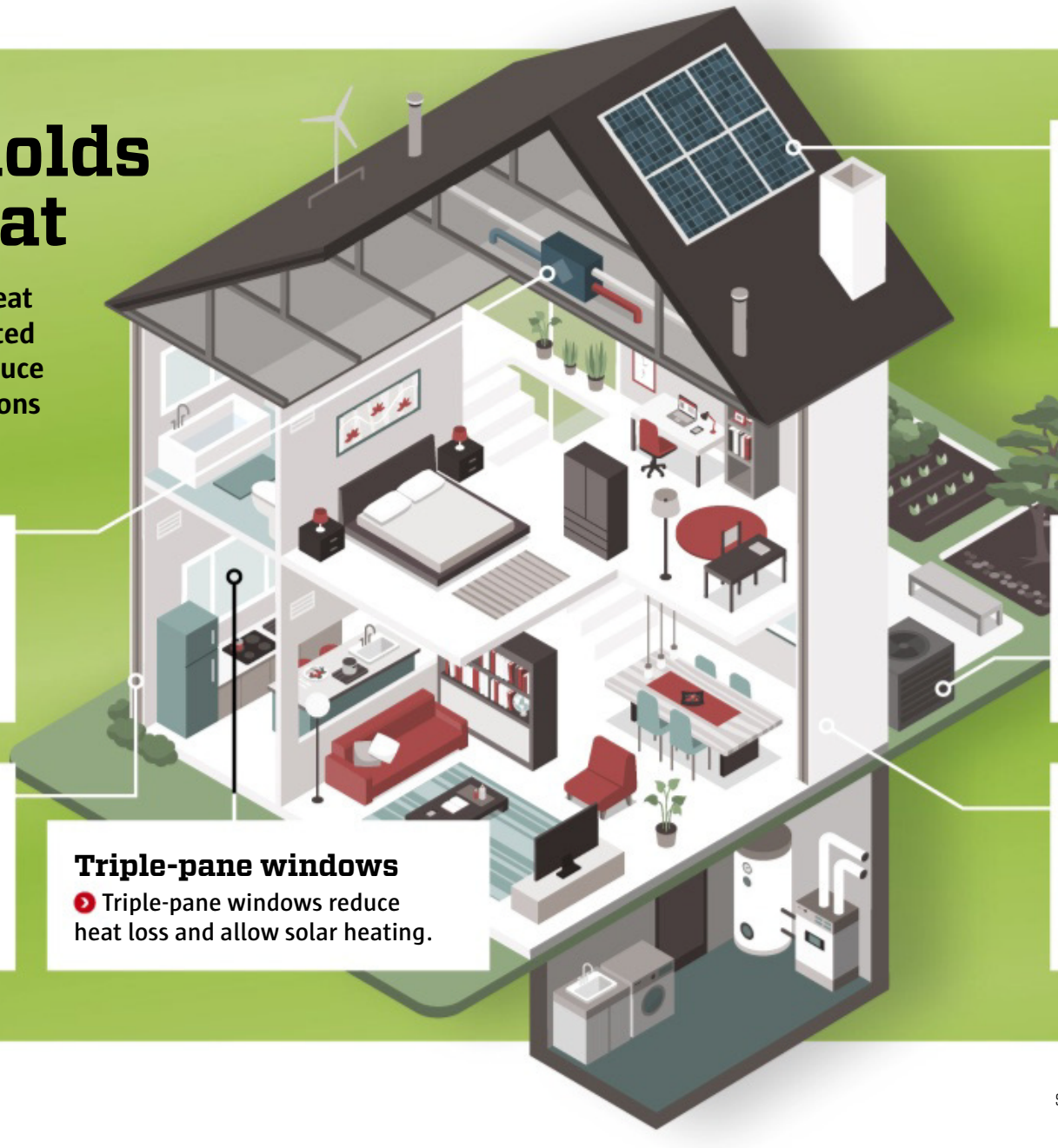
Higher temperatures mean that there is more energy in the atmosphere – and the energy fuels thunderstorms and tropical storms. The heat will also lead to more extreme precipitation patterns. Wet regions will typically be even wetter, and dry regions will be drier. Low-lying coastal nations will be repeatedly flooded by water from the ocean or the sky. And in dry regions which are far from the ocean, the precipitation will be so sparse and temperatures so high that farming will become impossible.

The result of the change will most likely be an influx of refugees from the most uninhabitable regions. A series of studies have concluded that climate change will force around 200 million people to leave their homes in 2050 – and the number will probably be much higher towards the end of the century if we do not curb the trends. Many of the refugees will head towards Northern Europe, where farming is still possible, and in some nations the refugees might make up the majority of the population.

Unlike the subtropics and tropics, Northern Europe might experience a brief improvement in farming conditions when

House holds on to heat

Smart thermostats, heat re-use and roof-mounted solar panels could reduce carbon dioxide emissions for a home to zero.



Solar cells

Solar cells produce all the power and heat that the house requires.

Heat pump

Pumps heat the house in the winter and discharge heat in the summer.

Smart thermostat

A smart thermostat turns down the heat at night or when the house is empty.

Heat exchanger

A heat exchanger reclaims outward-bound heat and heats incoming air.

Insulation

Up to 50cm of insulation keeps the house warm in winter and cool in summer.

Triple-pane windows

Triple-pane windows reduce heat loss and allow solar heating.

SHUTTERSTOCK

temperatures rise by the first one or two degrees, because plants such as corn will enjoy improved conditions.

However, drought and extreme weather phenomena will likely curb the improvement once temperatures rise even further. And the heat will also see a series of pests spreading towards the north in Europe, and further south in Australia. The cane toad, for example, is thought to be moving south into New South Wales at approximately 3-4km per year, based on assumptions about the species' environmental tolerances. But this may be punctuated by brief periods of relatively rapid movement, with the predictions further complicated by cane toads proving to adapt rapidly to Australian conditions.

Or consider the Colorado potato beetle, which can destroy potato crops in huge regions. They are rarely observed north of Germany, and then only in small numbers, probably because the winters are so cold that the beetles die. But according to Chinese and American scientists, a temperature rise of 2-3 degrees would allow the beetles to live and breed in major parts of Scandinavia.

The heat will also pave the way for animals that carry dangerous viruses. The bluetongue disease, which is carried by some midge species and affects cattle and sheep, is already heading up through Europe, partly because milder winters allow the midges to spread north. That could have major consequences for meat production.

But the heat is also likely to bring diseases that could affect people. Health authorities will hence face major new challenges that are only exacerbated in regions where populations have multiplied in size.

Cities must protect themselves

The growing population and reduced farmland will force us to find new solutions when it comes to providing food. GM crops that can resist a harsher climate will probably be necessary. And we must reduce our consumption of meat markedly, as meat production requires much more farmland. An American study concludes that by 2050 we could save some six million square kilometres of land if the people of the world all consumed only vegetarian food.

We will also have to invest in flood prevention. Coastal cities may need dikes and levees that can hold back water during severe storms and storm surges, and still

CHALLENGE

Billions lack food

The UN estimates that the Earth will need to feed more than 11 billion people in 2100. That could barely be achieved with the present climate, and in a world five degrees warmer, with extreme precipitation and drought, it would be almost impossible. The solution is to develop much more efficient agriculture than we have today.

FOOD

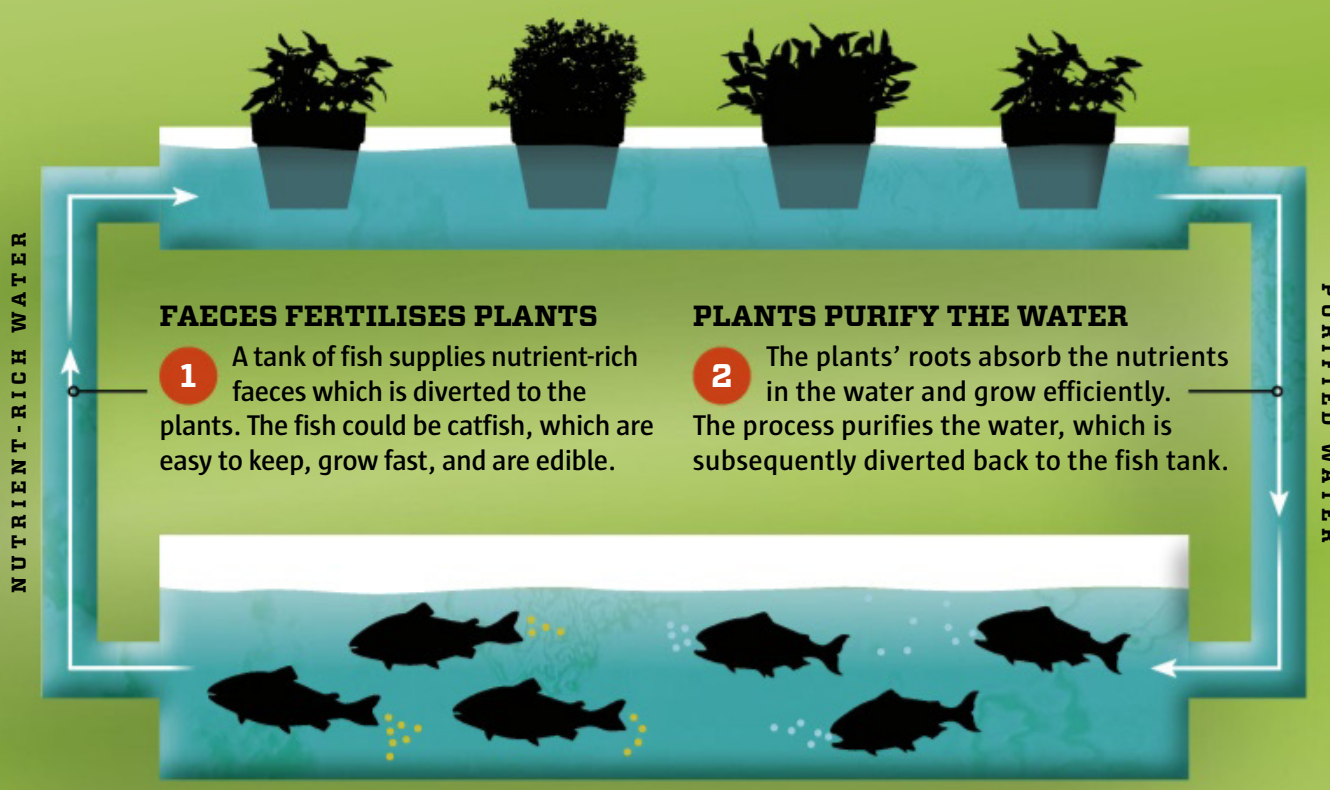
CHALLENGE

Agriculture shift leaves space for trees

'Afforestation' (creating new forests) will be a key strategy in the effort to remove carbon dioxide from the atmosphere. In order to get space for many more trees, we must reduce farmland. That could be done by consuming less meat, but we could do even more if we moved much of our food production to the cities.

Cities grow food

Farming must be moved to rooftops and huge greenhouses in cities – and fish will ensure a high yield with minimum effort.

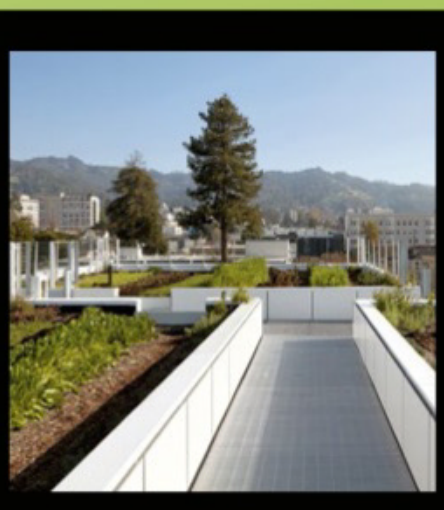


GM plants to provide extra food

High-yielding corn plants and salt-tolerant rice could ensure sufficient food for the world.

Scientists have two strategies for producing enough food in a world ravaged by flooding and drought. First of all farmers must grow more food per hectare. Scientists managed that in 2018, when they created GM corn which yielded 15% more corn per plant. Secondly, we need to grow crops in areas that used to be impossible to cultivate. Scientists have already changed the genes of rice so that the plants can tolerate more salt in the ground. That is a major advantage when farmland is often flooded by ocean water, which ends up in the ground water.

Gene modification could improve photo-synthesis in corn by increasing the plant's rubisco content.
SHUTTERSTOCK



STANLEY SAITOWITZ/NATOMA ARCHITECTS INC.

VEGETABLES ON ROOFTOPS ELIMINATE NOISE AND POLLUTION

In the Garden Village of Berkeley, USA, the roofs are linked with footbridges and equipped with raised garden beds and green-houses. According to studies, this type of vegetation both reduces noise and removes pollution from the air. Local food production also minimises the need to 'import' food from other places, delivering reduced transport carbon-dioxide emissions.

friendly energy for the entire world, 24/7. Regions close to the Equator will generate constant solar energy, while the belt of westerlies in the northern and southern hemispheres will generate wind energy. With such a system in operation, power stations could no longer be required.

In addition, we must phase out petrol-powered cars. In several European nations it is now cheaper to have an electric car than a petrol-powered car, and electric cars are quickly becoming more popular. But even in the most climate-conscious nations, electric cars still make up only a small percentage of total cars, so the struggle has not been won yet. And we need technological improvements that can reduce the pollution of climate-friendly cars even more. The production of electric car batteries pollutes, and the solution is either to improve battery technology or to replace them with fuel cells that are powered by hydrogen. The latter is probably the most promising solution, but the technology is not yet optimal.

The last major source of carbon dioxide is concrete, the production of which is responsible for about 8% of the world's total emissions, so that the concrete industry emits three times as much as the aircraft industry. New types of climate-friendly concrete will soon hit the market, such as biocement that is made by means of micro-organisms. In recent years, engineers have also experimented with using wood to replace concrete, while new technologies have enabled the design of wooden houses that can tower up to 85 metres or 18 storeys high. The strategy is promising, because trees remove carbon dioxide from the atmosphere and the carbon dioxide is subsequently stored safely in the walls of wooden houses. And even if the production of concrete increases in the decades to come, it will be possible, according to the International Energy Agency, to reduce the concrete industry's emissions of carbon dioxide by more than 25% by 2050, collecting and storing the gases emitted in the course of the production.

Trees reduce temperatures

Technology allowing a dramatic reduction of our carbon dioxide emissions already exists, and new ones are constantly being developed to help us fulfil our ambitious goals even faster. Still, several studies indicate that we need to add activities that

CHALLENGE

Extreme climate obstructs transport

A climate with extreme precipitation, higher temperatures and severe storms causes problems for all types of transport. Major water masses flood the roads, the heat makes rail tracks crooked, and an unstable atmosphere multiplies the risk of violent turbulence.

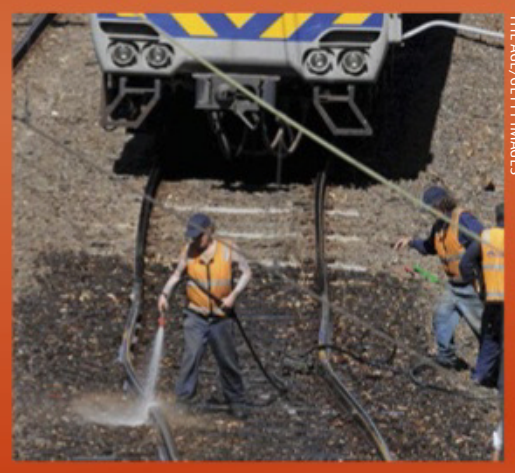
Lasers to save your flight

Tiny holes in the road, white rails and lasers could ensure that we can continue to go from one place to another in spite of climate challenges.

SHUTTERSTOCK

Roads that can swallow flooding events

Ordinary asphalt is dense, so all water has to be removed via gratings at the side of the road. Several companies are developing road paving with linked pores that allow the rainwater to pass through and then drain away.



THE AGE/GETTY IMAGES

White rails keep out the heat

Rail tracks expand and bend in the heat. A simple solution is to paint the rails white, so the heat is kept out. Moreover, some rail types have flexible connecting links that make sure the rails will not bend.

TRANSPORT

actively remove carbon dioxide from the atmosphere if we wish to avoid a temperature increase beyond 1.5 degrees. Several ground-breaking methods are now being tested around the world, but it remains unclear if they are sufficiently efficient to solve the problem. Luckily, another solution exists that we can implement right away: tree planting.

In 2017, scientists concluded that the re-establishment of former forests and forest protection could remove more than 7 gigatonnes of carbon dioxide from the atmosphere annually – more than all the emissions of North America. And the number could be more than twice as high if we are willing to change our eating habits. An American study shows that Americans' present food consumption requires almost eight times as much farmland as a vegetarian diet. Beef is the major culprit, as it requires 28 times as much land as chicken.

The transition to a diet without beef will become ever easier thanks to technological advances in the food industry. New plant-based minced 'meat' developed by American company Impossible Foods in 2019 attracted much attention during one of the biggest technology conferences in the US. The fake meat smells, tastes and feels like real minced meat, because the company has identified the proteins that give meat its smell, taste, and texture, then found comparable proteins in the plant kingdom. Moreover, the company uses genetically modified yeast to make some of the proteins.

Effort would save trillions

The world of 2099 will be markedly different from the present, no matter what we do. But if we focus on green energy, sustainable building materials and new food now, we can create a future in which we live on our own terms. Global warming will probably continue for a period of time even if we do our utmost – the world's average temperature will rise by 0.5 of a degree, and parts of the Arctic will experience a rise above 3 degrees. But the alternative is a future in which the climate is so extreme that we constantly struggle – a costly affair. When American scientists in 2018 calculated how much the US would save in the late 2000s if we focused on green technology and lowered the number of extreme weather phenomena, the result came out at US$224 trillion a year. SCI

CHALLENGE

Cars to be powered by green energy

In Australia, transportation was responsible for 18% of total greenhouse emissions in 2018; in Europe the figure is 30%. Cars are the worst – Australian cars emit roughly the same per year as Queensland's entire coal and gas-fired electricity supply. In order to reduce emissions, our cars must consume less energy and use climate-friendly energy sources – preferably without the use of polluting batteries.

ALEXTOV/GETTY IMAGES

Planes with lasers avoid turbulence

Global warming will cause more violent turbulence in airspace. Scientists from the Japanese space agency have developed a laser system that spots such 'invisible' turbulence 15km ahead of a plane, allowing it to steer clear.

further protection in a world where the ocean levels could rise by some 5cm a year.

Our homes must also be protected against the rough weather. Doors and windows must be reinforced to avoid damage during storms, while dense vegetation on rooftops could help keep out extreme heat. According to a Spanish study, plants on the roof curb 60% of incoming heat. Australian cities that already experience many scorching summer days will need such effective cooling solutions which do not, like air-conditioning, involve still heavier energy use.

A future in which we do not employ more green energy than today will see the world's known reserves of oil and gas being almost depleted. The emergency solution could be to base the world's energy production on coal, just as it was 200 years ago. Australia is rich in coal, and old mines elsewhere could be reopened. But coal is extremely polluting, so efficient removal of soot and sulphur from the emitted gases will be necessary, and such air purification might require 30% of the energy generated.

Ultimately, green energy will probably be our only option. Even then, frequent violent storms will mean that wind turbines and solar cells will require more constant and extensive maintenance, itself very costly.

Whether temperatures will rise by five degrees remains unknown, but most studies indicate that a considerable rise is inevitable if we do not act now. And even a rise of 1-2 degrees would have severe consequences. In either case, a major part of our technological development will need to focus on protecting ourselves against climate disasters, and to make sure that we can continue having our basic needs fulfilled. Although according to climate researcher Katherine Richardson, this type of climate change action is like taking aspirin against a life-threatening infection that we could have wiped out a long time ago by means of antibiotics – in the form of green energy. SCI

Shared and driverless cars

A smart, coordinated system of hydrogen-powered cars could make transport much more climate- friendly – and ensure that you always have access to a car.

Computers to coordinate shared cars

The car is driverless and part of a shared car system from which it can be requested via smart technology. Artificial intelligence coordinates the system to minimise car energy consumption.

Car printed in plastic

The entire car is 3D-printed in light, strong materials such as plastic, carbon fibre and light metal alloys. The new materials reduce weight and consequently energy consumption.

Motor powered by surplus energy

In a few years, surplus electricity from green energy sources can be used to split water into oxygen and hydrogen. The latter can be used as fuel.

Narrow tyres reduce friction

Rolling friction swallows some 15% of energy. Narrow tyres with high pressure can reduce friction by 30%.

GORAN MARINKOVIC/MICHELIN

LEND THE CLIMATE A HAND: HAVE FEWER KIDS

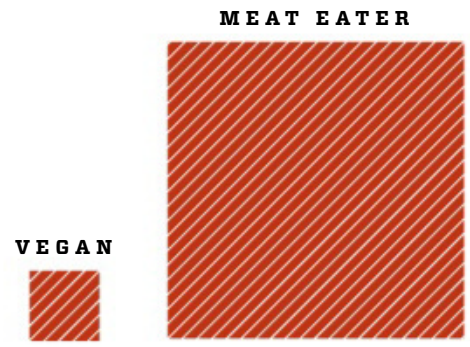
You know that you should reduce your carbon footprint, but you don't know where to begin? Scientists know what matters most. And if you hold off having kids, you can eat all the red meat you want...

Scientists guide you through the climate jungle

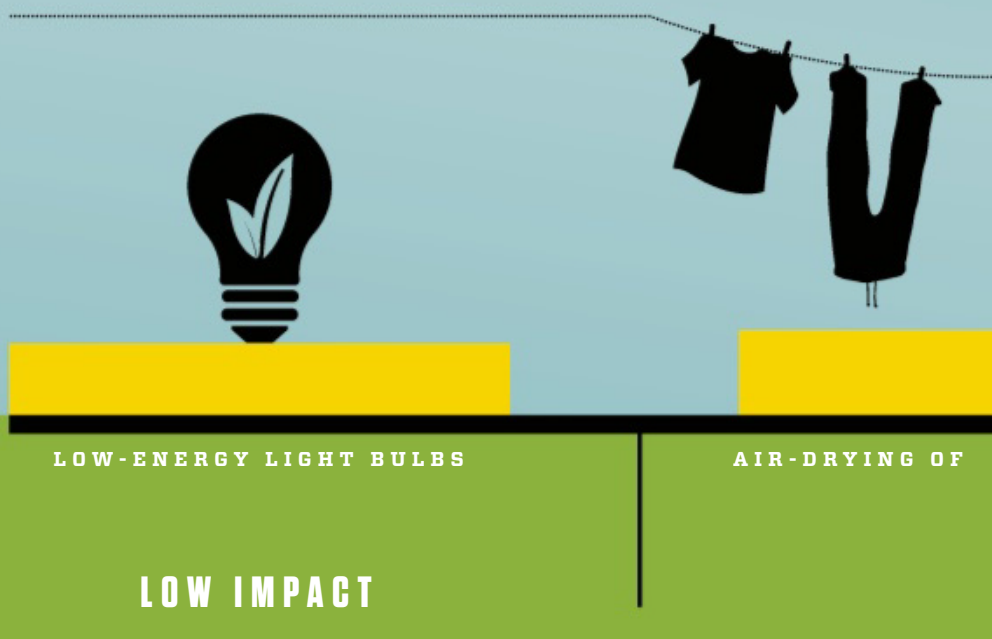
In 2017, Kimberly Nicholas from Lund University and geographer Seth Wynes compared 148 studies of carbon-reducing lifestyle changes such as recycling, washing clothes in cold water, and meat-free days. Their conclusion was clear: much of what you are already doing has almost no effect.

MEAT OCCUPIES HUGE QUANTITIES OF FARMLAND

The farmland that a meat eater requires in order to grow food for those animals is 18 times larger than the acreage required by a vegan. This contributes to climate change because, unlike forests, fields do not remove CO_2 from the atmosphere in the long term.



A meat eater occupies 18 times more land than a vegan.



By **Niels Halfdan Hansen**

Annual reduction:
0.8 tonnes of CO_2

Going vegan

Meat production emits major quantities of greenhouse gases, so vegans are automatically more climate-friendly.

Domestic animals such as chickens, pigs, and cows have their own carbon footprint. Unlike natural forests, cultivated fields and pastoral land cannot efficiently remove CO_2 from the atmosphere. The processing and transport of meat, milk and eggs also requires billions of kilometres of transport by truck and train annually. And not forgetting the fart factor – all ruminants (cows, goats and sheep) emit the aggressive greenhouse gas methane via stomach and intestinal gas. This means that if you eat meat, you put an extra load on the climate corresponding to 0.8 tonnes of carbon dioxide annually, compared to a vegan who does not consume products that are based on livestock farming. Domestic animals are, however, not the only ones that emit methane. It's also true for wild animals such as giraffes, deer, and wild cattle. But the reduction of natural populations does not neutralise the emissions from domestic animals. There are more than three times the cows in US farming today than there were bison on the prairie before humans came to North America.

Keep your feet on the ground

Annual reduction: 1.6 tonnes of CO_2

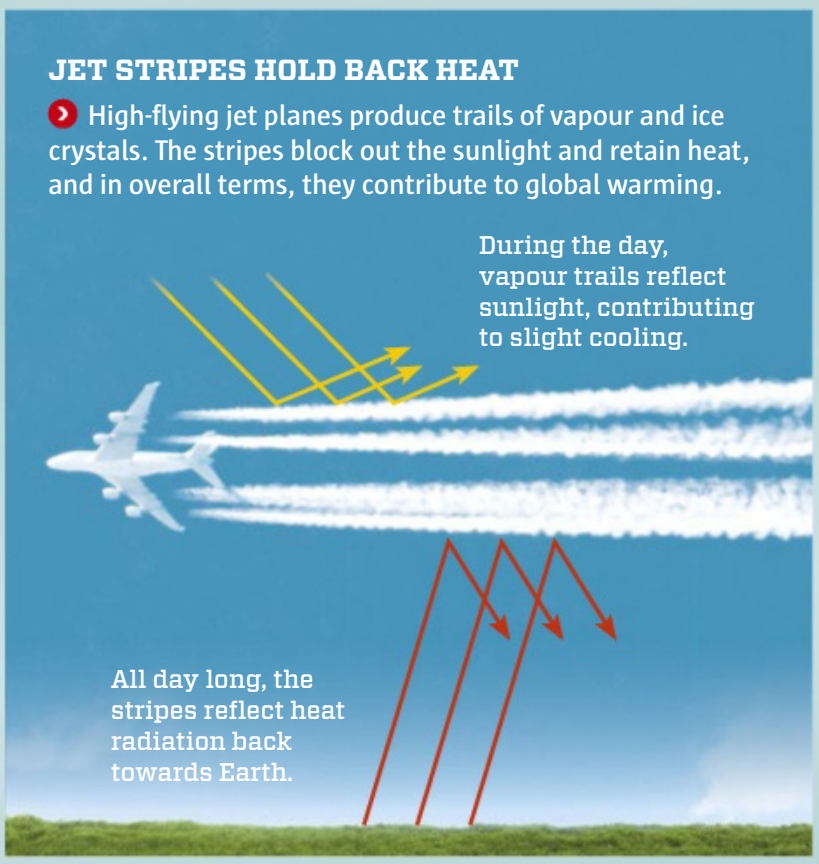
Airliners consume jet fuel that is based on crude oil, and they emit carbon dioxide. With increased global travelling, emissions from international aviation have doubled in the past 25 years, although individual planes have become more energy-efficient. According to scientists' calculations, for every long flight – such as to Europe and back – you do not take, you will reduce emissions by several tonnes of CO_2.

However, plane-fuel CO_2 emissions are not the only climate impact of aviation. The white stripes of water vapour and ice crystals in the sky behind high-flying jets also have an effect. The stripes reflect heat radiation sent into space back towards the Earth's surface, contributing to global warming.

SHUTTERSTOCK

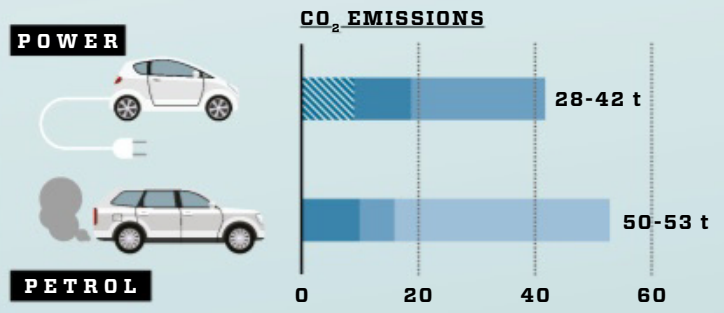
JET STRIPES HOLD BACK HEAT

High-flying jet planes produce trails of vapour and ice crystals. The stripes block out the sunlight and retain heat, and in overall terms, they contribute to global warming.



ELECTRIC CARS ALSO EMIT PLENTY OF CO_2

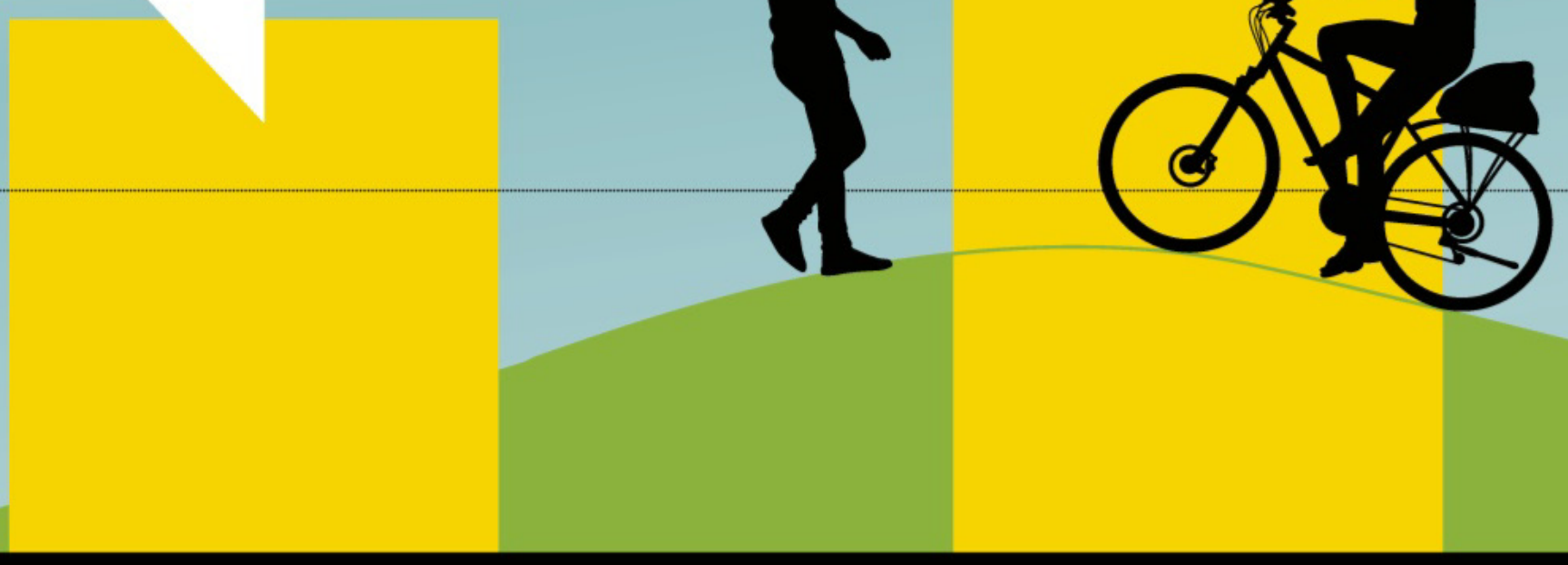
The production of electric cars and batteries emits CO_2, and if the power in your socket is not from green energy sources, the electric car will harm the environment almost as much as a petrol-powered car.



Sell your car

Annual reduction: 2.4 tonnes of CO_2

According to scientists, life without a car could save the atmosphere from 2.4 tonnes of CO_2 annually. The effect depends on what you do instead. If you cycle, the effect is the full 2.4 tonnes, whereas a change to public transport reduces the emissions by 25-75%. An electric car which is only powered by electricity from green energy sources could neutralise about 50% of a car's CO_2 emissions, but it will never be completely carbon-neutral.



GIVE UP ONE LONG FLIGHT

NO CAR

HIGH IMPACT

Annual reduction:

58.6 tonnes of CO_2

Give up one child

One Australian emits 16.45 tonnes of CO_2 a year. So the best thing you can do for the environment is to reduce population growth.

Humans are the unrivalled emitters of CO_2 to the atmosphere. A child who grows up in Australia can expect to emit around 1300 tonnes of CO_2 over the next 80 years; in Denmark or China half as much; in Qatar a huge 3000 tonnes. So if people in the western world have one baby less than planned, they not only save the world from a large-scale consumer, they delete several generations of CO_2 emissions when you count emissions from that child's children and grandchildren, etc. Scientists have named the phenomenon your 'carbon legacy', and according to calculations, the legacy in countries such as the US corresponds to 5.7 times the greenhouse gas for which you, the parent, are responsible.

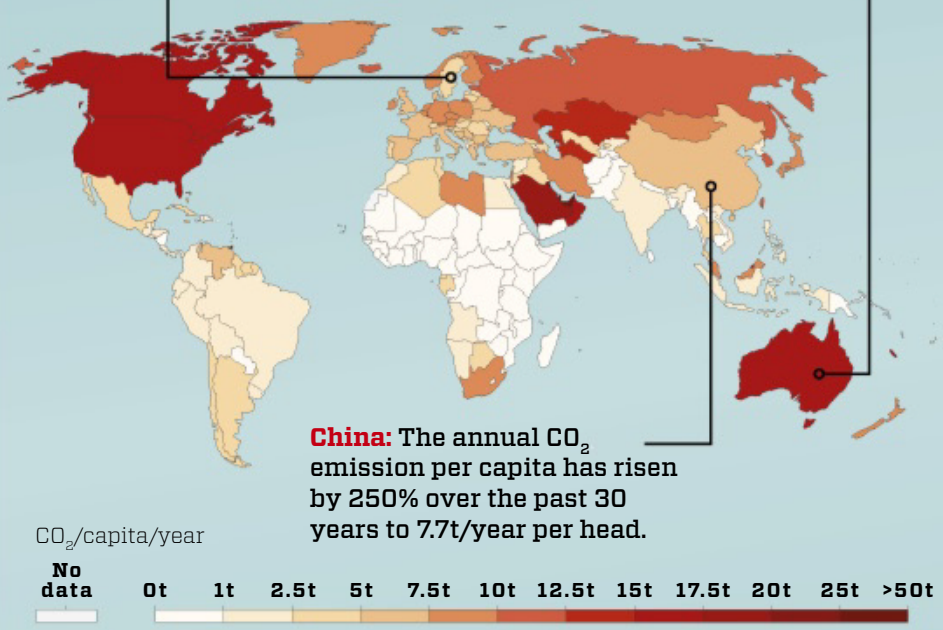
The average reduction resulting from one less child is 58.6 tonnes of CO_2 annually. In countries where energy sources are already greener, the figure will, of course, be reduced.

THE RICH WORLD DRIVES CLIMATE CHANGE

People in the rich nations of the world emit the vast majority of climate-changing greenhouse gases, but nations in rapid development such as China have gradually reached the same level of CO_2 emissions per capita per year.

Nordic countries: Lower than Australia, but still three times over the 2050 aim of 2.1t/year per head.

Australia: We're a heavy polluter at 16.45t/year per capita, slightly above the US figure of 15.74t/year.

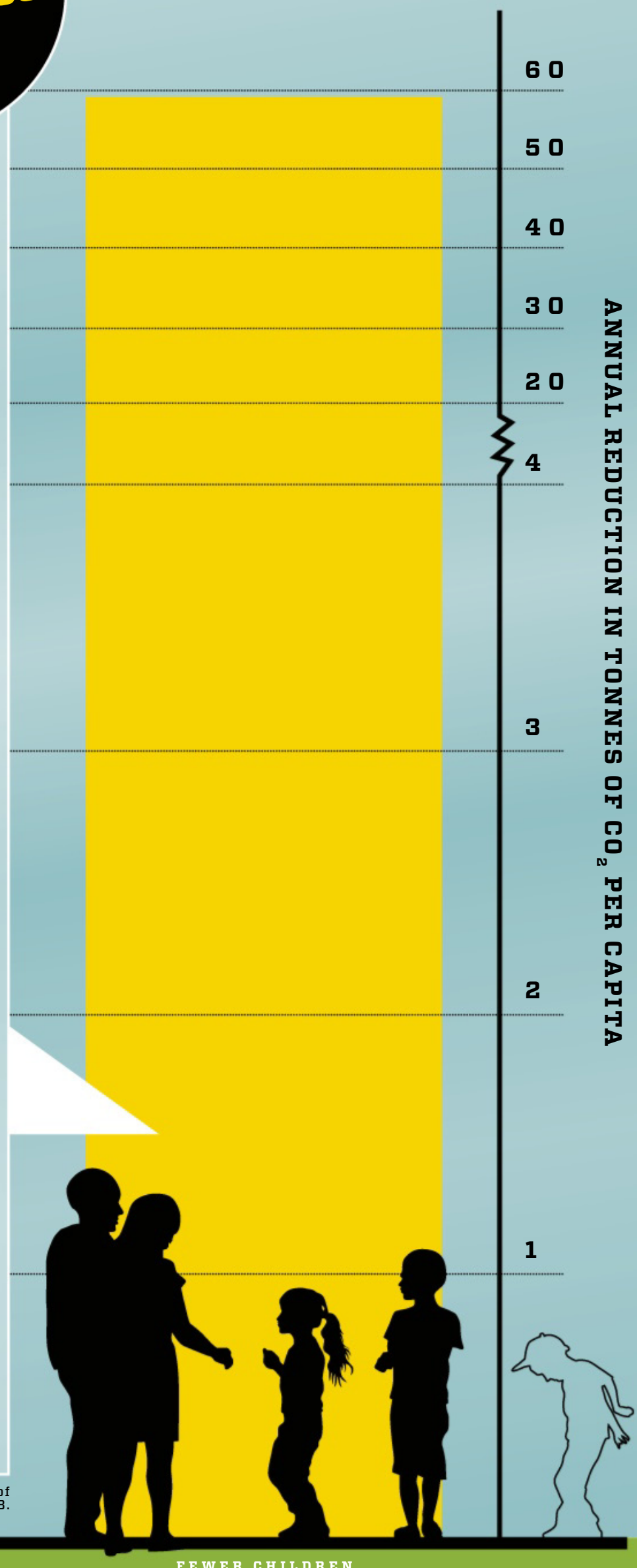


China: The annual CO_2 emission per capita has risen by 250% over the past 30 years to 7.7t/year per head.

CO_2/capita/year

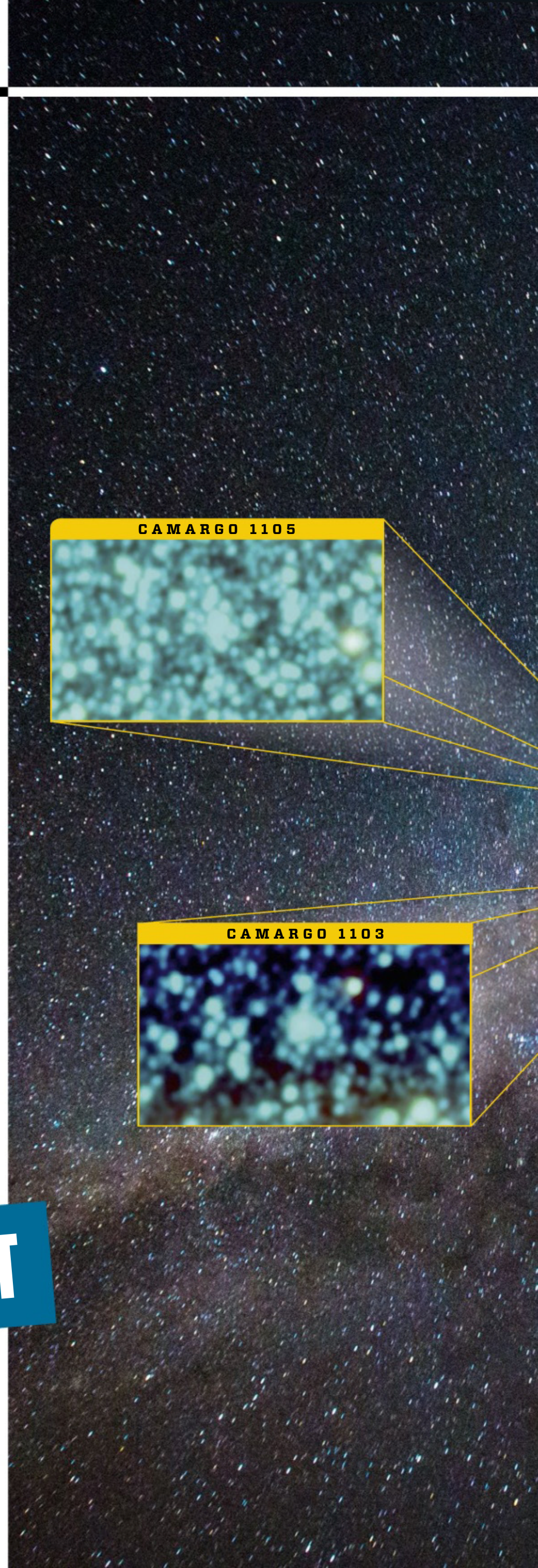
No data | 0t | 1t | 2.5t | 5t | 7.5t | 10t | 12.5t | 15t | 17.5t | 20t | 25t | >50t

Source: Fossil CO2 emissions of all world countries, EU 2018.



THE MILKY WAY FORMED FROM COSMIC CHAOS

New discoveries of globular clusters show that our part of the Milky Way is just a very young off-shoot. The centre of our galaxy includes stars that were born billions of years earlier. If these have planets, there might also be life there.



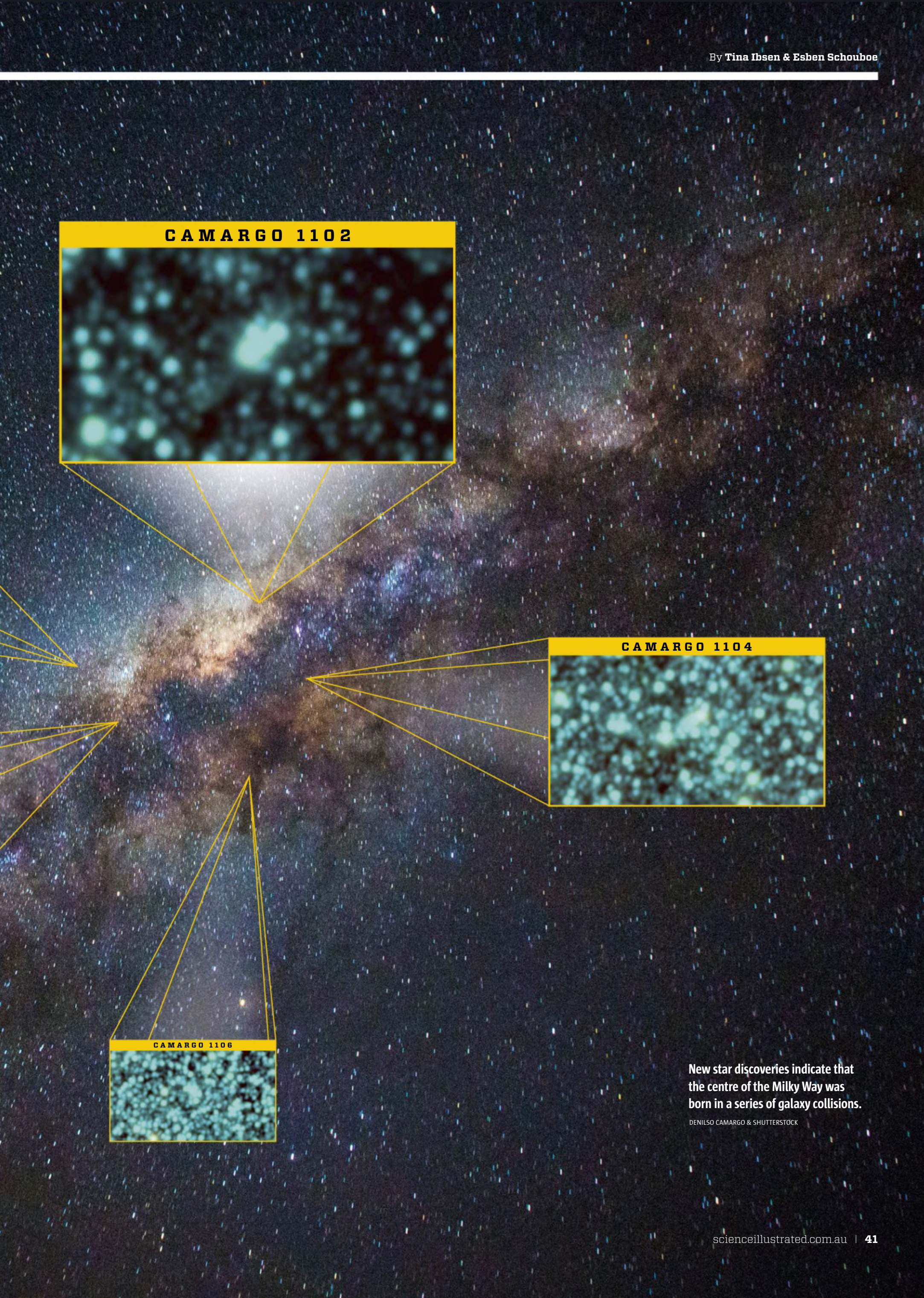
The chaotic lives of galaxies:

BIRTH

DEVELOPMENT

DEATH

By **Tina Ibsen & Esben Schouboe**



New star discoveries indicate that the centre of the Milky Way was born in a series of galaxy collisions.

DENILSO CAMARGO & SHUTTERSTOCK

BIRTH

The galaxies were born after the Big Bang, when material in the universe collected into stars and planets.

The Big Bang is still resounding through the universe. Clouds of gas and dust collapse under their own gravity, turning into the burning infernos that we call stars. Around them, in the remnants, planets form. A large cloud of stars, planets, and more gas and dust are united by gravity into a huge spiral. Many smaller clouds join over billions of years, and finally a bump emerges at the centre of the spiral. The Milky Way has been born.

This is how most astronomers know the story of our young galaxy. But recently they were shocked by new discoveries of globular clusters – ancient groups of stars – which reveal a more violent and surprising history. It now seems that many galaxies, bringing their own stars, planets, gas and dust, collided at inconceivable speeds in violent reactions that formed the Milky Way in the reverse order of what we used to think: the bump at the centre came first.

The new star discoveries may even help astronomers determine the likelihood of life on planets in other solar systems.

One galaxy becomes millions

Our Sun is just one star among hundreds of billions that make up the Milky Way, together with gas and dust. Our galaxy orbits other galaxies in galaxy clusters, and these orbit each other in superclusters, the biggest known structures in the universe. The most recent calculations show that some 10 million superclusters include two trillion galaxies in the visible universe. And yet we need not go far back in history before scientists' best estimate was... one.

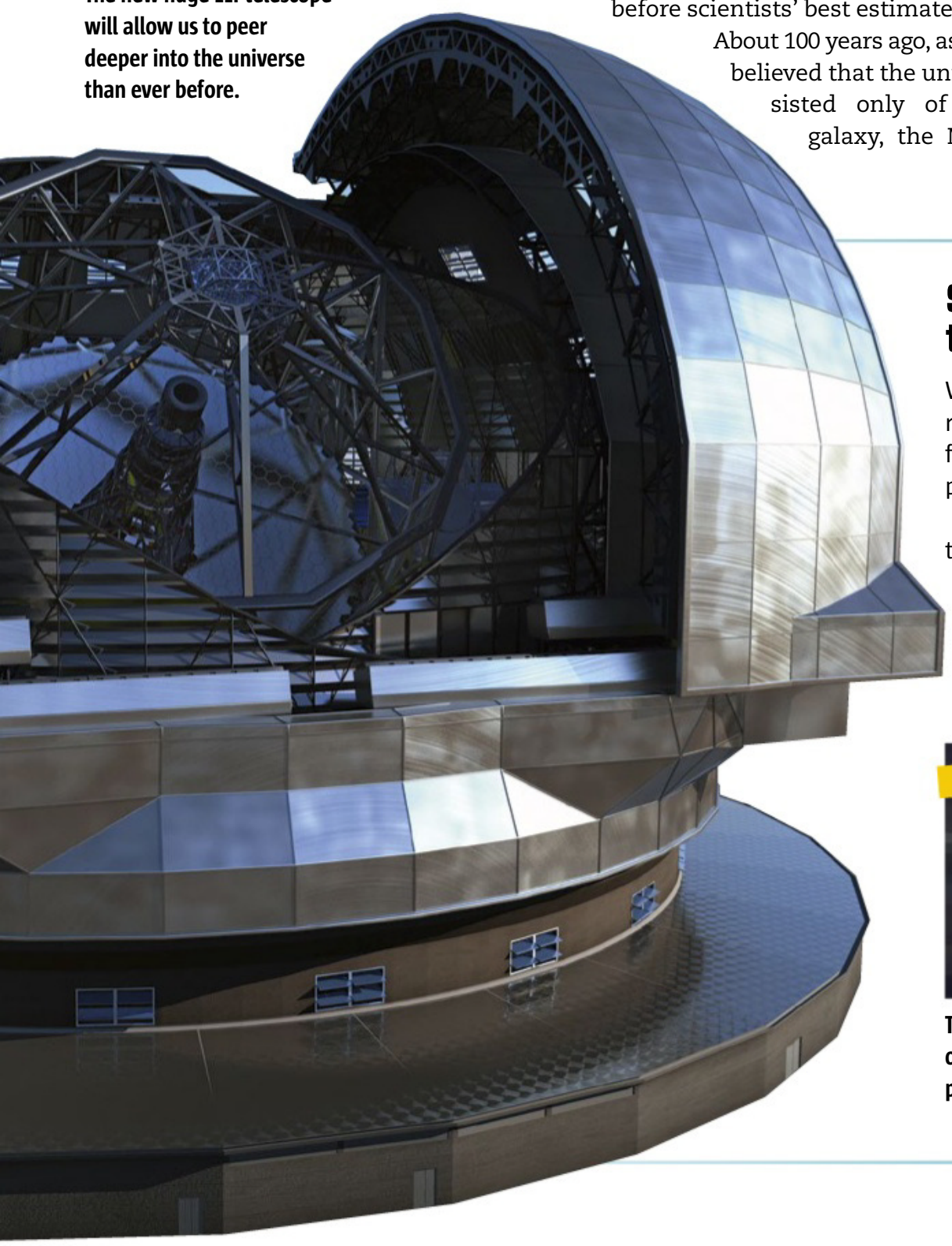
About 100 years ago, astronomers believed that the universe consisted only of our own galaxy, the Milky Way. Experts thought that the galaxy included stars and planets plus dust and gas united in nebulas.

Then in 1923, Edwin Hubble discovered nebulas outside the Milky Way, proving the existence of at least several galaxies.

Immediately after Hubble's revelation, astronomers began to research how these different galaxies formed, and why they don't all look the same. Since 1923, they have been trying to solve the mysteries of galaxy birth and development by studying the most ancient galaxies in the universe.

Light shows young galaxies

In basic terms, all astronomy involves collecting light by means of telescopes and then analysing where it comes from – or rather how far it has come. Light travels at a speed of 299,792,458 metres/second, and the universe is so big that light from remote galaxies has travelled for billions of years to reach our telescopes. The deeper astronomers look into the universe, the further back in time they peer. ▶



The new huge ELT telescope will allow us to peer deeper into the universe than ever before.

Super telescope to find the oldest galaxies

With a new, huge telescope, we will see galaxies far more remote than we can today. And as their light has travelled further, we will see galaxies earlier in their formation process. So we might see the universe's oldest galaxies.

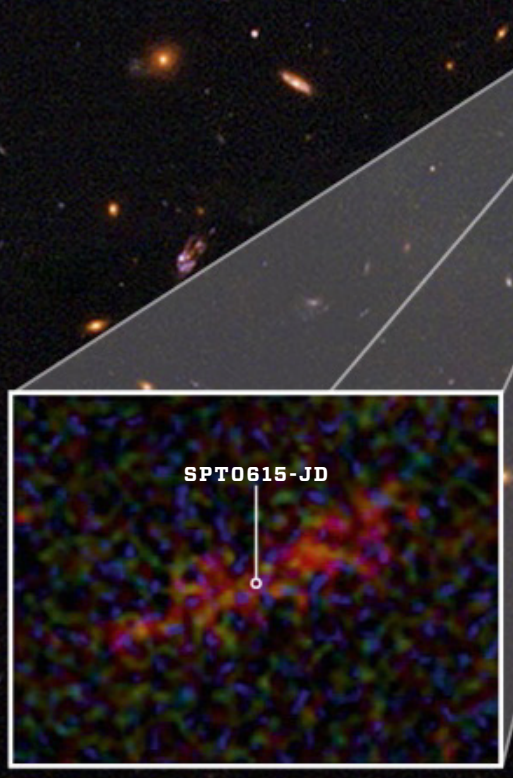
The ELT telescope will be able to peer deeper into the universe as its diameter (no less than 39 metres) will detect much weaker light than is possible today. It can also produce images of a very high resolution. Scientists plan to make some of the first observations with the telescope in 2025.

The European Extremely Large Telescope (ELT) will make observations at 16 times higher resolution than is possible with the Hubble telescope.

ESO/L. CALÇADA

The galactic time machine: light from remote galaxies

Observations of remote galaxies are a window into the past. Light from the remotest of galaxies in the universe has travelled more than 13 million years before reaching our telescopes, so we observe the galaxies the way they were when they emitted the light.

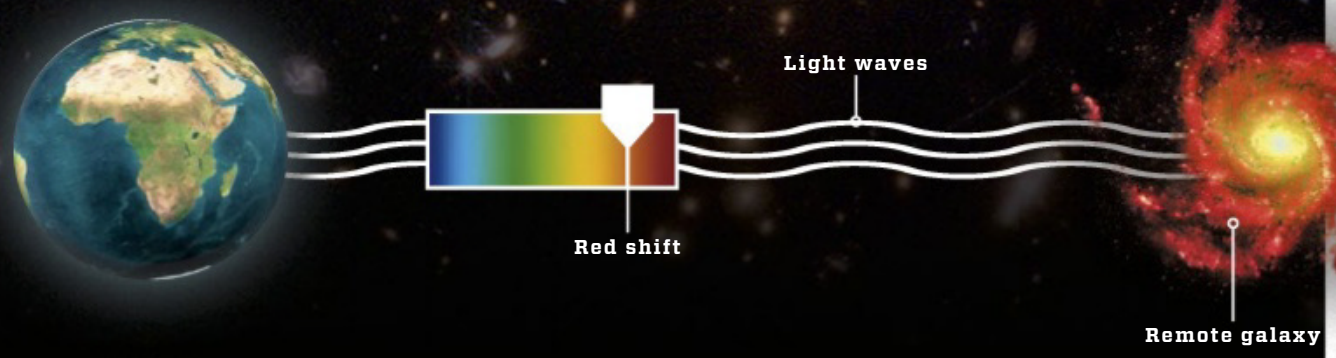


Galaxies show the past

1 SPT0615-JD is one of the most remote galaxies ever discovered. The light captured in this image was emitted 13.3 billion years ago, when the universe was 'young', around 500 million years old.

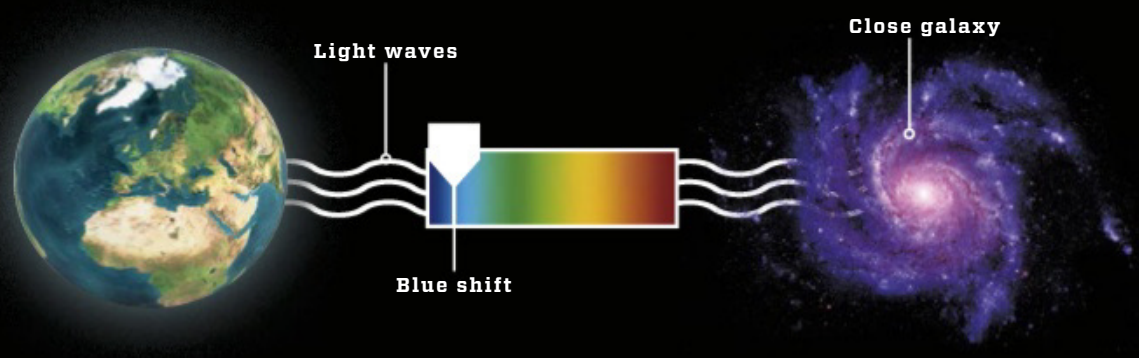
Remote galaxies are red

2 The further away galaxies are, the faster they are moving away from us, because the universe is expanding. Light from remote galaxies is hence 'stretched' into longer wavelengths, i.e. shifted towards red.



Close galaxies are blue

3 Light from approaching galaxies is squeezed together into lower wavelengths, so changes colour towards blue – a blue shift. A similar phenomenon makes an approaching ambulance siren sound higher in frequency than one moving away.



B. SALMON/STSCI/ESA/NASA

DEVELOPMENT

The galaxies of the universe form stars and merge with other galaxies in huge patterns over billions of years.

Spiral galaxies have got it going on...

Galaxies are divided into three types according to Edwin Hubble's model. Spiral galaxies such as the Milky Way create the highest numbers of new stars and are more variable than other galaxies.

Irregular galaxies

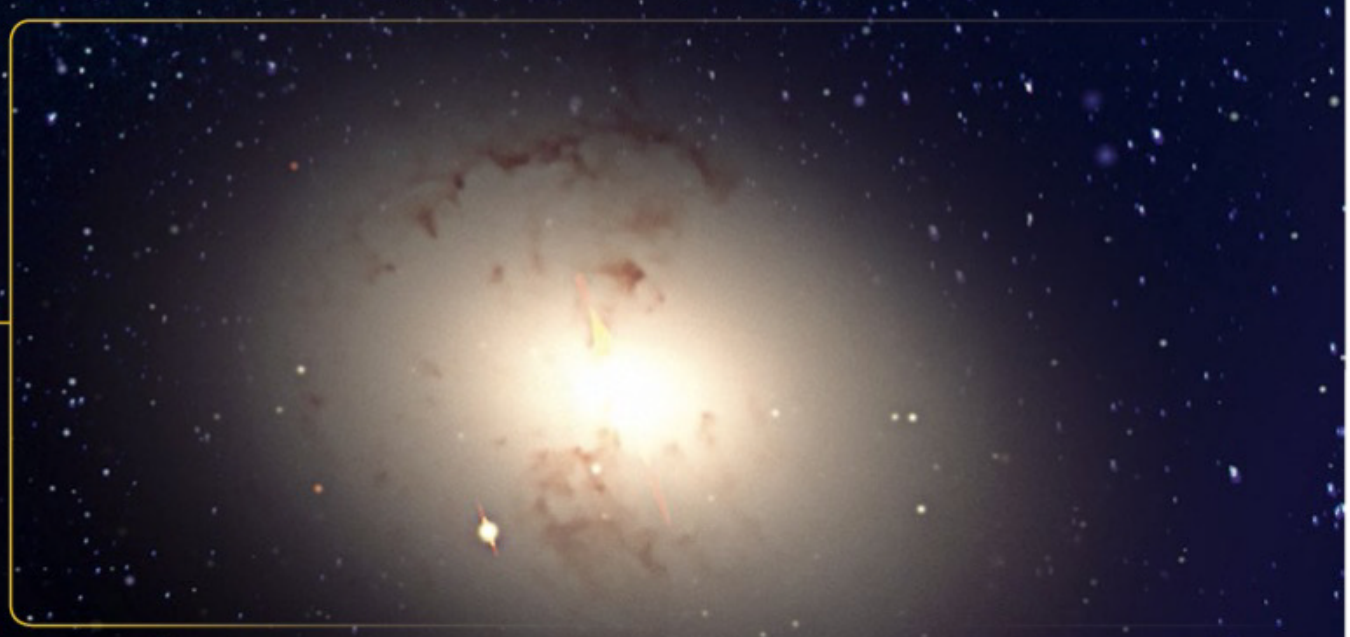
These galaxies have no distinct shape and often orbit bigger galaxies. They include far fewer stars than other types of galaxies.

Spiral galaxies

Spiral galaxies include far more gas and dust in their spiral arms. New stars can form there, so that spiral galaxies can be very dynamic.

Elliptical galaxies

Galaxies of this shape are the biggest astronomers know about. In elliptical galaxies, many of the stars are very old.



SHUTTERSTOCK

The oldest galaxies that have been discovered formed a few hundred million years after the Big Bang. The first galaxies of the universe were small, but many of the ones that astronomers can see in our neighbourhood today are much bigger. The conclusion is that the galaxies must have grown bigger over time.

The galaxies also come in several different forms. The Milky Way is a spiral galaxy, and it forms new stars all the time – averaging seven a year. Stars are born when clouds of gas and dust collect into dense balls. Elliptical galaxies, on the other hand, form almost no new stars, because they don't contain as much gas and dust.

The Milky Way is shaped like a fried egg with a central bump (the yolk) and a large, flat disc around it (the white). Our star – the Sun – and all of our solar system is located halfway into one of the spiral arms. At the centre of the galaxy, the concentration of stars is much higher, and the centre includes a large black hole known as Sagittarius A* which has a mass more than four million times that of the Sun. Our solar system takes about 250 million years to orbit the central black hole. While scientists have determined all these characteristics, they still do not know how the Milky Way ended up this way.

Collisions create characteristics

Collisions between galaxies now seem to be part of the explanation of the shape of the Milky Way. In early 2019, scientists from the LOFAR (Low-Frequency Array) project discovered 300,000 remote galaxies, of which several were about to collide and turn into larger galaxies. The scientists believe that the Milky Way grew bigger in the same way, and by capturing radio waves from the remote universe, they now aim to find out if young and small galaxies already include indications of differences. Such characteristics might mean that the big galaxies which form when small galaxies collide also develop in different ways. The differences between the young, small galaxies would offer a possible explanation of the extreme diversity of constellations we can see with our telescopes today – and not least a theory of how the Milky Way's life has progressed.

250

million years is the period it takes our solar system to orbit the centre of the Milky Way just once.

Metals indicate galaxy age

The mystery of the Milky Way cannot be solved by studying only the small galaxies. There, scientists can find out 'only' that the Milky Way probably formed via galaxy collisions – but they cannot get any further. If astronomy is to tell the whole story of the Milky Way – how many collisions formed it, when they happened, and how they happened – it requires a closer look at the age of different parts of our galaxy.

When astronomers are determining galaxy age, they consider when different stars formed. And this can be deduced from the distribution of elements in the stars.

Stars consist mainly of hydrogen and helium. But throughout their lives, heavier elements, i.e. metals, form in their interiors. When the stars die, the heavier elements are spread through space to form part of new stars. The very first stars had no heavy elements in their external layers, but the next generation of stars had a little metal

Cluster chaos reveals a violent past in a galaxy's life

Globular clusters are groups of stars located so close to each other that gravity holds them together, like a close family. They accompany each other for all of their lives, and scientists believe that they are some of the universe's oldest star groups. The Milky Way includes about 150 known globular clusters, whereas our neighbouring galaxy, Andromeda, includes 500 known globular clusters. The highest number of globular clusters is found in the M87 elliptical galaxy – no fewer than 10,000 clusters.

Astronomers can use the globular clusters' motions to calculate the size of a galaxy when the globular clusters began to orbit. The smaller a galaxy was, the more the globular clusters could influence it. The directions and speeds of globular clusters also reveal whether there were collisions in a galaxy's past. A globular cluster will move chaotically if it used to have a violent life with lots of galaxy collisions, but if the galaxy had a quiet development then the globular cluster is more likely to follow along with the rest of the galaxy's orbit.

The M80 globular cluster, located between our own solar system and the centre of the Milky Way, includes a high number of stars.

HUBBLE HERITAGE TEAM (AURA/STSCI/NASA)

DEATH

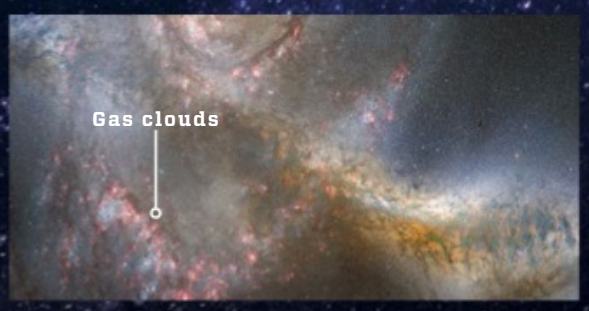
Galaxies die when they stop forming stars, such as after tremendous galaxy collisions.

Collision course: Andromeda hits the Milky Way

The Milky Way and our neighbouring galaxy of Andromeda are travelling towards each other at a speed of 400,000km/h. In about four billion years, they will clash in a fateful collision.

Andromeda travels fast

1 Today, we can barely see the Andromeda galaxy with the naked eye, but in a few billion years it will have come so close that it will take up much of the night sky.



Galaxies collide

2 Andromeda collides with the Milky Way. The gases of the two galaxies mingle, forcing hydrogen together and creating conditions for new stars to form.

Lots of stars form

3 The gravity of the two galaxies draws the gas clouds even closer together, and star formation peaks. New stars emit bluer light – unlike older redder ones.

In 3.75 billion years

In 3.85 billion years

In 3.9 billion years

in their external layers. They are known as metal-poor stars. Ever more heavy elements were included as time progressed, so that the newest stars are known as metal-rich stars. The Sun is a metal-rich star.

The existence of many metal-poor stars in a region therefore indicates an older part of a galaxy than would the existence of many metal-rich stars.

Star clusters are living fossils

Many of the metal-poor stars we know exist in globular clusters. These clusters are clumps of stars that are held together by gravity, accompanying each other in their cluster throughout their entire life-times. Because the metal-poor stars are very old, astronomers believe that these globular star clusters are some of the oldest 'structures' of the universe.

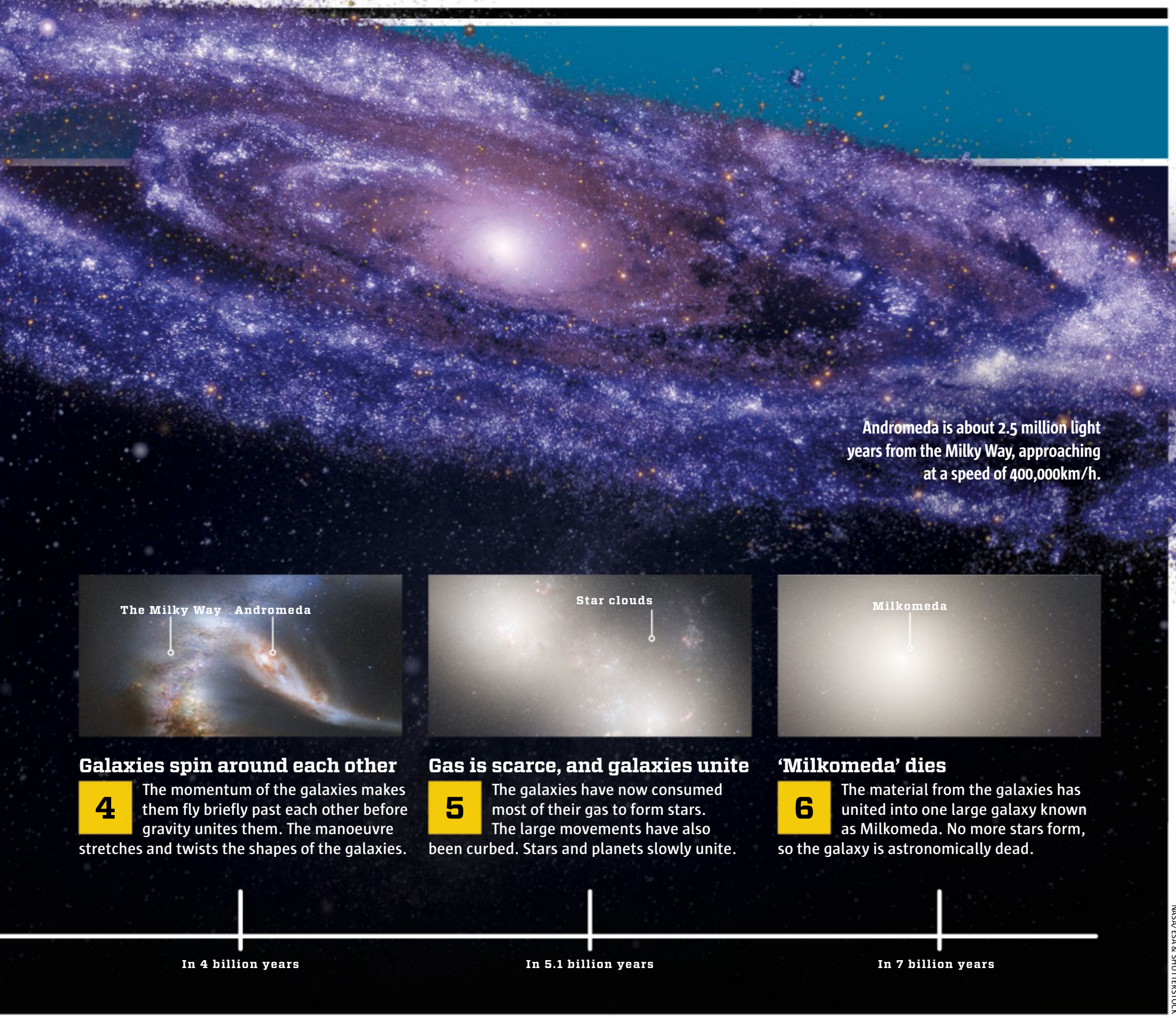
THE MILKY WAY

- **RADIUS:** 500 quadrillion km (15 zeros)
- **MASS:** 2.97 tredecillion kg (42 zeros)
- **AGE:** Some 13.5 billion years
- **STARS:** 200 billion

The close link between the stars in these globular clusters has proven a gold mine for galaxy research. The stars in the clusters formed at the same time, but have different masses. So scientists have been able to figure out the relationship between star development and size. The light of small stars is reddish and faint, whereas large stars are bright and bluish. Small, red stars live the longest, perhaps for trillions of years; the universe is not yet old enough for a small, red star to die. So red globular clusters mean old globular clusters, as the blue stars died billions of years ago.

When astronomers discover globular clusters with red stars, they have come across the oldest parts of a galaxy (scientists describe globular clusters as the universe's living fossils of galaxy formation). And such discoveries can determine whether the bump at the centre of the Milky Way or the disc around the bump was formed first.

The Milky Way includes more than 150 discovered globular clusters. Astronomers know that part of the Milky Way formed



NASA/ESA & SHUTTERSTOCK

when gas and dust collapsed under the influence of gravity after the Big Bang. However, the 150 globular clusters do not rotate around the centre of the galaxy at equal speed, and some rotate at a slightly different angle. The clusters that follow the disc were formed early, together with the rest of the Milky Way. Those that do not follow the disc, on the other hand, were formed later. This can help establish which parts of our galaxy were formed first.

The bump came first

When astronomer Denilso Camargo recently published pictures of five newly-discovered globular clusters, the astronomers of the world paid attention. The globular clusters are all located close to the bump at the centre of the Milky Way. And the clusters are 12.5-13.5 billion years old – all their stars are metal-poor. The results are surprising given that this type of globular cluster is normally found much further away from the centre of the Milky Way.

Metal-poor globular clusters at the centre of the Milky Way indicate that the central bump formed first, not the spiral arms. The bump resembles a small, elliptical galaxy, so scientists are now trying to work out if the Milky Way began its life with another shape.

The next question is how the elliptical galaxy was born. The newly found globular clusters' motions indicate that many galaxies collided to form a 'Baby Milky Way' which later developed spiral arms and became the galaxy that we know today. This theory conflicts with what astronomers used to think: that the Milky Way's exterior is a fusion of small galaxies and that the bump developed at a later point in time. The five new globular clusters indicate a more chaotic past for the Milky Way than scientists had previously believed.

Life in space is older than Earth

The development of the galaxies is not just a question of how stars form and large structures develop. The very conditions of life are at stake. When new stars form, so do new planets. The new discovery of globular clusters shows that star formation was common billions of years ago. Scientists can also assume that more planets were formed in this early period. More planets means more chances of Earth-like planets. And if life originates as soon as a planet can support it, then the majority of life outside Earth (if any) may have originated before our Earth was even formed. SCI

The Asian beauty rat snake strangles its prey instead of using venom – so it is harmless to people.

SHUTTERSTOCK

By **Gorm Palmgren**

Scientists' new weapon to save millions of snake victims

Two million people are poisoned by snake bites annually, and 130,000 of them die. The treatment has been the same for 100+ years, but now scientists are ready to combat the venom with an arsenal of antibodies and nanoparticles.

The East African farmer doesn't hear the faint rustle on the ground as he walks through his corn-field. A light grey snake rises slowly from the side, and when the small head hovers beside the farmer's hip, it opens its mouth wide and utters an ominous hiss. From the top of its ink-black mouth two backward-facing fangs quickly enter the farmer's forearm, leaving several drops of lethal neurotoxin.

At first, the farmer feels the venom only as a weak, tingling sensation. But after 10 minutes, the initial weak tinglings expand into involuntary muscle contractions, with sensory disturbances spreading through his arms and face. After 40 minutes, the farmer can no longer walk. After 45 minutes, muscular paralysis is making it difficult for him to breathe.

Throughout the world, some 2.3 million people are severely poisoned by snake bites annually. Of these 130,000 die, and another 400,000 become permanently disabled. The treatment of the victims is a huge challenge. Anti-venom is expensive to make, and often causes severe side effects. Given the rural scenarios likely for many snake bites, it can also be difficult to make sure that the right antivenom is available to small hospitals in potentially sparsely-populated areas. But now, scientists from the University of Costa Rica and the Technical University of Denmark have completed the development of new types of antivenom and DNA analysis techniques which may be able transform treatment of potentially deadly snake bites.

Goal to reduce deaths by 50%

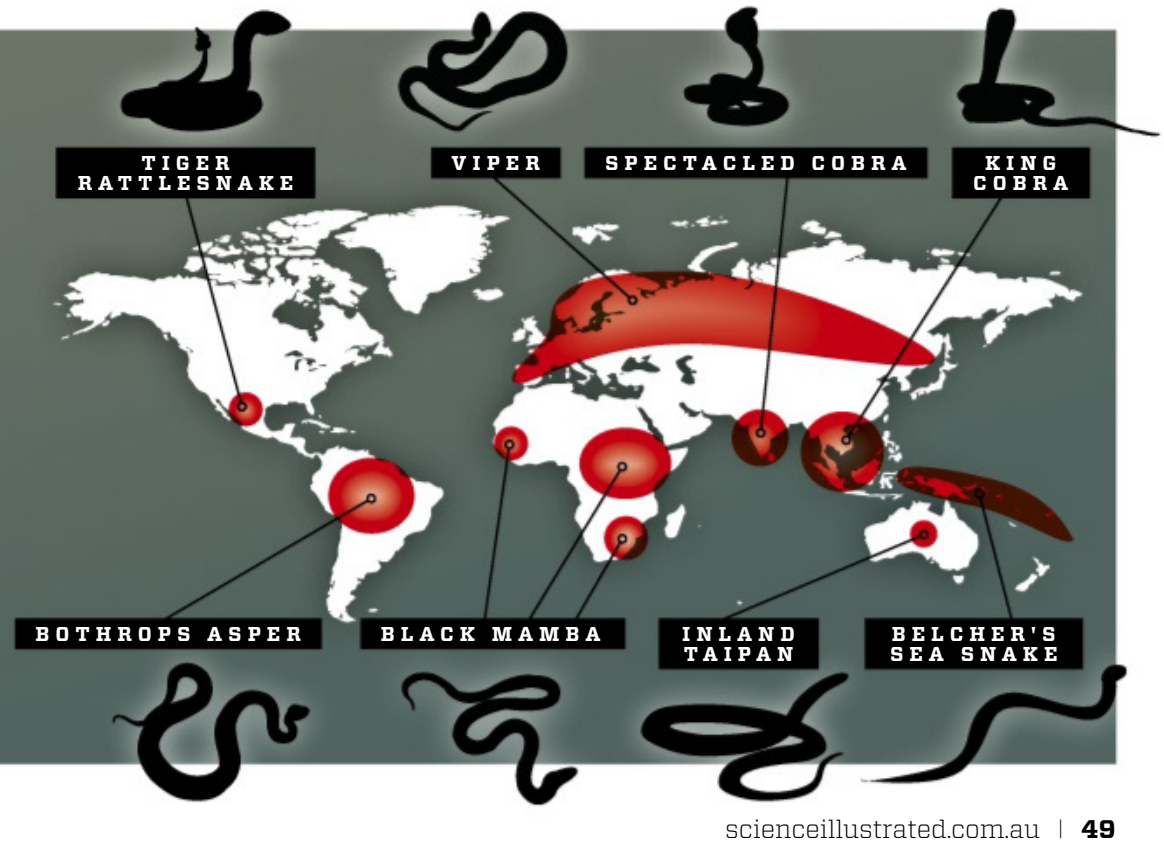
Most snake-bite victims in the world are farmers, attacked as they attend to their crops or handle their domestic animals. The situation is particularly severe in India, Africa, and Southeast Asia where the most poisonous snakes live – more than our fair share of them, of course, here in Australia.

According to the WHO, snake bites are a disease of poverty, the victims either not hospitalised in time or unable to afford the necessary treatment. This can be seen by comparing data from two islands — our own prosperous Australia, and the neighbouring island of New Guinea, where one in three people are poor. In both Australia and New Guinea there are about 100 different venomous snakes, but in Australia the snakes cause two deaths a year, compared to more than 1000 annual deaths as a consequence of snake bite in New Guinea.

Generally, venomous snakes are a relatively disregarded threat to health, despite claiming more victims than any known tropical disease, such as dengue fever. In 2018, the numbers made the WHO sound the alarm and introduce a plan which aims to reduce deaths and disability victims by 50% before 2030, and scientists are working hard on projects which could help give a fillip to those fine intentions.

Two elephants in one bite

Europe and North America don't have any very poisonous snakes, but these are very common in the rest of the world, particularly in India, South-East Asia, and of course Australia. However, the most poisonous snakes are not necessarily the most dangerous ones, and the hazard level of snakes is generally difficult for scientists to rank. Technically the inland taipan, which lives in dry areas of Australia, is one of the world's most poisonous snakes. A particular neurotoxin known as taipoxin makes the snake's venom cocktail so powerful that one single bite could kill two African elephants or 100 people. However, other snakes such as the South American *Bothrops asper* are much more aggressive to humans, and the Indian spectacled cobra is particularly dangerous because it seeks out villages and other inhabited areas.



SHUTTERSTOCK

One of the reasons why the antivenom that we use today is both expensive and involves severe side-effects is the way in which it is made: small quantities of snake toxin are injected into horses or sheep, which then produce proteins that can recognise the shape of the venom molecules, bind to them, and neutralise their effect. The anti-venom is subsequently extracted from the animals' blood and injected into people. The treatment is typically efficient and life-saving, but the side effects materialise because the antivenom from animals is considered as unwanted foreign bodies by the human immune system. Almost all patients have allergic reactions such as rashes, itching, and fever, and about a third enter anaphylactic shock, a hyperallergic reaction that can itself be lethal.

If the anti-venom had been produced in humans, patients would avoid the severe side-effects. But that is neither safe nor ethical. So scientists from the Technical University of Denmark and the University of Cambridge in the UK have cooperated to produce human-like antivenom in the lab.

Cocktail makes treatment difficult

In 2018, scientists managed to produce synthetic antivenom that neutralises the neurotoxin from Africa's biggest venomous snake, the black mamba. The synthetic antivenom is produced by placing millions of different viruses with antibodies on their surfaces in a culture dish in which the snake's venom molecules are attached to the bottom. The antibodies that recognise the snake venom bind to the molecules and so can be identified by the scientists. The antivenom has so far been tested on mice with promising results, but improvements are required before it can save human lives. Scientists discovered that the antibodies mainly neutralise one of the black mamba's venom types – dendrotoxin – whereas the effect on other types of toxin is not nearly as positive. Moreover, producing useful quantities of venom remains a challenge, although the new method is a huge step in the right direction.

2030

is the year by which the number of disability victims and deaths due to snake bites is hoped to be halved.

Whether the antibodies are produced in the laboratory or in horses, they still need to be customised for individual types of snake venom – and there are many of those. The black mamba's venom includes 41 different toxins, and snakes such as the king cobra have many more.

Nanoparticles capture the venom

In order to solve the problem of having to develop many different types of antivenom, scientists from Costa Rica and the US are now working on a universal antivenom that combats many different toxins at a time. Deliverance may come from tiny particles less than 0.0001mm in size: nanoparticles.

The size of the nanoparticles makes it possible for them to get up close to the snake's venom molecules in the body, bind to them, and consequently neutralise their effect. The scientists have tested a wealth of the particles on snake venom, and in 2018 they introduced a promising candidate. The special nanoparticle binds to a long series of cytotoxins known as PLA2 and 3FTx, which are among the common toxins of sea snakes, coral snakes, death adders, elapids, and cobras.

When the snakes have bitten their victim, the toxins enter body cells, causing cell death, blisters, open wounds, and dead tissue. At worst, an arm or a leg could wither.

Scientists demonstrated the nano-particles' effect by injecting the venom of the black-necked spitting cobra into the skin of mice. The result was an area of 63mm² in which all skin cells died. Subsequently, the scientists injected nanoparticles into the same area right after the venom, resulting in a markedly smaller dead area of only 13mm² – corresponding to a reduction of 80%. Even if the scientists waited half an hour to inject the nanoparticles, the dead area still became much smaller.

So the nanoparticles can significantly limit the effect of the spitting cobra's bite, and scientists expect that the effect will be just as good against a long series of other venomous snakes. That allows the nanoparticles a huge advantage as compared to existing antivenom. And at the same time they are much cheaper.

Doctors also often experience the problem that they do not know which snake the patient was bitten by, and that makes it difficult to prescribe the correct antivenom. So biochemist Stephen Mackessy from the University of Northern Colorado in 2018 developed a DNA analysis that can identify the snake in the same way that forensic pathologists identify criminals based on DNA data. The scientists need only 0.001g of the venom, a small enough quantity to be taken as a sample from the bite mark with a cotton swab. This method is also cheap and efficient.

Together these new techniques may hold the hope of meeting the WHO's ambitious aim of halving the number of snake-bite deaths and disability victims before 2030. SCI

ISTOCKPHOTO

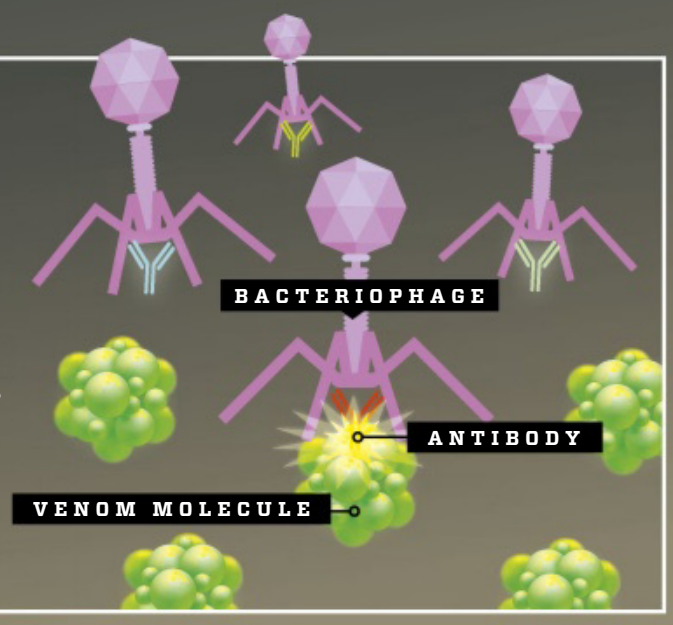
Australia's inland taipan is the world's most poisonous snake by venom, but behaviour can make other snakes more dangerous.

3 new weapons combat venom

Sophisticated DNA methods, synthetic antibodies and hungry nanoparticles – three new methods by which scientists hope to combat more snake venoms at once, while also avoiding severe side effects.

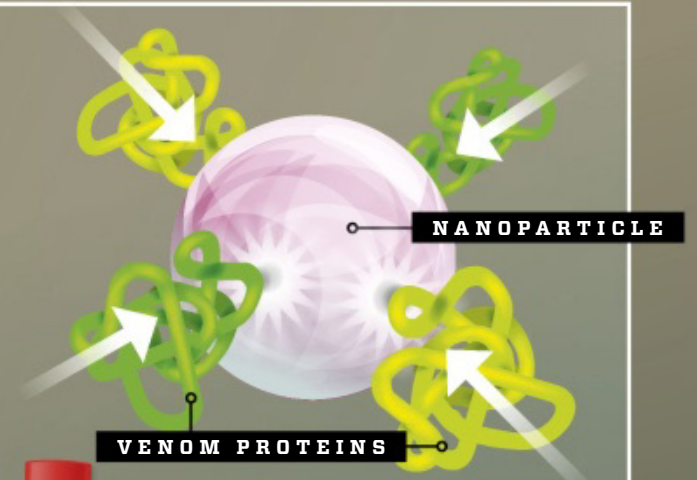
ANTIBODIES MADE IN THE LAB

Scientists gene splice millions of viruses known as bacteriophages to produce random antibodies on the surface. Subsequently the viruses are mixed with the snake's venom molecules in a culture dish. The viruses that have antibodies against the venom will bind to the molecules, and scientists can use them as antivenom.



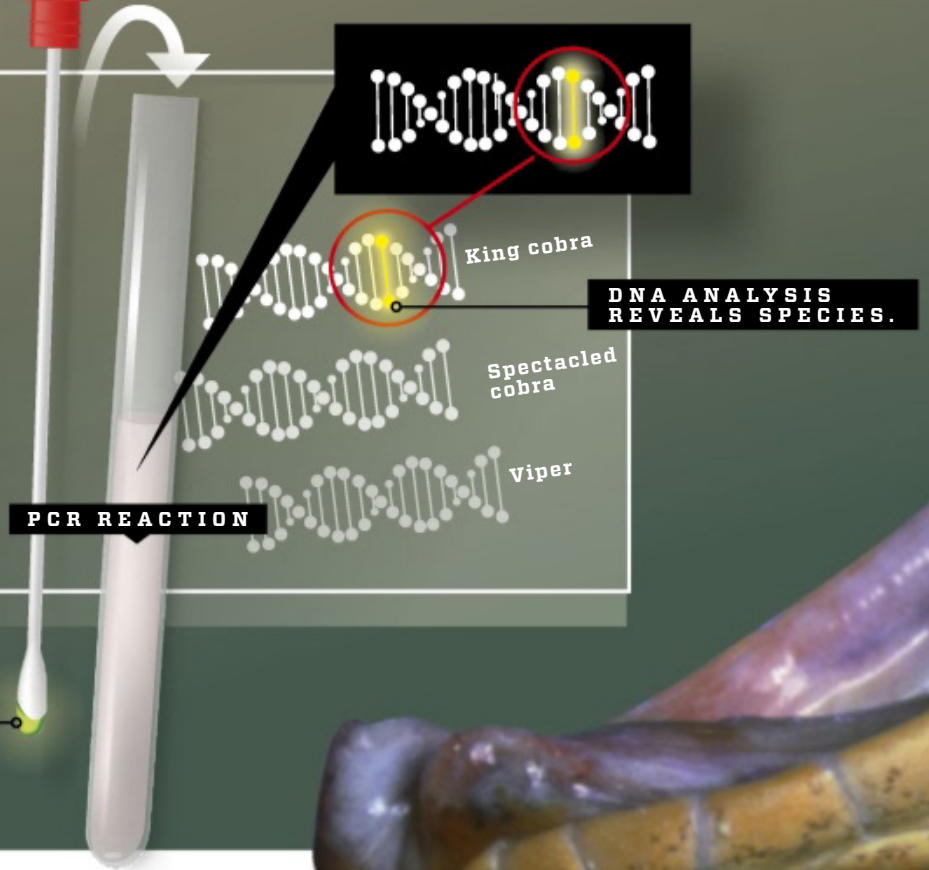
NANOPARTICLES CAPTURE THE VENOM

Nanoparticles are injected into the skin near the snake bite. The particles are less than 0.0001mm in size, allowing them to come close to the snakes' venom proteins in the body, which bind to the particles. The binding disturbs the venom, which loses its effect.



DNA FINGERPRINT IDENTIFIES SNAKE

In order to find out which snake has bitten a patient, scientists collect venom from the bite mark with a cotton swab. Subsequently the snake's DNA is copied, so a few DNA molecules from the wound become millions – a PCR reaction. The scientists can then identify the snake via DNA analysis.



Venom from one snake could include some 50 different venom proteins, making the bites difficult to treat.

VOLKER STEGER/SPL/SHUTTERSTOCK/SIDSE LANGE

With its huge wing area of more than 24m², Perlan II ascends more efficiently than any glider before it.

PERLAN II IS DESIGNED TO CLIMB ALL THE WAY TO THE EDGE OF SPACE. ORDINARY GLIDERS ARE USUALLY DESIGNED TO FLY LONG DISTANCES.

AIRBUS

By **Andreas Ebbesen Jensen**

To the edge of space... in an engineless glider

The Perlan II glider beat the world record, gliding through the air 23km above Earth's surface. Scientists aim to use the engineless plane to unveil the stratosphere's influence on weather phenomena and climate change.

On 2 September 2018, 13km above the Andes Mountains, pilots Jim Payne and Tim Gardner are flying the Perlan II glider. A propeller aircraft has lifted the 500kg glider from the ground, but has now disengaged, leaving Perlan II to climb higher on the wind alone.

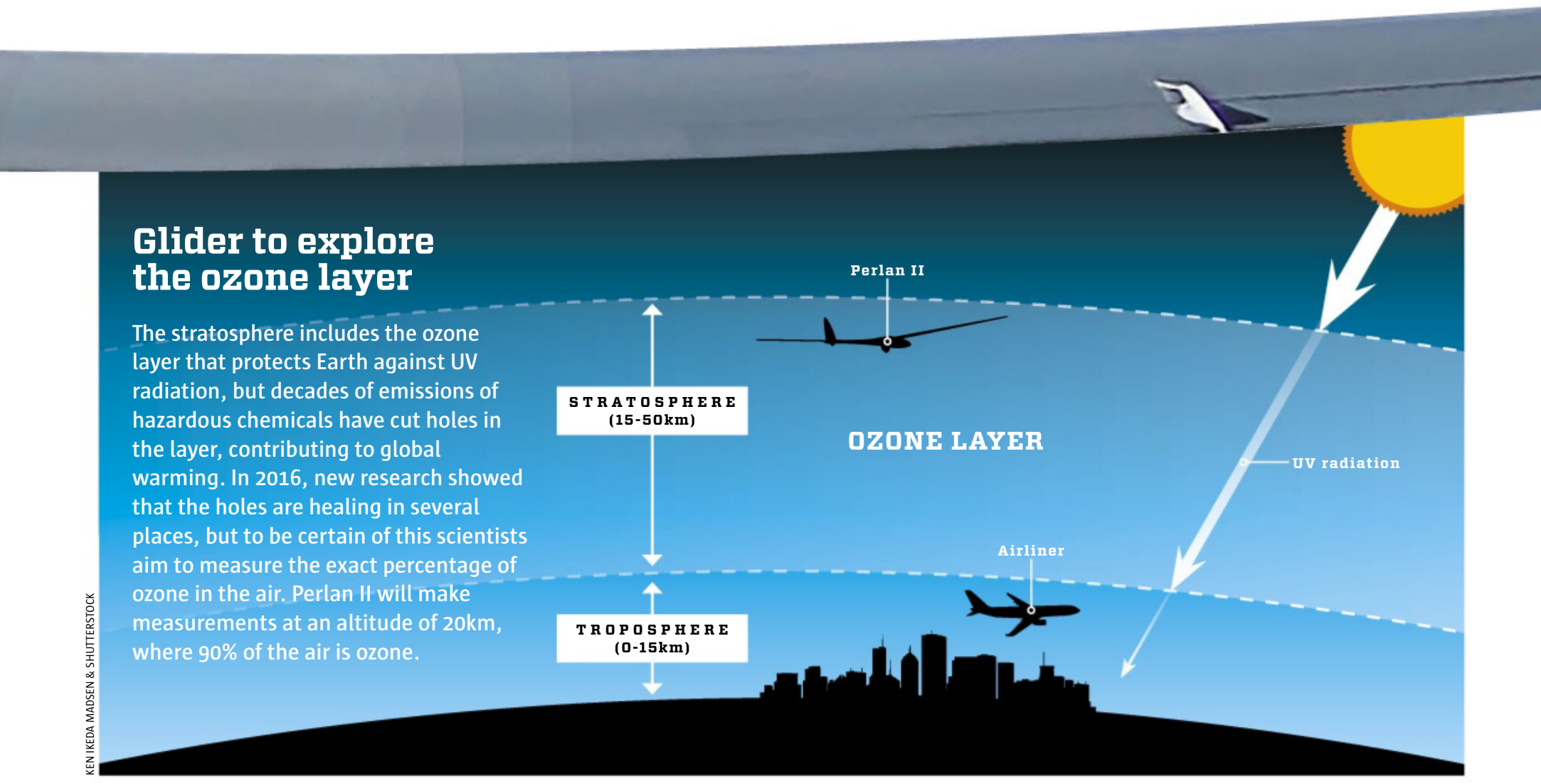
Perlan II has a wing span of 25 metres, and is designed for maximum lift when surfing on warm air currents from the mountains. The warm currents lift the plane past the Armstrong line at 19.2km. The atmosphere is now so thin that the blood in the pilots' bodies would boil were they not protected by the plane's pressure chamber.

Five hours after take-off, Perlan II is gliding 23km above Earth, almost 4km higher than any other engineless plane has reached. Only spy planes and air balloons have achieved similar altitudes.

Perlan II can glide at the edge of space and measure speeds, temperatures and chemical make-up of the winds without pollution from a petrol-powered plane engine. The measurements will teach scientists about phenomena in the stratosphere and so about weather and climate change – and perhaps even help mankind conquer the airspace of Mars.

Mountain waves paved the way

For many years, plane engineers believed that gliders could not possibly climb any higher than 15km above the Earth, because warm air normally stops rising at this point. NASA test pilot Einar Enevoldson proved them wrong. In the 1990s, he was determined to study the mountain 'waves' that occur when high temperatures close to Earth heat the air above mountain-sides. The waves produce a particularly forceful ▶



Glider to explore the ozone layer

The stratosphere includes the ozone layer that protects Earth against UV radiation, but decades of emissions of hazardous chemicals have cut holes in the layer, contributing to global warming. In 2016, new research showed that the holes are healing in several places, but to be certain of this scientists aim to measure the exact percentage of ozone in the air. Perlan II will make measurements at an altitude of 20km, where 90% of the air is ozone.

KEN IKEDA MADSEN & SHUTTERSTOCK

up-current when the polar jet-stream and the polar vortex merge. Enevoldsen discovered that these waves can reach as high as 39km into the atmosphere – which is more than twice as high as had been previously believed. In 2006, Enevoldsen and plane enthusiast Steve Fossett made plane history, beating the altitude record by gliding through the air a dizzying 15,544m above the Andes Mountains in Argentina, aboard the Perlan I glider.

Glider records weather and ozone

With wind speeds of 400km/h in the stratosphere, flying is rather risky; those powerful mountain waves could force planes into quick dives and hazardous spins. That original Perlan I mission ended with the pilots activating an emergency parachute.

On the other hand, planes have more to offer than weather balloons or satellites, which have been scientists' primary measuring equipment in the stratosphere since the 1970s. Weather balloons are unmanned and difficult to control, while satellites can't map variations in the stratosphere up close, as planes can.

Manned jet planes have flown even deeper into space than Perlan II, but their high speeds and major emissions of petrol fumes make it almost impossible to make accurate measurements in the stratosphere.

However, scientists can use Perlan II for controlled exploration by means of sensors on the glider which can measure pressure, air moisture and temperature.

For many years, meteorologists believed that weather was produced only in the troposphere, the air layer from Earth's surface to the stratosphere at an altitude of 15km. Today, we know that what happens in the stratosphere spreads downwards.

In the stratosphere, the polar vortex (a vortex of westerlies) blows in a circle around the polar region above Canada, Siberia, and Scandinavia. This vortex supports the jet streams that blow at lower altitudes. On the other hand, the polar vortex can also be influenced by Rossby waves from the troposphere. These waves are produced by the Earth's rotation and the difference between terrestrial and ocean regions. The waves rise and can break down the polar vortex, weakening the jet streams in the troposphere and leaving room for warm air to blow far north, while cold air blows far south.

Perlan II's research of wind, temperatures and chemistry in the stratosphere can teach scientists about these phenomena. In explaining key elements that contribute to producing the weather on Earth, this knowledge may be vital for long-term weather forecasts. This is particularly true in Northern and Western Europe, where the link between stratosphere and troposphere seems to be particularly strong.

Apart from teaching us more about the weather, the record-breaking glider will also measure ozone in the stratosphere. The data will be used to research the holes in the ozone layer produced by decades of greenhouse gas emissions that split ozone molecules on contact. Some of the major culprits were used in refrigerators up until 1987, when nations throughout the world agreed to phase out the gases from such common use. Perlan II will document to what extent the ozone layer is healing itself.

Next stop Mars

Perlan II glides in places where the air is 97% thinner than normal, and where temperatures reach as low as -70 degrees Celsius. Similar atmospheric conditions exist on Mars, where the oxygen-poor atmosphere will make it impossible to use combustion engines. Perlan II has shown that we can glide across long distances under the right conditions. Long distance transport will be vital if we wish to explore Mars and settle in several areas of the planet.

Back on Earth, Perlan II will continue its research of the highest air layers. Next year, Jim Payne and Tim Gardner will try to beat their own altitude record and reach 27km, surfing on the wild mountain waves. SCI

Pilots Jim Payne and Tim Gardner in the record-setting Perlan II glider.

AIRBUS

Mountain 'wave' lifts glider to the stratosphere

For only a few days a year, two major air currents combine forces over the Andes Mountains, producing a 30km-high wave of wind that can lift the Perlan II glider into the stratosphere.

The Perlan II glider pilots expect to set an altitude record of **27km**

Air currents meet mountain

1 In the summer, the polar jet stream is blowing across the Andes Mountains in Argentina at the same time as the polar vortex. When the two air streams pass a mountain at altitudes of 10km and 30km respectively, the air is forced upwards as it is cooled one degree per 100 metres, causing cloud formation and precipitation.

Warm air sends powerful waves into the stratosphere

3 Perlan II is lifted 12km by another plane, subsequently continuing its climb surfing on the mountain wave. The wave grows stronger as it ascends, because both the pressure and the surrounding wind speeds are gradually reduced.

Dry air descends

2 Once the air passes the mountain peak, it has dried, and is consequently heavier. Gravity will pull it downwards and the higher temperatures close to the ground heat the air, causing it to rise in the form of a mountain 'wave'.

The polar vortex
Precipitation cloud
The polar jet stream
Perlan II
Stratospheric mountain wave
25km
20km
15km
10km
5km
0
15-50km: the stratosphere
10-15km: the tropopause
0-10km: the troposphere

CLAUS LUNAU & PERLAN PROJECT

REGULAR SERIES

THE BATTLE OF THE BRAIN

The human brain is vulnerable to disease, but 170 billion brain cells fight for your survival, and scientists are ready to help them.

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Sclerosis
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Stem cells

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Pot vs concussion

PART 5
Antidote vs Alzheimer's

Sclerosis can cause severe signal problems in the brain, as seen in this scan.

SPL

By **Bo Christensen**

STEM CELLS SAVE THE BRAIN FROM SCLEROSIS

Inject your own cells into your blood vessels and protect the brain against attacks. New stem-cell treatment has had a surprising effect on sclerosis, and scientists are close to finding a cure which might eliminate the crippling disease once and for all.

The enemy has entered without your knowledge, and suddenly you are facing a highly trained killer who is already eating into the rest of your defence. Luckily, you know the strategy – you have seen the attacker before, and you know exactly which counter-attack is required to defeat him this time.

Every day your body is attacked by hungry viruses, bacteria and parasites that try to enter your cells and use them to mass-produce themselves. Fortunately your immune system makes sure that the vast majority of these alien organisms never gain a foothold sufficient that you can feel their effects. However, your immune system could also become its own worst enemy. The defence troops, your immune cells, might get so confused as to who is friend and who enemy that they attack the body's healthy tissue, affecting joints and skin as in people suffering from arthritis and psoriasis. But the attack could also affect the brain and the nervous system that controls everything from our motions to our memory. And when that happens, it may at worst cause disability. The state is chronic and known as multiple sclerosis, meaning 'many scars'.

Multiple sclerosis can cause paralysis and highly impaired motor function, but it can also affect your ability to learn and understand what happens around you, and so your ability to live an ordinary life. At this point in time, doctors are treating the disease with drugs that aim to curb the activity of the immune cells so they do not attack nerve cells to the same extent. However, the drugs cannot halt the immune system completely, because if they did, the patients ▶

BEFORE FIGHT

Insulation ensures quick signals

By means of special high-fat cells, the brain's nerve cells can quickly exchange electrical impulses.

Ions flow into the nerve cell

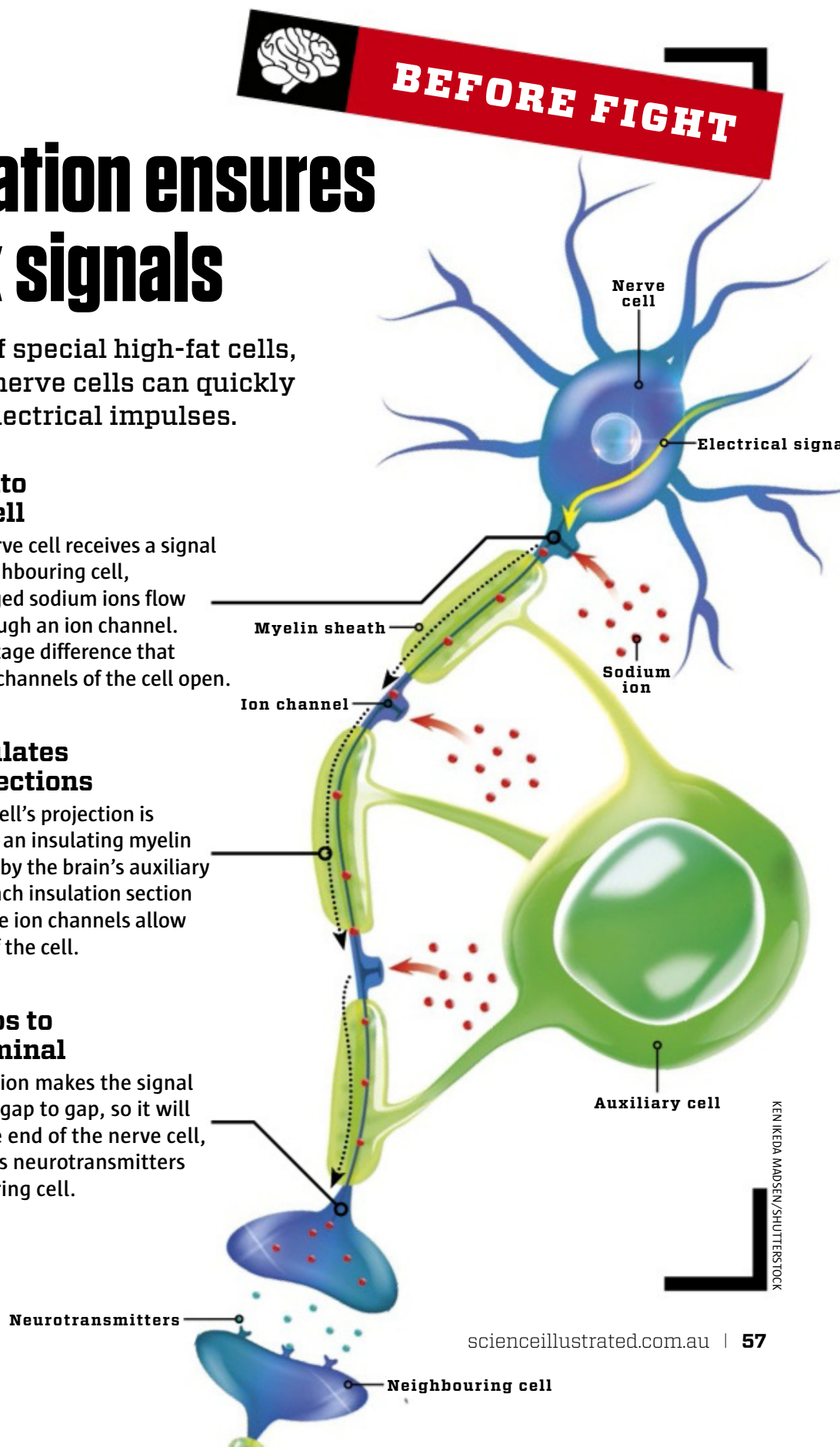
1 When a nerve cell receives a signal from a neighbouring cell, electrically-charged sodium ions flow into the cell through an ion channel. This causes a voltage difference that makes other ion channels of the cell open.

Myelin insulates the cell in sections

2 The nerve cell's projection is wrapped in an insulating myelin sheath produced by the brain's auxiliary cells. Between each insulation section is a gap where the ion channels allow ions in and out of the cell.

Signal jumps to the end terminal

3 The insulation makes the signal jump from gap to gap, so it will quickly reach the end of the nerve cell, where it liberates neurotransmitters to the neighbouring cell.



KEN IKEDA MADSEN/SHUTTERSTOCK

» would suffer the major risk of invasion by lethal infections. Doctors also use adrenocortical hormone, which curbs the infection caused where the immune system has attacked the body. However, the medication can neither cure sclerosis nor slow down the ongoing injury to the nervous system. And on some patients, the medication has almost no effect. So it is vital to the world's 2.3 million sclerosis patients that a new and more efficient treatment be developed.

Attacks on vital nerve cells

Specifically, multiple sclerosis develops when the body's immune cells attack particular high-fat auxiliary cells in the central nervous system known as oligodendrocytes. These high-fat cells produce myelin sheaths around the nerve cell's fibre threads, like

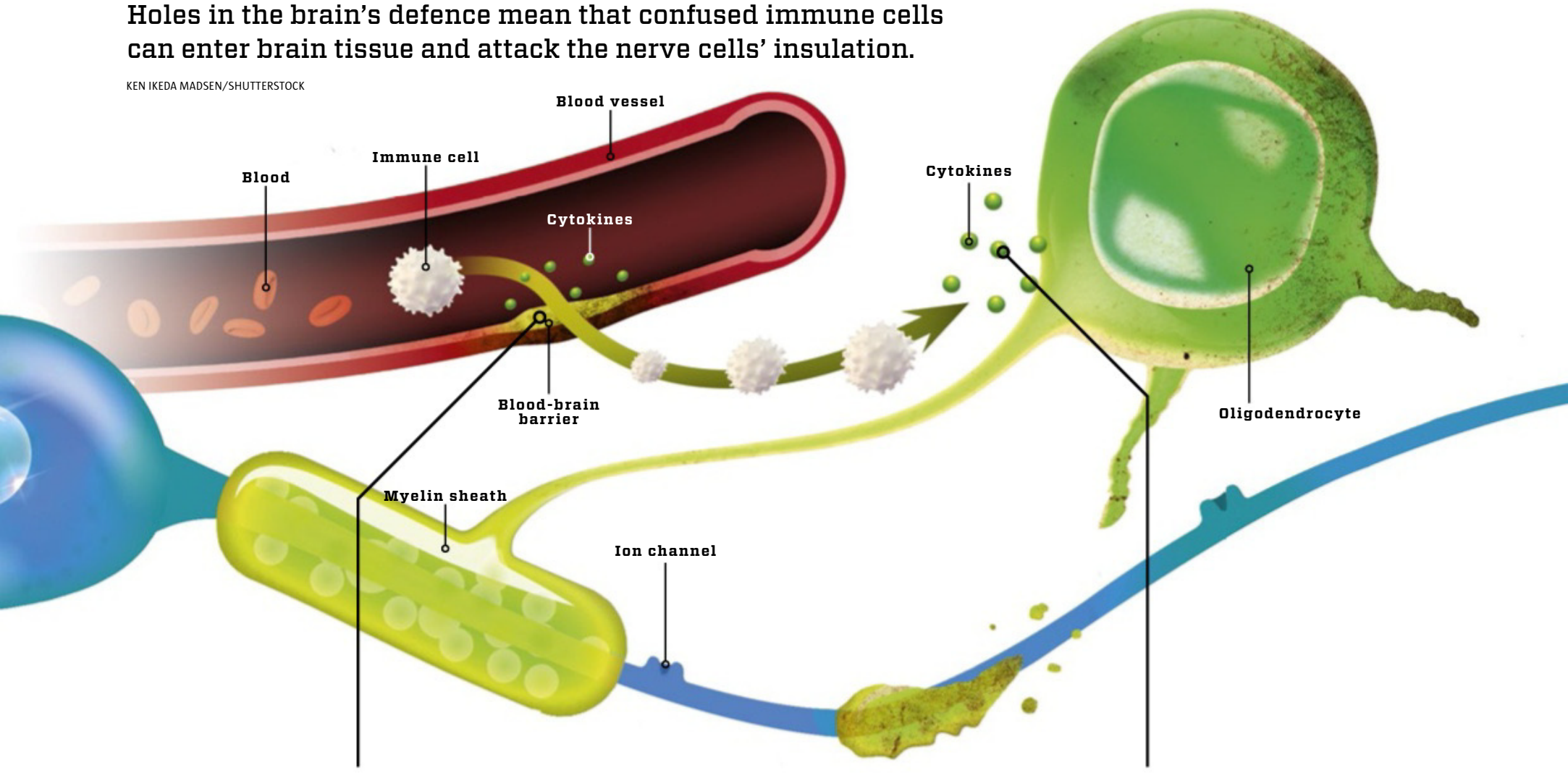
Several different stem-cell treatments, including blood stem cells, have already been tested successfully on sclerosis patients.

SPL

Immune cells break down the brain

Holes in the brain's defence mean that confused immune cells can enter brain tissue and attack the nerve cells' insulation.

KEN IKEDA MADSEN/SHUTTERSTOCK



Infection breaks down defence

1 The immune system's cells cause infection in a blood vessel in the brain by liberating cytokines, which are toxic to cells. The infection breaks down the blood-brain barrier, the important semi-permeable border between the brain's blood vessels and tissues, which normally keeps out bacteria and viruses.

Immune cells destroy insulation

2 Once the blood-brain barrier has been broken down, the confused immune cells can pass from the blood stream into the brain. There they liberate more infectious agents, which destroy the auxiliary cells and oligodendrocytes, and hence also the insulation around the nerve cell's end.

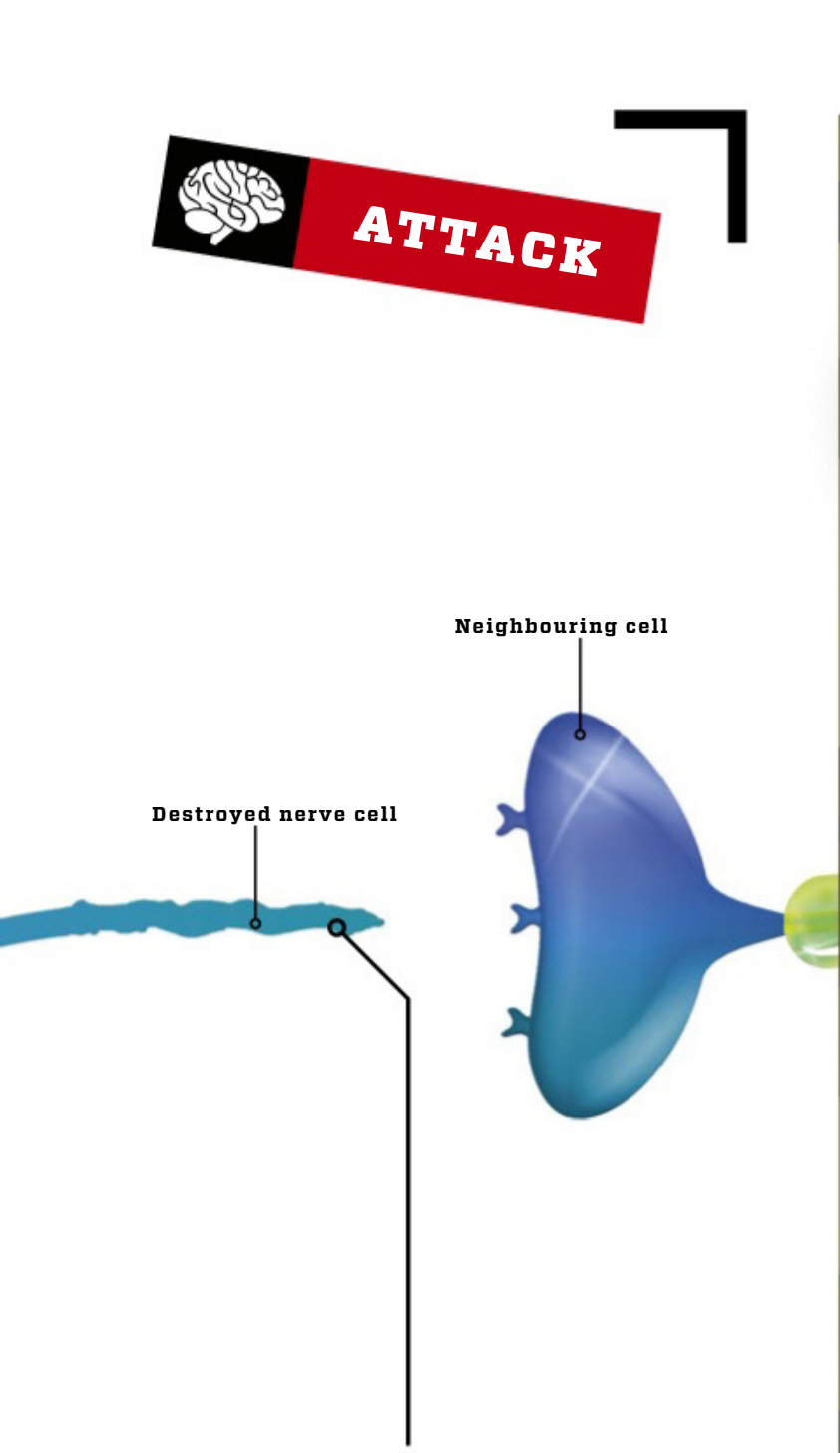
pearls on a string, helping the nerve cells send electrical signals to each other quickly and efficiently. Without the sheaths, the nerve cells communicate more poorly, and the fibre threads will often end up being destroyed to such an extent that the nerve cell cannot communicate with its neighbouring cells at all. This can influence not only our ability to think and understand but even our ability to move, so that in particularly severe cases the injuries cause paralysis.

Scientists do not yet know exactly why the immune system attacks the body's healthy cells, but research indicates that autoimmune diseases such as sclerosis might develop after an infection with a virus or bacteria. But even when the harmful organism, virus or bacterium has been removed, the immune system continues the killing – now targeting the oligodendrocytes, perhaps because their chemistry is somehow similar to the chemistry of bacteria and viruses. That is probably why multiple sclerosis develops, but nobody knows which viruses or bacteria trigger the disease.

Among the suspects that scientists have identified are herpes viruses 1 and 2, varicella-zoster virus (which causes chickenpox), cytomegalovirus, Epstein-Barr virus, and the measles virus. Several of those are relatively common virus types with which many of us have been infected at some point without developing multiple sclerosis. But genes also play a role, and many patients with multiple sclerosis have the HLA-class II tissue type, which is linked with autoimmune diseases in general. Genetics might also contribute to explaining why the disease is more common in some regions of the world – such as Northern Europe, where there is both a high rate of the above virus types and people with sclerosis genes. In Norway and Finland, 177 and 155 in 100,000 people have multiple sclerosis, far above nations further south such as Bulgaria, where the rate is 62 in 100,000 people. The Sámi people who live in Northern Norway and Finland develop the disease far more rarely than their fellow countrymen, with a rate of only 30-50 in 100,000 people. This indicates that it is not solely environmental factors that trigger the disease.

Also notable is that parents can pass the disease on to their children. If one parent has multiple sclerosis, the risk of the child developing the disease is 4%. That is 20-50 times higher than the risk for the general

ATTACK



Injuries slow down the signal

3 The signal can no longer jump between the myelin sheaths, making nerve cells communicate more slowly. In addition, the cell is more exposed without insulation and could end up being completely destroyed.

Sclerosis is in the genes

Scientists do not yet know why the immune system attacks the body's healthy cells. But according to statistics, the genes play a central role.

4 IN 100,000

people are diagnosed with sclerosis annually, the majority of whom live in Northern and Western Europe.

15-20%

of sclerosis patients also have a relative with the disease.

85% of all cases are characterised by severe and sudden attacks on different parts of the central nervous system.

4%

is the risk of developing multiple sclerosis if one of your parents has the disease.

SHUTTERSTOCK

population. If both parents have multiple sclerosis, the child's risk increases to 25%.

Stem cells may stop slaughter

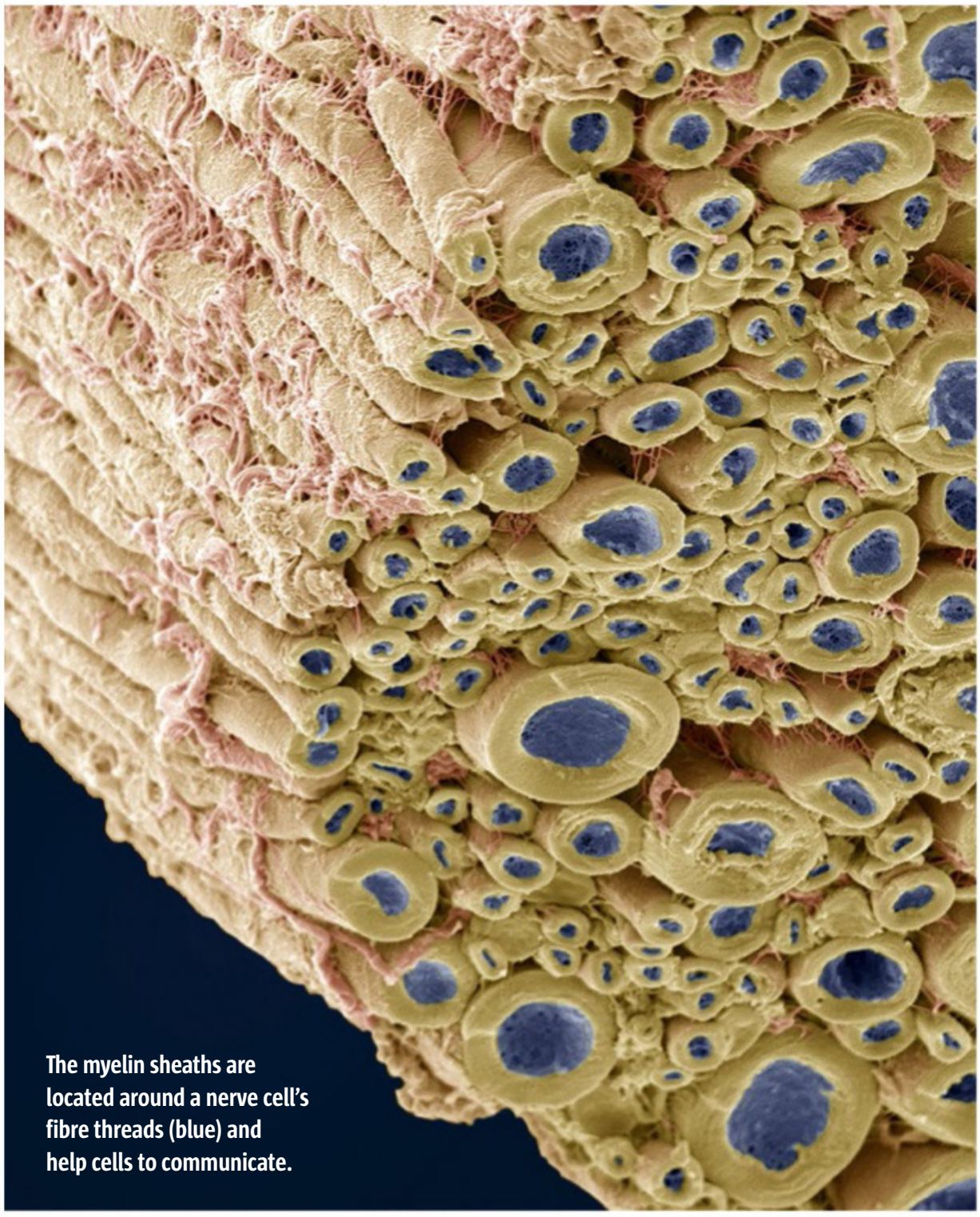
A brighter scenario may be developing for sclerosis patients. A series of research results indicate that stem-cell treatment could be extremely effective and, in rare cases, represent almost a cure against the aggressive disease.

Put briefly, stem cells are undefined cells that exist in all multicellular organisms — undefined in that they can develop into any and all types of cells. These cells have been used successfully to treat other diseases and injuries for many years, including injuries to the nervous system in the spinal column. And scientists are working on three different stem-cell sclerosis treatments, two of which have already been successfully tested on humans, while the third has already produced promising results in animals.

25%

is the risk that a child of two parents with MS will also develop the condition.

In the first treatment tested, scientists deliberately destroy the patients' immune systems by means of chemotherapy, then subsequently persuade the stem cells to build a new defence system from scratch. The stem cells used are blood stem cells, which can develop into immune cells. In this way, the patients effectively get a entirely fresh immune system, as they did when they were babies. That can be both good and bad. On the one hand it means that the immune system must get to know many harmful organisms all over again – with the patients meanwhile very vulnerable to a number of diseases that could, at worst, be fatal. But on the other hand, the immune system is no longer confused between friends and enemies. In this way scientists are able to halt the ongoing slaughter of the important myelin sheaths.



The myelin sheaths are located around a nerve cell's fibre threads (blue) and help cells to communicate.

STEVE GSCHMEISSNER/SPL

Embryonic cells repair the brain

Stem-cell treatment is already sufficiently recognised that it is offered to sclerosis patients in several Western countries, though only to the most badly affected on whom other drugs have no effect, given the risk of severe infection from the treatment is high. On the other hand, research shows that it can remove the disease's symptoms for at least three years in 85% of patients. After six years the percentage is approximately 65%, and after eight years still around 60% of patients have no symptoms – and for those in which the disease does return it often manifests in a milder version.

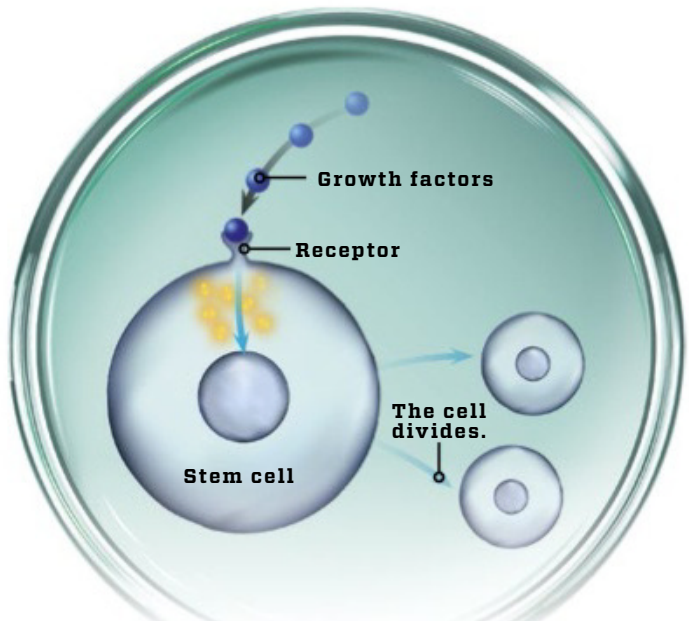
Another type of stem-cell treatment being developed, but not yet offered in hospitals, has the potential not only to curb the immune cells but also to repair some of the damage the immune system has already inflicted on the nervous system. This is made possible by means of mesenchymal stem cells, which exist in the bone marrow and can develop into bone, fat, and cartilage cells. Scientists extract the stem cells from the patients' own pelvis bone marrow with a needle and subsequently inject them into the blood stream, where they travel to the nerve cells. There they emit growth factors which make the nerve cells repair themselves. So the patients avoid having their immune systems destroyed, and face a much lower risk of severe infection.

One more stem-cell treatment, which is currently being tested on humans, makes use of stem cells from the early stages of fertilised eggs – embryonic stem cells. These cells have the potential to develop into any cell type, and scientists use this ability in the lab, where the stem cells are converted into early stages of the high-fat cells that help nerve cells to communicate – the oligodendrocytes themselves.

If scientists manage to replace the damaged nerve cells with cells made in the lab, it could not only provide a treatment for some of the world's 2.3 million sclerosis patients, it might further pave the way for the use of stem cells in the treatment of other disorders that originate in the brain, such as spastic paralysis in children. SCI

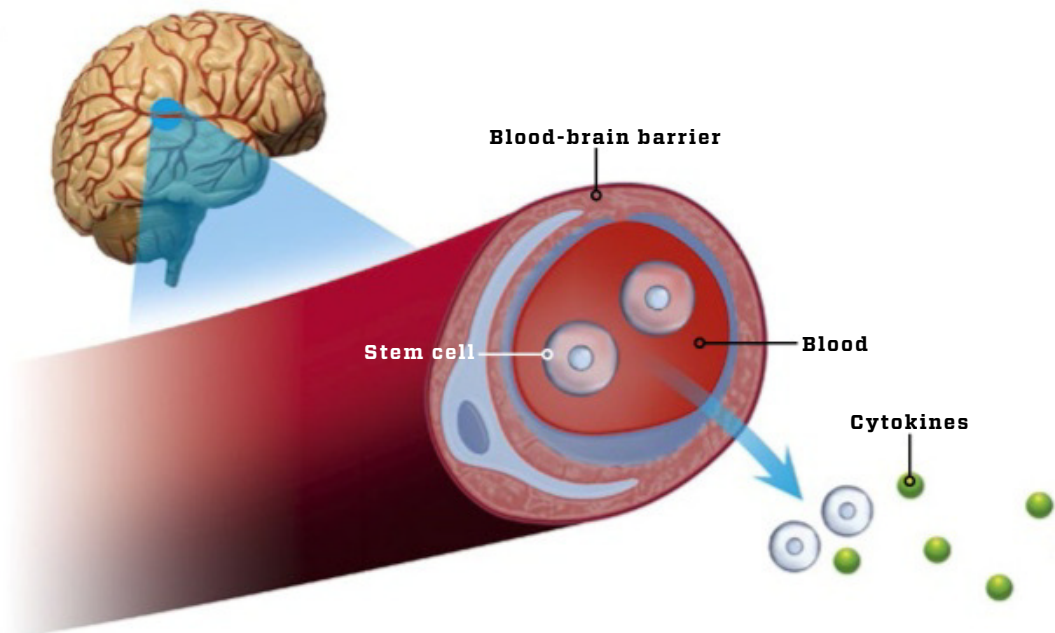
Using the body's own cells to help the brain

Stem cells from the patient's own pelvis function as a private rescue service that helps the destroyed nerve cells regenerate and also helps prevent the stray immune cells from spreading more toxins.



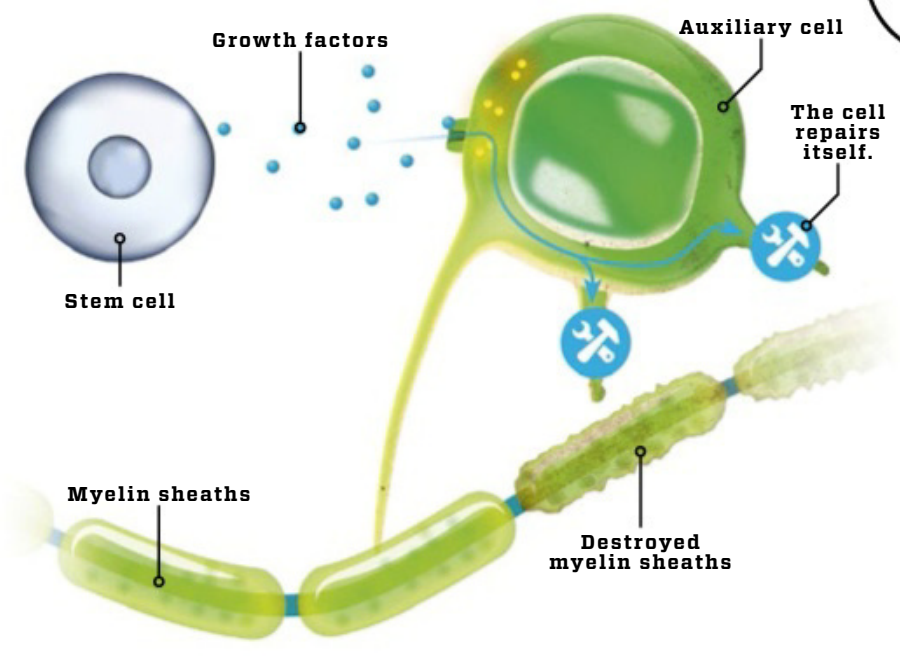
Stem cells retrieved from the bone marrow

1 Scientists extract mesenchymal stem cells from the patients' pelvis bone marrow with a needle. The scientists then mix the stem cells with a fluid that contains growth factors; the growth substances settle on the surface of the stem cells and make them divide.



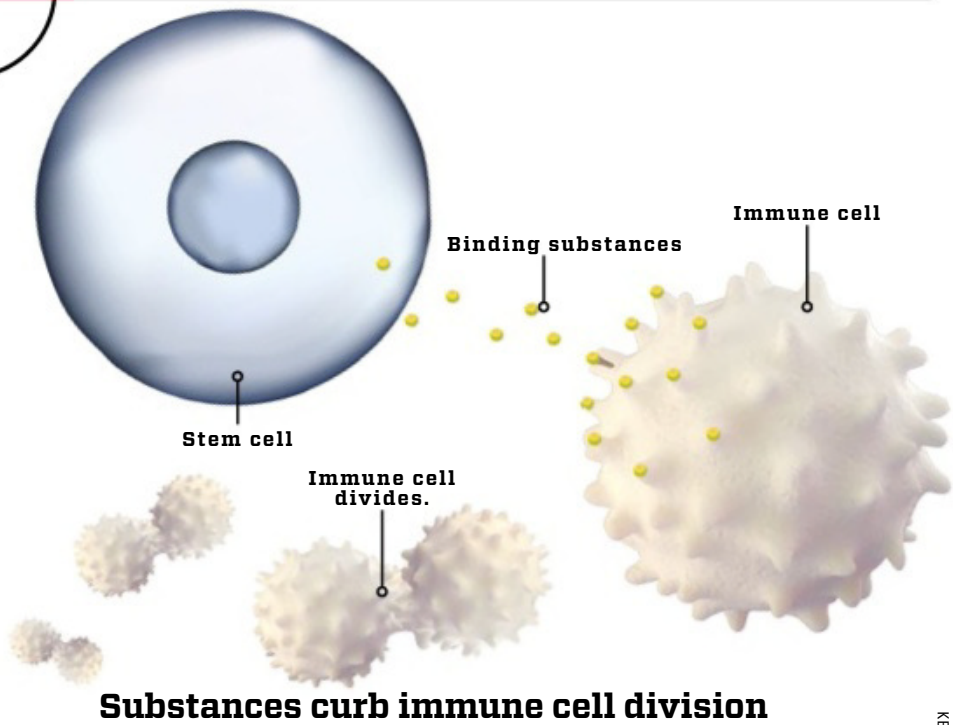
Cells travel to the brain

2 Scientists inject the stem cells into a blood vessel in the arm, from which they travel to the brain. The stem cells are attracted by the toxic cytokines from the immune cells, potentially making them pass through the blood-brain barrier, which already has holes in it.



Growth factors repair damaged cells

3 Once the stem cells are inside the brain, they liberate a series of growth factors which settle on receptors on the outside of the auxiliary cells' membranes. This makes the cells divide, so there are more of them, but it also makes them repair the damage that the immune cells have already caused.



Substances curb immune cell division

4 The stem cells also liberate other substances that bind to the immune cells and curb the production of the infectious agents – the toxic cytokines. The substances also slow immune cell division, so they prevent any further damage to the nerve and auxiliary cells.

KEN IKEDA MADSEN/SHUTTERSTOCK

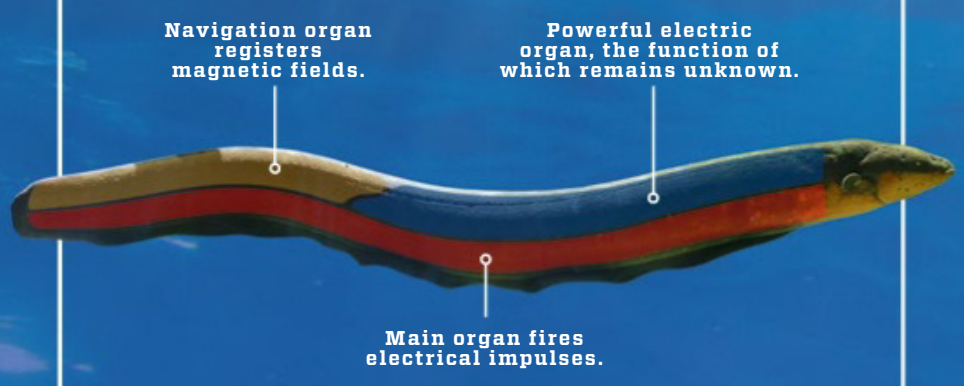
High-voltage animal kingdom

NATURE'S ELECTRICIANS

Paralysis-inducing electric shocks. Eyes that produce lightning. Living solar cells. Nature's current-carrying creatures use the forces of electricity for hunting, navigation, even for climbing vertical rock walls.

Three oblong organs generate electricity

The electric eel is like a swimming bag of batteries. It has three electric organs which resemble voltaic piles – an early battery type that consisted of stacked zinc and copper discs.

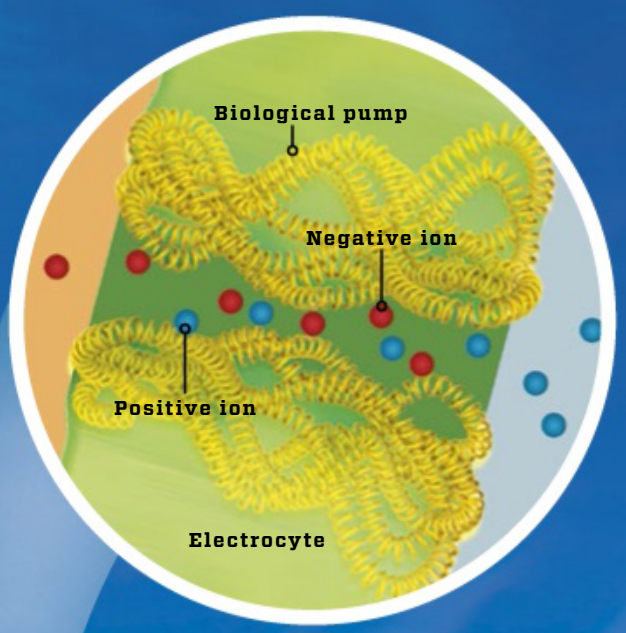


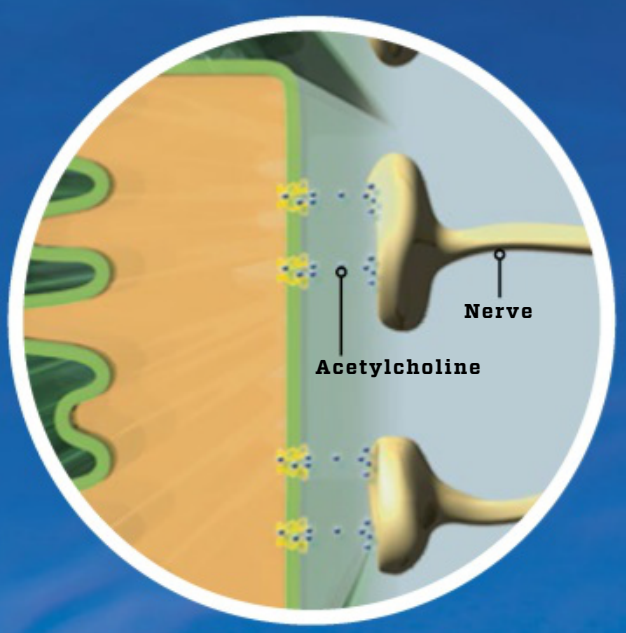
600 volts to paralyse prey and predators.

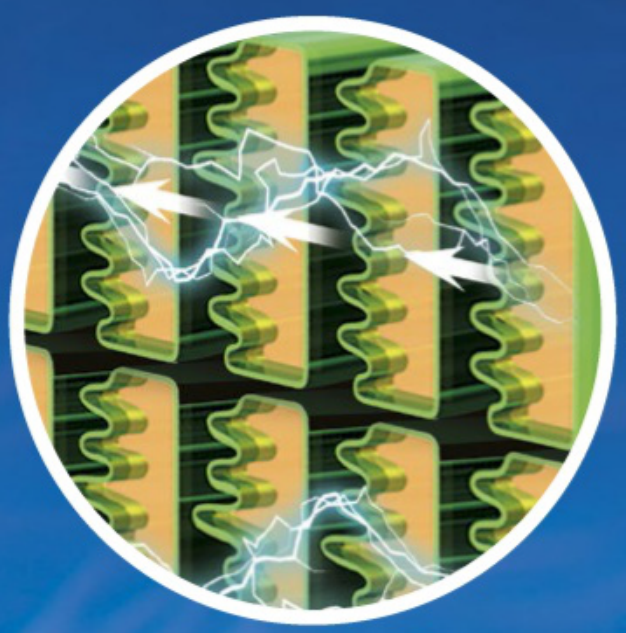
By **Lea Milling Korsholm** & **Lars Thomas**

Electric cells to paralyse prey

The South American electric eel can generate up to 600 volts which it uses for both defence and attack. The powerful discharges can leave even large animals unconscious, allowing the eel to consume them at leisure – or take flight.







2 **Biological pumps** in electrocyte cell membranes send negatively-charged ions out of the cell and positively-charged ions into the cell, causing a voltage difference of about 0.1V between the outside and the inside, converting the cell into a small battery.

3 **When the eel wishes to emit a shock**, nerves release neurotransmitting acetylcholine. This makes the closest electrocytes fire their 0.1V spark, influencing the next ones in the sequence to do the same thing, creating a wave.

4 **The wave of firing flows** through the animal's entire body in a mere two milliseconds. An adult electric eel may have some 6000 electrocytes, so if they are all influenced and fired, the result can be a shock of around 600V.

1 **The eel's electric organs** consist of flat, disc-shaped cells, **electrocytes**, that are stacked very closely together.

An adult eel has around 6000 electrocytes, each creating 0.1 volt, so a full firing can result in a total delivery of around 600 volts.

CLAUS LUNAU & NORBERT WU/MINDEN/RITZAU SCANPIX

Hornet power! Yellow cells work like a solar array.

The oriental hornet has developed special cells on the surface of its body which function like rooftop solar cells.

Scientists used to think that plants and a few bacteria were the only things that could absorb energy directly from sunlight. But it turns out that the oriental hornet uses specialised cells in its exoskeleton to generate electricity from the sun. The yellow areas of its body contain the xanthopterin pigment, and scientists isolated this pigment from the hornet and used it in a normal solar-cell electrode. When the electrode was subjected to intense light, energy was transmitted to the pigment solution, which subsequently generated electrical energy. The hornet's solar cells liberate only 0.335% of available solar energy, so the insect has to complement the sunlight's energy with solid food.

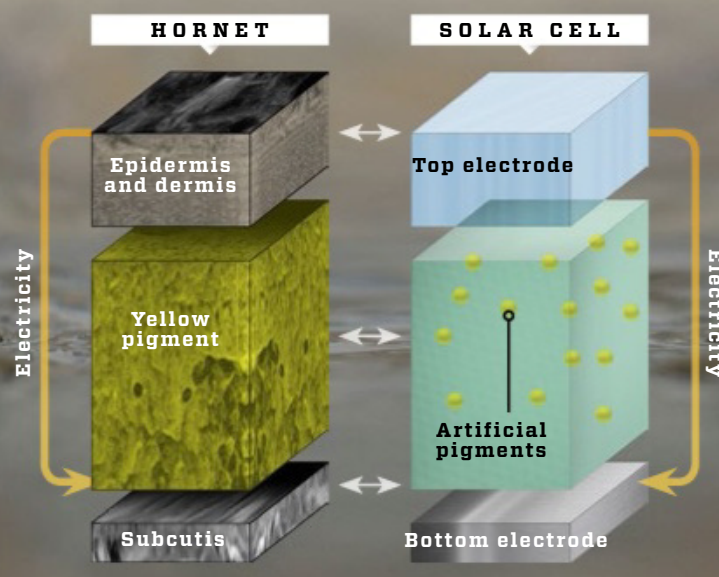
New cells harvest solar energy.

Yellow cells on the abdomen of the hornet contain the xanthopterin pigment which converts sunlight into electricity.

KEN IKEDA MADSEN & SHUTTERSTOCK

Pigment converts sunlight into power

The hornet's epidermis and subcutis function like the top and bottom electrodes of a solar cell. Between the two layers, the hornet has a yellow pigment that functions like the artificial pigments of a solar cell: when the sunlight affects the pigment, the solar energy is converted into a flow of electrons.



Echidna's sixth sense reveals hidden worms and ants

The Australian echidna, or spiny anteater, shares with the platypus the status of being the only egg-laying mammals living on dry land. But it shares something else with the platypus — an electric sixth sense.

Free nerve endings in the echidna's beak act as electrical receptors to pick up the very weak electrical signals that all living creatures generate from, for example, nerve paths making muscles move. These enable the echidna to locate worms, ants and termites that hide in the ground or in rotten tree trunks. Depending on whether it is a short-beaked or long-beaked echidna, it may have either 400 or 2000 electrical receptors in total.

Snout registers down to 1.8 millivolts.

The echidna's receptors can pick up weak electrical signals from creatures wriggling in the ground.

JIRI LOCHMAN/NATUREPL

Fish uses electricity to hunt

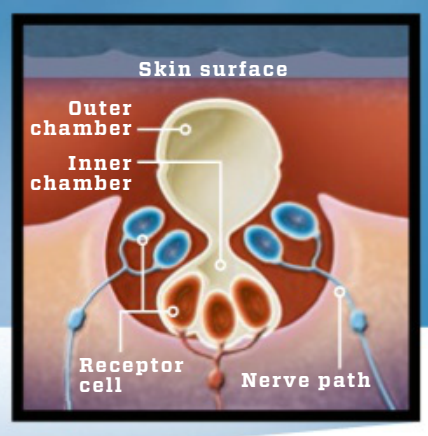
By emitting ripples of electrical signals from tail muscles, this elephant-nose fish can hunt in pitch darkness. Sensitive cells in its 'chin' and elsewhere function as receptors to pick up the echo of prey.

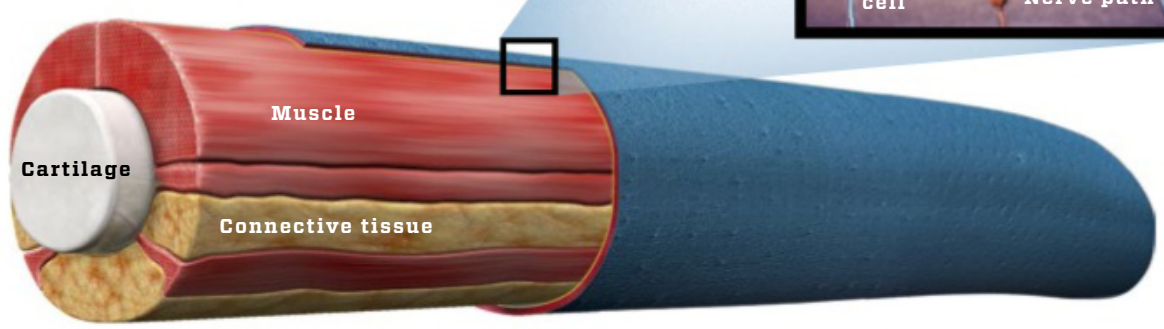
CLAUS LUNAU & PAT MORRIS/ARDEA.COM

The chin is hyper-sensitive

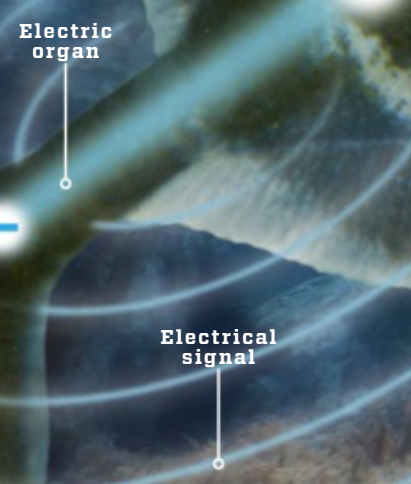
The skin on the trunk-like mouth extension of *Gnathonemus petersii*, also known as Peters' elephant-nose fish, is equipped with 500 of its skin's total 4000 receptors. So this 'chin' is extra sensitive to weak electric signals from prey hidden in the mud of a river bed, which are 'illuminated' by signals emitted from its tail. The skin is highly insulating so it does not allow passage of electrical impulses direct from the tail muscles. The receptors consist of two slime-filled insulating chambers that control separate receptor cells.

Cross-section of electroreceptor



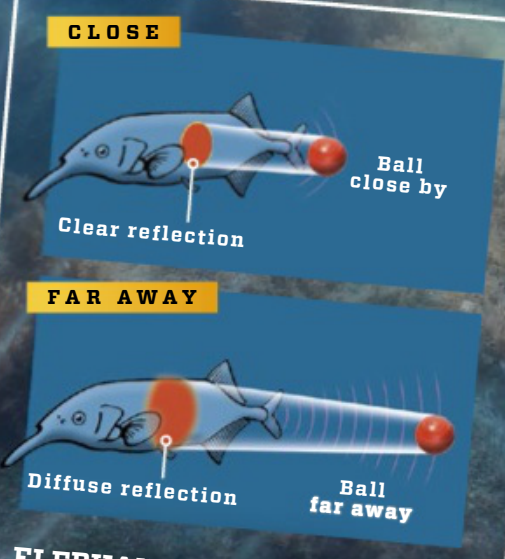


100 signals per second emitted.



Waves of electricity scan the dark river water

The elephant-nose fish emits electrical signals from two muscle bundles in its tail-head. This happens up to 100 times per second. The electric signals spread like rings in the water around the elephant-nose fish. Special skin receptors sense reflections of these signals, which are interrupted by objects in the water, such as prey. The skin receptors register the interruptions and send a message to the brain. Based on the messages from the many receptors, the brain produces an internal 3D image of the unknown object.



ELEPHANT-NOSE FISH USES POWER AS A RULER

Biologists have studied the elephant-nose fish's ability to measure distances by placing balls in different positions. The scientists discovered that the fish can estimate distances down to a few millimetres by using its electrical sense. The fish uses the fact that the electric reflection from the ball becomes ever more vague with distance. Based on the degree of clarity, the fish estimates the distance.

Sharks feel the heartbeat of prey

Sharks use electricity to sense the outside world, and indeed hammerhead sharks could not survive without their delicate electrical sense.

As a supplement to sharks' excellent senses of vision and smell, their snouts are lined with ampullae of Lorenzini – small pores filled with an electrically conductive gel. These ampullae are influenced by even very weak electrical discharges, with their reactions carried to a bundle of nerve threads at the bottom of each ampulla, which sends a message to the brain.

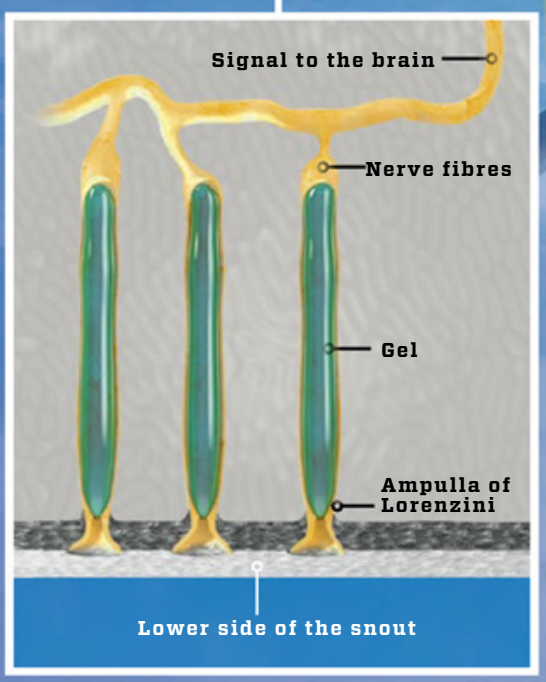
One single ampulla of Lorenzini can react to just five billionths of a volt, so that a shark can find a shrimp based only on the slight electrical charge generated by the shrimp's heart. The lower side of a hammerhead shark's head is lined with ampullae. According to some scientists, the hammerhead shark uses its special head shape to make an electrical 3D image of the creatures located right beneath its head. The ability is vital, as the shape of the shark's head means that it has a huge blind spot under its snout and around the mouth. Experiments have shown that if the shark's electrical sense is blocked, it has difficulties finding and catching its prey.

Gel picks up electric signals

1 **The lower side of a hammer-head shark's** head is dotted with ampullae of Lorenzini that consist of a pore leading to a canal filled with electrically conductive gel.

2 **If a shark comes** into contact with an electric field, such as from a fish hiding beneath the sand, the current is carried away from the skin to the pores of the ampullae.

3 **Subsequently, the current flows** through the gel to affect the nerve fibres. An impulse is passed on to the brain, which forms an image of the creature beneath the sand.



Gecko feet are studded with electromagnets

It isn't suction discs or super-glue that allows a gecko to cling to difficult surfaces at tricky orientations. The gecko is climbing using an electrostatic effect.

Geckos are known to be able to climb all surfaces, from vertical walls to the under-side of a window sill. They can do this thanks to a phenomenon known as Van der Waals force.

All atoms are made up of positively-charged protons and a cloud of negatively-charged electrons that are in constant motion. In molecules with many atoms, the electrons can move freely between the many clouds that surround each atomic nucleus. If the electrons unite at one end of the molecule, it is temporarily negatively charged, whereas the opposite end becomes positively charged. The result is volatile electromagnetism that briefly binds the molecules in the gecko's feet to the window sill.

A gecko's feet contains about 2 billion electromagnetic bindings that help it stick to any surface.

FRANS LANTING/MINT IMAGES/IMAGESELECT

By means of electrically-sensitive ampullae, hammerhead sharks can spot creatures hiding beneath the sand.

CLAUS LUNAU & WILDESTANIMAL/GETTY

Current-sensitive gel spots the prey.

Electromagnetism makes the gecko stick.

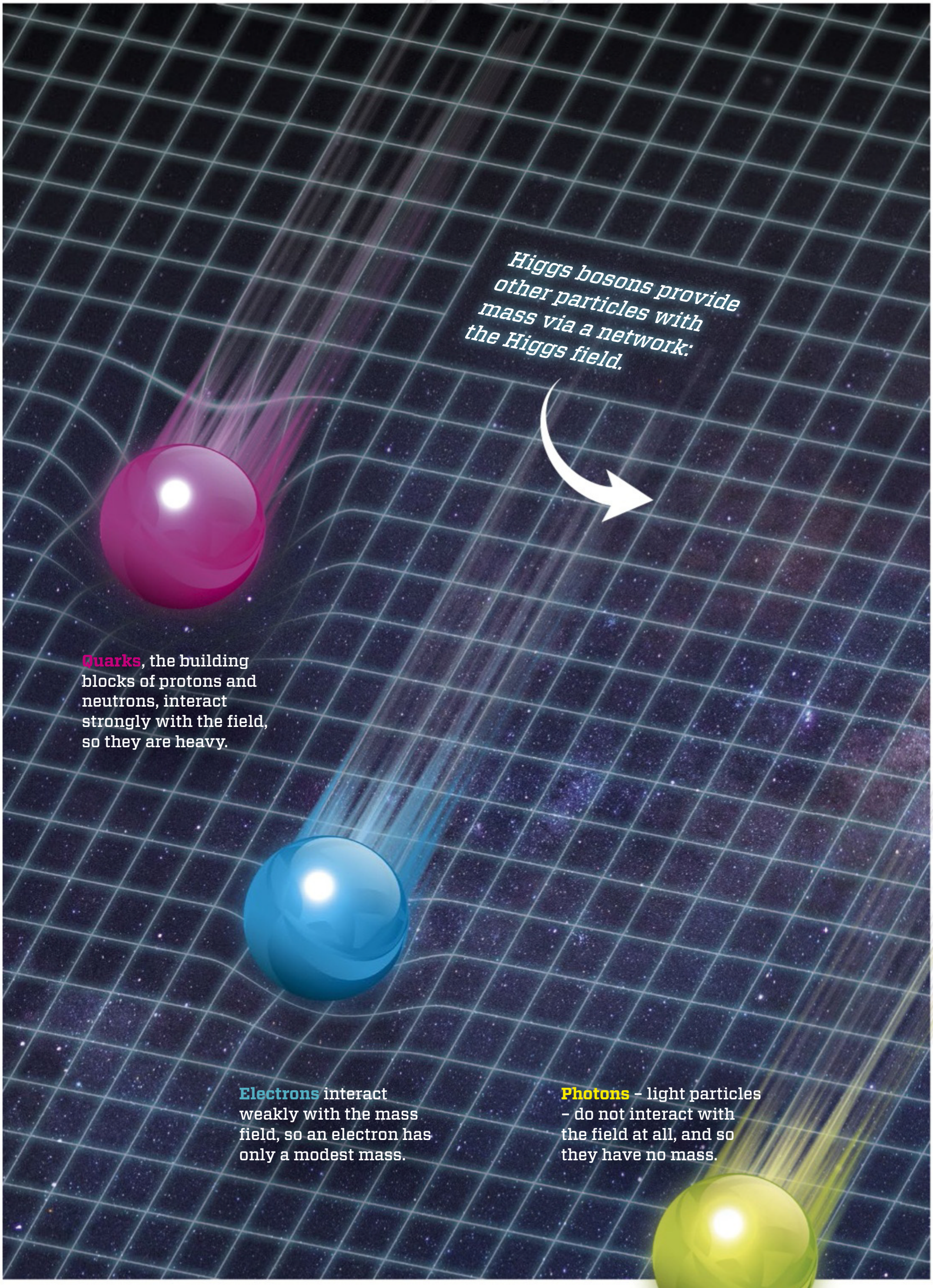
Fish eyes can kill!

The stargazer (*Astroscopus*) spends most of its life hiding in the sand. Its front fins function as shovels that dig to bury the fish, leaving only its eyes, gills, and nostrils protruding. By inhaling water through the nose and out through the gills, the stargazer produces small ripples on the ocean floor that resemble activity by small fish. The ripples attract bigger prey, and when it comes close enough, lightning strikes. The stargazer's eyes include four extra muscles that form an electrical generator. The muscles emit electric charges of up to 50 volts – more than enough to paralyse the prey. The stargazer then opens its mouth quickly to 'vacuum' up its lunch.

The stargazer can pop out its killer eyes and rotate them individually by filling a cavity behind the eyes with liquid.

50 volts dart from the eyes.

PASCAL KOBEH



KEN IKEDA MADSEN

18+

WHAT IS AVAXHOME?

AVAXHOME-

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Unlimited satisfaction one low price
Cheap constant access to piping hot media
Protect your downloadings from Big brother
Safer, than torrent-trackers

18 years of seamless operation and our users' satisfaction

All languages
Brand new content
One site

AVXLIVE.ICU

AvaxHome - Your End Place

We have everything for all of your needs. Just open https://avxlive.icu

By **Rolf Haugaard Nielsen**

Higgs boson pairs could reveal the origin of all mass

In every corner of the universe, Higgs bosons cooperate to give mass to all atomic building blocks. Physicists aim to produce the particles in pairs to reveal how their teamwork allowed matter to beat antimatter after the Big Bang.

A network of Higgs bosons encloses the entire universe, from the remotest of galaxies to the innermost cells of humans. Although it is neither visible nor directly measurable, the Higgs field is certainly stable – otherwise Earth would become weightless at regular intervals. Since the beginning of the universe, the Higgs field has been constantly active to ensure that all atom building blocks – such as quarks and electrons – have mass. The question of how this mass field works, however, has tormented physicists ever since the Higgs particle materialised for the first time in their detector in 2012.

CERN physicists now aim to reveal the secret of the field by producing Higgs boson pairs, and studying how they react with each other. The production will begin when an updated version of the Large Hadron Collider (LHC) is completed in 2021 after two years of upgrading. By then, physicists hope to be able to solve the mystery of why everything has mass. And further, the Higgs pairs might allow us a peek into the world of dark matter.

Pairs keep Higgs field active

Although nobody has yet studied the nature of the Higgs field, physicists have an idea of how the network works, based on existing physics theories. The Higgs field provides the particles with energy and, according to Albert Einstein's famous equation $E = mc^2$, energy equals mass.

The Higgs field can be compared to an electric field between positively and negatively charged electrodes, but with one crucial difference: an electric field disappears when the voltage difference between the electrodes is neutralised. The Higgs mass field, however, is active throughout the universe eternally, because the Higgs bosons constantly react with each other. The reactions maintain the charge of the field, providing elementary particles with their mass.

Each building block of atoms with mass interacts differently with the Higgs field. Quarks interact intensely with the field, and so are relatively heavy. Electrons interact more weakly, so these particles are lighter.

But it is unknown how the Higgs boson reactions keep the field active all the time. The LHC will try to find the answer.

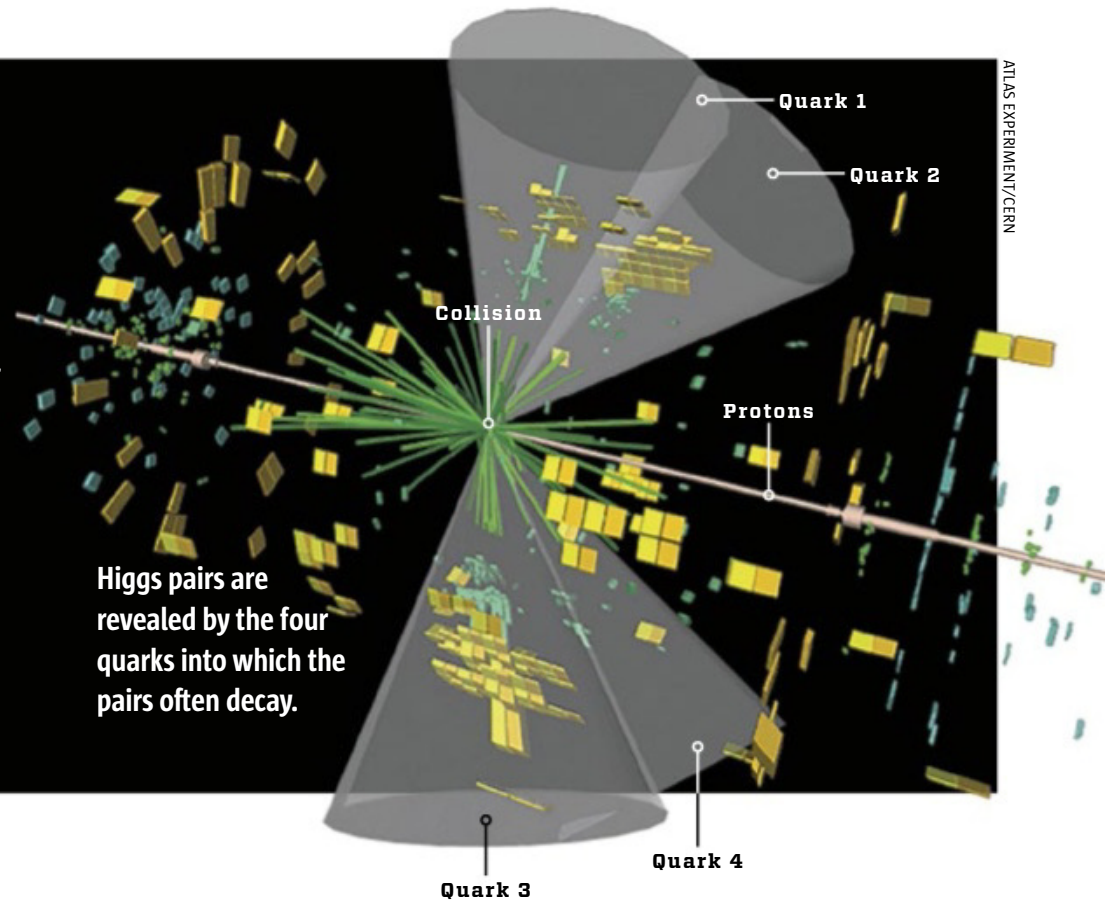
Frequent decay is a clue

While the LHC has probably already produced around 1000 Higgs boson pairs, they are so rare that they drown under the noise of the showers of particles produced in trillions of collisions since the experiments began in 2010. But a new discovery boosts optimism.

When physicists discovered the Higgs boson in 2012, it was revealed by the rare decay into two high-energy gamma photons. But last year, physicists observed a Higgs boson that decayed into two heavy bottom quarks, which can be produced only in high-energy proton collisions such as in ▶

Accelerator is prepared for the search for Higgs pairs

When the protons of the Large Hadron Collider particle accelerator collide with an energy of 13 trillion electronvolts, one Higgs pair will theoretically occur for every 2000 individual Higgs bosons. The rarity has made it impossible yet to prove pair production. But in 2016, the large ATLAS detector found a possible Higgs pair, providing physicists with an idea of what to look for. In order to intensify the search, the LHC has been improved twice. Before the next experiments in 2021, the detectors are being upgraded to enable them to find more Higgs pairs. The accelerator itself will be adjusted in 2024-2025, boosting the collision rate to 10 billion proton collisions/second and improving the chances of producing a Higgs pair.



ATLAS EXPERIMENT/CERN

Higgs pairs are revealed by the four quarks into which the pairs often decay.

the LHC. This type of decay is believed to occur in 60% of the cases where the LHC produces an individual Higgs boson. But the same is true when Higgs bosons are produced in pairs, so physicists now know what to seek in order to identify Higgs pairs in the huge quantities of data – the simultaneous formation of four bottom quarks.

This clue improves the chances of the LHC in its lifetime up until 2035 revealing the secret partnership of Higgs bosons and determining how they produce the eternal, universal mass field.

Higgs pairs reveal primordial soup formula

The LHC has previously produced a version of the primordial soup of the universe that existed for about one microsecond after its formation. But the Higgs pairs represent yet another tiny step back to the formation of the primordial soup, in which the Higgs field originated one trillionth of a second after the Big Bang. Before then, the brand new universe had, according to the theory, expanded faster than the speed of light for an ultra-short period known as 'the inflation'. The explosive expansion was powered by hypothetical particles known as inflatons. When the Higgs field originated, there was a phase transition (as when steam cools into liquid water), and the field converted the energy of the inflatons into mass in the shape of the quarks and antiquarks of the primordial soup. If scientists manage to produce enough Higgs pairs and reveal how the particles cooperate, physicists can calculate the energy density of the original Higgs field and so learn more about the intensity of the phase transition.

If the formation of the original Higgs field triggered an extremely intense phase transition, it might have caused instability that could explain why all the universe's galaxies consist of matter. This victory of matter over antimatter has been a mystery for decades. According to physics theory, the exact same number of quarks and antiquarks would have formed. But if so, the universe's myriad galaxies would not exist, since when matter and antimatter meet, the particles destroy each other. So for every one billion antiquarks, at least a billion and one quarks must have been produced. The surviving quarks subsequently formed the first atoms.

40

times as many pairs of Higgs bosons as from the LHC should be delivered by the new Future Circular Collider.

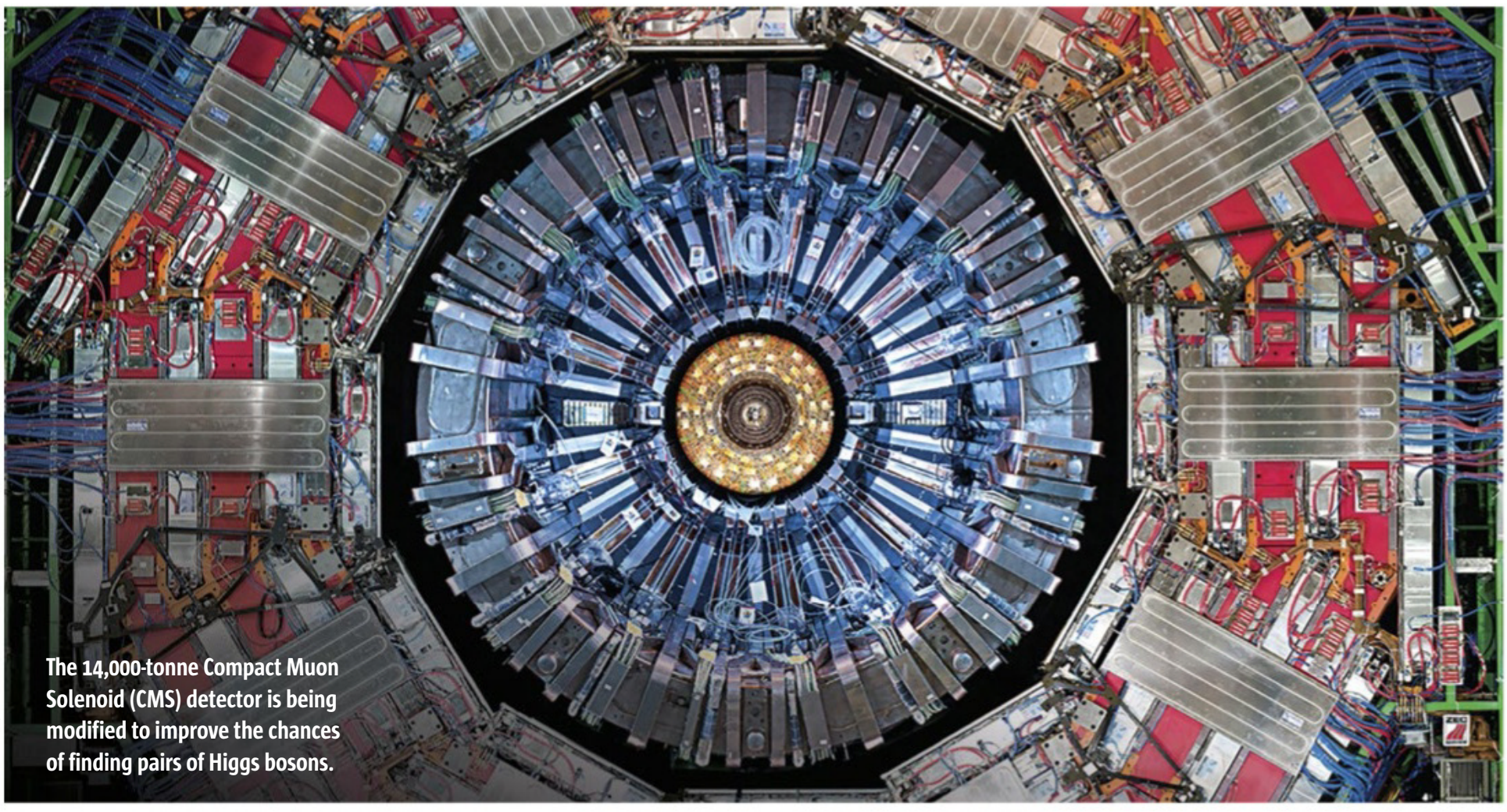
Dark Higgs bosons at play

Decades ago, the Higgs bosons and their mass field were added to physicists' standard model to explain how all atomic building blocks get their mass. When the LHC experiments produced the Higgs boson, the standard model seemed to have been definitively proved. But the model includes holes, and cannot explain the dark matter that according to astronomers makes up 85% of the total mass of galaxies.

However, Higgs boson pairs could allow us a peek at the hidden world of the dark matter. New physics theories of everything involve the existence of unknown twins of the standard model's Higgs boson, and one of these twins creates a dark matter field that provides the dark matter with mass. If the Higgs boson twins exist, physicists will, with the updated LHC, find up to six times more Higgs pairs than indicated by the standard model. The deviation will be strong indirect proof of the existence of dark matter.

If the LHC cannot produce enough pairs of Higgs bosons, the Future Circular Collider will be ready to take over in the 2040s. The huge accelerator can collide protons seven times more forcefully than the LHC, promising at least 40 times more Higgs pairs.

So physicists will stand a much better chance of solving the mystery of matter beating antimatter, the existence of dark matter, and why all the individual building blocks of atoms have mass – whether in galaxies, in the Sun, or in humans. SCI



MICHAEL HOCH/MAXIMILIEN BRICE

The 14,000-tonne Compact Muon Solenoid (CMS) detector is being modified to improve the chances of finding pairs of Higgs bosons.

Right after the Big Bang, the Higgs field gave mass to matter

One trillionth of a second after the Big Bang, the Higgs field provided both matter and antimatter with mass. Physicists aim to recreate the moment in which the field originated, to understand why antiparticles lost the battle and all known galaxies consist of matter.

The universe grows

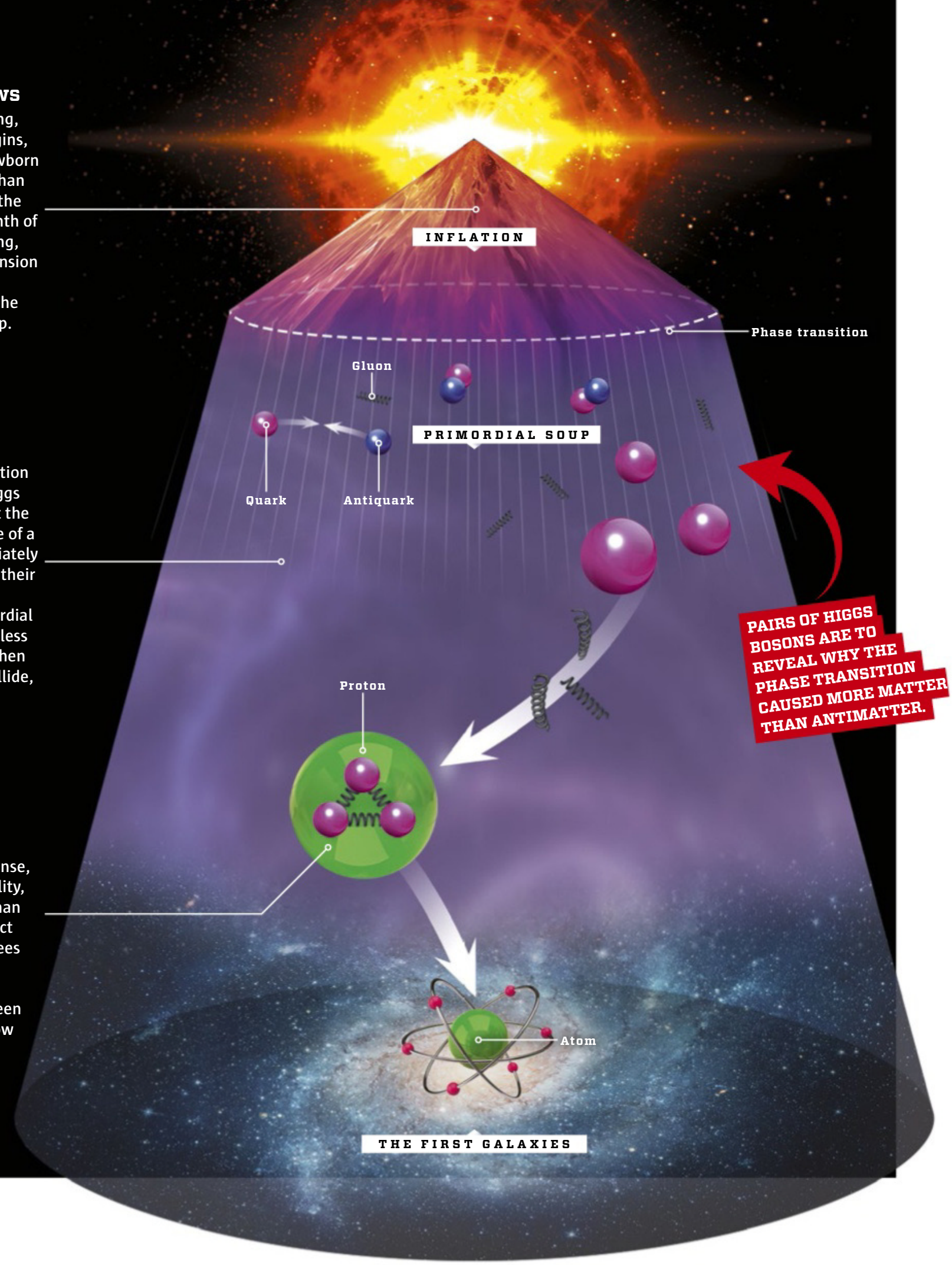
1 After the Big Bang, the inflation begins, in which the newborn universe expands faster than the speed of light. When the inflation stops one trillionth of a second after the Big Bang, the energy from the expansion is included in a phase transition that produces the universe's primordial soup.

The Higgs field is activated

2 The phase transition activates the Higgs field throughout the universe, which is the size of a football. The field immediately gives mass to quarks and their antiparticles (antiquarks) which make up the primordial soup, together with massless force carriers (gluons). When quarks and antiquarks collide, they destroy each other.

Matter beats antimatter

3 If the phase transition is intense, it causes instability, producing more quarks than antiquarks. Gluons connect the surplus quarks by threes in protons and neutrons, which become atoms and galaxies. Reactions between Higgs boson pairs may now show what the phase transition was like.



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MA/SI70

3D printers save sick skeletons

Rubber spines and ceramic implants – doctors can now 3D-print spare skeleton parts, which are more durable and can help patients with bone cancer.

With powder made of calcium phosphate and fat, scientists from the University of Southern Denmark can 3D-print a ceramic material that grows together with the existing bones. In experiments with mice, the artificial bones even produced marrow.

PARTICLE3D.COM

CERAMIC PRINTS | 3D printed ceramics can grow together with living bone tissue.

By **Andreas Ebbesen Jensen**

ROBERT CLARK/NAT GEO/GETTY IMAGES

Hip prostheses can work loose from the bones to which they are attached. With 3D-printed hip sockets made of titanium, doctors can create accurate, durable implants with pores that allow bone and implant to grow together.

| TITANIUM HIP | Customised hip implants made of titanium are better when attached to the bones.

ADAM E. JAKUS/DIMENSION INX

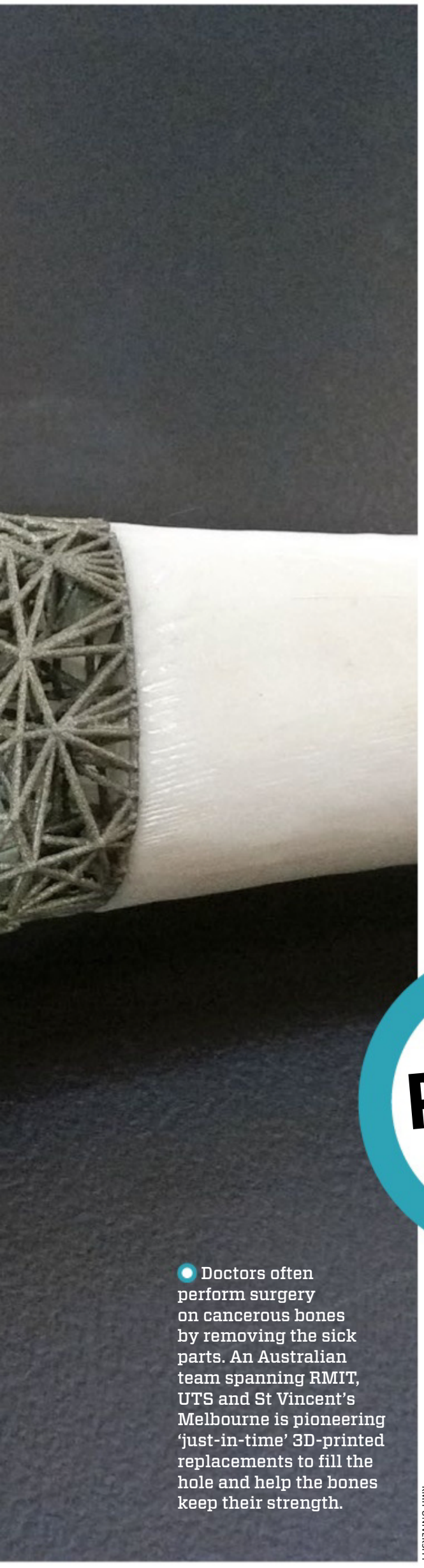
A 3D-printed version of the human spine is made of a hyperflexible material. It can be implanted as a type of scaffolding for new bone tissue to grow on. The hyperflexible bones are converted into ordinary bones.

| RUBBER BONES | A hyperflexible material can help organic bones grow out.

| BONE FILLING | Removed bone segments are replaced by 3D-printed copies.

PhotoDoc

3D PRINTERS SAVE SICK SKELETONS.



Doctors often perform surgery on cancerous bones by removing the sick parts. An Australian team spanning RMIT, UTS and St Vincent's Melbourne is pioneering 'just-in-time' 3D-printed replacements to fill the hole and help the bones keep their strength.

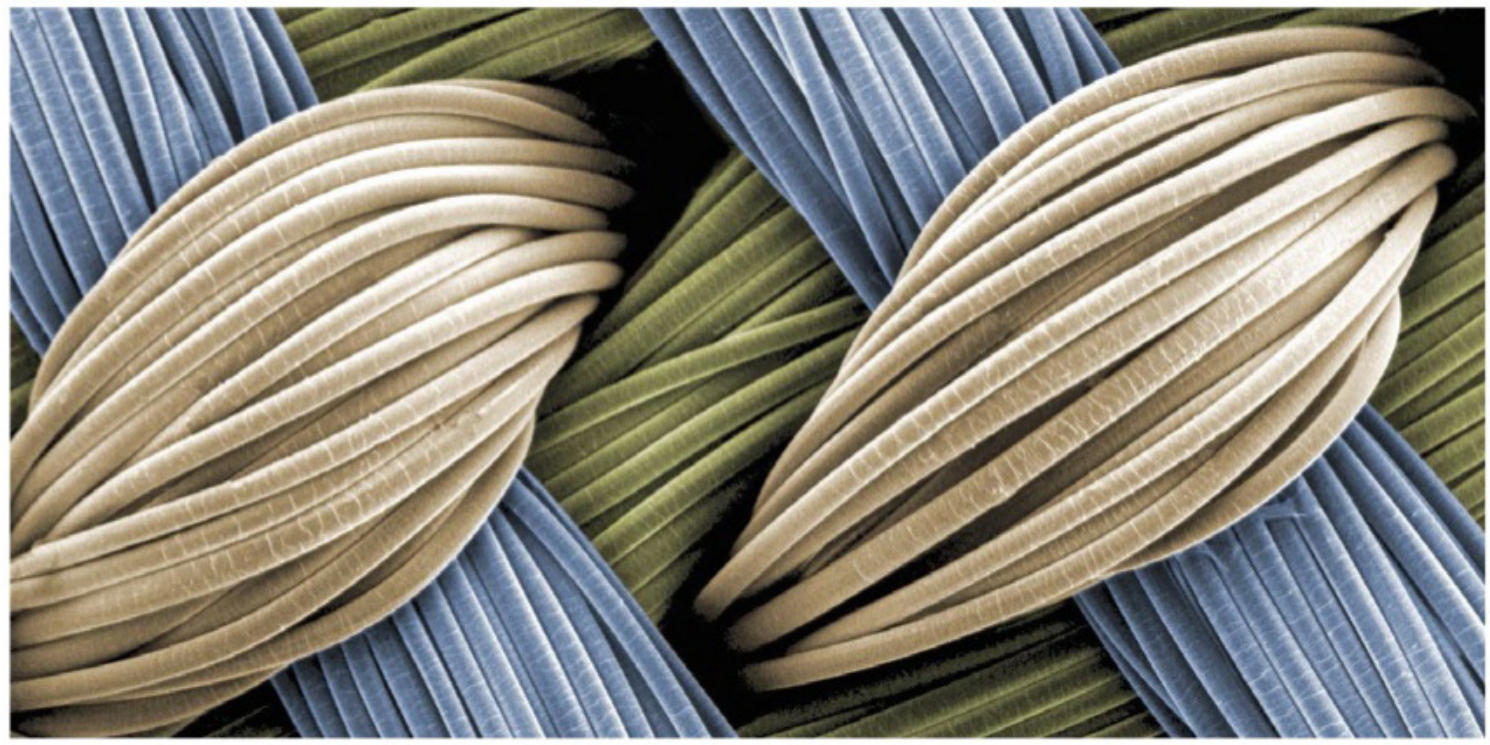
RMIT UNIVERSITY

Patients suffering from excessive bone growth are often in severe pain. With 3D printing, doctors can quickly and cheaply make a required replacement metal implant that will maintain size and shape.

VCG/GETTY IMAGES

CERVICAL VERTEBRA | Metal replaces bones that grow too much.

Scientists have developed synthetic cartilage consisting of seven layers of interwoven fibres, each thinner than a human hair. The fibres make up 3D scaffolding that is supplied with gel to which stem cells can attach to form new cartilage.



COURTESY OF FRANK MOUTOS AND FARSHID GUILAK

| ARTIFICIAL CARTILAGE | 3D scaffolding made of microscopic fibres is printed and converted into synthetic cartilage.

DR. SELENE PAREKH/DUKE UNIVERSITY

A 69-year-old pilot had his ankle replaced after damage by arthritis and bone cysts. By means of CT and MRI scans, doctors made a 3D-printed copy of the talus bone, which is difficult to treat. The 3D-printed ankle worked perfectly.

| ANKLE REPLACEMENT | 3D printers help scientists treat bone diseases in new ways.

Canadian scientists replaced 70% of the dachshund Patches' skull with titanium after removing a tumour the size of an orange. Scans determined the size of the tumour, so the 3D-printed skull section could be customised down to the location of the screw holes.

DAN LOPEZ & MICHELLE OBLAK/UNIVERSITY OF GUELPH

| NEW SKULL | The dog Patches got a new 3D-printed skull following brain surgery.

FABIAN SOMMER/DPA/RITZAU SCANPIX

PhotoDoc

3D PRINTERS SAVE SICK SKELETONS.

The world's first face transplant was carried out in 2005. Today, surgeons analyse the patient's skull in detail before surgery, via 3D-printed models of the head. With the models, surgeons can recreate missing bone structures beforehand, allowing the surgery to be performed more quickly, and involving fewer surprises.

SKULL MODELS | Prior to a face transplant, an exact copy of the skull is printed.

Instant Expert: Smelling & tasting

The sense of smell ensures your survival

Taste and smell are among our most sensitive of senses. Emotions and experiences that we link with taste and smell often determine if we like a food or think that its smells horrible. So while some may think of sweets and snugness when they smell menthol, others think of sore throats.

The sense of smell is one of the oldest senses in mammals, and even though humans have a poor sense of smell compared with some, such as dogs, smells still play an important role in our lives. And taste impressions don't solely originate from the taste of the tongue, but are more a combination of taste and smell. Hence our food loses much of its taste when we have a cold.

Olfactory sensations originate when scent molecules stimulate olfactory cells in the nasal mucosa. The cells' nerve threads pass up through small holes at the bottom of the skull to the olfactory nerve and on to different brain centres.

Taste sensations originate from stimulation of the taste buds of the tongue by molecules dissolved in mouth saliva. We can register a total of five different taste types: sweet, sour, salt, bitter, and umami. All taste sensations are different combinations of those five.

Apart from providing the food with taste, the senses of smell and taste prevent us from eating or breathing harmful substances that smell or taste bad, such as ammonia vapour or sour milk.

Body odours play an important role in parents' recognition of their children, and in newborn babies' ability to differentiate their mothers from other women. Smells also affect our sexual behaviour. When they ovulate, women are more attracted than at other times in their menstrual cycle to men who smell of testosterone.

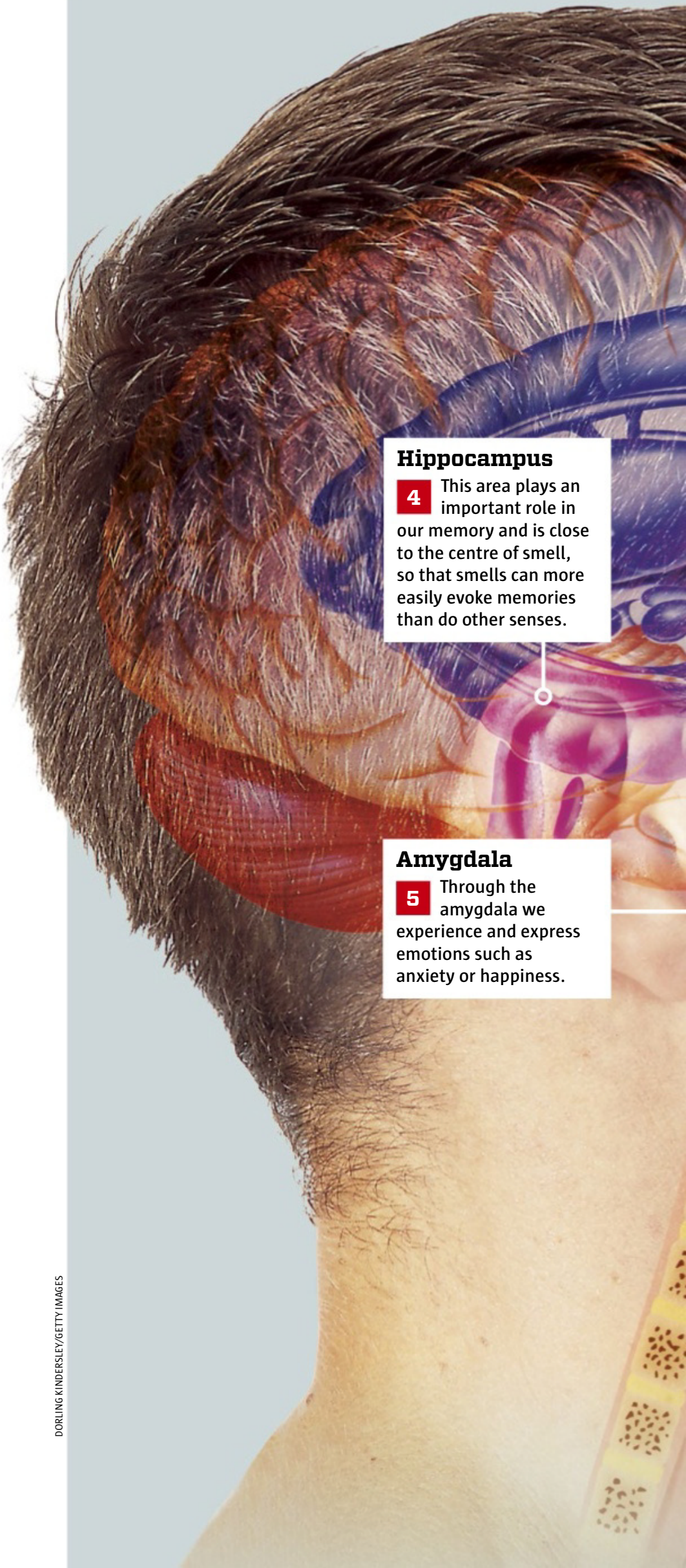
Although the ability to differentiate between the five taste sensations is congenital, the senses of taste and smell are not fully developed at birth. Some babies dislike the smell of rotten onions or liquorice, whereas others like the smell of sweat. And the emotions we feel when we smell or taste something can significantly influence how we interpret the same impressions later. If we eat spaghetti and immediately get an upset stomach, we will probably be put off spaghetti for a good while. The smell of Christmas meals, on the other hand, are likely to elicit pleasant memories in many people.

Apparently, our genes play a role in the tastes we like. People who do not like lemons and vinegar possibly have more sour taste genes, hence are more sensitive than people who don't taste sour things as strongly.

One of the reasons our senses of taste and smell are not fully developed at birth is that humans can live in many different ecosystems. So we need to learn to differ between edible and non-edible food in any given place, such as fish in the ocean or fruit in the forest. It would be a problem if we had been born liking only fish, then ended up being raised in a desert. So our senses of taste and smell help us survive almost anywhere on Earth.

A baby navigates according to a highly developed sense of smell. The smell of mother and breast milk triggers the suction reflexes, making the baby try to find the breast. The sense of vision does not work properly until after a few weeks.

ANNE RIPPY/GETTY IMAGES



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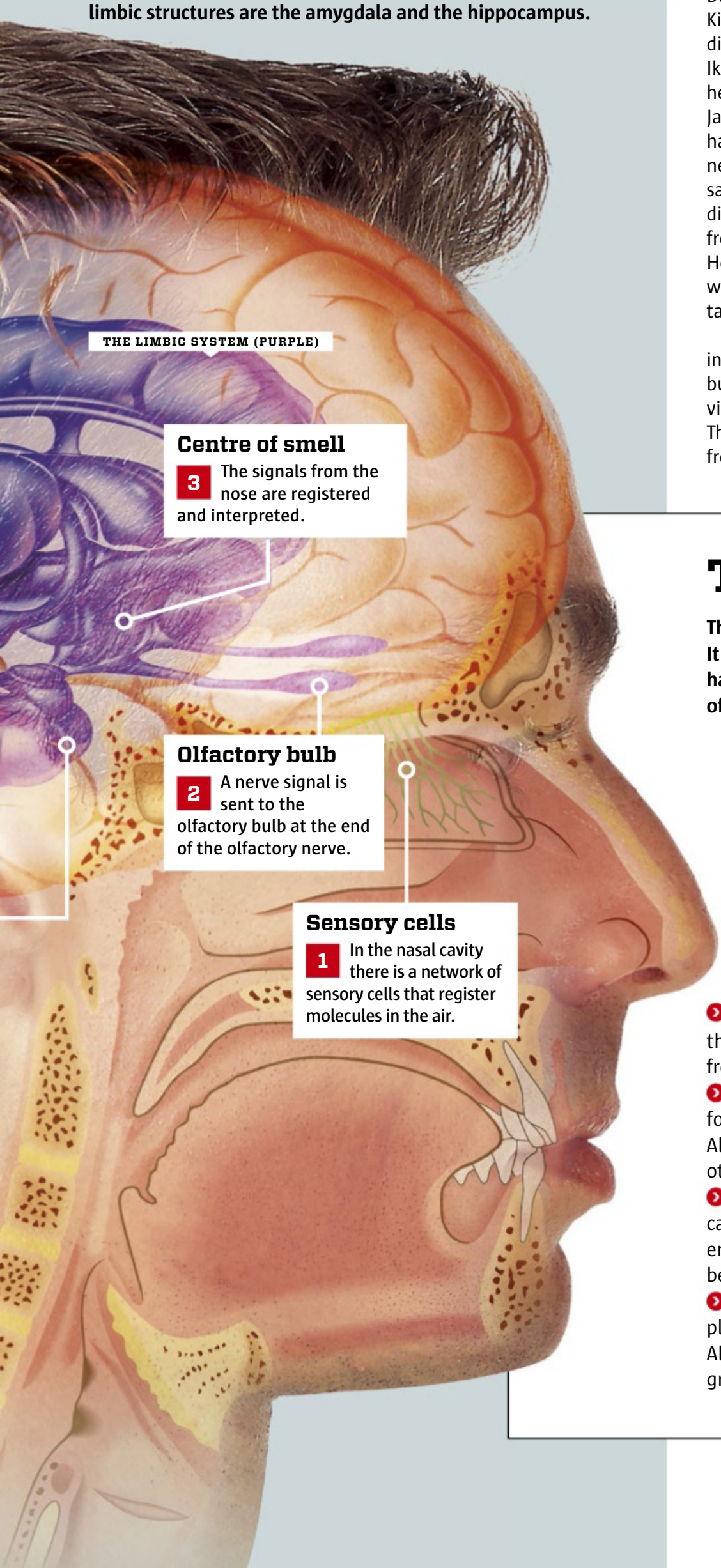
Sense of memories

Smells are the sensory impressions that most easily evoke memories, due to the short distance between the smell receptors of the nose and the limbic system in which emotions and memory are processed. The most important limbic structures are the amygdala and the hippocampus.



The fifth taste

For decades, schoolchildren had learned that the tongue has taste buds for four taste sensations: sweet, sour, salt, and bitterness. But in 1908, Japanese chemist Kikunae Ikeda (1864-1936) discovered a fifth taste: umami. Ikeda spotted the umami taste as he was eating dashi, traditional Japanese seaweed soup. The soup had a familiar taste which was neither sweet nor sour, bitter or salty. So Ikeda went to his lab to discover that the secret taste came from the L-glutamate amino acid. He named the taste "umami", which means "pleasant, savoury taste" in Japanese.

Fat, carbohydrates and proteins in food have no taste in themselves, but they trigger taste sensations via their break-down products. The individual sugar molecules from carbohydrates, mono and di-saccharides taste sweet, whereas L-glutamate, which is the most common building block of proteins, causes the umami taste.

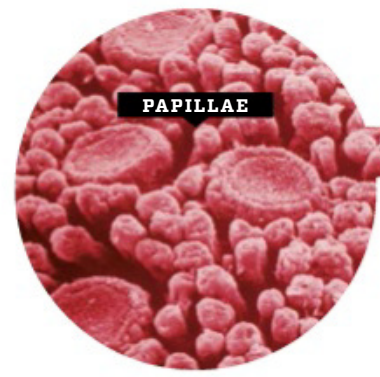
Umami is rather weak, even in high concentrations. Since the 1980s, research in taste has intensified and, in 2002, scientists identified the taste receptor that allows us to taste umami in high-protein food.

SHUTTERSTOCK

In the Japanese kitchen, the umami taste is often marked by the use of seaweeds, fish, mushrooms, and soy.

Tongue taste-testing

The sense of taste is very important for our well-being and survival. It is the last checkpoint before we eat or drink things that might be harmful. The sense of taste must both estimate the nutrition value of the food and protect us against eating something toxic.



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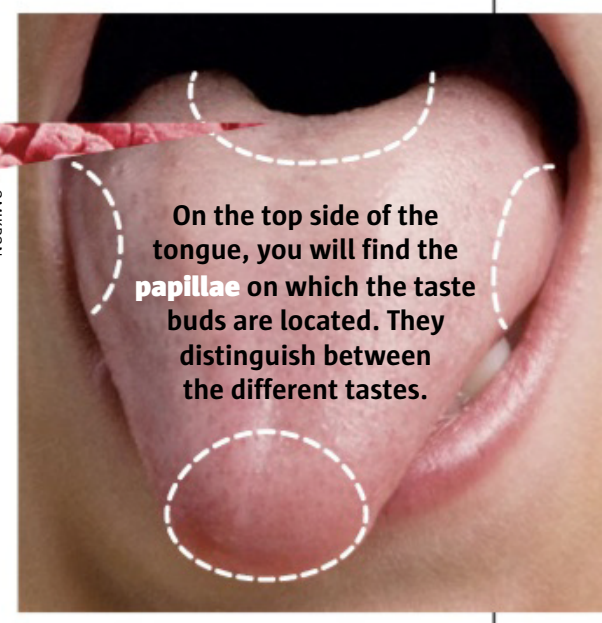


SHUTTERSTOCK

The tongue's taste areas are located at the front, the back, and on the sides.

- **Salty**: Salty food keeps up the body's salt balance. Known from capers, salty nuts, soy.
- **Sour:** Poisonous or tainted food often has a sour taste. Also known from lemons and other harmless things.
- **Sweet:** Sweet food includes carbohydrates, which re-energise you. Known from fruit, berries, honey, and treacle.
- **Bitter:** Many poisonous plants have a bitter taste. Also known from coffee, green tea, dark chocolate.
- **Umami:** Amino acids, which are the building blocks of enzymes and proteins in the body, are responsible for the umami taste, which is known from bouillon, Parmesan cheese, fish, shellfish, mushrooms, and seaweeds.

Test Yourself

SEE THE ANSWERS ON PAGE 11

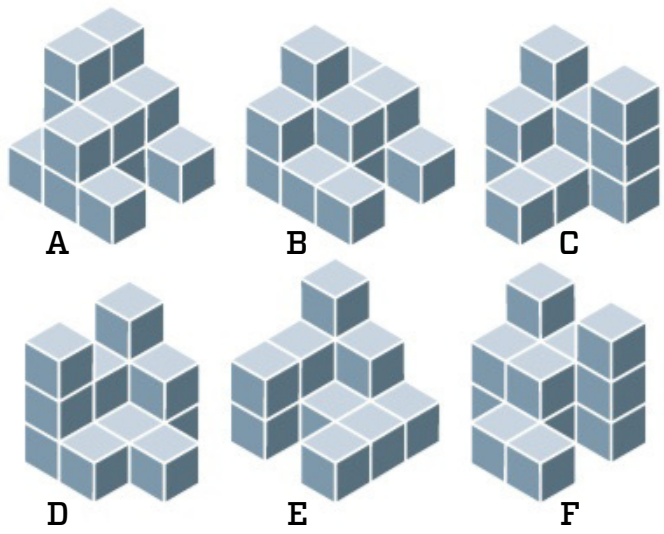
MIND-BOMBS!

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

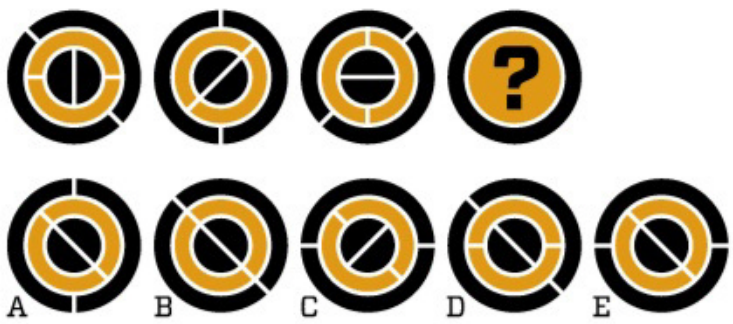
Editor: **Nanna Vium** //
Text & Art: **Anker Tiedemann**

VISUAL INTELLIGENCE

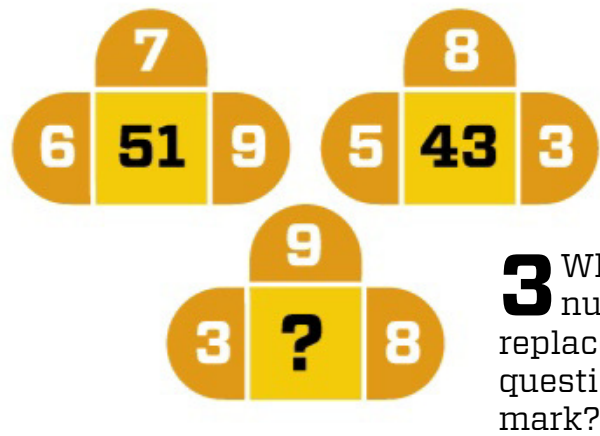
1 Which two figures can be combined into one large cube consisting of 27 small ones?



2 Which figure replaces the question mark?

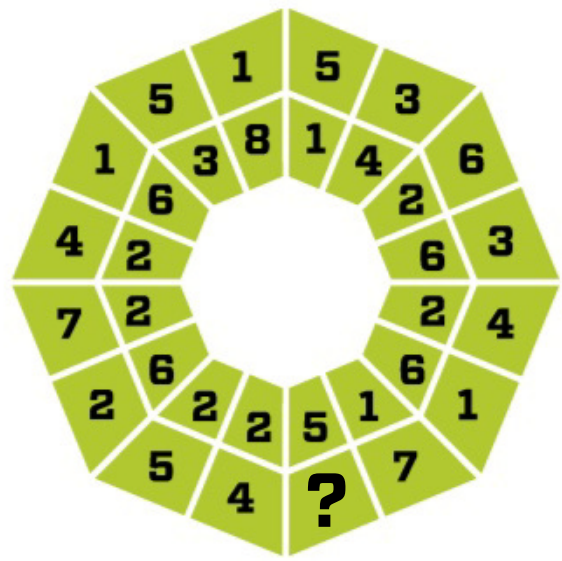


NUMERACY



3 Which number replaces the question mark?

4 Which number should replace the question mark here?

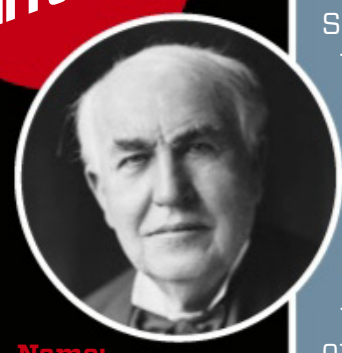


LOGIC

5 The two barrels include a total 120 litres of wine. The small barrel can be filled twice with the wine from the big one, and there will still be 15 litres left in the big one. How many litres can each barrel hold?

6 Which figure in the bottom row should be yellow?

Scientist in Focus



CREATIVE COMMONS

Name: Thomas Alva Edison

Life span: 1847-1931

Talented vendor and inventor

Since he was very young and sold newspapers, Thomas Edison had been eager to succeed in life. He became an inventor, and by means of business talent and a good deal of creativity, he managed to become one of the greatest inventors that the world has ever seen.

7 What was his first major invention, consisting of tin-foil, a can and a needle?

A) The cattle prod
B) The phonograph
C) The telephone
D) The battery

8 He competed against Nikola Tesla to be the inventor of ... ?

A) The camera
B) X-rays
C) Fuses
D) The light bulb

9 Thomas Edison took out many patents. How many in the US?

A) 43
B) 216
C) 1093
D) 8659

10 Edison had a disability he believed helped him to be an inventor. Which?

A) Deafness
B) Blindness
C) Spastic paralysis
D) Muscular atrophy

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