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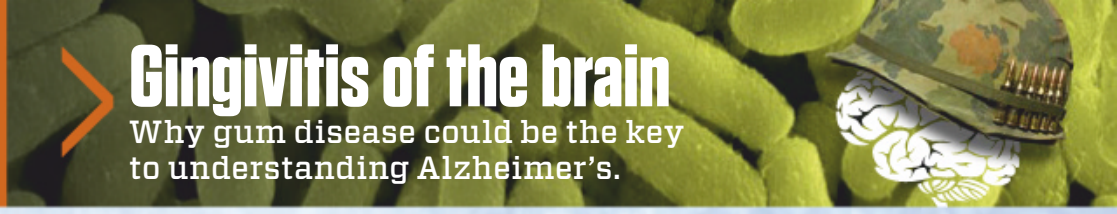

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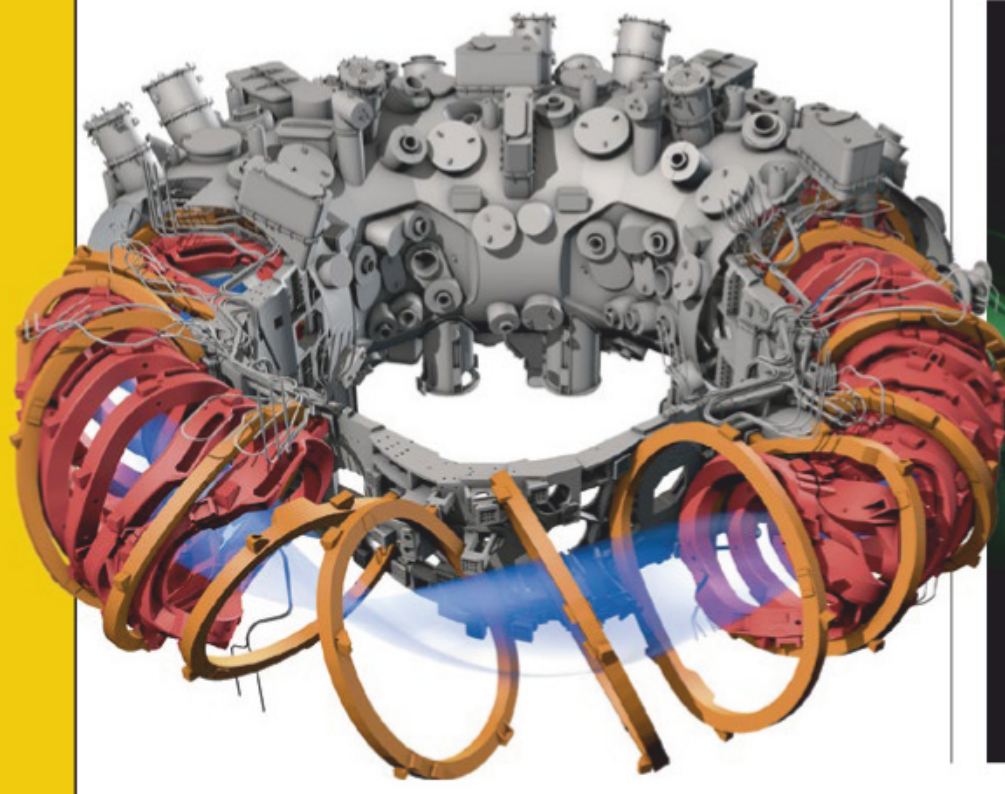

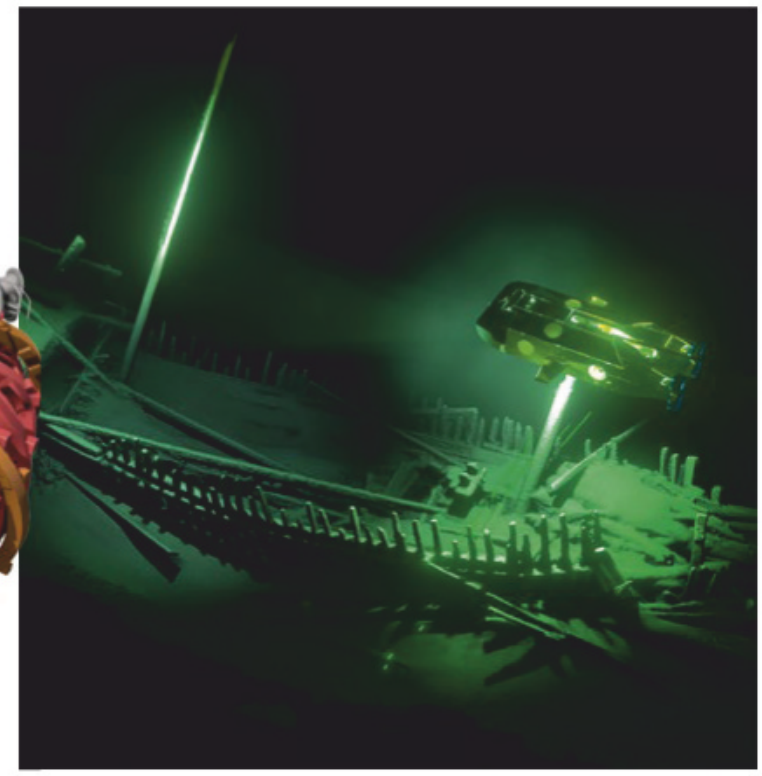

AUSTRALIAN SCIENCE ILLUSTRATED

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

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NEXTMEDIA
Executive Chairman David Gardiner
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Science Illustrated is published 8 times a year by nextmedia Pty Ltd
ACN: 128 805 970
Level 8, 205 Pacific Highway, St Leonards NSW 2065

www.scienceillustrated.com.au
To subscribe, call 1300 361 146 or 9901 6111 or visit mymagazines.com.au

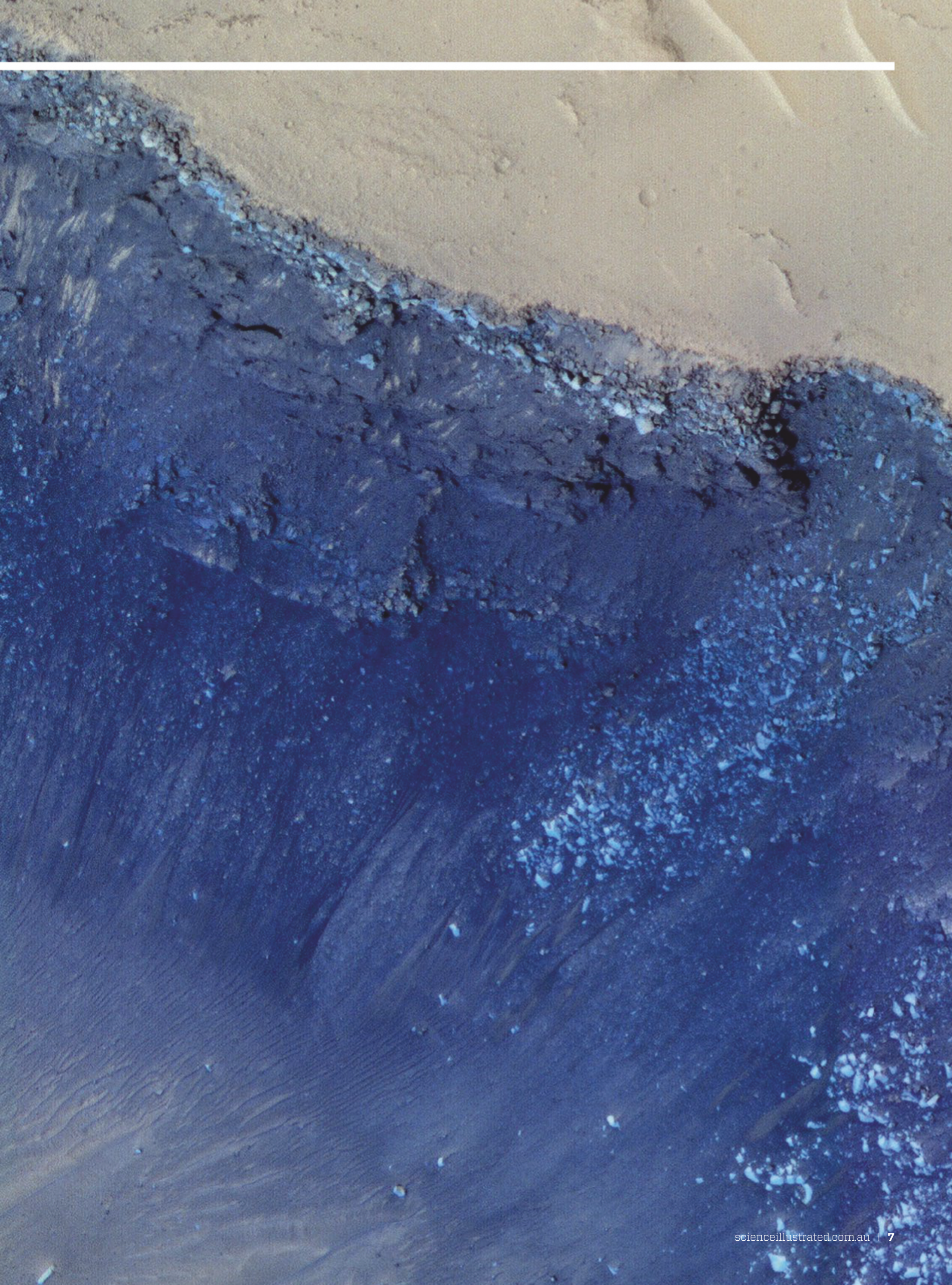
THE SCIENCE ILLUSTRATED CREDO
We share with our readers a fascination with science, technology, nature, culture and archaeology, and believe that through education about our past, present and future, we can make the world a better place.

Blue planet: Do water drops draw dark lines on Mars?

Landslides are constantly changing the Martian landscape. In this photo of the Cerberus Fossae region taken by NASA's Mars Reconnaissance Orbiter, the blue surface lacks the oxidised iron dust which elsewhere gives Mars its rusty red colour. However, scientists still ponder over the thin dark lines. According to one theory, salts on the surface cause water vapour to condense from the atmosphere into drops that push the sand grains in a 'flow' through the landscape, leaving these clear paths. The light dots are larger stones.

Photo // NASA

UNIVERSITY OF ARIZONA/JPL-CALTECH/NASA



Skin sight: Caterpillars can feel colours with their skin

Colour is a matter of life or death for peppered moth caterpillars, because they disguise themselves to avoid being consumed by birds. But how do the larvae know what colour to choose? Scientists painted over the eyes of 321 caterpillars and then placed them on different branches. The blind caterpillars still changed colour to match the branches they were placed on. It turned out that the caterpillars could 'feel' colours via light-sensitive proteins in their skin. In some cases, the caterpillars' 'skin sight' was even better than their eyesight.

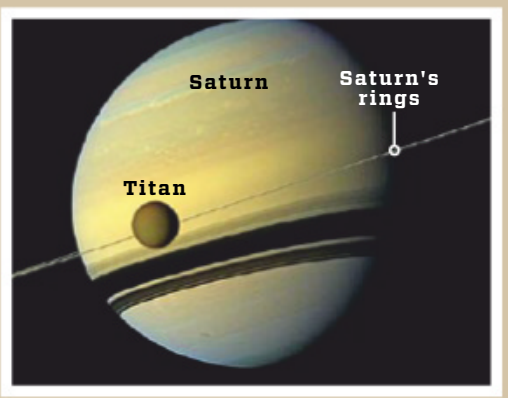
Photo // Arjen Van 't Hof

UNIVERSITY OF LIVERPOOL

Drone will search for life on Saturn moon

A flying laboratory will explore one of the Solar System's biggest moons in search of amino acids and other molecules that could offer evidence of life.

AEROSPACE NASA has completed its plans for the next major expedition to one of the most fascinating worlds in the Solar System. A drone is to explore the surface of Saturn's Titan moon, which hosts a varied landscape that resembles Earth's in many ways. The moon is Saturn's biggest, and has an atmosphere, rocks, rivers, deserts, and oceans. Titan's atmosphere, like Earth's, consists mostly of nitrogen, but the rocks are believed to be frozen water ice, while the rivers and oceans consist of ethane and methane that exist on Earth only in their gaseous states; they are liquid on Titan because the temperatures there max out around -180°C. In spite of the cold, scientists believe that Titan's combination of water and organic molecules could have provided a breeding ground for the important amino acids that are the building blocks of proteins and DNA. This is the evidence for which the drone, named Dragonfly, will search.



NASA

In 2012, the Cassini space probe took this photo of Titan orbiting in the same plane as Saturn's iconic rings.

Dragonfly will be the size of an average car, and will fly around Titan by means of eight rotors mounted on four arms, powered by a radioactive generator. Titan's atmosphere is about four times as dense as Earth's, and gravity is also lower, so it will require 38 times less energy to lift the 300kg drone than on Earth. While Dragonfly will not be equipped with a robotic arm like the Martian rovers, the drone's landing gear is equipped with cylinders that contain small drills, so the drone can collect mineral samples and analyse them. It can also examine the surface's chemical make-up by aiming neutron rays towards it, measuring the reflected radiation.

The space probe carrying Dragonfly to Titan will be launched in 2026, and will arrive in 2034.

The most recent major mission to Saturn was carried out by the Cassini space probe, which orbited Saturn in 2004-2017 before the mission was ended by Cassini burning up in the gas giant's atmosphere.

Those brush turkeys on your block have ancient ways

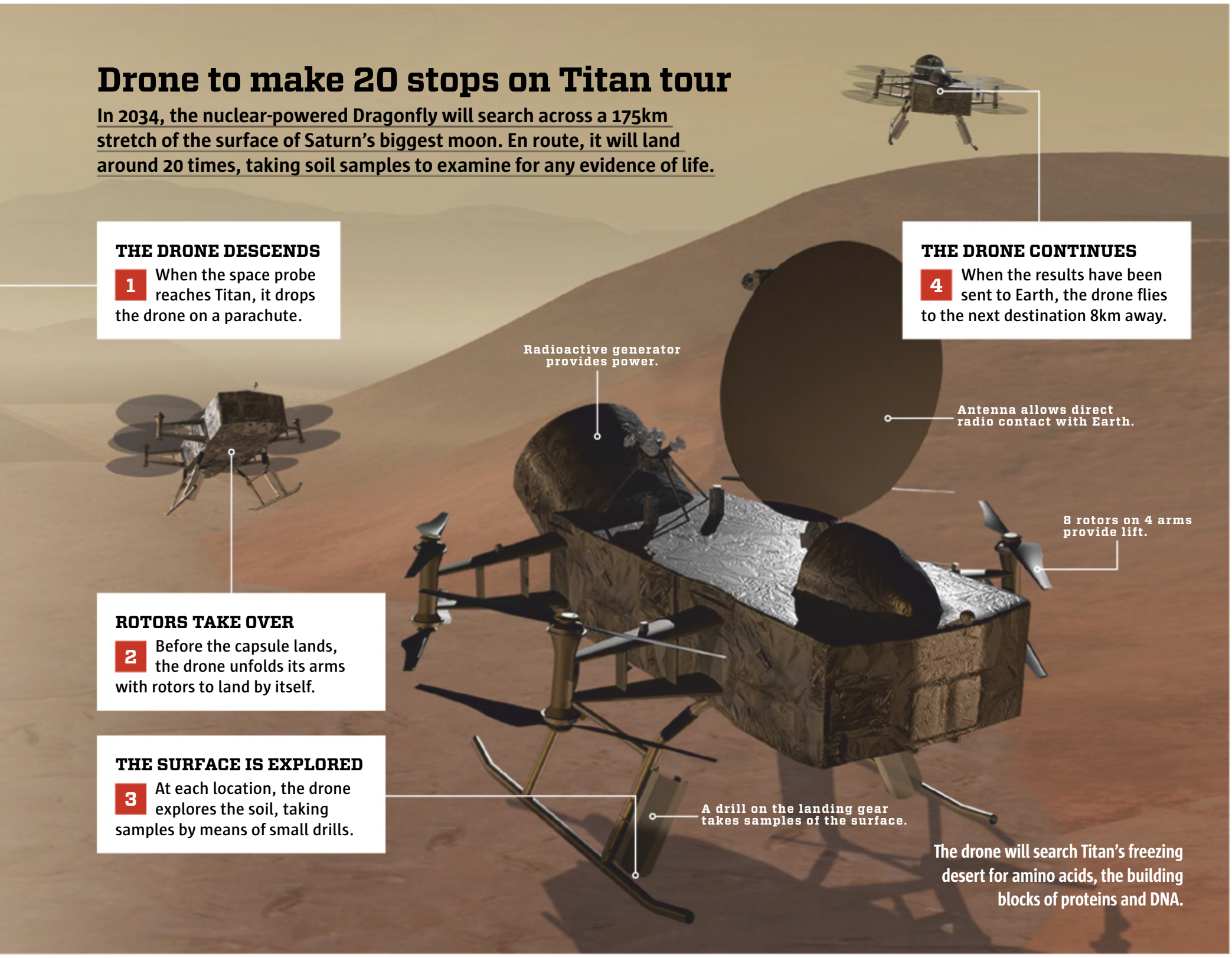
WILDLIFE One of the oldest models of how Australian land birds organised reproduction is provided by the malleefowl, brush turkey, emu and the southern cassowary, the handful of birds that do not pair up and do not feed their offspring, says Professor Gisela Kaplan in *Bird Bonds* (Macmillan Australia, RRP $34.99). These species are living symbols of a very ancient world. In malleefowl and brush turkeys, the only parental involvement is the female's laying of eggs into a mound the male has prepared. When the hatchlings emerge, they are on their own, and are among the most independent (precocial) of any birds. However, this model of reproduction has not taken off. Unlike mammals, most avian offspring have parental support: about 95% of all birds have both parents care for offspring, compared with just 5% of mammals.

ISTOCKPHOTO

Brush turkey hatchlings (left) go it alone from day one, whereas 95% of birds have both parents care for offspring.

Drone to make 20 stops on Titan tour

In 2034, the nuclear-powered Dragonfly will search across a 175km stretch of the surface of Saturn's biggest moon. En route, it will land around 20 times, taking soil samples to examine for any evidence of life.



NASA & THE JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY LLC

Sabre-toothed enamel reveals cats' destiny

PALAEONTOLOGY The sabre-toothed cat, with its impressive canine teeth, became extinct some 10,000 years ago, but not, as scientists used to think, because it was outcompeted by other predators. New studies indicate that it fell victim to climate change and the resultant shifts in the landscape.

Scientists from Vanderbilt University in the US have analysed 700 teeth from a series of prehistoric predators discovered in La Brea Tar Pits in California, an area rich in fossils from the many animals that died there after becoming stuck in the tar.

The scientists measured two isotopes of carbon in the teeth, because tooth enamel in all animals can reveal what they ate. The relationship between the two isotopes differs depending on the vegetable food consumed.

The teeth's isotopic ratio is passed through the food chain from herbivores to carnivores, allowing scientists to determine the type of prey that predators fed on. The analyses showed that the up-to-300kg sabre-toothed cat did not hunt its prey on the open grass plains, as palaeontologists used to think, so they did not compete with prehistoric wolf species for prey such as bison and horses. Instead they hunted in the forest, where they could kill smaller animals such as deer and tapirs.

The scientists conclude that the sabre-toothed cat did not reach extinction due to competition with other predators, rather because climate change altered the vegetation. As the forests shrank and the open grass plains spread, the sabre-toothed cats' habitat became smaller and prey more scarce.

MAURICIO ANTÓN & SHUTTERSTOCK

Analyses of sabre-toothed cat teeth show that they hunted in the forest, and that it was climate change rather than wolves that led to their extinction.

BY THE WAY

ASIANS FOUND CONSOLATION IN CANNABIS 2500 YEARS AGO

In a 2500-year-old burial site in China, scientists have discovered wooden containers with stones that bear evidence of burnt marijuana. The containers were probably used in religious rituals during which greaving survivors enveloped themselves in a cloud of the euphoriant when they said goodbye to their loved ones.

XINHUA WU & SHUTTERSTOCK

AND TALKING OF CANNABIS...

CANNABIS WORKS BETTER THAN PAINKILLERS

Canadian scientists have discovered how the hemp plant produces painkilling chemicals by the name of flavonoids, and that their effect is 30 times better than the acetylsalicylic acid included in pain-killers. The flavonoids might replace powerful painkillers such as highly addictive morphine.

SHUTTERSTOCK

VIKINGS HAD ACCESS TO POT IN AMERICA

Discoveries of cannabis pollen in a settlement in Newfoundland, Canada, show that Vikings used the plant around the year 1000, either as an intoxicant or for textiles and rope. The plant does not grow there, so the Vikings must have brought it from places further south. In Norway, there is also evidence of Vikings using hemp.

344 FIRST LIGHT/IMAGESELECT

CANNABIS CAN KILL RESISTANT BACTERIA

An ingredient of cannabis, CBD, could become a new weapon in the struggle against infection. Australian scientists have discovered that the ingredient can kill bacteria resistant to antibiotics. CBD is also being investigated for purposes such as treating concussion (see last issue) and children with epilepsy.

SHUTTERSTOCK

SHUTTERSTOCK

Snow guns could stabilise the ice off West Antarctica if a region three times the size of Fiji were to be supplied with artificial snow for 10 years.

New rescue plan: snow guns to save Antarctica's ice

CLIMATE The sea ice off Antarctica is collapsing, with possible global consequences. Without the sea ice, the continent's huge glaciers will slide more quickly into the ocean, accelerating the melting and making ocean levels rise.

In recent years, several scientists have proposed drastic measures to stabilise the sea ice, including artificial islands or submarine walls that could keep warm ocean currents away from the ice. Now, scientists from the Potsdam Institute for Climate Impact Research in Germany have introduced a new idea for a rescue plan: snow guns.

The scientists have carried out computer simulations showing that if the area where the glaciers flow into the ocean were to be reinforced with artificial snow, the ice could be stabilised. Over a period of 10 years, the snow guns would spread at least eight trillion tonnes of snow across an area no smaller than 52,000km^2.

This will require a huge feat of engineering. The ocean water for the snow will require pumping an average of 640 metres to the snow guns. Then it must be desalinated and cooled before it can be spread as snow. The scientists have calculated that 12,000 large wind turbines could generate the energy to pump the water. They admit that the project is very ambitious, not least because it is to be carried out in one of the world's most hostile environments, but they also emphasise that it is worth the effort, as the threat from the melting ice is so severe that the price to prevent it can never be too high to pay. If the sea ice collapses, global ocean levels could rise by 3 metres, causing coastal flooding globally, according to scientists.

8 billion tonnes

is the quantity of artificial snow required under a new plan to stabilise the sea ice off Antarctica.

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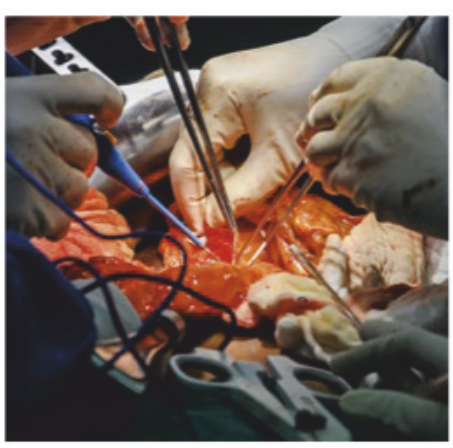
Organ transfer early warning system

MEDICINE A new technique can make life safer for patients who receive a new organ. Currently, patients must consume drugs that suppress the immune system so it will not attack the new organ. But this involves a risk of infection that the body will then be unable to combat.

Instead of suppression, the new idea developed by scientists from the University of Minnesota, USA, teaches the immune system to accept the new organ before it is transplanted. This mimics how the immune system normally learns to accept the body's own cells: dying cells flow with the blood stream to the spleen, where they are introduced to immune cells and are accepted as the body's own cells. The immune system will subsequently not attack similar cells in the body.

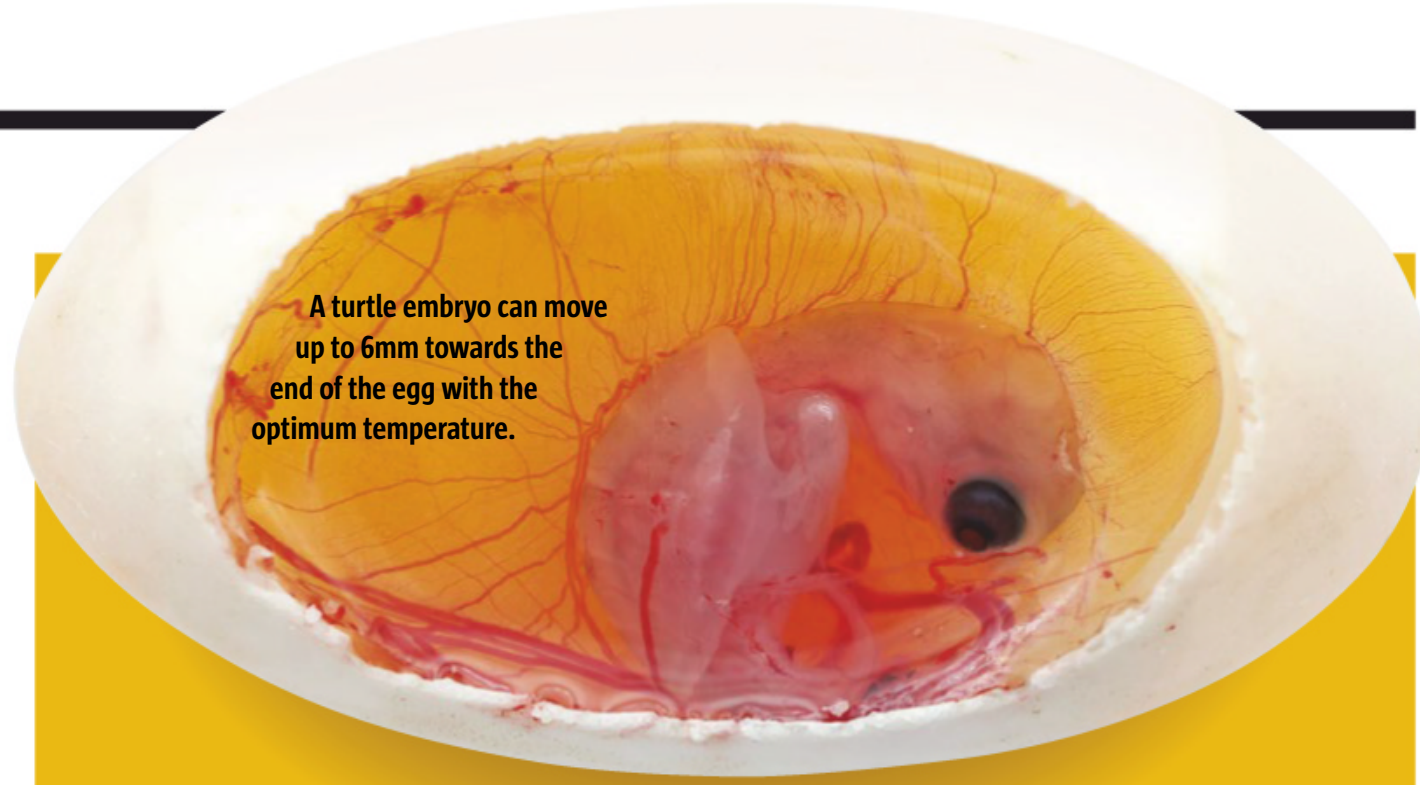
In experiments with diabetic macaques, the scientists treated blood cells from a donor monkey with a substance called ECDI, which makes cells commit suicide. Subsequently, they injected the cells into a diabetic monkey, whose immune system came to consider the cells as its own. One week later, when scientists transplanted pancreatic cells from the same donor, the cells were accepted.

As the transfer of cells and tissue happens twice, the donor must be alive. This is the case in transplants of kidneys, parts of the liver, and pancreatic cells.



SHUTTERSTOCK

An organ transplant is more successful when the receiver's immune system is prepared in advance.



A turtle embryo can move up to 6mm towards the end of the egg with the optimum temperature.

Turtles actively choose gender equilibrium

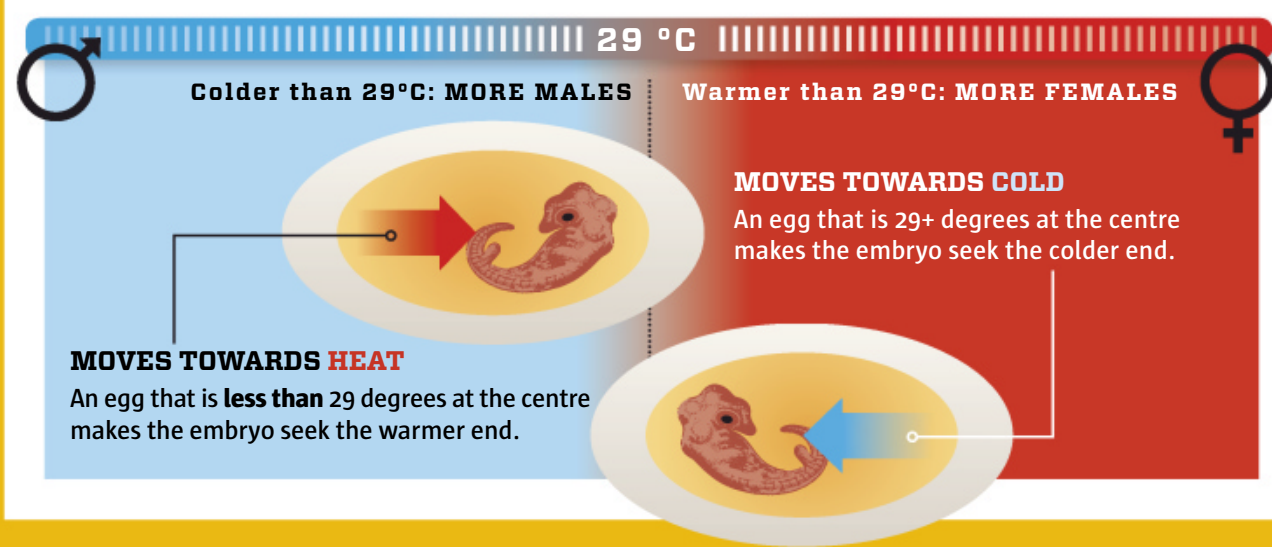
Temperature determines whether a turtle embryo becomes a male or a female, but the embryo can move inside the egg to affect its outcome.

ZOOLOGY Very slight temperature differences in the embryonic stage determine whether a turtle becomes male or female. Zoologists used to think that the gender choice is accidental, but it is not that simple, according to new experiments made by Chinese scientists from the Chinese Academy of Sciences. In the experiments, the scientists used eggs from the *Mauremys reevesii* fresh water turtle. The eggs were placed in a special nesting box which kept a temperature variation of up to 4.7 degrees from one end of the eggs to the other. The scientists had treated half of the eggs beforehand with capsazepine, which destroys the embryos' ability to feel temperature. The scientists then measured how the embryos moved inside the eggs. The untreated embryos moved up to 6mm, whereas the treated embryos remained in the same place. The measurements also showed that the untreated embryos always moved towards a temperature of 29°C, which results in a 50/50 split of males and females. The experiment indicates that the embryos can choose their own gender, but instinctively approach the temperature that results in an equal distribution of males and females.

The balance-seeking mechanism means that the turtles are not as vulnerable to a warmer climate as scientists feared. The same could be true for several reptile and fish species where genders are determined by temperature.

Embryos seek out the right temperature

A temperature of 29 degrees is perfect for turtle eggs, as it results in an even split of males and females. It turns out that embryos seek out this temperature inside the egg.



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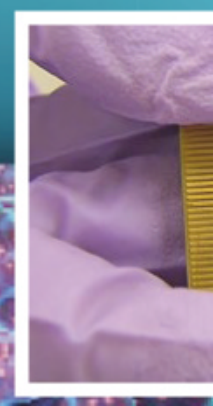
Chip to more rapidly spot hereditary diseases

In the future, a hand-held device may scan its way to sick genes much more cheaply and quickly than today.



MEDICINE Scientists from the University of California have invented a bioelectronic chip that can identify sick genes in a few minutes. The chip combines the special electrical qualities of the material graphene with CRISPR technology, which scientists use to insert or remove genes into organisms. CRISPR works by means of the scissor molecule of Cas9. Scientists supply the Cas9 with guide RNA which matches the sequence that scientists would like to find, and using this CRSIPR can spot the very DNA sequence that causes the malfunction of a gene.

The biochip is made of a layer of graphene that is linked with two electrodes which continuously measure the electrical resistance of the material. On the graphene is a layer of Cas9 molecules that are designed to search for a specific sick gene.

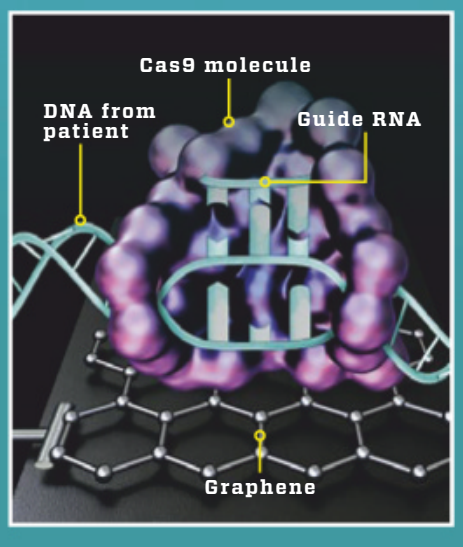
Scientists need only then place a DNA sample from a patient on the chip. The Cas9 molecules begin to scan the sample's DNA strands, and when a molecule encounters and recognises the sick gene, a slight electric impulse is triggered which alters the electric conductivity of the graphene. The change is registered by the electrodes, and the scientists know that the sick gene is present in the DNA sample. The scientists behind the CRISPR chip believe that the technique could quite easily be expanded to search for several sick genes in one DNA sample.

Using this method the CRISPR chip can produce a result much faster than can existing methods. Normally it is necessary to use the PCR method to copy the DNA that is to be examined millions of times before it can be scanned for specific genes. That process requires far more time, and more expensive equipment.

So far they have tested the chip on DNA samples from patients with gene mutations that cause sickle cell anaemia blood disease and DMD muscle disease. In the future, the chip will make it easier to spot these types of sick genes early, so that patients are treated faster – perhaps even before the physical symptoms materialise.

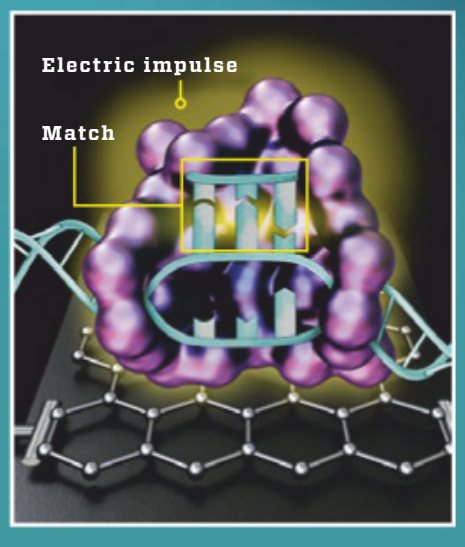
Scissor molecule feels its way to sick genes

A new biochip allows scientists to quickly spot a sick gene in a DNA sample. The chip uses interaction between the Cas9 scissors that find the gene and the graphene carbon material, which registers the find.



DNA STRAND IS OPENED AND SCANNED

1 The Cas9 scissor molecule pulls the DNA strand in to open it. The molecule is equipped with guide RNA, which is compared to the DNA strand.



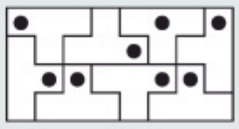
SCISSOR MOLECULE FINDS A MATCH

2 When the Cas9 encounters the sick gene, the open DNA strand fits perfectly with the RNA strand. The match triggers a slight electric impulse in the Cas9 molecule.

VISUAL INTELLIGENCE

PROBLEM 1:
C. When, in each row, you move right or down, orange moves counter-clockwise, and black changes between 2 positions.

PROBLEM 2:



NUMERACY

PROBLEM 3:
2411. By calculating vertically and using the elimination method, you get: orange = 1, black = 2, blue = 3, and green = 4.

PROBLEM 4:
1. The number 2 in each triangle equals the top number minus the two bottom ones.

LOGIC

PROBLEM 5:
Adam 39, Eva 26. The distributions of 1½ and 1 correspond to 3/5 and 2/5, so Adam gets 3/5 of 65 = 39.

PROBLEM 6:
36. 1/2 + 1/4 + 1/6 = 11/12. The 3 water drinkers must correspond to 1/12 of the total number of guests, that makes up 3 × 12 = 36.

SCIENTIST IN FOCUS

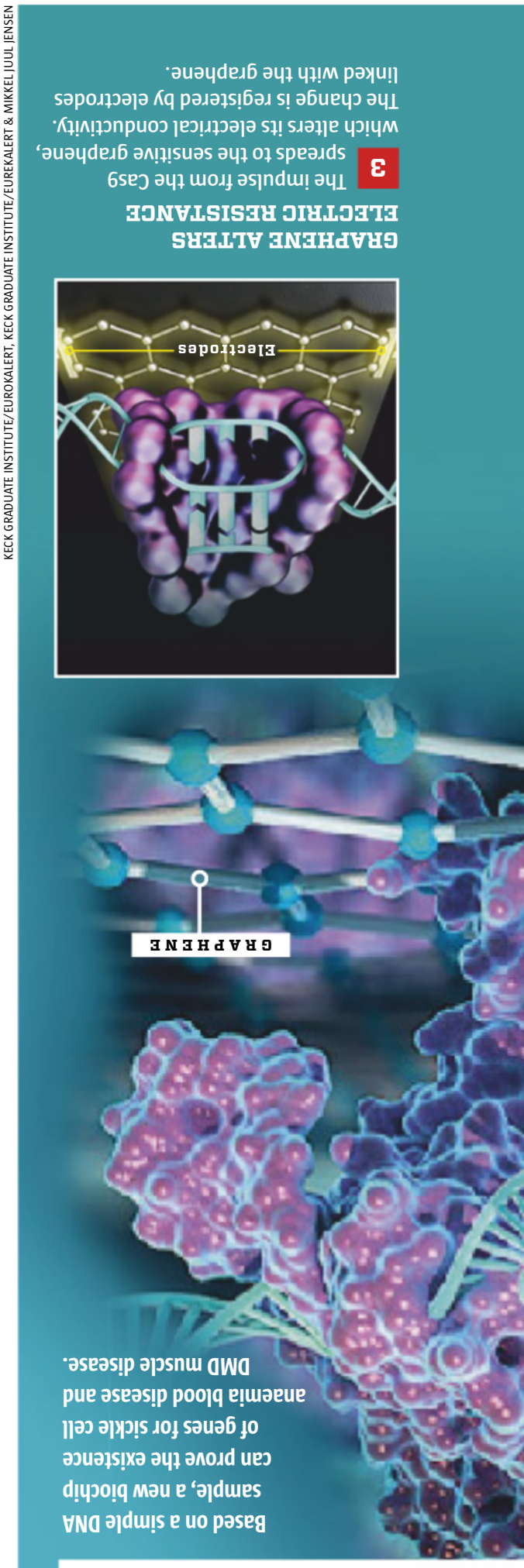
7: C) Henry Heimlich. The doctor behind a manoeuvre to clear airways worked with Armstrong on a pump for heart and lungs.

8: C) Challenger. The shuttle exploded due to a leak in the right rocket booster.

9: D) The Pacific. After the rescue, the Apollo 11 astronauts were quarantined for 18 days.

10: B) Eagle. Armstrong steered the module onto the Moon's surface, before saying the famous words: "The Eagle has landed."

Test yourself Answers to p82. No peeking!



KECK GRADUATE INSTITUTE/EUROKALERT, KECK GRADUATE INSTITUTE/EUREKALERT & MIKKEL JUUL JENSEN

GRAPHENE ALTERS ELECTRIC RESISTANCE

3 The impulse from the Cas9 spreads to the sensitive graphene, which alters its electrical conductivity. The change is registered by electrodes linked with the graphene.

Based on a simple DNA sample, a new biochip can prove the existence of genes for sickle cell anaemia blood disease and DMD muscle disease.

Scientists to examine the world's oldest ice

A 1.5-million-year-old ice core from Antarctica is to tell us about past ice ages – and might predict new ones.

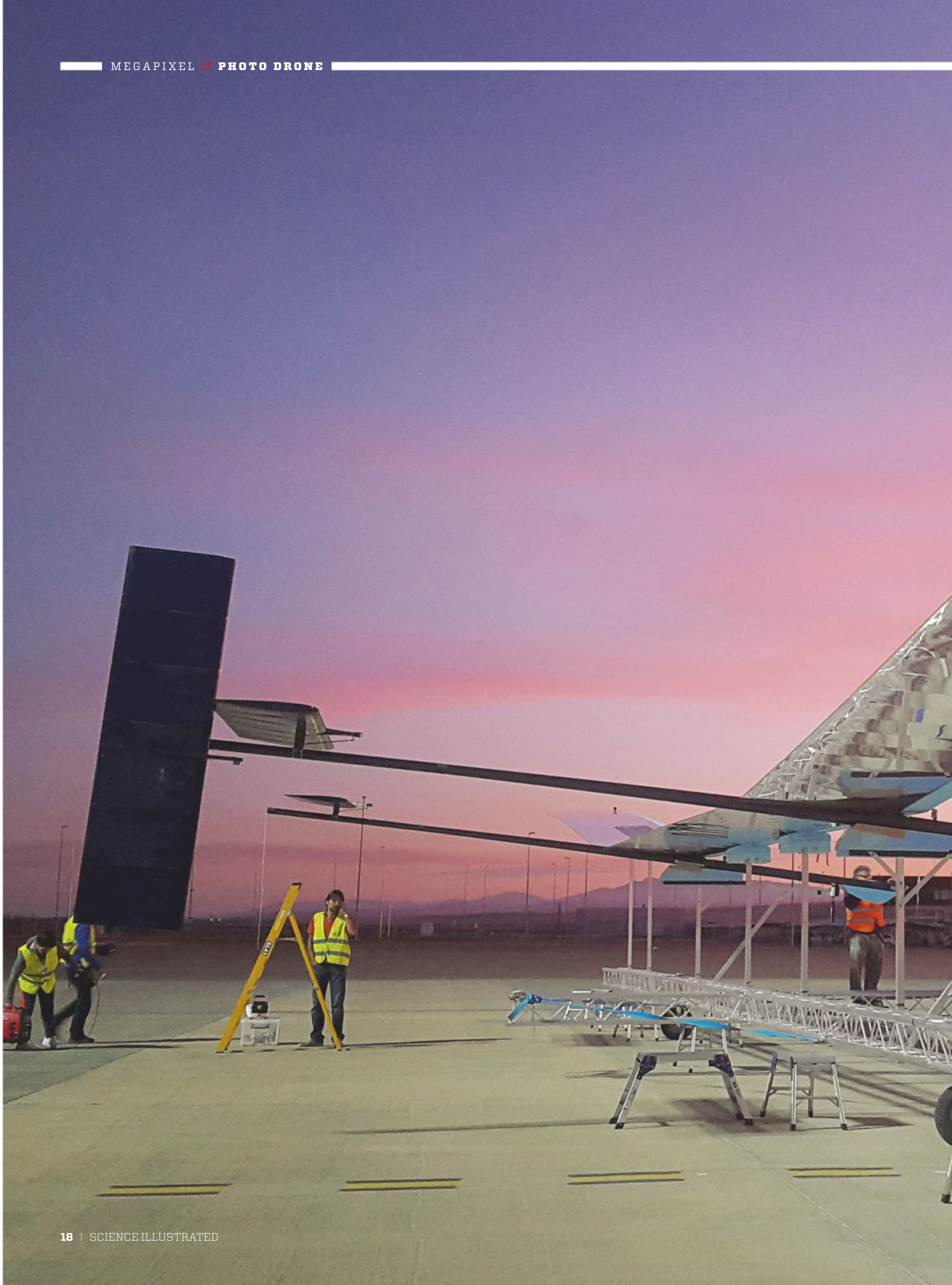
THIBAUT VERGOZ, FRENCH POLAR INSTITUTE & SHUTTERSTOCK

GEOLOGY European climate researchers will drill down to the world's oldest ice to learn more about Earth's ice ages, with the aim of extracting an ice core that reaches 2.7km down below the surface of the Antarctic ice – although the scientists estimate that it will take five years to get there. The lower part of the ice core will be 1.5 million years old, and will hopefully include distinct layers telling us about climate change on Earth from then until now.

The scientists consider one question to be particularly important. From ocean floor drilling, they know that a change in the rhythm of ice ages began some 1.2 million years ago. Before then, ice ages set in at intervals of about 40,000 years, but since then the intervals have increased to 100,000 years. Perhaps the explanation is to be found in atmospheric composition and temperature, which is exactly what can be deduced from the ice core. The atmosphere's content of CO_2 and other gases can be ascertained from small air bubbles, and the relationship between different isotopes of oxygen and hydrogen reveals temperature.

The ice core can also be used to compare the past and present climate – and perhaps even predict that of the future. Scientists will be able to see how much CO_2 the atmosphere contained at times when the climate changed suddenly from a warm period to an ice age, and whether there was a specific critical point that might have triggered the shifts.

ATMOSPHERIC CO_2 results in warmer climate, but it might trigger an ice age in the long term through changes in ocean currents.



High flyer: Drone remains aloft for three months

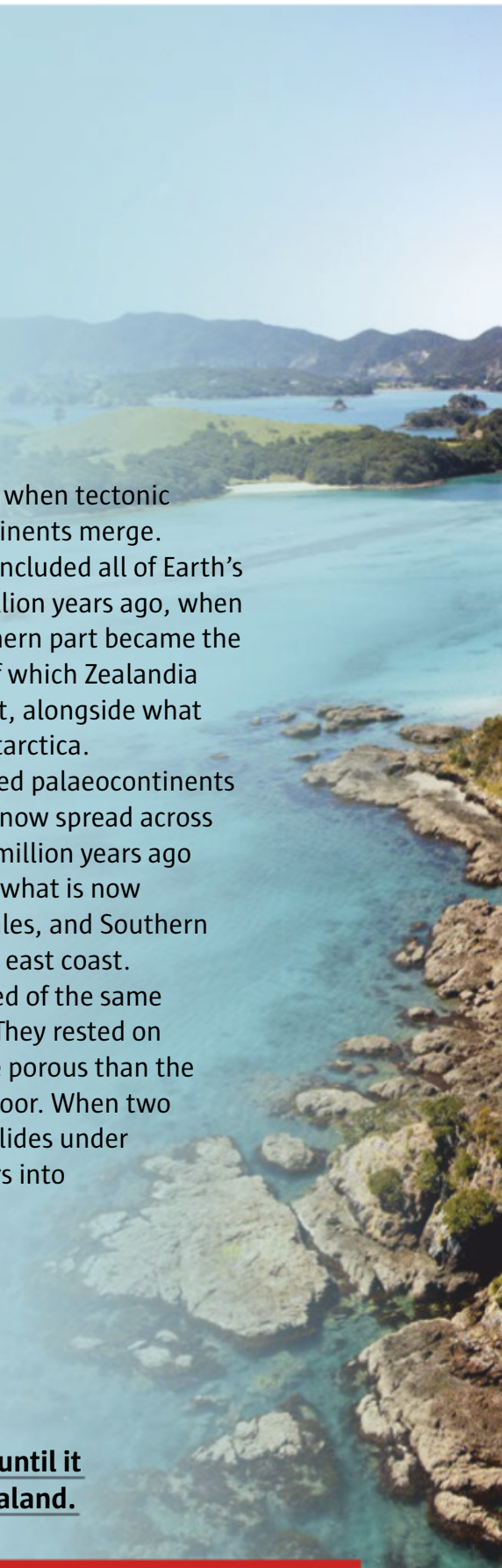
Despite its weight of 149kg and wing-span of 38 metres, the ASTIGAN A3 drone is designed to remain in the air for up to 90 days, taking photos of dwindling polar ice which scientists can use to research climate change. It achieves the feat by means of two solar-powered propellers, absorbing sunlight as the drone flies some 20km above the Earth, twice as high as airliners. Indeed ASTIGAN A3 is a 'pseudo satellite' because it flies so high, but is far more flexible than satellites in permanent orbits.

Photo // Astigan Ltd.

ASTIGAN LTD.

Do missing continents like Atlantis exist?

Atlantis? Maybe not. But there are vast land areas that did once sink beneath the waves... and one of them is now New Zealand.



GEOLOGY According to Greek legend, Atlantis was an island the size of a continent in the mid-Atlantic which vanished at some point into the ocean. Atlantis probably did not really exist, but its geological counterpart, the continent of 'Zealandia', did.

Zealandia is located under the ocean surface in the South West Pacific, and only its highest mountains rise above the water, forming what we know as New Zealand. But this modern country's land is only around 7% of the total area of the crust that constitutes the continent's bedrock.

Around 83 million years ago, the tectonic plates under Zealandia began to part, stretching and thinning out the crust on which Zealandia rests to such an extent that the entire continent slowly sank below the ocean surface. Only later did it rise again above the waves.

Zealandia is not the only continent that 'vanished'. Geologists have discovered evidence of a series of continents from further back in Earth's history that no longer exist – such as the palaeo-continents, which are prehistoric and do not immediately correspond to any of today's seven continents. Some of the palaeocontinents were supercontinents that originated when tectonic plate motion made smaller continents merge. The supercontinent of Pangaea included all of Earth's landmasses up until 280-230 million years ago, when Pangaea broke in two. The southern part became the supercontinent of Gondwana, of which Zealandia made up the southern east coast, alongside what would become Australia and Antarctica.

Scientists have also discovered palaeocontinents that were smaller, their regions now spread across different continents. Some 500 million years ago Avalonia, for example, included what is now Southern England, Southern Wales, and Southern Ireland plus the North American east coast.

The paleocontinents consisted of the same bedrock as modern continents. They rested on continental crust, which is more porous than the crust that makes up the ocean floor. When two tectonic plates collide and one slides under the other, ocean crust disappears into Earth's interior, but continental crust remains closer to the surface and can continue to form continents.

Geological forces drowned Zealandia

Zealandia has a long, tough geological history. Tectonic forces tore the continent until it drowned – and subsequently rose above the surface again in the shape of New Zealand.

United continents

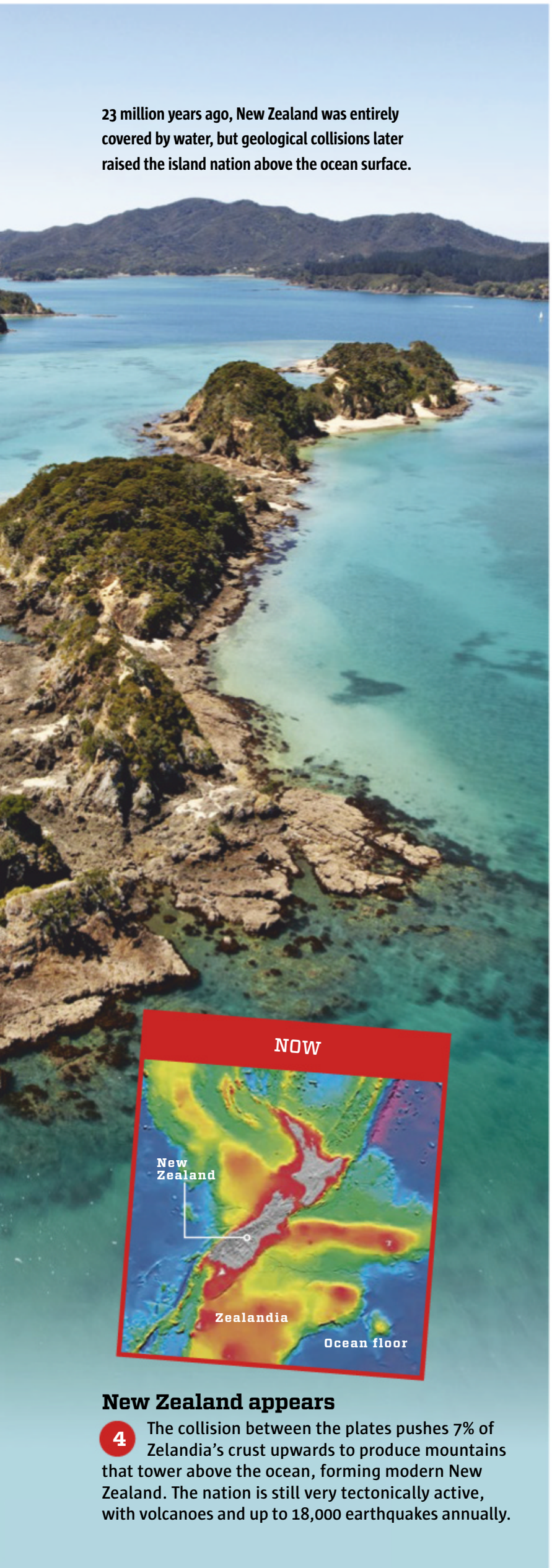
1 Zealandia is a part of Gondwana, a supercontinent that consists of many of the modern continents. Zealandia is located on Gondwana's east coast, under which two tectonic plates meet.

Zealandia shakes loose

2 The tectonic plates move apart from each other. Zealandia is forced away from the rest of Gondwana, stretching the continental crust on which Zealandia rests.

Continent drowns

3 The continental crust has thinned so much that all of Zealandia has sunk into the ocean. Now the tectonic plates change direction, collide, and produce a subduction zone.



23 million years ago, New Zealand was entirely covered by water, but geological collisions later raised the island nation above the ocean surface.

New Zealand appears

4 The collision between the plates pushes 7% of Zelandia's crust upwards to produce mountains that tower above the ocean, forming modern New Zealand. The nation is still very tectonically active, with volcanoes and up to 18,000 earthquakes annually.

NIWA & LARA KAY PHOTOGRAPHY/GETTY IMAGES

TOP 5 · Where is the wettest place on Earth?

RITZAU SCANPIX

1 Mawsynram, India

An average annual rate of precipitation of 11,871mm. The village of Mawsynram in India's East Khasi Hills district is the world's wettest place, with more than 28 times Australia's 2018 average precipitation of 413mm.

SOHRA, INDIA
11,777mm OF ANNUAL PRECIPITATION

2 Sohra gets all its precipitation in the summer. In the winter it does not receive one single drop.

TUTENDO, COLOMBIA
11,770mm OF ANNUAL PRECIPITATION

3 Tutendo gets a lot of rain due to warm moist Pacific air that is forced upwards by mountains.

CROPP RIVER, NEW ZEALAND
11,516mm OF ANNUAL PRECIPITATION

4 Precipitation near the small Cropp River is caused by the heat in the south-western Pacific.

SAN ANTONIO, EQUATORIAL GUINEA
10,450mm OF ANNUAL PRECIPITATION

5 The rain here is the result of intense thunderstorms from December to February.

Why does dew fall at night?

METEOROLOGY In summer, the lawn is often wet in the morning even though no rain has fallen. The moisture comes from water vapour in the air that has condensed into dew because of falling temperatures.

Relative humidity describes how much of the air's maximum potential water vapour content is currently 'filled'. The colder air is, the less 'room' it has for water vapour, so cold air reaches its maximum moisture capacity quicker than does warmer air. The relative air humidity is highest around sunrise, which is typically the coldest time of day. For example an air mass with 10g of water vapour has a relative humidity of 50% at a temperature of 23°C, but at least 100% at 17°C. When the temperature falls to a level where the relative humidity exceeds 100 %, the moisture will be deposited as dew or rime (icing) on cold surfaces.

SHUTTERSTOCK

Cooling makes the water vapour of the air condense into dew and rime icing.

INSIDE THE BODY

Why do I feel cold taking a warm shower?

The cold and hot nerves of the skin follow the same path to the brain. Sometimes they cross-influence each other's electrical signals so that exposure to heat activates the cold nerves, causing goosebumps.

THERMO RECEPTORS

WHERE: The peripheral nervous system.
WHAT: Thermo receptors that feel cold and heat follow the same nerve paths and might affect each other.

SHUTTERSTOCK

WEATHER PHENOMENA · Where does the name *el Niño* come from?

El Niño is Spanish for 'Jesus', and describes the recurring climate phenomenon that reverses certain weather patterns. The phenomenon was so named because it was discovered around Christmas, when meteorologists recorded a weak, warm ocean current along the coasts of Peru and Ecuador.

WINDS BLOW HEAT WESTWARDS

1 Normally, the trade winds blow warm surface water consistently from east to west along the Equator. Cold bottom water rises off South America's west coast, while warm surface water causes rain in the Philippines.

HEAT INTENSIFIES WIND

2 The moist air rises, leaving low pressure. Air will always travel from high pressure towards low pressure, so the wind from the east intensifies, and the cycle continues.

EL NIÑO CHANGES EVERYTHING

3 Every four years or so, the trade winds weaken. Without the pressure from these winds, warm surface water travels back to South America, causing an *el Niño* event where the self-perpetuating cycles of wind and water change direction.

DROUGHT AND RAIN CAUSE CHAOS

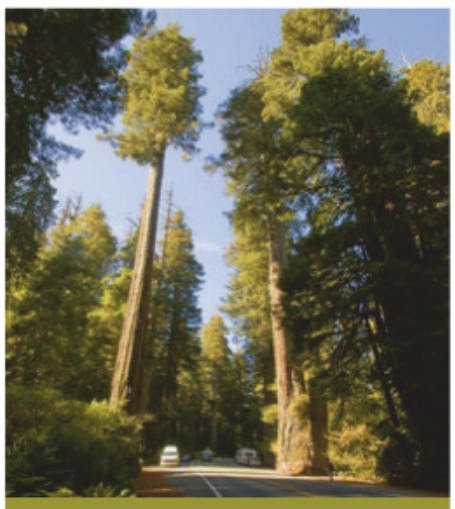
4 *El Niño* events normally last 1-2 years, and can have major global consequences. Precipitation is shifted so that Australia, Brazil, Indonesia and parts of Africa are more prone to drought, while Ecuador, Peru and Chile experience heavy rain and the risk of flooding.

SHUTTERSTOCK

WORLD RECORDS

Which coniferous tree is the tallest in the world, and where is it located?

In a park on America's west coast, one tree towers above all others in the world: the 115m-high Hyperion, named after one of the Titans of Greek mythology. Hyperion is a type of redwood that doesn't live anywhere else in the world as it requires a particular combination of moderate coastal climate and fog.



ACROTERION

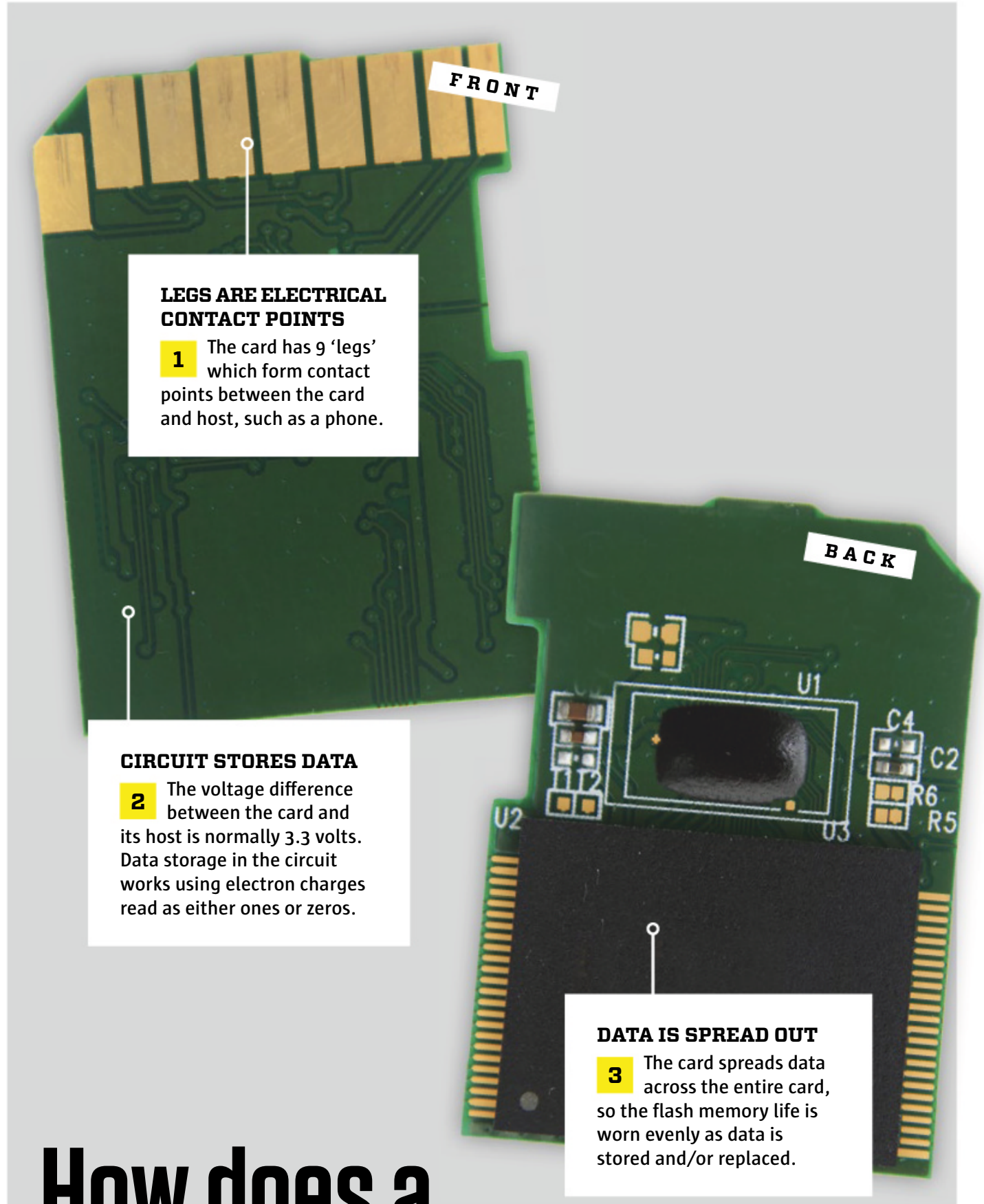
115

metres is the height of Hyperion, the world's highest conifer.

Huge American tree

WHERE: Redwood National and State Parks a few kilometres inland from the US west coast.

WHAT: The world's tallest coniferous tree, Hyperion – a redwood of the *Sequoia sempervirens* species.



LEGS ARE ELECTRICAL CONTACT POINTS

1 The card has 9 'legs' which form contact points between the card and host, such as a phone.

CIRCUIT STORES DATA

2 The voltage difference between the card and its host is normally 3.3 volts. Data storage in the circuit works using electron charges read as either ones or zeros.

DATA IS SPREAD OUT

3 The card spreads data across the entire card, so the flash memory life is worn evenly as data is stored and/or replaced.

How does a memory card work?

I can store hundreds of photos on my digital camera. They are stored on a memory card, but how does it work?

TECHNOLOGY Digital data – such as a digital photo – consists of a large quantity of ones and zeros. The job of a memory card is to store the digital data without any loss, and in such a way that the data is easy to restore.

On a memory card, the card's electrical circuit is used as storage for electrons that can be contained in areas on the thin surface, and retained even when no power is applied. The storage is very stable – data can be stored for years and read without any harm done.

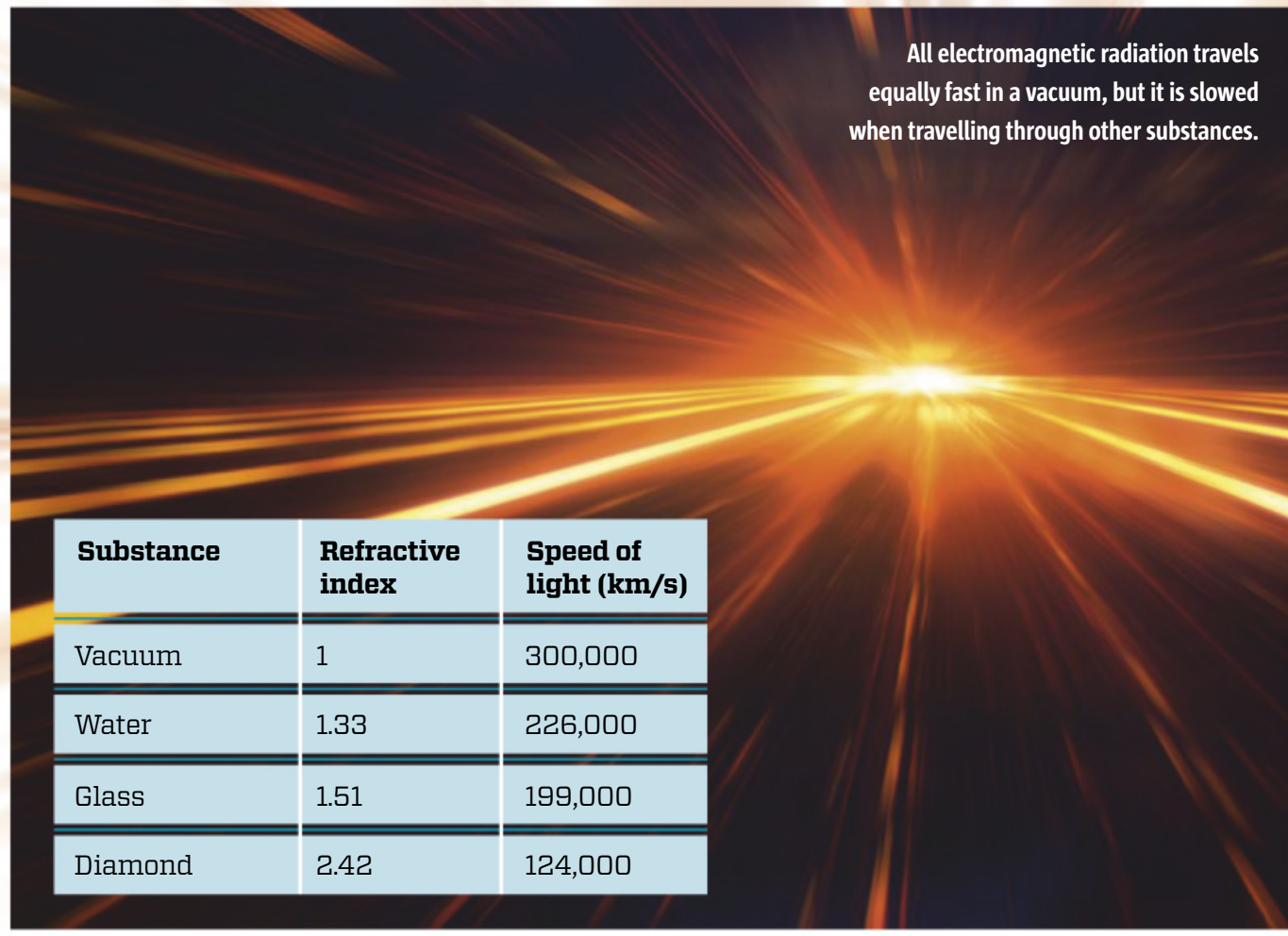
When read back, these electrons pass through a gate one after another, and if the total quantity of electrons reaches a certain level, that area is read as a one. If the quantity is smaller, the area is read as a zero.

The most widely used memory card is the SD (Secure Digital) card, developed in 1999.

SHUTTERSTOCK

Does all light travel at the same speed?

PHYSICS Yes, all light, indeed all electromagnetic radiation (visible light, X-rays, radio waves, ultraviolet) travels at the same speed of 300,000km/s *in a vacuum*. These types of electromagnetic radiation differ from each other in their different wavelengths and frequencies, but the two numerical values are linked so that when you multiply them, the result will always be the speed of light: 300,000km/s. However, when light travels not through a vacuum but through other substances such as air or water, the speed is reduced. The substance's refractive index describes how much it is slowed; the higher the refractive index, the lower the speed of light.



All electromagnetic radiation travels equally fast in a vacuum, but it is slowed when travelling through other substances.

Substance	Refractive index	Speed of light (km/s)
Vacuum	1	300,000
Water	1.33	226,000
Glass	1.51	199,000
Diamond	2.42	124,000

SHUTTERSTOCK

WHAT IS THIS? · Upside-down rainbows

An upside-down rainbow is not a rainbow, but rather a circumzenithal arc that is produced without rain.

1 The circumzenithal arc develops due to refraction. When light travels from one material to another, it is bent. In this photo, the sunrays are hitting ice crystals high in the sky.

2 Light with long wavelengths – red and orange – is bent the least. Shorter wavelengths– blue and purple – are bent the most. The different angles split white light into its constituent colours.

3 The ice crystals causing the circumzenithal arc are located in thin cirrus or cirrostratus clouds high in the sky. Such arcs can be observed when the Sun is lower than 32° above the horizon.

ECKHARD SLAWIK/SCIENCE PHOTO LIBRARY

Why do nuclear power stations have such large chimneys?

A nuclear power plant uses the energy of radioactive decay to generate electricity. But nothing is burning, so what is emerging from the power plants' huge chimneys?

TECHNOGLOGY The tall structures of nuclear power plants look like large chimneys, but are actually cooling towers, and what emerges at the top of them is nothing but water vapour. The cooling towers help the power plant get rid of heat that has not been converted into electricity.

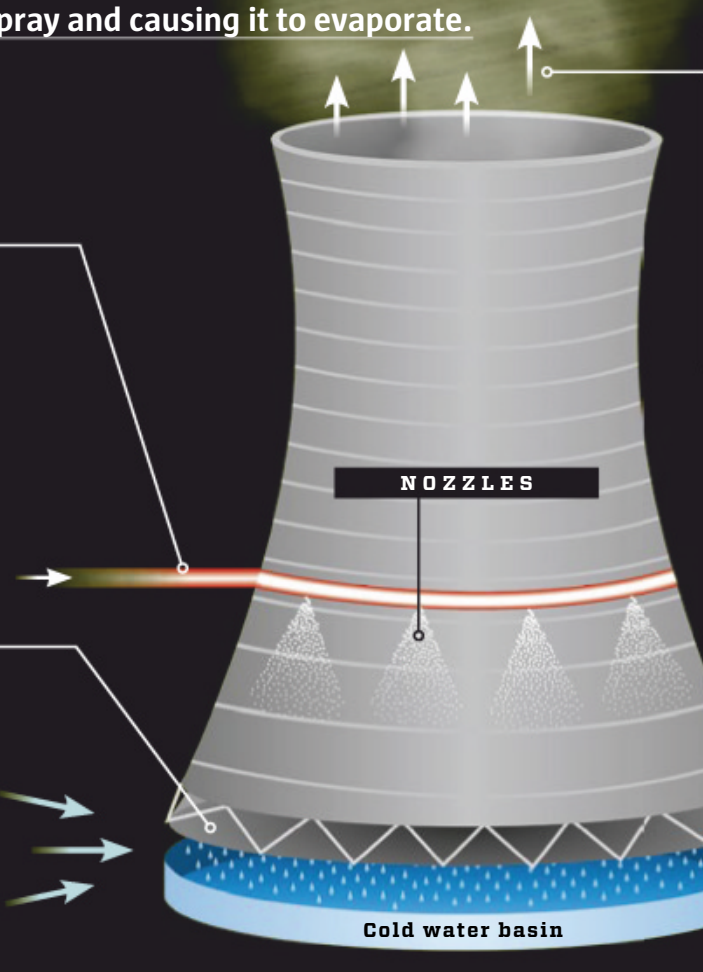
A nuclear power plant generates power based on the energy of radioactive fuel rods that are often enriched with uranium. The rods are immersed in water, which is heated substantially by the radioactive decay in the rods. The water also becomes highly radioactive, so it is kept within a closed circuit, while a heat exchanger transfers the energy to another water circuit, which produces vapour that powers the turbines and generators to generate electricity.

A third water system cools the vapour from the turbines, producing water that can flow back to the heat exchanger. The water of the third system is pure, but is too hot to be diverted directly into a lake or river. The cooling tower is the last step of this third system, and it emits surplus heat to the surroundings.

The special tower shape, with a wide bottom and top and a narrower centre, improves its efficiency. At the bottom, a large volume is needed to turn warm water into spray. At the top, the large volume is used to mix the warm moist air with cool air from the surroundings. The narrower central passage accelerates the warm air so that it rises more quickly. The cooling towers are often more than 100 metres high to ensure that the clouds of fine water drops do not affect the immediate vicinity.

Cooling towers eliminate surplus heat

The large towers of a nuclear power plant clear away surplus heat by turning pure water into spray and causing it to evaporate.



WARM WATER IS TURNED INTO SPRAY

1 Water warmed by surplus reactor heat is diverted into the cooling tower, where it is sprayed out through nozzles and evaporates.

COLD AIR PRODUCES RAIN

2 Cold air is absorbed at the bottom of the tower, making most of the water vapour condene into cold drops which end up in a basin. From there, it can be reused for more cooling.

WARM AIR RISES

3 Warm moist air from the cooling rises inside the tower. When it makes contact with cool air at the top, pure white water vapour is produced.

The large 'chimneys' of nuclear plants are cooling towers. They emit pure water vapour into the atmosphere.

Shark school: Mangrove kindergarten for youngsters

Many young animals are in constant danger of falling prey to hungry adults, but lemon shark females send their offspring to a natural kindergarten where nature offers protection. When the mothers are about to give birth, they head back to their own birthplace off the Bahamas, where they leave their offspring among the tightly spaced roots of mangrove trees, out of the reach of adults. The young sharks spend the first few years of their lives there, then move on, with the females returning to the safe haven when they themselves give birth.

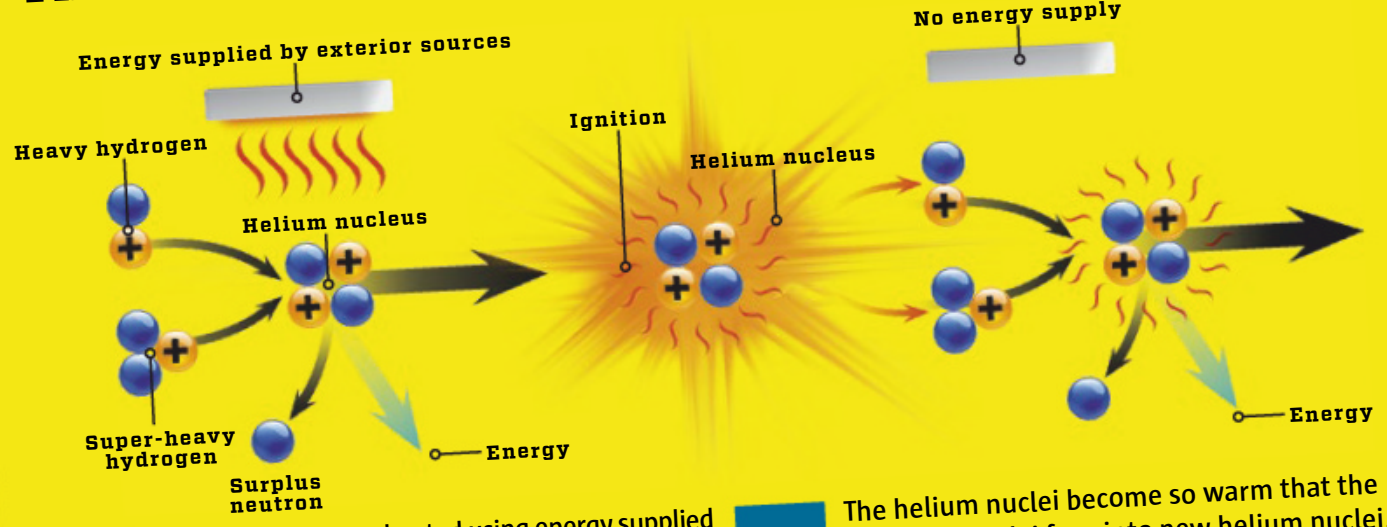
Photo // Shane Gross

NATURE PICTURE LIBRARY

WILL FUSION DELIVER AN INFINITE POWER SUPPLY?

Fusion could deliver clean, safe and inexhaustible energy, but copying the Sun's processes requires the world's most extreme equipment. Physicists are now taking the next step, by filling a reactor with real fuel.

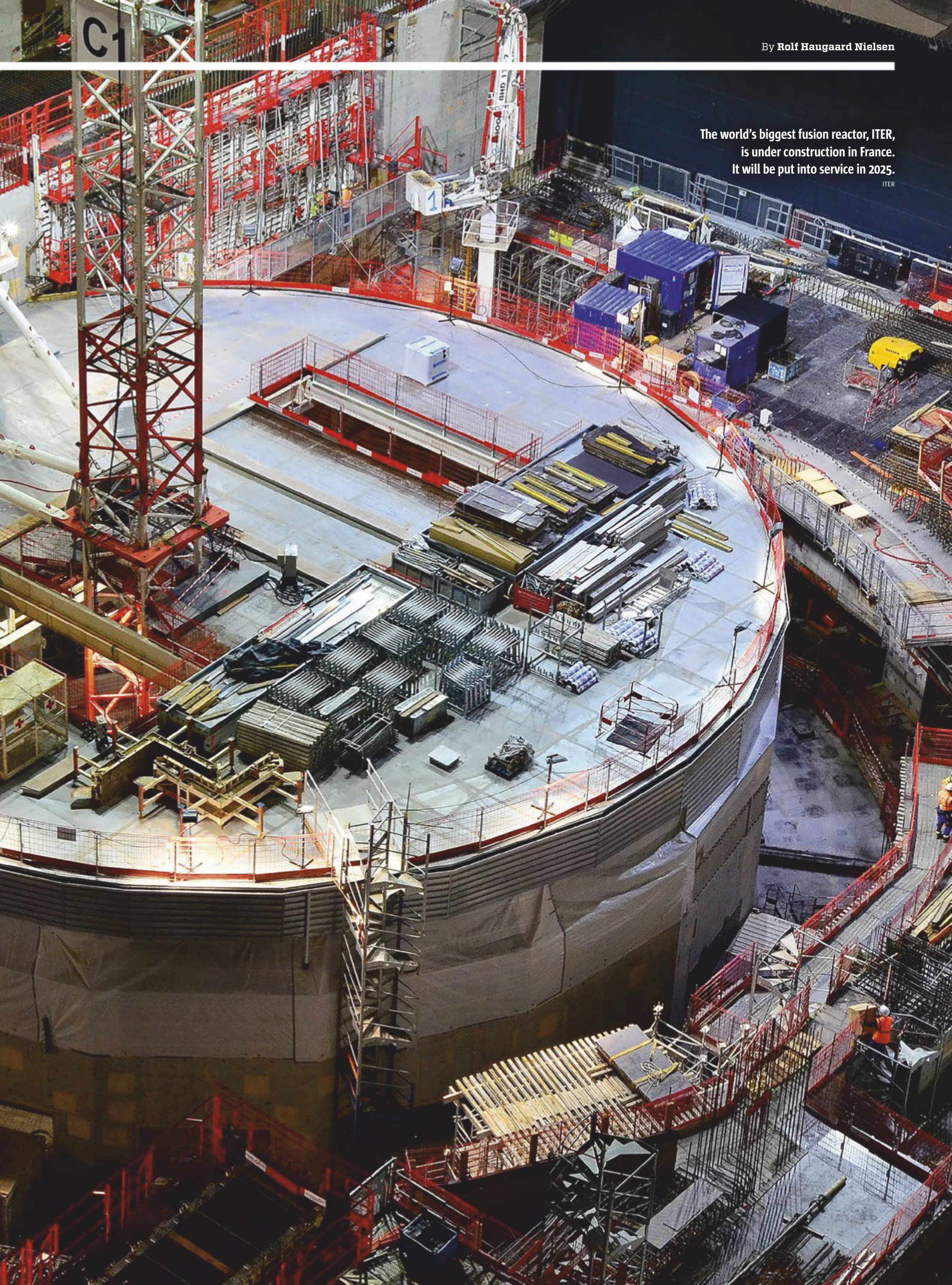
The aim is a self-propelled fusion process



1 Hydrogen nuclei are heated using energy supplied from the outside, making heavy and super-heavy hydrogen fuse to produce warm helium nuclei.

2 The helium nuclei become so warm that the hydrogen nuclei fuse into new helium nuclei, triggering more fusion – known as 'ignition'.

By **Rolf Haugaard Nielsen**



The world's biggest fusion reactor, ITER, is under construction in France. It will be put into service in 2025.

ITER

Getting fusion to work is rather like trying to light a fire using soaking wet wood. The positively-charged hydrogen nuclei repel each other, doing their utmost to avoid contact. Success requires the world's most extreme equipment to force reluctant hydrogen atoms together either with very high temperatures or under intense pressure. But if successful, the energy triggered by the fusion could provide us with cheap – and clean – electricity.

The struggle to create a practical fusion process has being going on for decades. Sometimes a solution has seemed tantalisingly close, but then an experimental error or new barrier has left scientists wondering whether a practical fusion process will ever be achieved. But they have not given up, and physicists are currently taking new steps towards this energy source of the future. In late 2020 the European JET reactor, the biggest of the existing test reactors, will be filled with heavy and superheavy hydrogen. JET is currently the only fission test reactor that can handle real power plant fuel; the others employ only heavy hydrogen, and that delivers too little fusion to be useful in a practical power station.

These JET experiments are a preview for a next-generation fusion reactor, ITER, which will be eight times bigger, and is already under construction in France. This fusion flagship is due to begin experiments in 2025, aiming for the first self-propelled fusion process to generate large quantities of energy.

The possibilities of fusion energy are tremendous. The raw materials are heavy hydrogen extracted from ocean water, plus superheavy hydrogen made from lithium. Ocean water will be plentiful forever, and known lithium reserves will last more than a thousand years, making fusion energy an almost inexhaustible energy source.

Laser competes with reactors

Most fusion plants follow one of two main roads to fusion power. One is laser fusion, in which the USA is the leading nation. High-energy laser beams bombard a hydrogen pellet from all sides, compacting the hydrogen so intensely that it fuses into helium. In 2014, the huge NIF laser facility extracted 1.5 times as much energy from a small hydrogen pellet as the energy that the laser beams pumped into the fuel. But physicists did not achieve their goal of making the fusion processes continue on their own once they had been triggered.

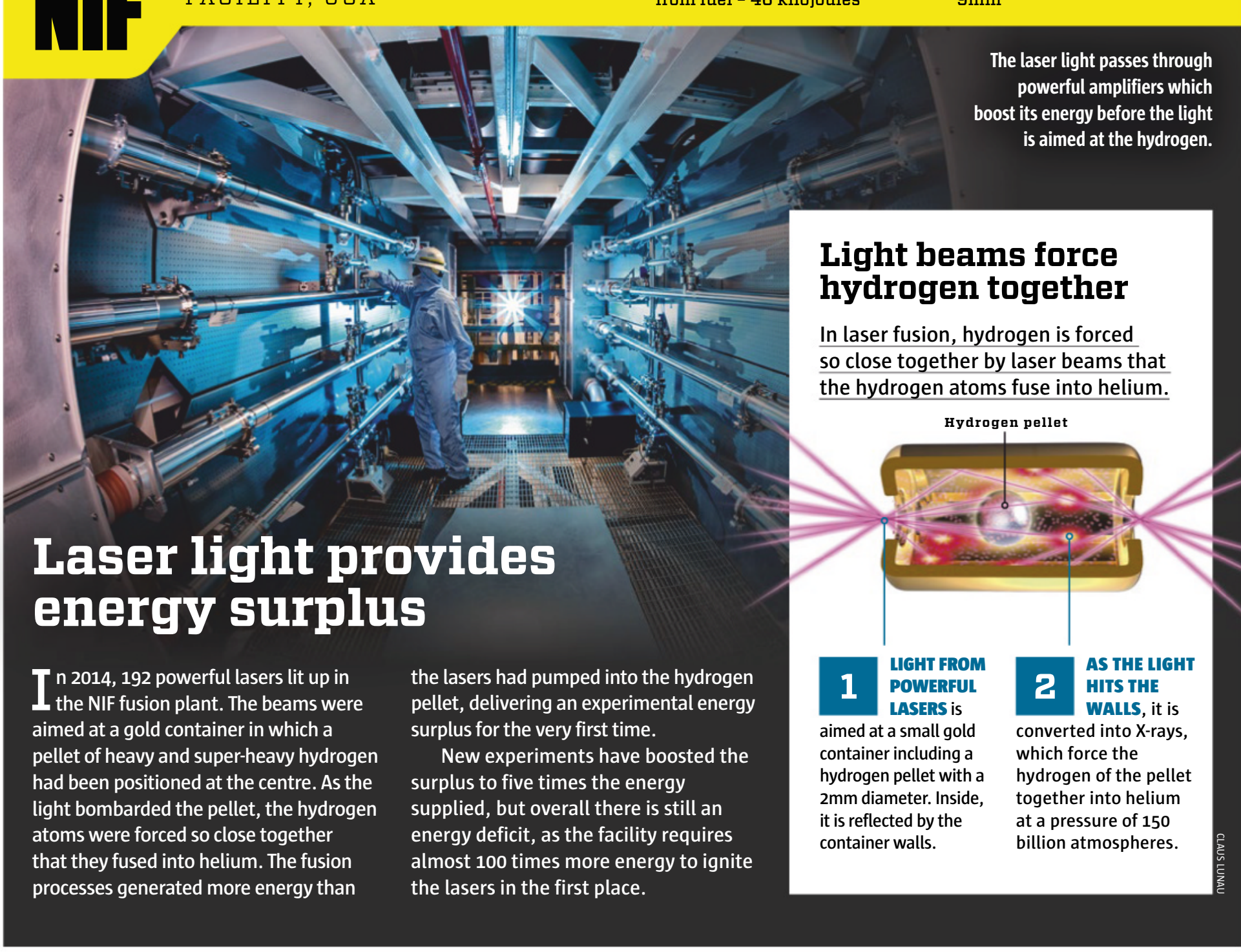
From this background, the reactors have now taken over as fusion's best bet for success, with two technologies in 'hot' competition. Both processes heat the hydrogen to a plasma in which the nucleus and the electrons are separated while trapped in a powerful magnetic field that prevents them touching the reactor wall and becoming cooled. The ▶

NIF

NATIONAL IGNITION FACILITY, USA

RECORD: energy surplus from fuel – 46 kilojoules

CYLINDER SIZE: 9mm



The laser light passes through powerful amplifiers which boost its energy before the light is aimed at the hydrogen.

Laser light provides energy surplus

In 2014, 192 powerful lasers lit up in the NIF fusion plant. The beams were aimed at a gold container in which a pellet of heavy and super-heavy hydrogen had been positioned at the centre. As the light bombarded the pellet, the hydrogen atoms were forced so close together that they fused into helium. The fusion processes generated more energy than the lasers had pumped into the hydrogen pellet, delivering an experimental energy surplus for the very first time.

New experiments have boosted the surplus to five times the energy supplied, but overall there is still an energy deficit, as the facility requires almost 100 times more energy to ignite the lasers in the first place.

Light beams force hydrogen together

In laser fusion, hydrogen is forced so close together by laser beams that the hydrogen atoms fuse into helium.

1 **LIGHT FROM POWERFUL LASERS** is aimed at a small gold container including a hydrogen pellet with a 2mm diameter. Inside, it is reflected by the container walls.

2 **AS THE LIGHT HITS THE WALLS**, it is converted into X-rays, which force the hydrogen of the pellet together into helium at a pressure of 150 billion atmospheres.

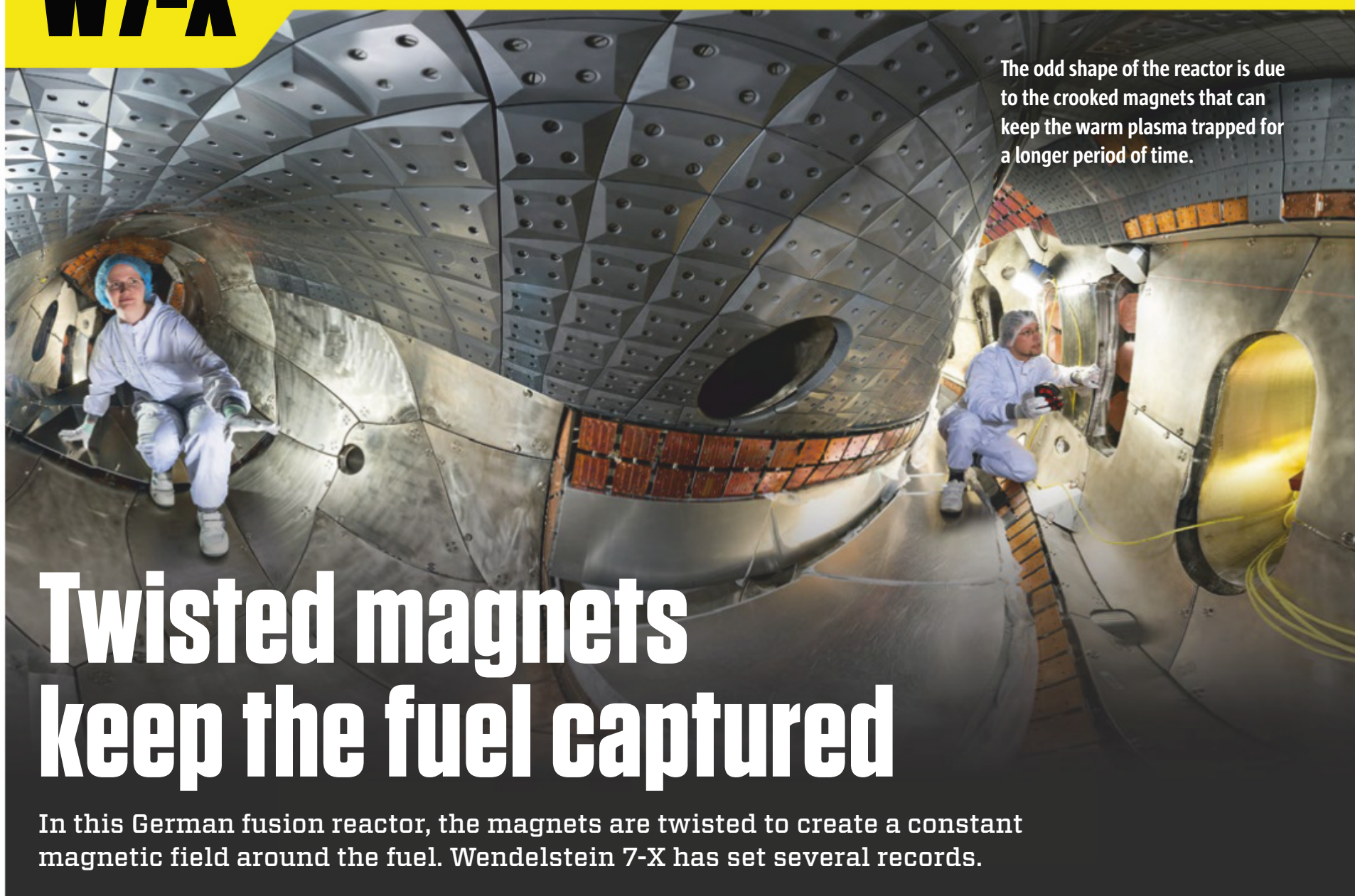
CLAUS LUNAU

W7-X

WENDELSTEIN 7-X, GERMANY

RECORD: Longest capture – 100 seconds

REACTOR SIZE: Diameter of 16 metres



The odd shape of the reactor is due to the crooked magnets that can keep the warm plasma trapped for a longer period of time.

Twisted magnets keep the fuel captured

In this German fusion reactor, the magnets are twisted to create a constant magnetic field around the fuel. Wendelstein 7-X has set several records.

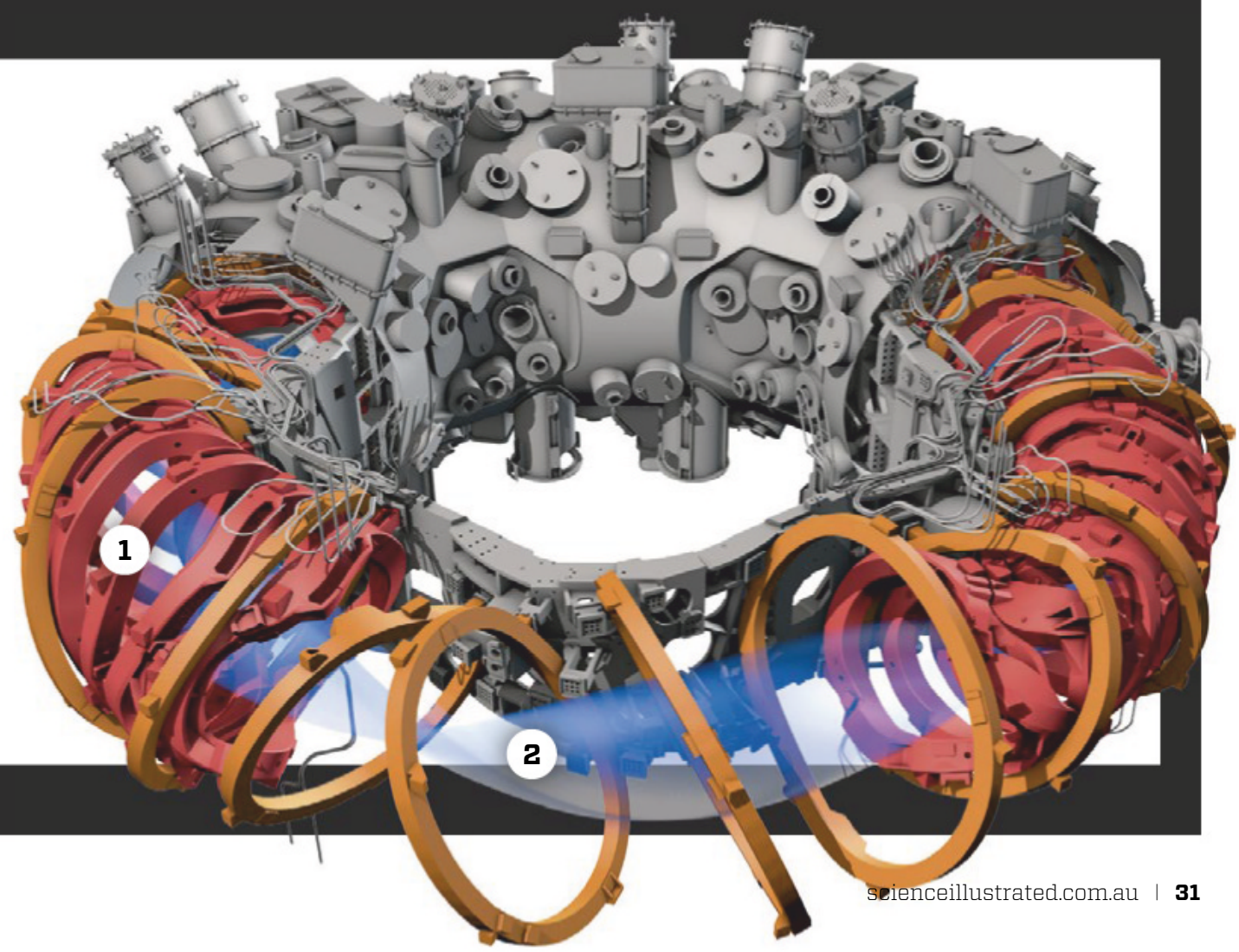
In a fusion reactor, hydrogen is heated to at least 100 million degrees, turning it into electrically conductive plasma. To avoid the fuel touching the reactor walls and getting cooled (stopping the fusion), it is trapped in a magnetic field. The Wendelstein 7-X reactor has kept the hydrogen plasma trapped for 100 seconds, which is the current record for this reactor type, known as a stellarator. This reactor is the biggest of its kind. The magnetic rings surrounding the reactor have been twisted into odd shapes to create a magnetic field which is as uniform as possible. The German physicists aim to keep the fusion fuel trapped for half an hour at a time.
The test reactor has already set another record: the highest energy density of fusion plasma, with about one sextillion particles per cubic metre.

Stellarator runs continuously

The Wendelstein 7-X is a stellarator. The reactor has a more stable magnetic field so it can keep up the fusion for a longer period of time. But it is difficult to construct.

1 **TWISTED** magnetic coils produce a stable magnetic field that is uniform throughout the ring.

2 **THE HYDROGEN PLASMA** is contained so it cannot touch the reactor walls.



VOLKER STEGER/SCIENCE PHOTO LIBRARY & IPP

first type is the classic reactor, such as JET and ITER (see right), which are known as tokamaks. This reactor type is easier to build, but has the disadvantage that a tokamak can confine its fusion fuel in the magnetic cage for no more than one hour at a time. Then the reactor must be emptied and new fuel pumped in and ignited. In a practical plant this process would have to happen quickly enough that consumers wouldn't experience outages in supply.

The other reactor type is the stellarator, in which the magnets have twisted shapes to produce a more stable magnetic cage which could, in theory, be kept going for years. New fuel can be added to the reactor on a continous basis, like feeding more coal into a boiler. However, the twisted magnets make it extremely complicated to construct a stellerator. In 2003 the Germans building the Wendelstein 7-X, one of the world's first large stellarators, were on the verge of giving up. But they persisted, and the reactor is now running smoothly and has managed to keep its fuel captured for 100 seconds at a time after only a few years of experiments. The existing world record of 6.5 minutes, which was set by the small French tokamak of WEST in 2003, is still yet to be beaten, but the German physicists estimate that they will manage to keep the fuel captured for half an hour at a time in the Wendelstein 7-X. A new German-American joint project extending the experiments at Wendelstein 7-X has been announced.

Hot plasma escapes the cage

None of the major modern experimental reactors will achieve 'break-even' where more power is generated than is consumed in heating the fuel. But they uncover the challenges that need to be solved, paving the way for real fusion power plants. At JET, the scientists will gain invaluable experience from the upcoming experiments with 'real' fuel consisting of both heavy and super-heavy hydrogen. So far, physicists have been reluctant to use superheavy hydrogen in their reactors, because it is radioactive, so that expensive safety measures are required.

However, the biggest challenge consists in trapping the fusion plasma for longer periods of time. To prevent the hot and turbulent fuel escaping and contacting the reactor wall, it is necessary to enclose the reactor ring in magnetic fields that are both stable and extremely powerful. The older JET reactor uses only ordinary magnets and can keep the fuel trapped for just a few seconds. But next year, a more efficient magnetic cage will be tested in the Japanese JT60-SA tokamak reactor, which has been upgraded

JET

JOINT EUROPEAN TORUS, UNITED KINGDOM

Reactor is filled with super-heavy fuel

In 2020, real power-plant fuel will flow into the world's biggest fusion reactor, JET. Back in 1997, the reactor set a record that still stands.

In 1997, the world's biggest fusion reactor, JET, generated 16 megawatts of energy using heavy and super-heavy hydrogen fuel – the mixture that will be used in real fusion power plants of the future. Normally, test reactors employ only heavy hydrogen as fuel, because having 50% superheavy hydrogen would emit 60-90 times more neutrons, making the reactor radioactive, so scientist can no longer enter it to make changes. The JET experiments were brief, but set a fusion power generation record that still stands: an output of 16MW for one second, though consuming 24MW for heating.

In the autumn of 2020, JET scientists will once again resume experiments in the ageing reactor, aiming for a longer period, again with fuel consisting of heavy and super-heavy hydrogen. They aim to maintain an energy production of 10-15MW for five seconds at a time.

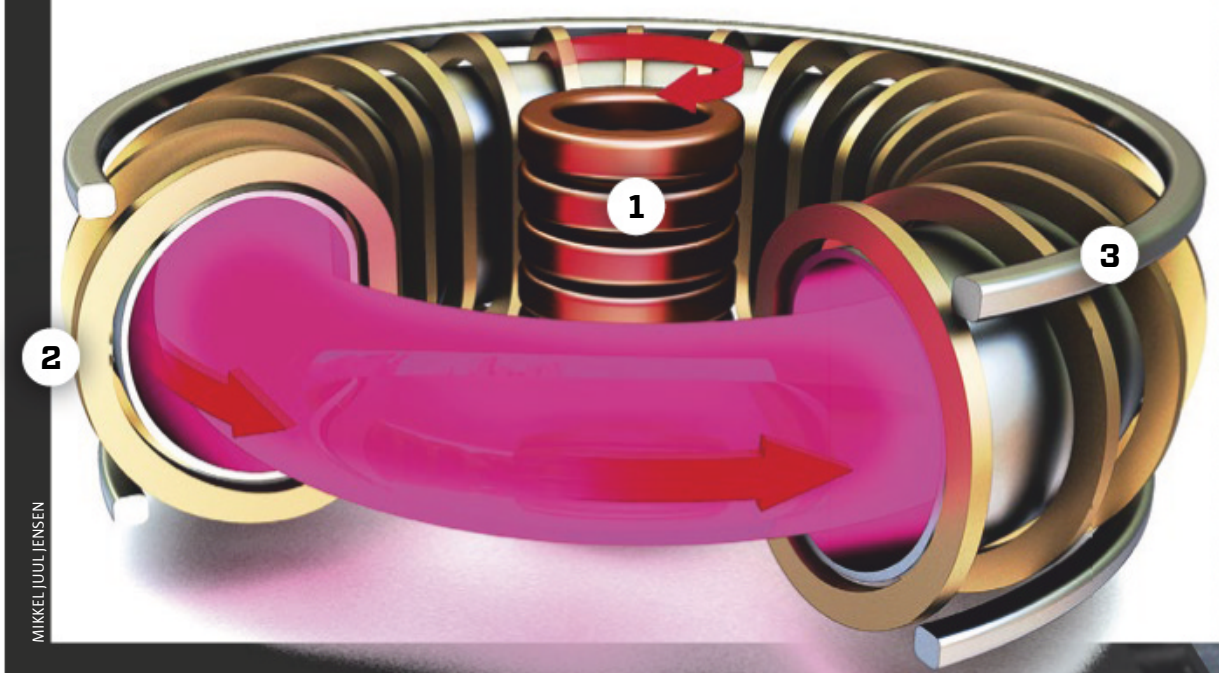
Tokamak reactor to be rebooted

JET is a tokamak reactor, the most simple and technically most stable reactor type, though it requires regular rebooting.

1 **A MAGNETIC COIL** at the centre of the reactor ring attracts the conductive plasma made of atomic nuclei and electrons towards the centre.

2 **D-SHAPED** magnets prevent the hot plasma from touching the reactor wall to be cooled, but there is a larger gap between coils on the outside than on the inside, so the magnetic field is weaker on the outside.

3 **TWO CIRCULAR** magnets compensate for the weakness on the outside, but the plasma can still be captured for a maximum of one hour before it comes into contact with the reactor wall.



MIKKEL JUUL JENSEN

RECORD:
Highest energy production – 16MW

REACTOR SIZE:
Diameter of 5.9 metres

The JET reactor will experiment with superheavy hydrogen as fusion fuel.

BERYLLIUM
Parts of the reactor ring are lined with beryllium tiles that do not absorb the superheavy hydrogen in the reactor fuel.

TUNGSTEN
The used fuel flows out at the bottom, where the tiles are made of tungsten that can tolerate the high temperatures.

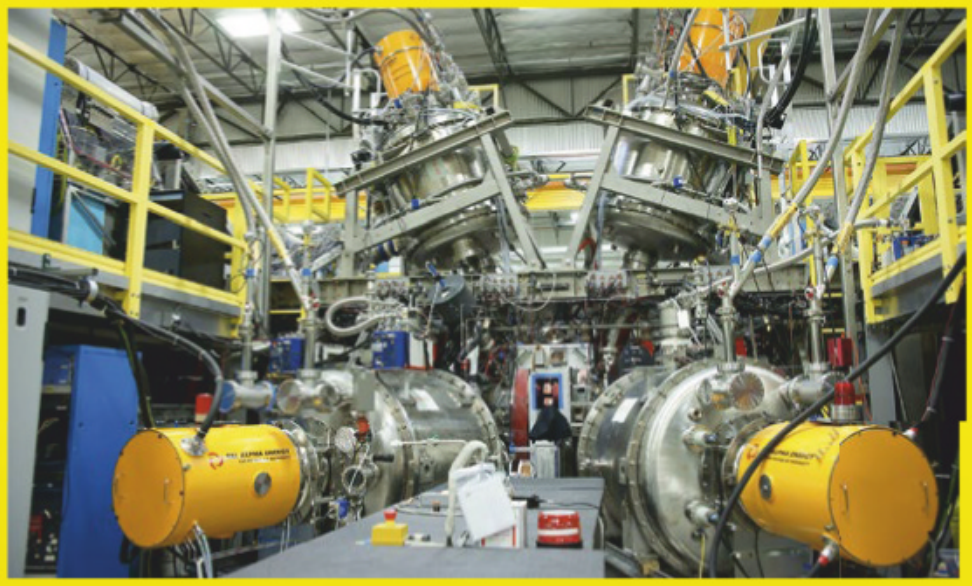
FUSION WILD CARDS challenge the giants

So far, fusion has required huge reactors, but smaller equipment using different technologies could yet prevail.

TAE TECHNOLOGIES:

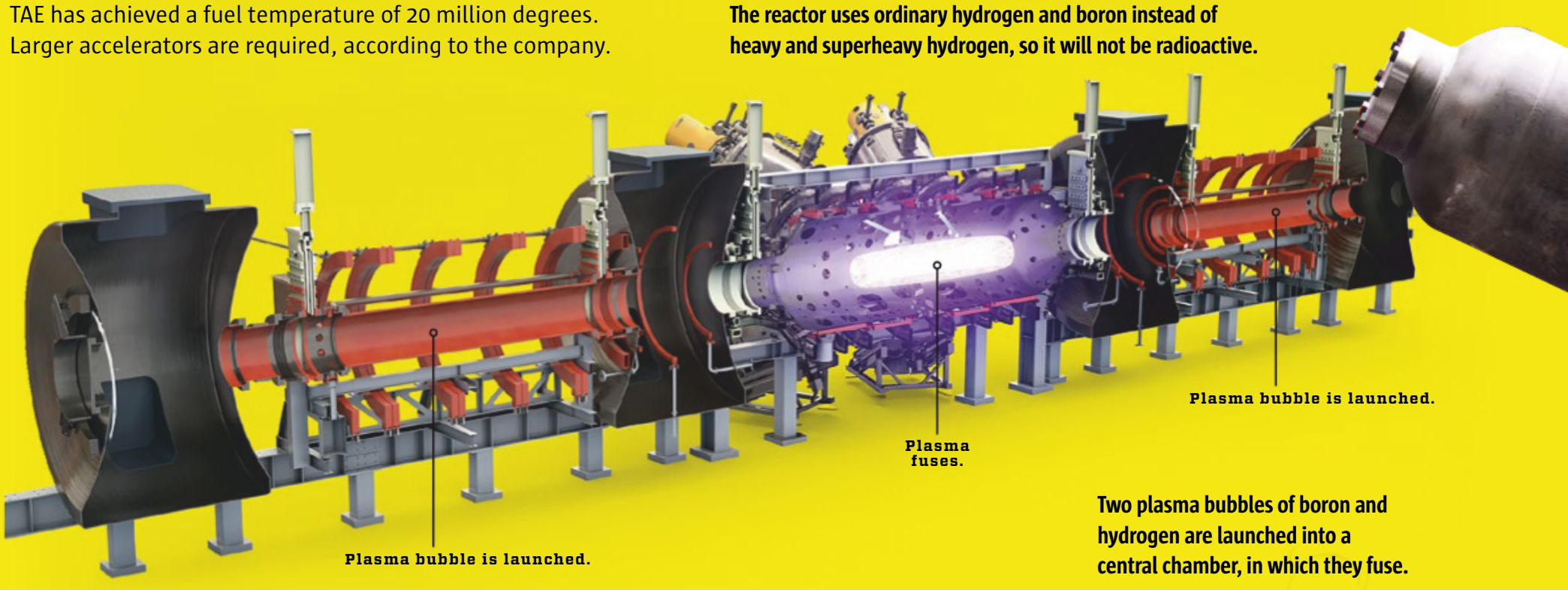
Fusion without radioactivity

Fusion power without any neutron radiation – that's what the American company TAE Technologies aims to achieve by making ordinary hydrogen nuclei protons fuse with boron atoms. When a boron-11 atomic nucleus swallows a proton, fusion power is released as the boron nucleus is converted into three helium nuclei. No neutrons are emitted in the fusion, so the reactor is not radioactive. The disadvantage is that the temperature in the power plant must be one billion degrees. That is to be achieved using an accelerator that makes plasma bubbles collide. In a 30-metre-long prototype, TAE has achieved a fuel temperature of 20 million degrees. Larger accelerators are required, according to the company.



TRI ALPHA ENERGY

The reactor uses ordinary hydrogen and boron instead of heavy and superheavy hydrogen, so it will not be radioactive.

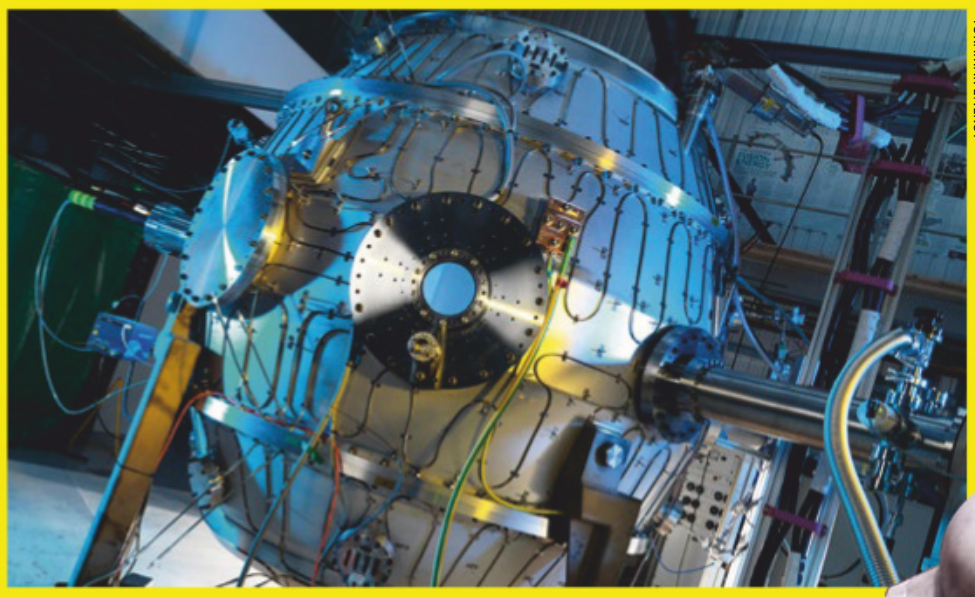


Two plasma bubbles of boron and hydrogen are launched into a central chamber, in which they fuse.

TOKAMAK POWER:

Ball reactor uses cheap magnets

The English company Tokamak Energy has built a small ball-shaped tokamak reactor with a diameter of only 2 metres, which was in 2018 heated to 15 million degrees by means of fusion fuel. The next step will be to increase the temperature to the 100 million degrees required in a power station. Normally, fusion reactors use superconducting metallic magnets that must be cooled with helium, but the reactor is so small that it is possible to use superconducting ceramic magnets, which are cooled with cheap liquid nitrogen. Tokamak Energy hopes that the combination of the ball-shape and ceramic magnets will pave the way for a supply network with many small and cheap fusion power plants.



TOKAMAK ENERGY

The ball-shaped reactor has a diameter of only 2 metres, and it operates without superconducting metallic magnets.

GENERAL FUSION:

Hammers cause fusion with shock waves

This fusion reactor looks like a hedgehog, but the 20 ‘spines’ are 100kg hydraulic pistons that hit the reactor tank at a speed of 200km/h. The strikes trigger shock waves that force a bubble of heavy and super-heavy hydrogen together. The Canadian company General Fusion has built a prototype, which could generate a major energy surplus on a larger scale if the plasma bubble survives for one second.

GENERAL FUSION

20 hydraulic hammers hit the reactor at the centre, causing shock waves that make hydrogen and superheavy hydrogen fuse.

with superconducting magnets to keep the fuel confined for 100 seconds at a time.

In order to take the next step towards the clean and inexhaustible energy source of the future, scientists are now constructing the most extensive and complex reactor yet, requiring an investment around A$30bn. The reactor, ITER, is under construction in the South of France in a cooperation between the EU, the US, Russia, Japan, China, India, and South Korea. The structure is as high as a 15-storey building and the reactor will weigh 23,000 tonnes, with a ring diameter of 19.4 metres surrounded by huge, superconducting magnets up to 25 metres high.

ITER aims to pass the crucial milestone where the fusion processes continue unaided when the heating apparatus is deactivated. In the burning plasma, the super-hot helium nuclei from the fusion collide with more hydrogen nuclei, heating them and creating continous fusion. The power generation continues as long as new fuel is added and as long as the magnetic cage can keep the fuel captured. The aim is to maintain the confinement for an hour at a time. Experiments with real heavy and superheavy hydrogen fuel should begin in 2035, with the process generatiing 10 times more energy than the reactor consumes. A later aim is to increase this energy surplus to 30 times the quantity supplied.

It is still unknown whether the successor of ITER will be a tokamak or a stellarator. The results generated by the Wendelstein 7-X could be so positive that the stellarator becomes the more successful technology. Or one of the alternatives that private companies are testing on a small scale could end up overtaking the incumbent giants.

Ocean water replaces coal

The first fusion power plant is expected to supply electricity to the grid around 2060. No matter which version becomes most successful, fusion will be a safe energy source because there is no risk of out-of-control chain reactions as can happen in today's nuclear power plants. If the fuel supply stops, the reactor comes to a halt, like a car running out of petrol. Fusion also leaves none of the highly radioactive fuel waste which must be stored for 100,000 years, as the only residual product is helium.

Heavy hydrogen from 40 litres of ocean water and superheavy hydrogen from 5 grams of lithium – corresponding to the contents of a mobile phone – can supply as much energy as 40 tonnes of coal, and will neither pollute the air nor emit CO_2. Fusion could therefore play a major role in the climate-neutral energy supply of the future. SCI

ITER

INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR, FRANCE

New reactor to generate surplus energy

In 2035, the huge ITER reactor will begin experiments, which aim to produce self-propelled fusion.

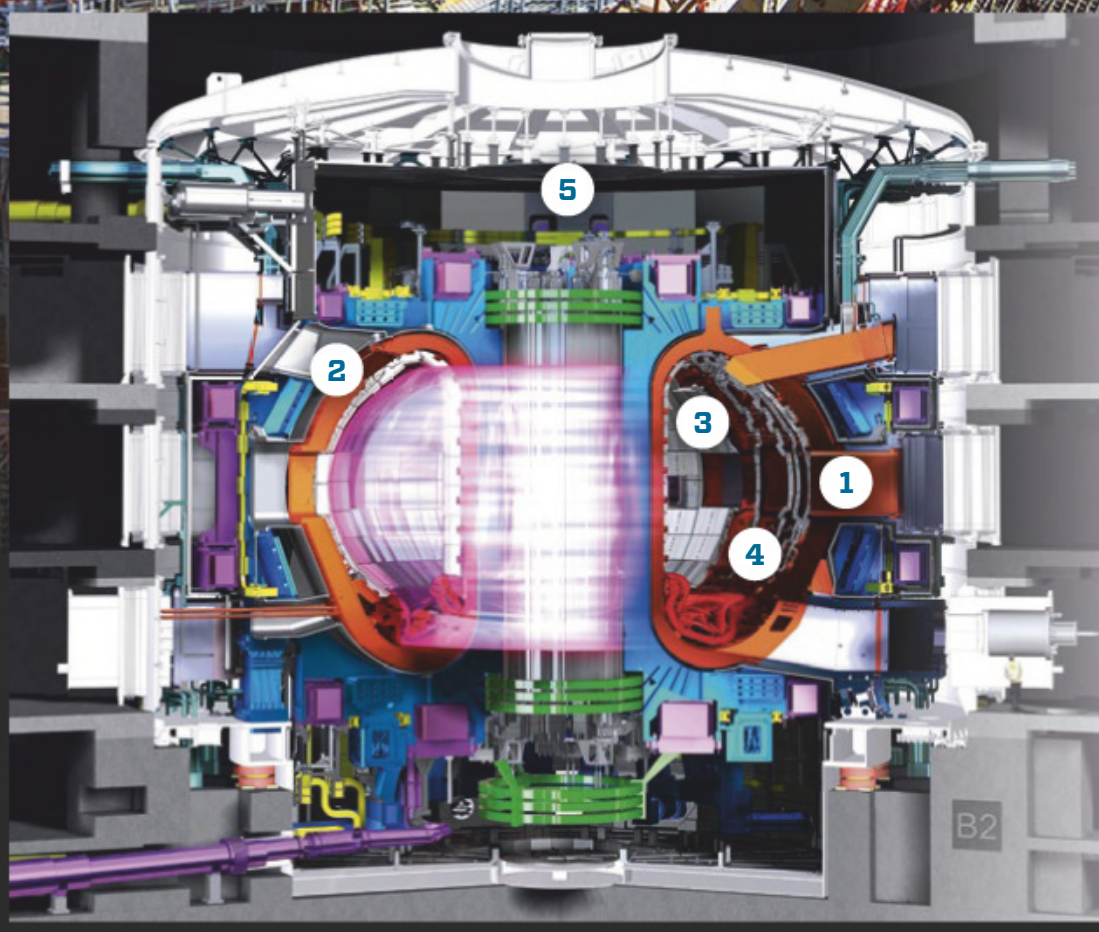
In 2015, when ITER initiates the first experiments with heavy hydrogen fuel, several fusion research records are likely to be broken. The fuel must be heated to 150-200 million degrees, beating the former record of 140 million degrees. Moreover, the plasma must be trapped in the magnetic cage for 8 minutes at a time – the existing record is 6.5 minutes.

The first 10 years of experiments will test ITER thoroughly, preparing everything for the experiments with real power-plant fuel of both heavy and superheavy hydrogen from 2035, where the helium nuclei produced in hydrogen fusion will get more energy, and those extremely hot helium nuclei will collide with the plasma's hydrogen nuclei, heating them, and causing more fusion, producing more helium nuclei. In this way the plasma is 'ignited', so the fusion will continue for up to one hour at a time, generating more energy than was consumed to start the process.

AIM OF RESEARCH:
30 times energy surplus

REACTOR SIZE:
Diameter of 19.4 metres

A 30m-high concrete shield is to surround ITER's reactor ring, which will have a 19.4m diameter.



ITER generates fusion power with extreme heat and cold

1. **THE FUEL** of the reactor ring is heated to plasma at 150m°C by means of microwaves and high-energy hydrogen atoms.
2. **SUPERCONDUCTING MAGNETS** around the ring and down through the centre trap the plasma so it will not touch the reactor wall.
3. **TILES** that weigh up to 4 tonnes protect the reactor and magnets against heat and radioactivity. Robots maintain the tiles.
4. **THE INSIDE WALL** behind the tiles is lined with lithium that absorbs neutrons, converting them into superheavy hydrogen.
5. **A FREEZER** surrounding the reactor ring cools the magnets to -269°C with liquid helium to make them superconducting.

ITER

DAI KUROKAWA/EPA/RITZAU SCANPIX & MATTHEW FIELD & SHUTTERSTOCK

SCIENTISTS AIM TO REVIVE EXTINCT AND ENDANGERED ANIMALS BY MEANS OF SPERM, EGGS AND SKIN FROM 'FROZEN' ZOOS.

By **Andreas Ebbesen Jensen**

Frozen DNA to revive extinct animals?

ONE BY ONE FROM NOAH'S FREEZER

Using DNA from zoological freezers, scientists aim to manipulate cells and create new, healthy animals in the lab, bringing them back from extinction.

Shortly before Easter in 2018, a rhino called Sudan passed away. Sudan was the world's very last male northern white rhino, but an emergency plan was initiated before he died. Biologists took samples from the rhino and sent them to San Diego in California, where they were placed in a huge zoological freezer.

The Frozen Zoo in San Diego is just one frozen store that zoologists are stacking with sperm, eggs, skin and other cells from turtles, penguins and many other endangered animal species. The freezer functions as a Noah's Ark on ice, from which scientists hope to revive a series of threatened animal species.

Scientists will revive the animals using culture dishes in the lab, manipulating cells in new ways. If successful, the same methods could one day also benefit people, treating diseases which cannot presently be cured.

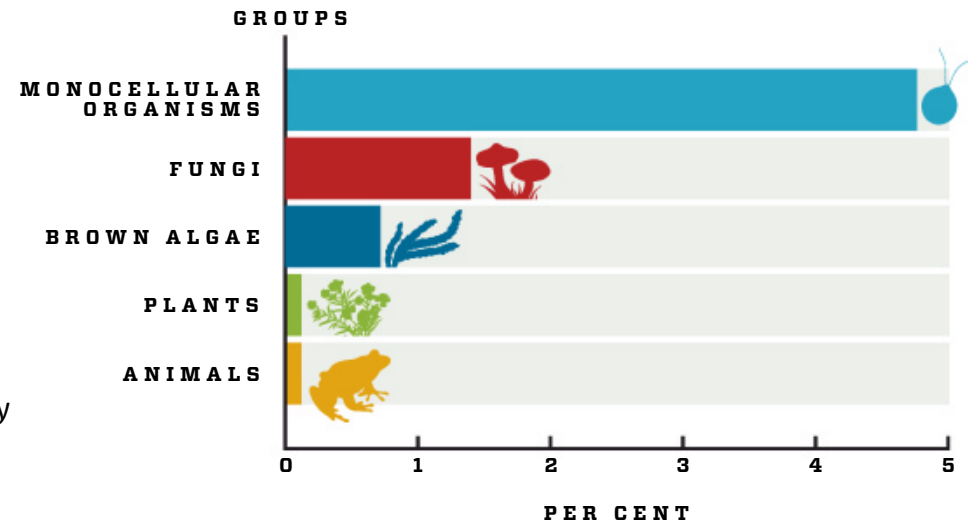
Rapid extinctions

We are living in a time that scientists are calling the sixth mass extinction, with animals and plants becoming extinct at a rate unequalled since the asteroid strike 66 million years ago which led to the extinction of the dinosaurs. Today it is farming, pollution and poaching that constitute an equal threat. Every day, some 5 to 55 animal and plant species disappear, a pace so rapid that several scientists estimate that half of the world's species could be gone by 2050.

The most common way of preserving an endangered animal species is to protect its habitat. Many endangered species – such as the Javan rhino in Indonesia and the ▶

DNA puzzle to save endangered animal species

Biologists estimate that our planet hosts 10-15 million plant and animal species, of which we have identified only around 10%. Yet the Earth BioGenome Project aims to study the DNA codes of all animals and plants on Earth. The sequencing will deliver a better chance of reviving or reestablishing populations because it would avoid inbreeding difficulties and allow the use of genetically-similar species as surrogate mothers. Scientists from Oakland in the US have sequenced DNA from three severely threatened parrot species, using the data to reestablish a population with healthy genetic variation. The scientists behind the Earth BioGenome Project believe that it will take 10 years to collect DNA data animal and plant species into an open database which scientists throughout the world can use to save animals.



HARRIS A. LEWIN ET AL.

Biologists are sequencing the DNA of all the world's species. This is how far they have progressed.

'Tiny' is a mouse that was grown from cells taken from a mouse tail. Scientists converted the tail cells into embryonic cells, which developed into an embryo carried to term by a surrogate mother.

QI ZHOU

world's smallest porpoise in the Gulf of Mexico – now live in nature reserves. Authorities are working towards the jailing of more poachers, the curbing of illegal deforestation, and the reduction of CO_2 emissions.

But some species are already so badly reduced that none of these solutions will be enough – as with the northern white rhino. There are simply not enough individuals left for the species to survive. And that is where scientists' frozen zoos enter the scene.

Rhinos made in culture dishes

The freezers of the San Diego Frozen Zoo include tissue samples from 1000 animal species. Apart from the northern white rhino, the freezer contains samples from 'Lonesome George', a male Pinta Island tortoise that died in 2012. Scientists hope to revive the species by means of his cold DNA.

Frozen animal samples have already proven their worth. In the 1980s, only 18 black-footed ferrets remained in the world. In 2008, scientists inseminated a female with sperm that had been frozen since the 1980s, and that became the beginning of a new life for the species. Now there are around 300 black-footed ferrets in the wild.

Scientists from frozen zoos can also fertilise eggs outside the womb. Females get a hormone that stimulates egg production. When the eggs are mature, they are removed with a hollow needle, placed in a culture dish and mixed with thawed sperm cells. When the egg cells have been fertilised, biologists can insert the early embryo into a surrogate mother.

Although artificial insemination with frozen sperm is possible, each and every different animal species is a new challenge, because scientists must sequence the genome and adapt methods to the reproduction of that particular species. With the northern white rhino, biologists have long struggled with these challenges, and there are other issues as well for this almost-extinct species. The last two living females are the child and grandchild of Sudan, the last male, so scientists must also avoid the potential problems of inbreeding. In 2019 scientists for the first time fertilised eggs taken from the two females with frozen sperm from two other rhinos, Saut and Suni, that died in 2006 and 2014 respectively.

50

% of the world's animal and plant species could be extinct by 2050.

But there are not enough eggs and frozen sperm to revive a healthy population with gene variation sufficient to avoid inbreeding problems. So scientists are developing new stem-cell techniques allowing them to convert frozen skin cells into new egg and sperm cells. In this way scientists can make eggs and sperm using cells taken from many other northern white rhinos.

Mouse tail becomes a mouse baby

Scientists have already successfully 'reprogrammed' cells in this way. In 2009, Chinese researchers turned skin cells from a mouse tail into pluripotent stem cells. These cells are able to develop into any body cell type, unlike tissue-specific stem cells that develop only for specific tasks. The conversion from skin cells into pluripotent stem cells usually involves scientists adding a retrovirus which replaces skin cell genes with copies of its own genes. The skin cells are 'reset' and can subsequently develop into any type of cell. The Chinese scientists made the pluripotent stem cells develop into embryonic stem cells and subsequently inserted the embryo into a surrogate mother, which finally gave birth to the mouse Tiny – the first ever animal to be created by means of pluripotent stem cells.

Now the time has come for the northern white rhino, and frozen skin cells will again vital for reviving the species. Scientists aim to convert the skin cells into pluripotent stem cells and add genes from ovaries and sperm, making the cells develop into germ cells that will subsequently pass through the meiosis process in which they divide into four, halving their number of chromosomes from 46 to 23. When an egg cell is fertilised by a sperm cell, they each have 23 chromosomes, which combine into the 46 that exist in the rest of the body's cells.

Scientists are constantly developing the method. The most recent breakthrough came in 2018, when germ cells developed into oogonia, the initial stages of eggs.

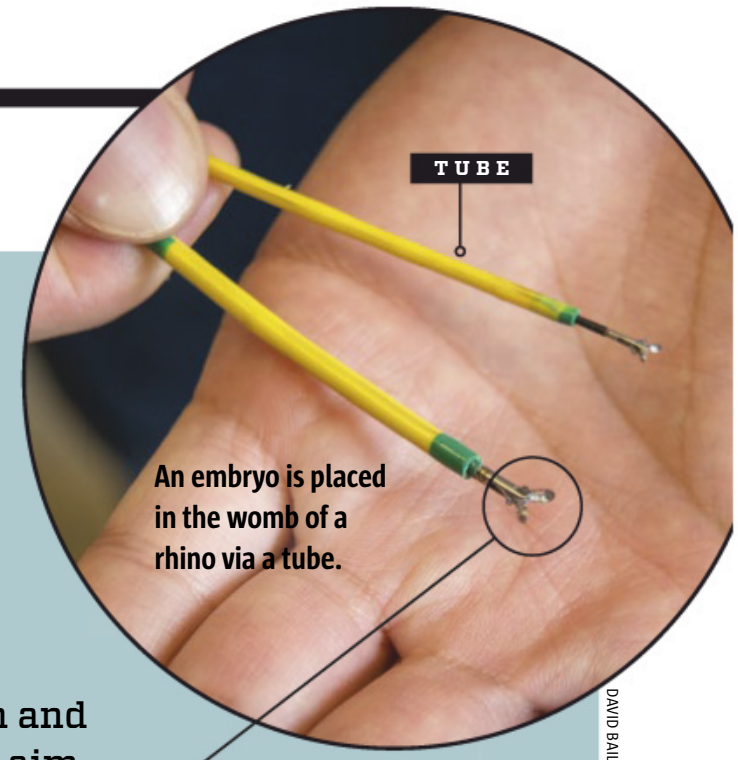
Biologists have sequenced the genomes of the northern and southern white rhinos to confirm that southern white rhinos can act as surrogate mothers for their northern relatives if scientists manage to develop egg cells that can be fertilised and turn into embryos.

Stem cells can treat diabetes

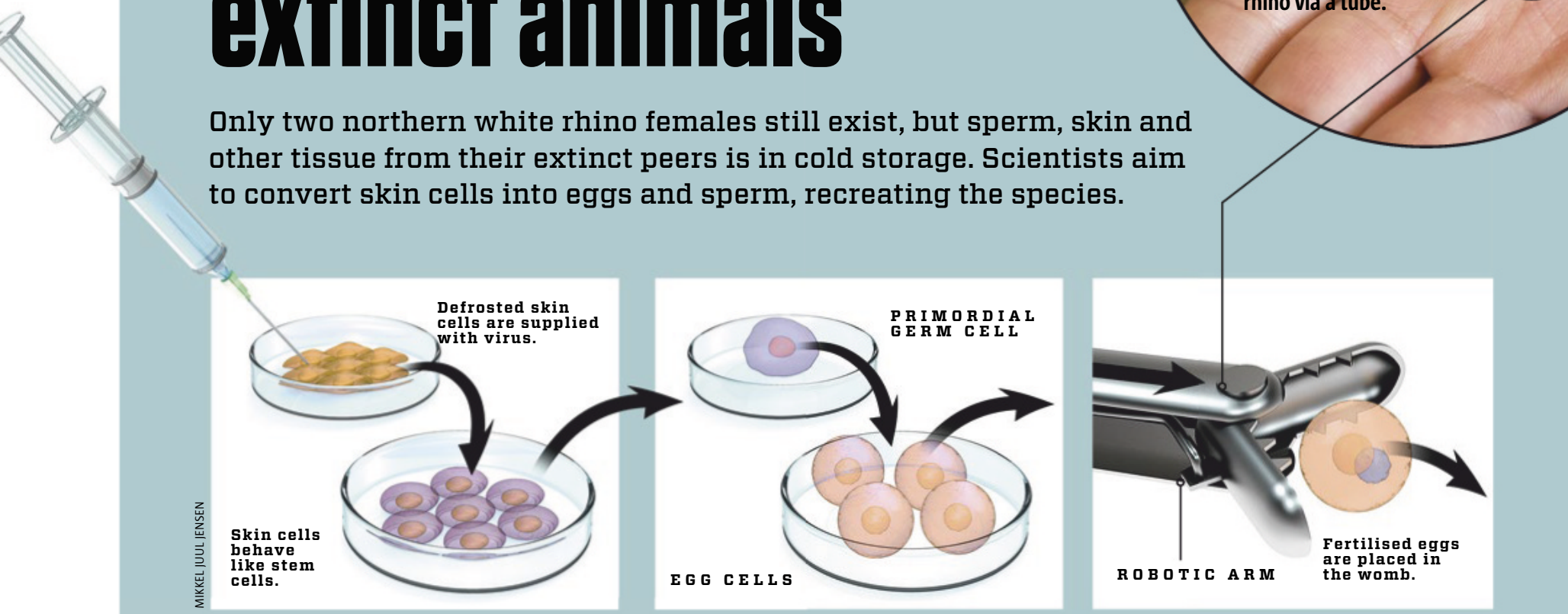
The research of frozen zoos might benefit not only thousands of animal species; it might offer solutions that can be applied to humans. The reprogramming of cells could lead to new treatments, given that several incurable human diseases are caused by failing cells. This is true for diabetes, when insulin-producing cells do not function. If doctors can instruct pluripotent stem cells to behave like insulin-producing cells, they might be able to transplant such cells into diabetics – and cure the disease. SCI

Stem cells revive extinct animals

Only two northern white rhino females still exist, but sperm, skin and other tissue from their extinct peers is in cold storage. Scientists aim to convert skin cells into eggs and sperm, recreating the species.



DAVID BAILLOT/UC SAN DIEGO JACOBS SCHOOL OF ENGINEERING



MIKKEL JUUL JENSEN

Virus converts skin cells into stem cells

1 Scientists add a retrovirus to skin cells. The virus includes genes from stem cells that exist in eggs and can develop into any type of body cell. The virus replaces genes in the skin cells with its own genes, so the skin cells change into pluripotent stem cells.

Stem cells become egg cells with tissue from ovaries

2 With a mixture of proteins and hormones, the stem cells develop into primordial germ cells. Subsequently scientists add tissue from the oviducts of a rhino, triggering the meiosis process by which the germ cells divide and become egg cells that can be fertilised.

Eggs are fertilised and placed in surrogate mother

3 The eggs are fertilised with sperm that is either defrosted or made by means of stem cells and other tissue, such as the eggs. A robotic arm navigates the narrow cervix and ‘shoots’ an embryo through the hollow arm into a closely-related surrogate mother's womb.

Edward is the third southern white rhino ever born as a result of artificial insemination. He was born in July 2019 in San Diego Zoo.

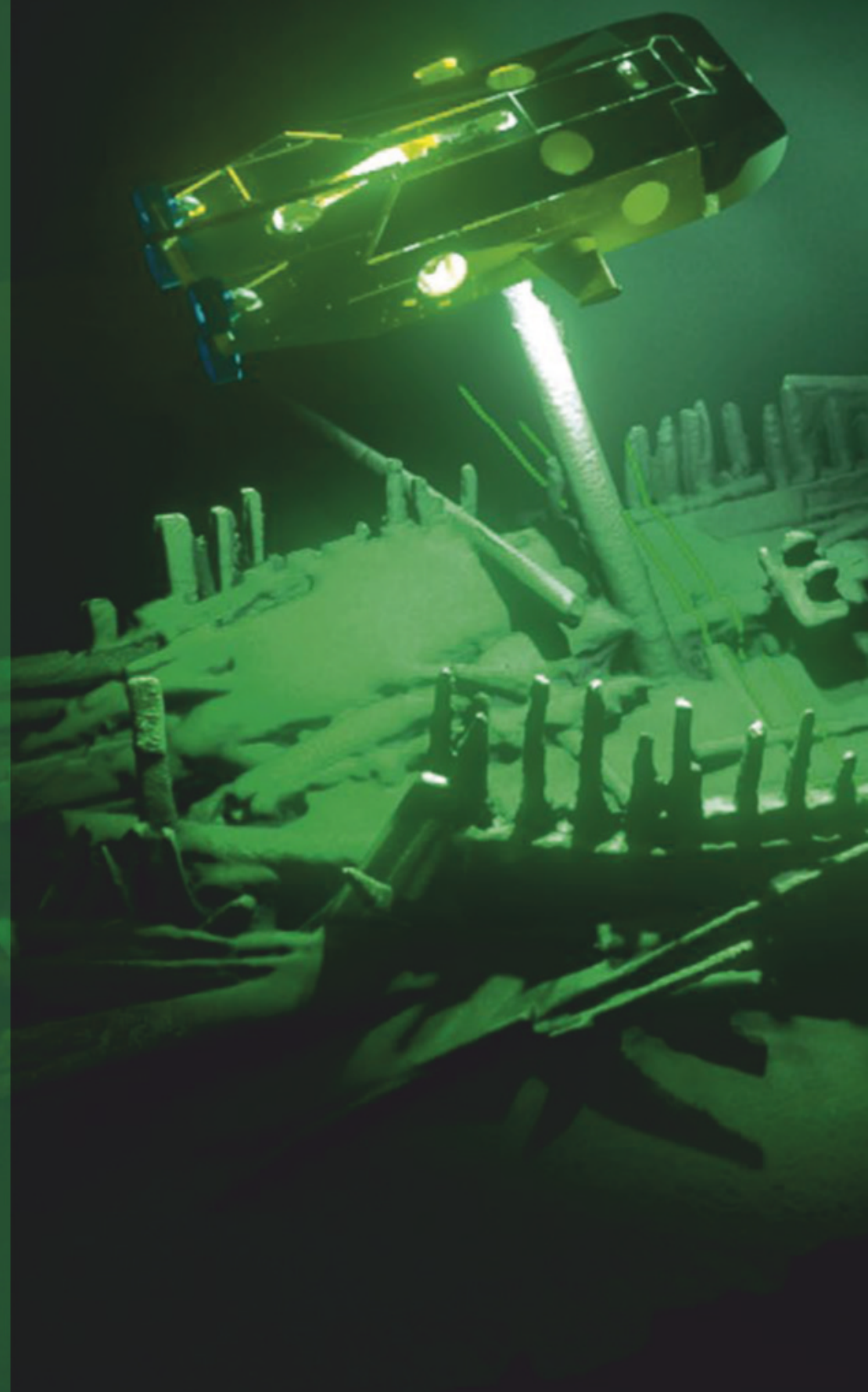
KEN BOHN/POLARIS/RITZAU SCANPIX

DEEP SEA EXPEDITION REVEALS HOW THE BLACK SEA PRESERVES THE PAST

The world's oldest ship has been discovered in a remarkable state of preservation on the floor of the Black Sea, where oxygen-free conditions have maintained the wreck as a time capsule. Robots with 3D scanners, sonar and deep-sea cameras are shedding light on this unique environment.

REACH SUBSEA

The robotic exploration of the Black Sea was just one part of the biggest ever underwater archaeological project.



By **Andreas Ebbesen Jensen**

Shipwrecks thousands of years old are remarkably well preserved by the Black Sea's unusual conditions.
RODRIGO PACHECO-RUIZ

The five rivers of the Danube, Dniester, Dnieper, Don and Kuban annually direct 354 cubic kilometres of fresh water into the Black Sea's top layer. But this nutritious river water paradoxically leads to an oxygen-free dead zone at greater depths.

SHUTTERSTOCK

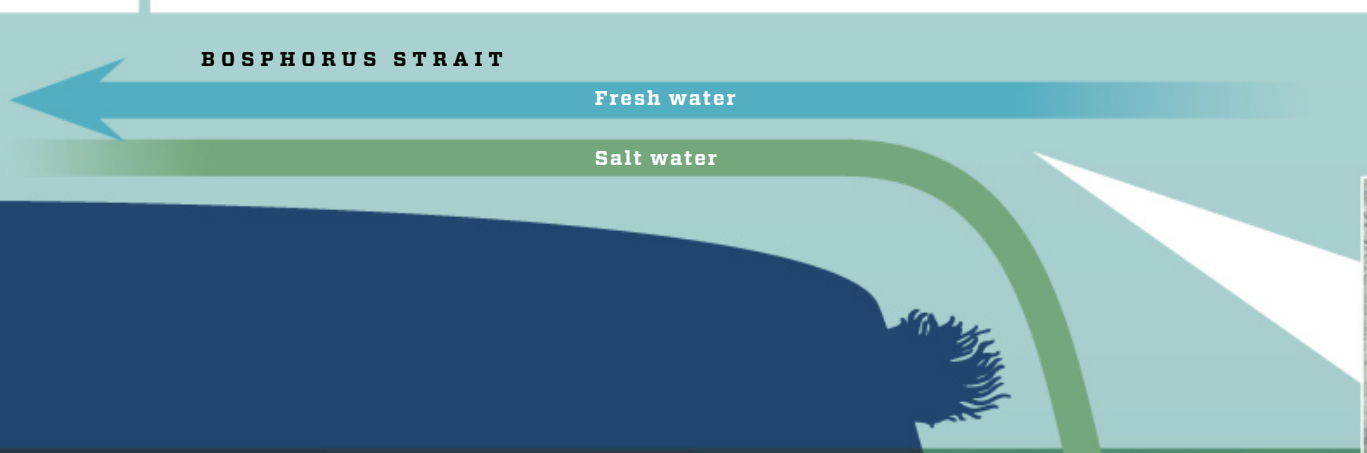
Toxic environment keeps the past preserved

Termites, sandworms and wood-consuming bacteria are absent from the large, oxygen-free zone on the Black Sea floor. Sunken ships can remain intact for thousands of years thanks to the different water layers and a sulphate-consuming bacterium that poisons the water so that no other organisms can survive.

CLAUS LUNAU/LOTTE FREDSLUND

Oars are dipping rhythmically into the grey-green surface of the Black Sea as a 23-metre Greek merchant ship loaded with oil jars and spices makes its way between the independent colonies and city states along the coast of the isolated sea above the eastern end of the Mediterranean. But a storm is rising, and frothing waves crash high across the deck of the wooden ship. The crew rows for all it is worth, the 15 to 25 sailors aboard still hoping for a season of profitable trading. But 80km from the Bulgarian coastal town of Burgas, it's all over; the cascades of water overturn the merchant ship. It sinks to the sea floor, and oblivion – until now.

In the autumn of 2017, during a three-year research project, archaeologists came across the almost intact wreck resting on the Black Sea floor. A carbon-14 test revealed that the ship had sailed at least 2400 years ago, during the Peloponnesian War between Athens and Sparta. So the ship is the oldest



Narrow strait is the Black Sea's only regulator

1 The Black Sea basin includes some 547,000km^3 of water that can escape only via the 750m-wide and 110m-deep Bosphorus Strait, where an overlying flow of mixed river and salt water passes an underlying flow of salt water from the Mediterranean. The narrow passage means that only some 0.14% of the Black Sea water is replenished annually.

intact wreck ever discovered, and yet its state of preservation is incredible, as if it sank mere months ago.

No fewer than 66 wrecks were uncovered during the three-year expedition, and their well-preserved construction, ropes and ornamentation are re-writing what we know about ancient boat design, much of which was previously deduced from pictures on vases and other objects from the time. Equally fascinating is what the finds reveal about the Black Sea's extreme conditions and how they were created. The research expedition and its underwater robots have uncovered many of the secrets behind the birth of the Black Sea.

Major mapping expedition

In 2015, a group of 70 underwater archaeologists, geologists and engineers from 15 nations set out to explore the Black Sea and map more than 200km² of ocean floor. The research project was called the Black Sea Maritime Archaeology Project – or Black Sea MAP – and its general mission was to find out how ocean level rises after the most recent ice age some 12,000 years ago affected and flooded early civilisations along the Black Sea coast.

90

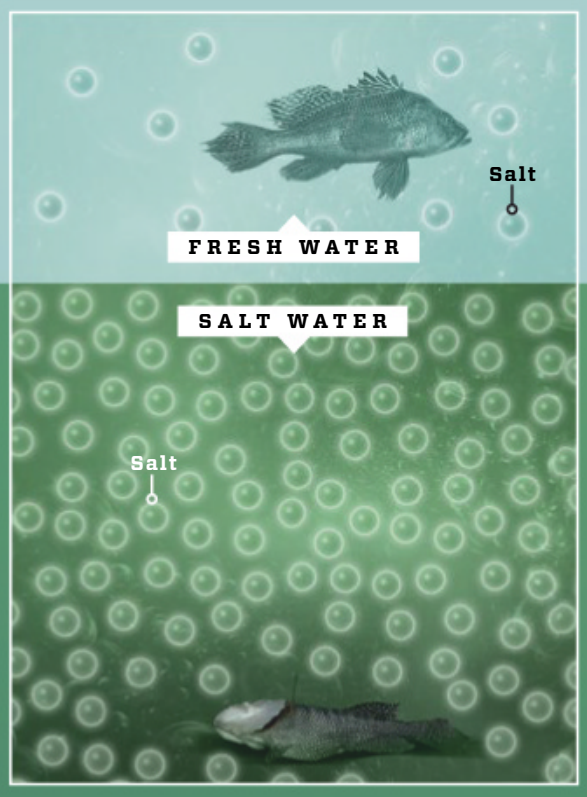
% of the Black Sea floor is a stagnant, oxygen-free toxic zone.

One of the aims of Black Sea MAP's very comprehensive mapping of the Black Sea floor was to find out how quickly the Black Sea originated and how it became the layered, oxygen-poor and toxic sea that exists today. But the extensive studies also delivered a surprising and unexpected archaeological by-catch.

In the autumn of 2016, the Black Sea MAP published the discoveries of no fewer than 40 remarkably well-preserved shipwrecks on the sea floor off Bulgaria. The ships dated back to a period of a thousand years from the Byzantine Empire in the 900s to the Ottoman Empire that existed up until the 1900s. However, a final surprise awaited the third and last expedition in the autumn of 2017, when the contours of a 23-metre-long ship appeared from the depths .

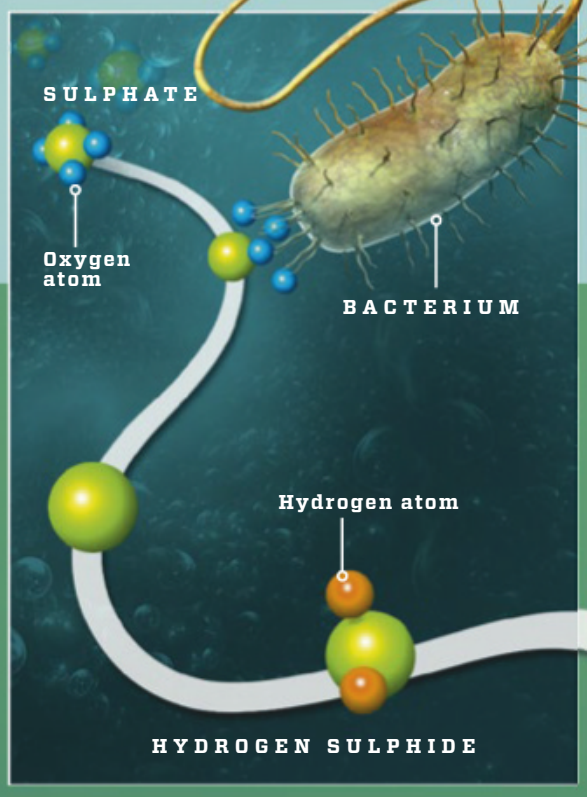
Robots mapped out sea floor in 3D

The project's archaeologists watched the wrecks appear on the sea floor below the Black Sea MAP's main research vessel, the Stril Explorer. From the ship's deck, the scientists studied their computer screens as their two remotely-operated underwater vessels explored the depths. The ROVs ▶



Water density differences create well-defined layers

2 The brackish water and salt water are located in layers in the Black Sea, as the concentration of heavy salt molecules gives the waters different densities. The top 100 metres of water includes 1.7% to 1.8 % salt. Deeper down, over a few metres, the salt content increases to 2.1%. The difference causes a barrier that prevents the layers from mixing, and the depths receive no new oxygen from above.



Bacteria eliminate all life with toxic gases

3 The deep waters originally included oxygen, but over thousands of years, microbes used the oxygen to break down nutrition that sank from the top layers. Bacteria then began to peel oxygen atoms off sulphate, which then absorbed hydrogen to form toxic hydrogen sulphide. The toxin has eliminated all life on the sea floor except for a few highly resilient bacterium species.

Hydrogen sulphide and the lack of oxygen on the Black Sea floor conserve wrecks.
RODRIGO PACHECO-RUIZ

AXEL SCHMIDT/NORD STREAM 2

Oil vessel became a lab

The 76m-long Stril Explorer was designed for oil and gas exploration, but is an ideal research vessel for finding shipwrecks in the Black Sea.

UNIVERSITY OF SOUTHAMPTON

Drill cores disclose sea birth

From the ship, archaeologists could drill 12m-long samples of the sea floor. Analyses and dating of the drill-core layers can reveal how the Black Sea formed.

MMT

Robots scanned sea floor

The ship's two underwater craft were developed to monitor the state of oil pipelines, but they are also ideal for searching the sea floor and photographing wrecks.

UNIVERSITY OF SOUTHAMPTON

Camera captures the past

One underwater robot is equipped with three Ultra-HD cameras which took detailed photos of the remarkably preserved ropes and trimmings of the ancient shipwreck.

18+

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AVAXHOME-

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▶ were equipped with HD cameras, lights and sophisticated sonar that mapped out the sea floor accurately by means of acoustic signals. "It felt like travelling back in time," said archaeologist Helen Farr.

Some 2km below the Black Sea surface, one underwater robot, the Survey Interceptor, found a 23-metre-long wreck. A fragment of the ship was brought to the surface so that the scientists could run a carbon-14 test to establish the age of the wood.

Carbon dating examines the decay of the unstable radioactive version of carbon, ^{14}C, that exists in organic material such as bones and wood. While they are alive, organisms absorb new ^{14}C continuously, but from the moment of death – in this case when the tree was felled – only decay takes place, with the radioactive carbon atoms converted into stable nitrogen atoms, ^{14}N. The number of ^{14}C atoms is halved after 5730 years, so that by counting the concentrations of atoms in the sample, scientists can determine when the organism died.

At best, carbon dating reveals the age with an uncertainty of 25 years, and the sample from the wreck showed that it was made of wood felled in the fourth century BC. That makes this the world's oldest intact ship discovery.

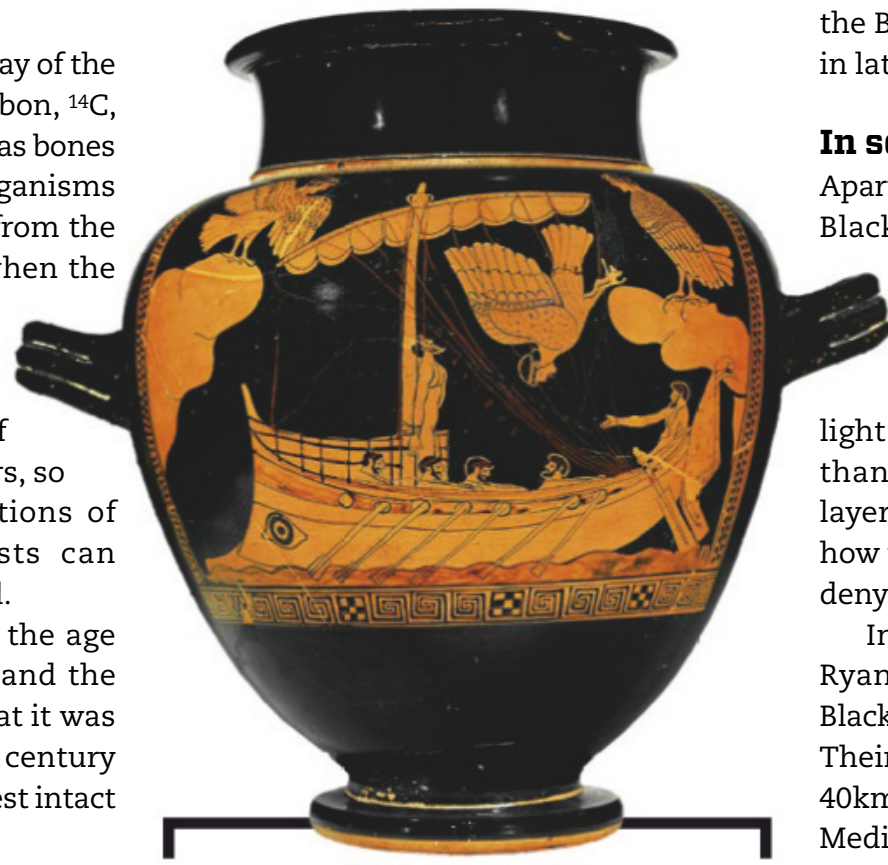
The archaeologists believe that the ship is a Greek merchant vessel from a time when the Black Sea was a busy trading route for the Ancient Greeks. Indeed the ship is very similar to a design depicted on a few Greek vases and murals from the time, the most famous of which is the Siren Vase, showing the legendary hero Odysseus tied to the mast of a similar ship as sirens try to lure him with their irresistible call.

In spite of the ship's age, the mast, rudder and rowing benches were all intact on the wreck, which rested side-down on the sea floor. The ROV's three cameras took thousands of high resolution photos that were later united into one 3D portrait.

Time machine

The Ancient Greeks called the Black Sea the *Pontos Axeinos* – the inhospitable sea. Back then the name was probably describing the sudden storms and dense fog of the sea's surface. But the Black Sea MAP project has revealed that the Greek name also describes the conditions down in the depths. In most seas there are sand worms, termites and carbon-consuming bacteria which, together with oxygen, slowly break down the hull. Wooden ships are normally completely consumed after 100 years or so. But in the Black Sea, the ships have been entombed and protected in a sterile time capsule of inhospitable chemistry.

The Black Sea has no oxygen from a depth of about 200 metres downwards. Instead the depths host the world's highest concentration of toxic hydrogen sulphide. Only a few microbes can live there, making the sea floor an ideal grave for shipwrecks.



FACTS

- **NAME:** Siren Vase, exhibited in the British Museum, London.
- **HEIGHT:** 34 cm.
- **SUBJECT:** Legendary hero tied to the mast of a Greek ship.
- **IMPORTANCE:** One of very few depictions of this type of vessel.

AKG-IMAGES/RITZAU SCANPIX

This time capsule exists because the Black Sea is connected with the Mediterranean via the Bosphorus Strait. The Strait is about 33km long and flows past Turkey's biggest city, Istanbul. In the narrowest places the passage is only 750 metres wide, and the water depth never exceeds 110 metres. This operates like a valve, passing out some 385km³ of brackish water annually from the Black Sea, a mixture of salt water and fresh water from rivers, while only 175km³ of salt water flows back in through the Strait from the Mediterranean. Because water's density increases with salt content, the more mobile brackish water will always be located at the top, while the rest of the water in the Black Sea is completely stagnant and never replaced. The lack of circulation of fresh water and its replenishing oxygen has turned about 90% of the Black Sea into an oxygen-free zone in which almost no life exists. However, the quality of preservation still came as a surprise.

"I never expected to find a completely intact ship from antiquity at a depth below 2km," said research head Jon Adams when the Black Sea MAP published the discovery in late 2018.

In search of the Great Flood

Apart from the world's oldest shipwreck, the Black Sea MAP found 65 other preserved wrecks from different time periods down on this toxic ocean floor. But the project's primary purpose had been to sweep the sea floor to shed light on the Black Sea's origin. Using more than 400 drill samples from the lowest layers, scientists could analyse when and how the Black Sea originated, confirming or denying a much debated theory.

In 1998, American geologists William Ryan and Walter Pitman argued that the Black Sea originated from a natural disaster. Their theory claimed that after the ice age, 40km³ of salt water a day flowed from the Mediterranean through the Bosphorus in a flow equivalent to 200 Niagara Falls. In just 300 days the water flooded a fertile plain around a lake of fresh meltwater from ice-age glaciers, producing a sea of isolated and stagnant salt water. The coast around the lake was pushed about 1.5km inland; the population was forced to move.

According to the geologists, a narrative about the flooding was passed from generation to generation until the 900s BC, when it was written down in the Old Testament as the story of Noah's Ark and the Flood.

As the Black Sea MAP archaeologists drilled further, extracting cores from ever greater depths of the sea floor, they were passing through a story archive of the sea's creation. The different layers from different areas of the sea floor can be dated by their sediments, deposits of loose particles, which also reveal a wealth of information about the climate of the past, the temperature of the sea water, changes of global ocean currents, the salt content of the water, and sea levels – from which scientists could deduce the story of the Black Sea's formation.

Magnesium reveals slower action

The sea-floor sample drilling was carried out from the Stril Explorer, with the samples subsequently analysed by the British Ocean Sediment Core Research Facility, which ▶

Head of Research Jon Adams shows a 3D-printed model of one of the project's wreck discoveries.

DAVID PARRY/PA WIRE/RITZAU SCANPIX

dated the sediments by means of an ITRAX core scanner which functions by bombarding the sediment core with X-rays. The X-rays force atoms in the sediment to emit fluorescence radiation, which a detector picks up and converts into a digital signal that scientists can analyse.

The levels of elements such as potassium and magnesium in a sediment core each provide information on different aspects of the climate. Magnesium exists in salt water, so that by analysing the concentration of this element in different sediment cores, the scientists could establish when the salt water from the Mediterranean started to spread into the Black Sea, and how long it took to fill the basin.

The Black Sea MAP researchers have now been able to reject the controversial flooding hypothesis about the birth of the Black Sea, after decades of widespread dissemination. They are still working their way through all the sediment cores, but their interim results show that the Mediterranean's flooding of the Bosphorus Strait happened gradually over thousands of years from about 16,000-10,000 years BC. But although the Black Sea was not formed by major and sudden flooding, the rising water levels nevertheless had major consequences.

Settlement slowly abandoned

Shortly before the end of the project in 2017, the scientists aboard the Stril Explorer found what they had originally hoped to discover. On the floor of a former valley off the Bulgarian coast, there was a Bronze Age settlement, which was flooded by the Black Sea between 3000 and 1200 BC. By sending a powerful acoustic signal through the sea floor, the archaeologists identified remains of wood, ceramics and furnaces buried 2.5m further down in the mud. Variations in the acoustic reflections revealed the different objects, and also that the location later became an anchoring point and harbour for ships.

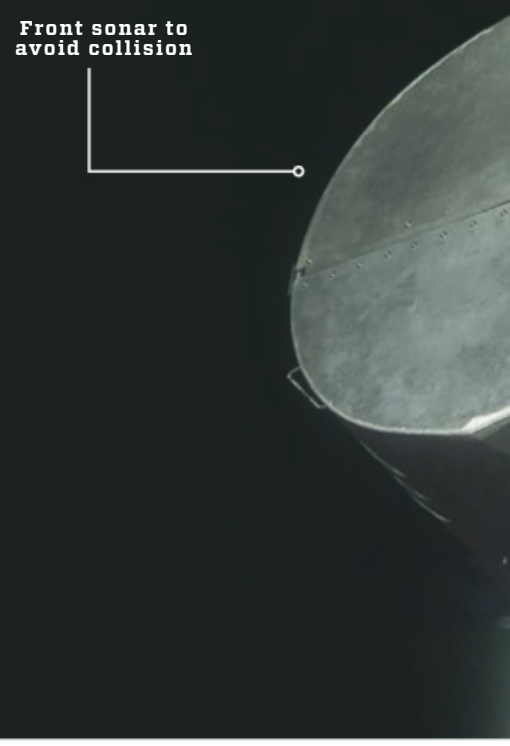
Over thousands of years, when the Black Sea was inundating the area, a unique time capsule formed. The top layer of the sea became the 'pantry' of the region, the upper oxygen-rich layers having been full of life both historically and now, where it includes 180 fish species. But this lid of nutritious fresh water was probably, and paradoxically, the factor that killed all life at greater depths.

When nutritious water from the rivers flowed into the salt water of the Black Sea, bacteria used the dissolved oxygen in the water to oxidise the nutrients so that these could be more easily absorbed. When all oxygen was gone, the organisms began to peel oxygen atoms off the sulphates of the sea water, instead producing a ferocious cocktail of toxic hydrogen sulphide which has since killed all life.

Now there is every indication that the nutrition-poor water of the depths could at some point take over the entire Black Sea. According to some scientists the top layer has been reduced in depth from 140m to 90m over the past 60 years. Ongoing change could destroy the region as a fishery. On the other hand, the world's biggest museum display cabinet would then be complete. SCI

With a top speed of 15km/h, the Survey Interceptor underwater robot is three times faster than any competitor. The robot is an ROV (remotely operated vehicle) that has scanned 1250km of the Black Sea floor. Its speed demands a lot from the instruments, which must be able to process data as quickly as the ROV travels.

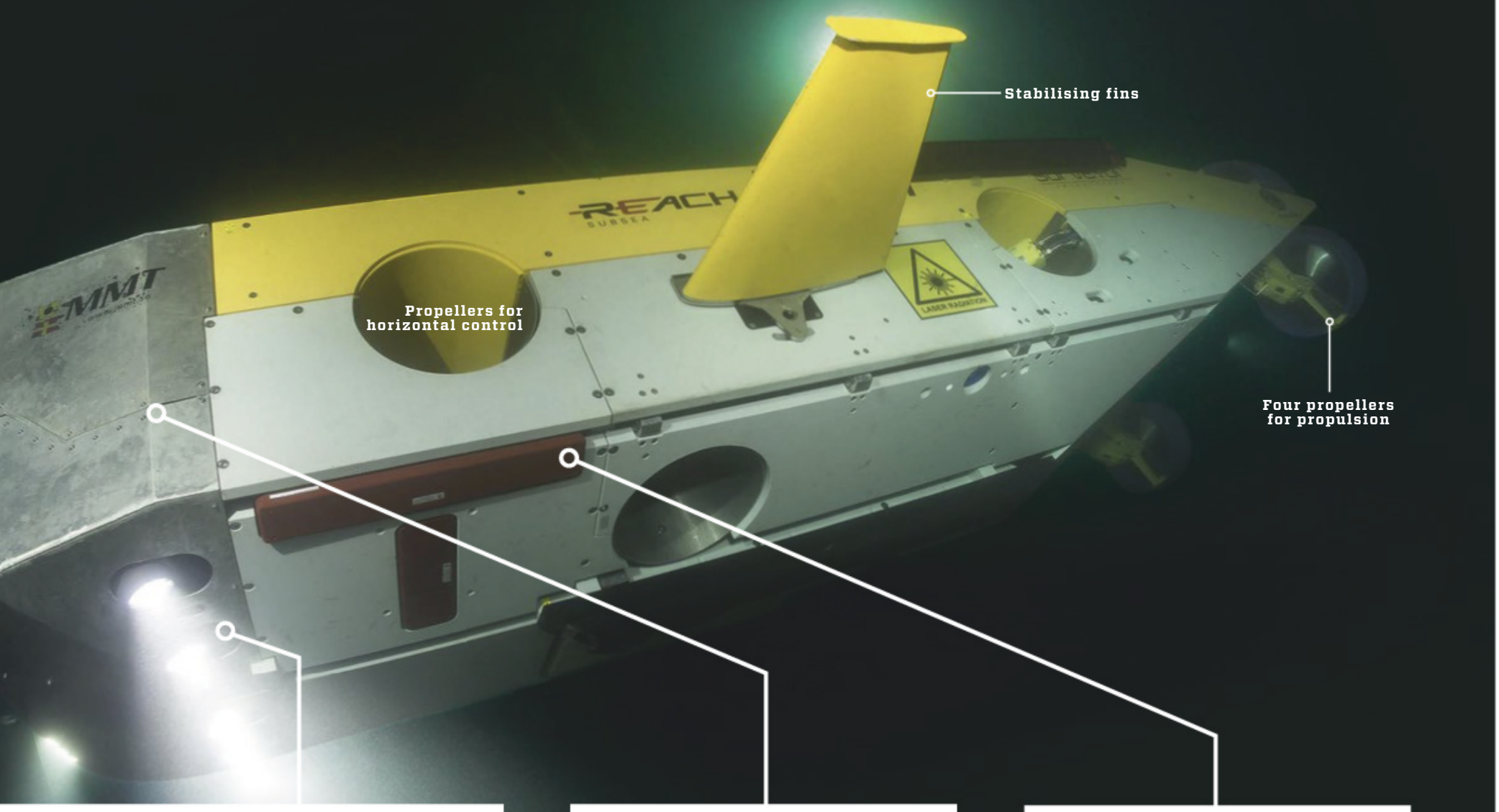
JONAS DAHM/MMT

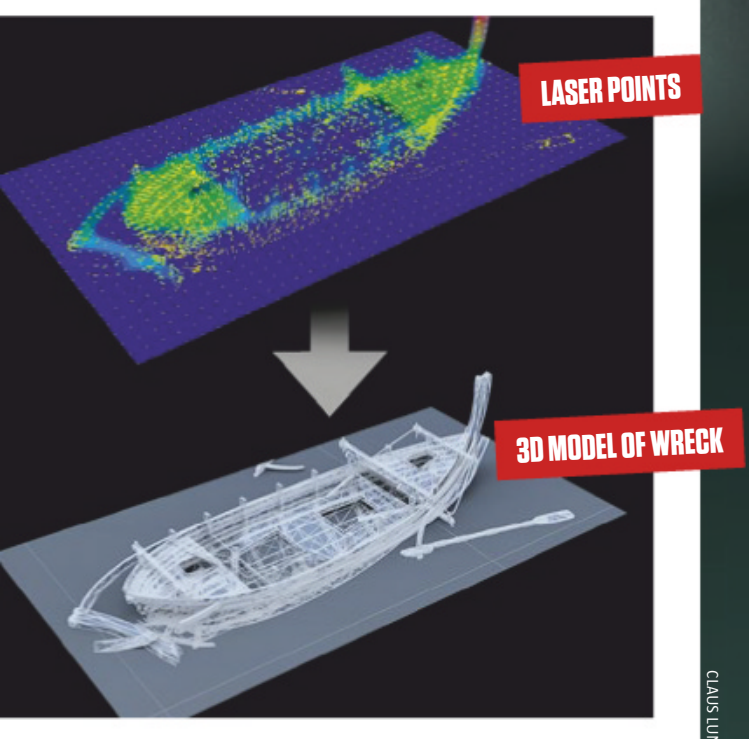


LASER DATA AND PHOTOS PRODUCE 3D MODELS

To reproduce the sea floor in as much detail as possible, the Survey Interceptor is equipped with three Ultra-HD cameras which take thousands of photos at **8-10 times higher resolution** than standard HD video. A laser scanner also measures the sea floor's spatial shape at different depths by generating **clouds consisting of millions of points** which can subsequently be overlaid onto the UHD images so that photogrammetry software can convert the images and scanner data into 3D models (of a wreck, for example). Six LED spots and a stroboscope lamp ensure sharp pictures, typically taken from 5 metres above the sea floor.

Rapid underwater robot sheds new light on the sea floor

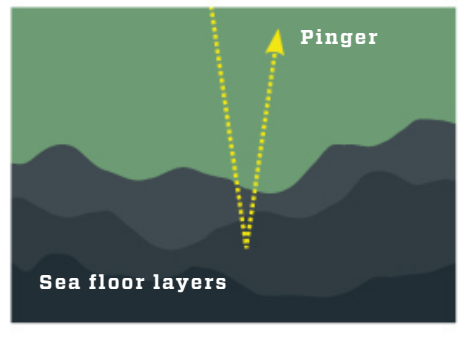




CLAUS LUNAU

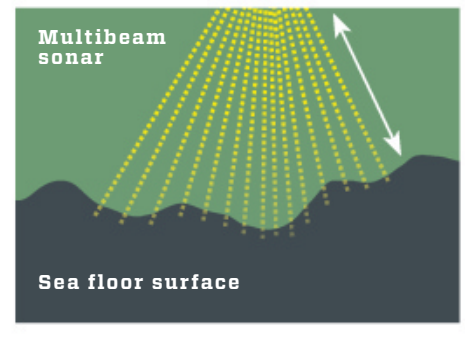
PINGER PEELS LAYERS OFF THE SEA FLOOR

With an acoustic 'pinger', the ROV can identify abandoned settlements and other objects up to 2.5m below the sea floor as the high-frequency acoustic signal is reflected by deeper layers. The pinger and sonar are at the front of the ROV so propeller noise does not interfere.



800 SONAR SIGNALS 'PAINT' THE OCEAN FLOOR

From 20 metres above the sea floor, the ROV emits sound waves from a multibeam sonar. The signal is reflected and picked up as 800 individual points, with the time and intensity of the reflected signal identifying surface altitude differences, hardness, and any objects.



LOTTE FREDSLUND

SCIENTISTS SEE THE LIGHT...

Both wave and particle... Both visible and invisible... Light is full of intriguing qualities, and scientists are now using them to revolutionise such different areas as screen technology, energy storage, and cancer treatment.

→ LIGHTING

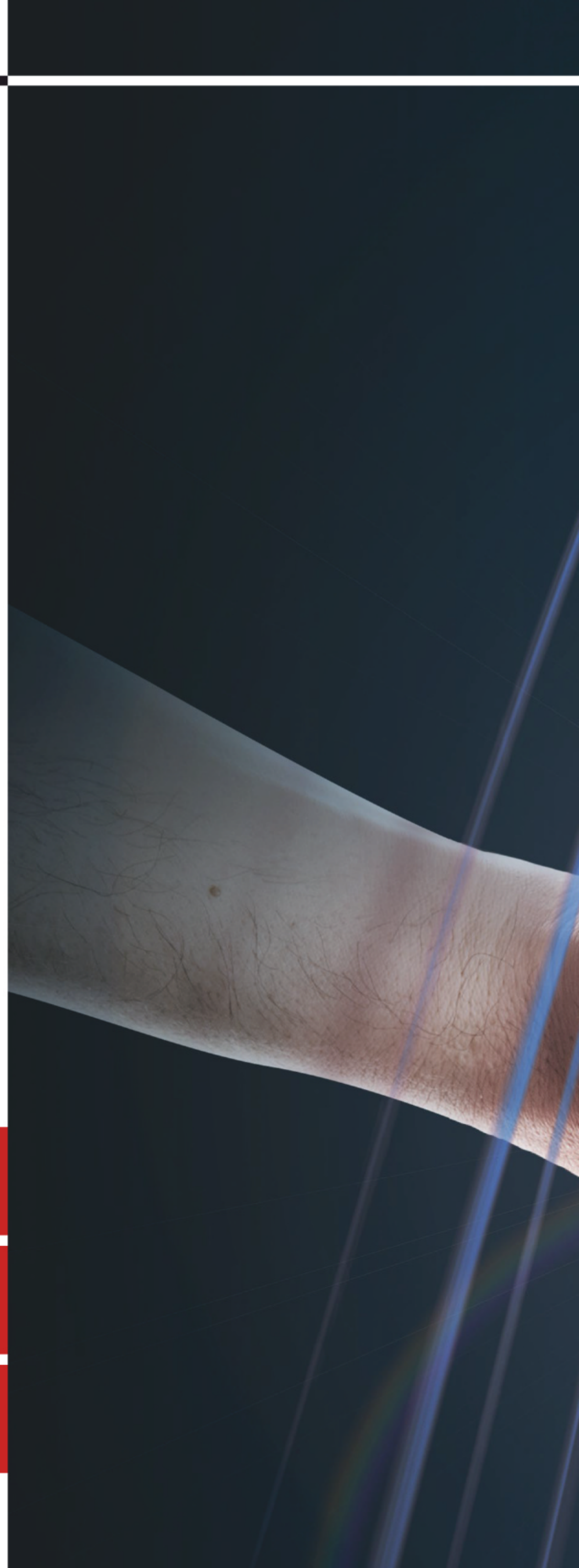
White laser light will replace LED bulbs, and quantum dots can result in sharper, more energy-efficient displays.

→ ENERGY

Artificial photosynthesis stores solar energy as fuel, and drones are charged wirelessly with power from laser networks.

→ HEALTH

Light therapy focuses on cancer cells, malaria mosquitoes are shot down with laser guns, and a microscope takes photos without shadows.



By **Mikkel Meister**

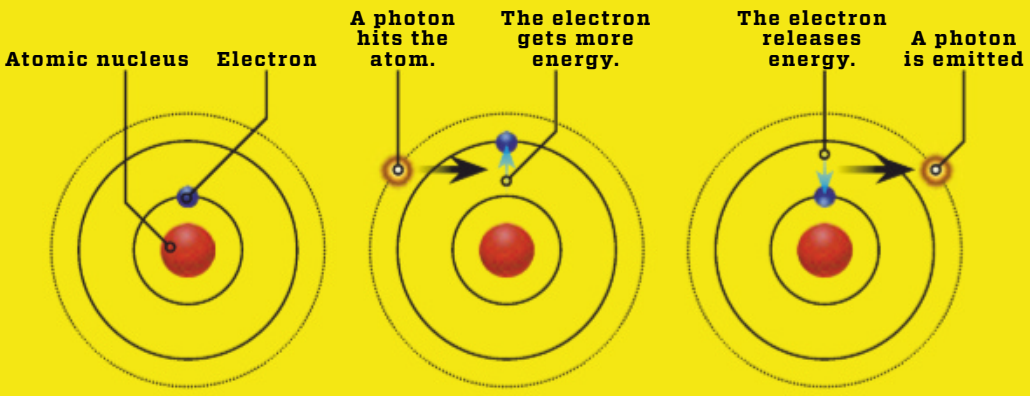
Scientists can now send wireless power, and make shadows disappear, by using the unusual qualities of light.

SHUTTERSTOCK

WORTH KNOWING ABOUT **LIGHT**

Excited electrons make atoms emit light

Electrons around an atom can be in different energy states. In the ground state, the energy level is low, but if the electron is disturbed by a light particle, a photon, its energy makes the electron 'leap' to a higher energy state: an excited state. However, the electron quickly falls back to the lower state, and when it does, the energy is released in the shape of a new photon. The phenomenon is used in a laser, where the electrons in a material such as a gas are excited, and the photons are concentrated into a beam by means of mirrors. Photons that excite each other always have the same wavelength, and so laser beams are only one colour.



When an atom is hit by a light particle (photon), the electron is supplied with energy that it can later emit in the shape of light: the principle of a laser.

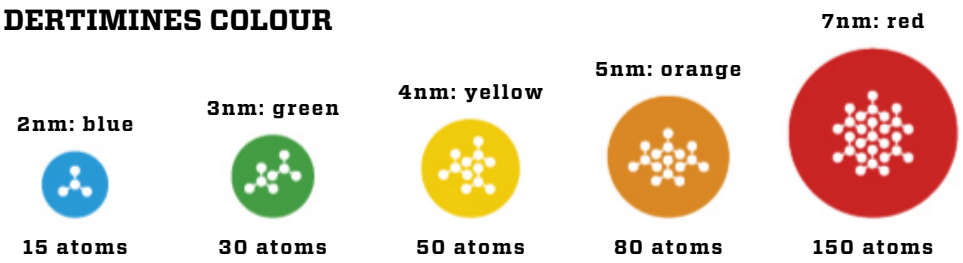
SHUTTERSTOCK

Quantum dots produce clear colours

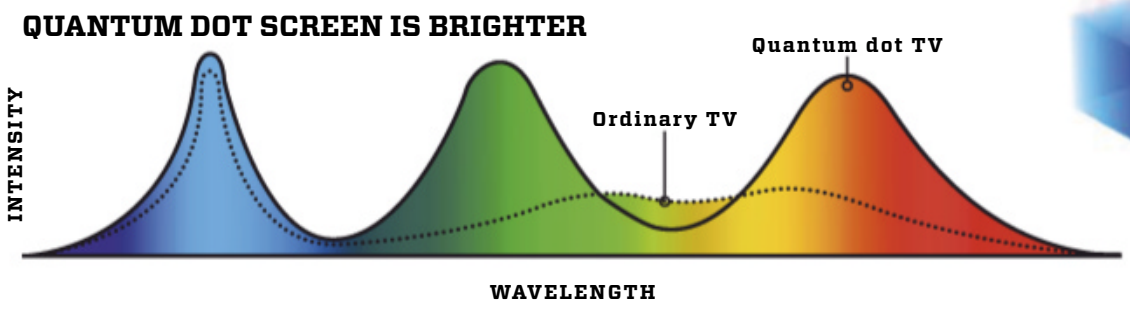
Quantum dots are nanoparticles made of a semiconductor material that emits light of different colours, depending on their size. A quantum dot with a diameter of two millionths of a millimetre is blue when it is illuminated. Quantum dots can provide us with TV and smartphone screens which deliver improved colour performance, because their spectral lines are narrower (the peaks of the chart below). In other words, the primary colours of red, green, and blue can be distinguished more clearly from each other, allowing more nuances.

The quantum dots can also save power. In an ordinary LED screen, the light normally comes from a rear or side panel that sends blue light through a yellow layer of phosphorus. By replacing the phosphorus with quantum dots that emit up to 99.6% of the source light again, less of the original energy is lost, making the screen brighter, or for the same brightness consuming less power.

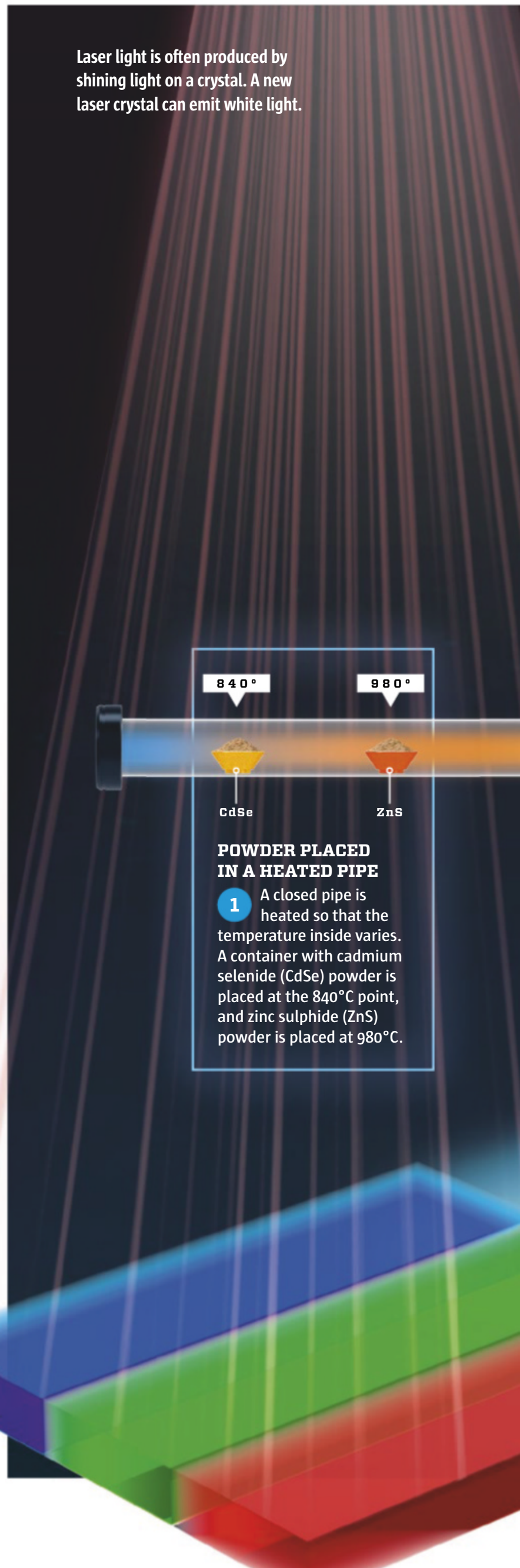
SIZE DERTIMINES COLOUR



QUANTUM DOT SCREEN IS BRIGHTER



Laser light is often produced by shining light on a crystal. A new laser crystal can emit white light.



POWDER PLACED IN A HEATED PIPE

1 A closed pipe is heated so that the temperature inside varies. A container with cadmium selenide (CdSe) powder is placed at the 840°C point, and zinc sulphide (ZnS) powder is placed at 980°C.

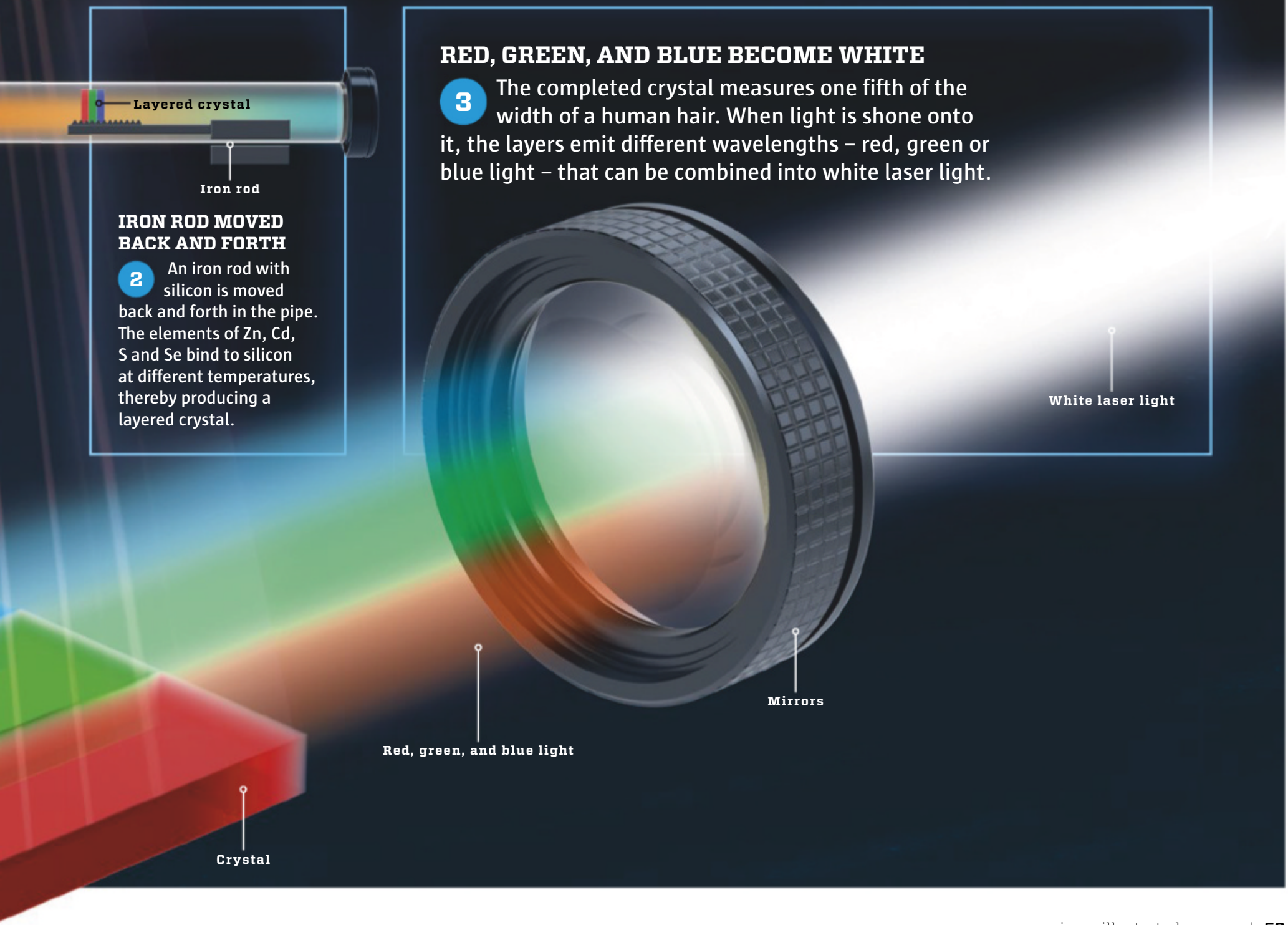
White laser light becomes the new electric light bulb

So far, all laser light has been coloured, but now scientists have for the first time created a white laser that can be used for lighting purposes.

Lasers are accurate and more energy-efficient than the LEDs or light diodes currently used in electric light bulbs and TV screens. So far, it has only been possible to create coloured laser light, but scientists from Arizona State University have now managed to make a crystal that produces white laser light. The crystal emits three different colours – red, green, and blue – but they can be mixed by means of mirrors to produce white light.

The new laser crystal measures only one fifth of the width of a human hair and is made by growing nanosheets – layers that consist of zinc sulphide, cadmium sulphide and cadmium selenide alloys. The nanotechnology, which is known as MSHN (Multi-Segment Heterostructure Nanosheets), displays up to 70% more colours than LEDs, and with much lower electricity consumption. They could both replace LED light bulbs and provide computer and smartphone screens with more contrast and improved colour saturation.

White laser light may also make the wireless internet of the future, 'Li-Fi', much faster. Li-Fi uses light pulses from the lighting of the room instead of radio waves. Li-Fi with LEDs can be 10 times faster than Wi-Fi, and by changing from LEDs to white laser, the speed is improved another 10-100 times.

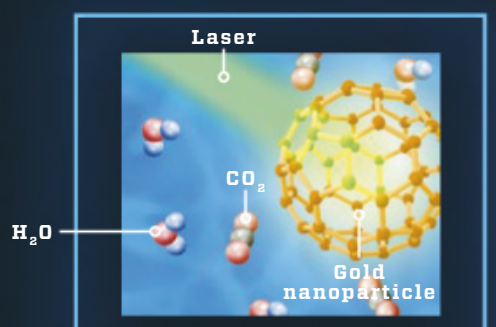


CLAUS LUNAU

Scientists store solar energy with artificial photosynthesis

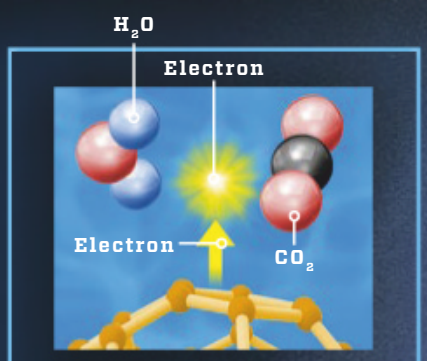
With water and nanoparticles, scientists have stored solar energy in the lab by converting it into fuel that can be used any time.

The storage of solar and wind energy is one of the major challenges we face in changing electricity supplies to renewable energy. Now scientists from the University of Illinois have found an efficient method for storing solar energy. The method binds the light's energy in fuel such as propane with the assistance of CO_2 and gold nanoparticles, mimicking plants' photosynthesis, in which the energy of light is converved into glucose. The process removes CO_2 from the atmosphere, and scientists are developing new types of fuel cells that convert propane into electricity without emitting CO_2. In this way, the artificial photosynthesis could help reduce global warming.



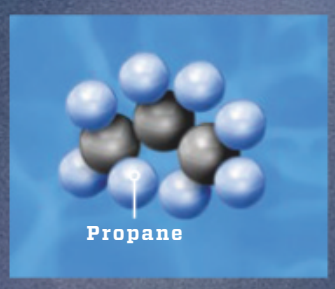
LIQUID ILLUMINATED BY LASER

1 A liquid with gold nanoparticles, CO_2 and water molecules is illuminated with a laser. It emits green light at a wavelength of 532nm – the same part of visible light that plants use.



RELEASED ELECTRON TRIGGERS REACTION

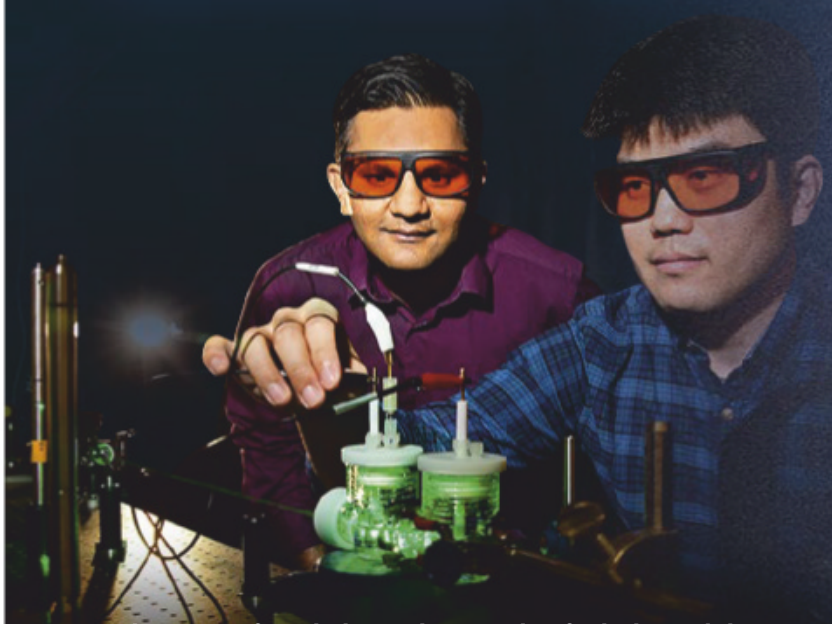
2 The gold nanoparticles absorb the light and release electrons. They make CO_2 and water (H_2O) react with each other in the same way as do plants when converting solar energy into glucose.



WATER AND CO_2 BECOME FUEL

3 The reactions between CO_2 and HO produce long hydrocarbon compounds such as propane, which store the energy from the light chemically and can be converted into power later.

CLAUS LUNAU



The energy from light can be stored as fuel, showed the two scientists in this experiment that mimics plant photosynthesis.

FRED ZWICKY

In photosynthesis, plants bind solar energy chemically in the form of glucose.

SHUTTERSTOCK

WORTH KNOWING ABOUT LIGHT

Is light made of particles, or waves, or both at once?

Is light particles or waves? This question was the subject of disagreement for a long time, until physicists in the early 1900s concluded that light is both. The double nature of light is known as wave-particle duality, and is a fundamental phenomenon in quantum mechanics.

According to Einstein, light can be considered to be energy packets, photons, that make a substance liberate an electron when it absorbs the energy of the photon. But the famous double-slit experiment proves that light is also waves. In the experiment, light is directed through two narrow slits. If light were particles, any given photon could pass through either one or the other slit, so the result would be two stripes of light. But in fact the light waves also interfere, amplifying or weakening each other, resulting in stripes of light and shadow. This can only occur if the light is acting as a wave, passing both slits at once.

The light does not arrive only directly opposite the slits, instead producing an interference pattern of light and shadow.

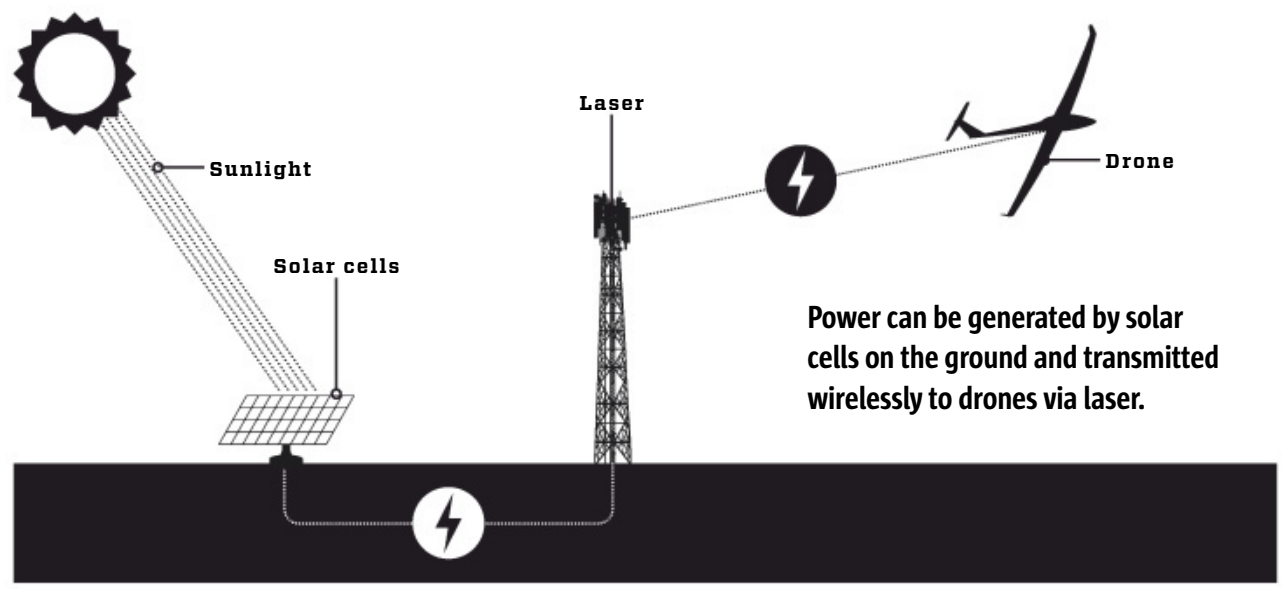
KEN IKEDA MADSEN/SHUTTERSTOCK

Laser light sends power wirelessly to drones

A drone or a plane that can remain in the air for days or weeks and carry out measurements or monitoring – that is the vision behind a new technology allowing wireless power transmission by directing laser light towards the craft from masts on the ground.

Laser light is emitted in a concentrated beam that corresponds to the size of a solar-cell panel on the drone. When the laser light hits the solar cells, the photon energy is converted into electricity in the solar-cell material. The power from the solar cells is stored in a battery on the plane which powers the plane's electric motor. So the plane is charged in mid-air. The laser mast includes a tracker that detects the craft's position, and the power for the network can be retrieved from a solar cell system.

The company behind the technology, PowerLight Technologies, has demonstrated that a drone with a normal battery capacity for five minutes of flight can remain in the air for more than 12 hours with wireless charging. In the longer term, the technology might be used to power satellites in a low Earth orbit.



Power can be generated by solar cells on the ground and transmitted wirelessly to drones via laser.

KEN IKEDA MADSEN/SHUTTERSTOCK

Laser gun to zap 80 malarial mozzies a second

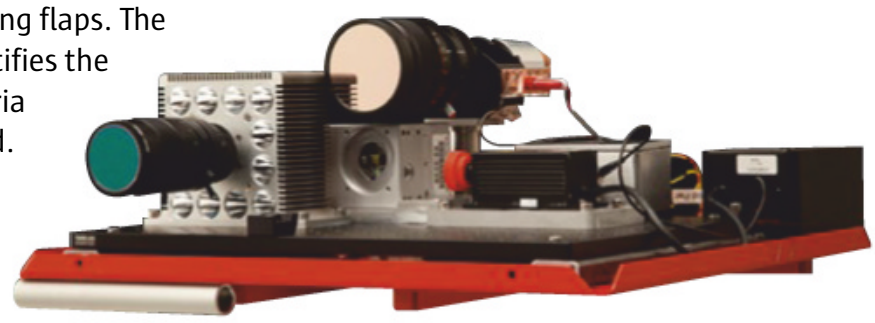
Every year, 200+ million people are infected with malaria. The infected mosquitoes can be eliminated with a new method that uses a laser to track and shoot them.

A new weapon has entered the struggle against malaria mosquitoes and other insects that transmit diseases. Photonic Fence is a laser gun that uses a combination of a video camera, LEDs and a laser to spot and kill insects indoors.

The invention has not yet been completed, but the planned device consists of two parts. The identification element registers when the insects get within shooting range. The tracker part consists of a video camera, infrared light diodes and a special film that reflects infrared light from a wall. The camera is hooked up to a computer with image analysis software that can recognise the mosquito's silhouette when the reflected light hits it from behind. The tracker module continuously registers the insect's position, and using the supplied coordinates a green laser beam is fired to illuminate the mosquito, while a photo diode registers any intensity differences in the light reflected from the mosquito's wing flaps. The frequency of the wing flaps identifies the insect species, and if it is a malaria mosquito, the lethal laser is fired. The prototype can eliminate 80 mosquitoes per second, but the aim is to achieve a much higher number.

The laser gun identifies malaria mosquitoes by their wing flaps before shooting them down.

EMMA R. MULLEN ET AL./OPTICAL SOCIETY OF AMERICA

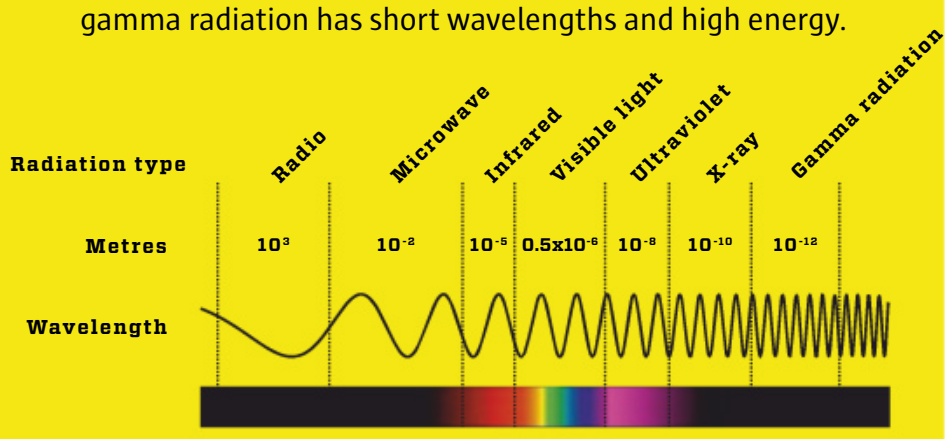


WORTH KNOWING ABOUT LIGHT

Beyond our vision: most electromagnetic waves are invisible

The light that we can see with our eyes is a small part of an electromagnetic spectrum that also includes radio waves, microwaves and X-rays. Visible light is electromagnetic radiation with a wavelength of 400-700nm (billionths of a metre). We see the different wavelengths within the visible spectrum as different colours, whereas white light includes all wavelengths.

Electromagnetic radiation is a type of energy that spreads in the form of electric and magnetic fields set perpendicularly to each other. The energy is inversely proportional to the wavelength. Radio waves are characterised by long wavelengths and low energy, whereas gamma radiation has short wavelengths and high energy.

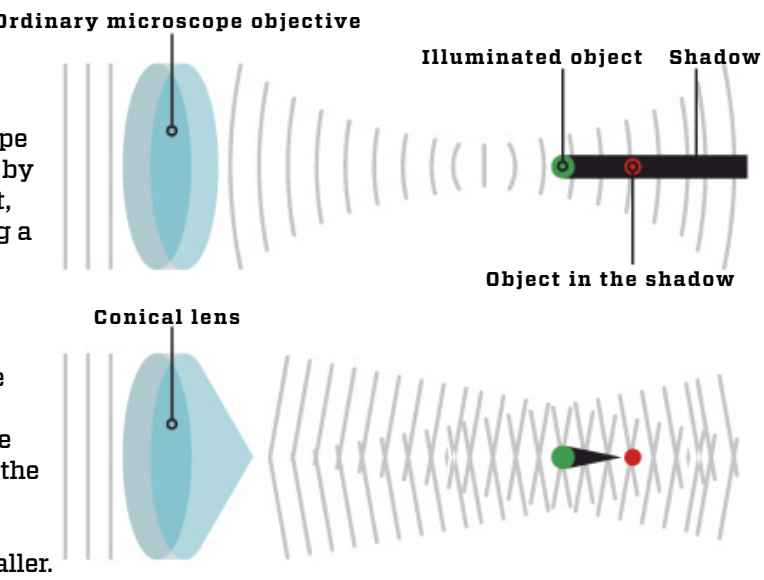


Visible light is the section of the electromagnetic radiation spectrum with wavelengths of 400-700nm.

Seeing into the shadows

Light waves that reconstruct after encountering an obstacle such as body tissue – this is now possible with a new type of microscope that can image the body's interior much more sharply.

When light in an optical microscope hits a non-transparent object, a shadow pattern is produced. This phenomenon, known as diffraction, is due to light waves being bent by the edges of the object and spread in all directions. Scientists from the German University of Freiburg and the Leica Microsystems company are trying to make the light reappear on the opposite side of the object. By using a conical lens, the scientists can create Bessel-like light beams that 'heal' themselves after meeting an obstacle. This avoids the shadow pattern, so scientists can get clear microscope images in which no areas are hidden by stripes and blurring.



In an ordinary microscope, shadowing is produced when an object is illuminated. With a new lens, the shadow can be avoided.

Light focuses on cancer

Doctors can aim laser cancer treatment directly at sick cells while protecting healthy ones. A shining radioactive material activates the cell toxin inside the cancer cell.

Breast cancer often spreads to the bone marrow, where it is difficult to combat the cancer cells without killing vital stem cells. Now, scientists from Washington University in the US have discovered a method to focus on the cancer by means of light.

The new technique uses a cancer drug that is harmless until it is subjected to light. This light therapy is already used to treat tumours close to the skin, where the drug is activated by illuminating the patient with blue or red light. With the newly-developed method, the drug is illuminated inside the cell. A light-activated chemotherapy drug is first introduced into the bone marrow by means of nano-capsules. On the surface of the capsules is a substance, LLP2A, which binds to the VLA-4 molecule on the cancer cells. Subsequently, radioactive FDG, fludeoxy-glucose, is injected into the bone marrow and absorbed by GLUT proteins on the cancer cells. FDG emits light that activates the drug inside the cell. As the stem cells of the bone marrow do not have the same combination of the VLA-4 molecule and the GLUT protein as cancer cells, they are not harmed by the treatment.

CLAUS LUNAU

CAPSULES ENTER THE DRUG INTO THE CANCER CELLS

1 Nanocapsules with light-sensitive cancer drugs are introduced into the bone marrow, where the capsules bind to a molecule on the cancer cells, transferring the medication to them.

HUNGRY CELLS SWALLOW RADIOACTIVE SUBSTANCE

2 Particular radioactive substances, FDG, are introduced into the bone marrow. As cancer cells have a higher metabolism than ordinary cells, they absorb much more of the radioactive substance.

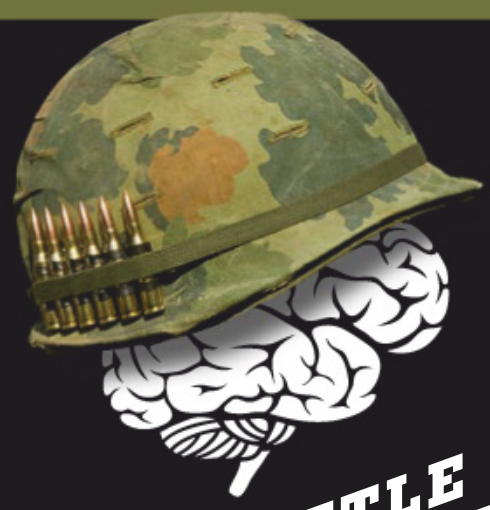
BLUE LIGHT ACTIVATES DRUG INSIDE THE CELL

3 The radioactive substance emits ultraviolet and blue light that activates the light-sensitive drug in the cancer cell, killing it. The bone marrow stem cells remain unaffected.

Light therapy activates cancer drugs with a lamp. Now doctors can also shine light inside a cell.

RAPIDEYE/GETTY IMAGES

SERIES FINAL



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.

Alzheimer's patients lose brain tissue in areas including the hippocampus centre of memory.

SCIENCE PHOTO LIBRARY/SHUTTERSTOCK

By **Bo Karl Christensen**

FINDING AN ANTIDOTE TO SLOW DOWN ALZHEIMER'S

A surprising discovery has provided scientists with a new main suspect – toxic gum bacteria – in the mystery of Alzheimer's. And they are ready to stop the villain with an unexpected weapon.

Your brain is a fortress, its more than 600km of blood vessels protected by a wall known as the blood-brain barrier. This wall consists of three almost impenetrable layers of cells, so that only oxygen, nutrients and a few other substances are allowed to pass from the blood into the cells of the brain. Bacteria and viruses are efficiently excluded.

In a few cases, however, microbes do manage to enter the brain. There they immediately encounter the brain's second line of defence – immune cells known as microglia. These recognise the intruders, swallow them, and break them down. If the microbes are in the majority, the brain has one final weapon left. The nerve cells liberate beta-amyloid, which encapsulates the microbes and kills them.

These defences provide a remarkably high level of protection for your sensitive nerve cells, but even the best defence can be caught off-guard. The intruders can settle permanently in the brain, and even turn its own weapons against you. The result is that healthy brain tissue is slowly broken down. A new experiment has revealed that this is exactly what happens in the brains of Alzheimer's patients, and scientists have identified the responsible microbe – the bacterium that causes gum infection. A new drug is now in the pipeline, and could halt the malignant disease.

Scientists search for the cause

More than 30 million people suffer from Alzheimer's globally, and the number could be set to triple over the next few decades as the global population grows older. As of ▶

BEFORE FIGHT

Protein stifles unwanted intruders

For decades, beta-amyloid has been considered a disease-causing nuisance. Now scientists have discovered that it is an important part of the brain's defence against microbes.

Nerve cells release protein

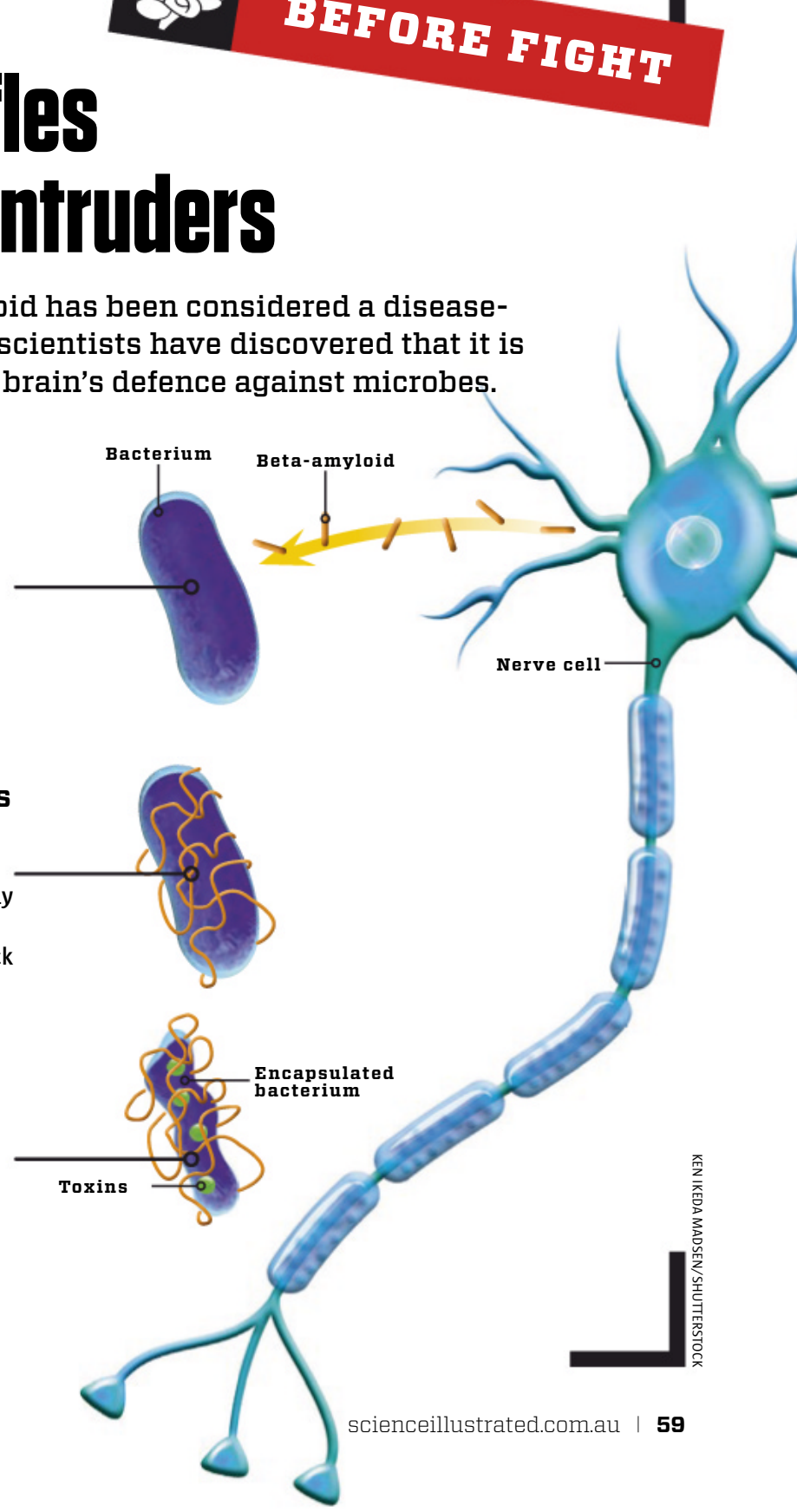
Bacteria or viruses that enter the brain make the nerve cells destroy one of their own proteins and release the fragments, beta-amyloid, to their surroundings.

Substance encapsulates intruders

Beta-amyloid binds to the bacterium or virus, gradually producing a capsule around the intruder so that it is unable to stick to the cells of the brain.

Bacterium is poisoned and dies

The beta-amyloid capsule probably actively kills the bacterium by producing toxic substances in the bacterium and by perforating its cell membrane.



KEN IKEDA MADSEN/SHUTTERSTOCK

now we have no cure, nor any drugs that can reliably curb the course of the disease.

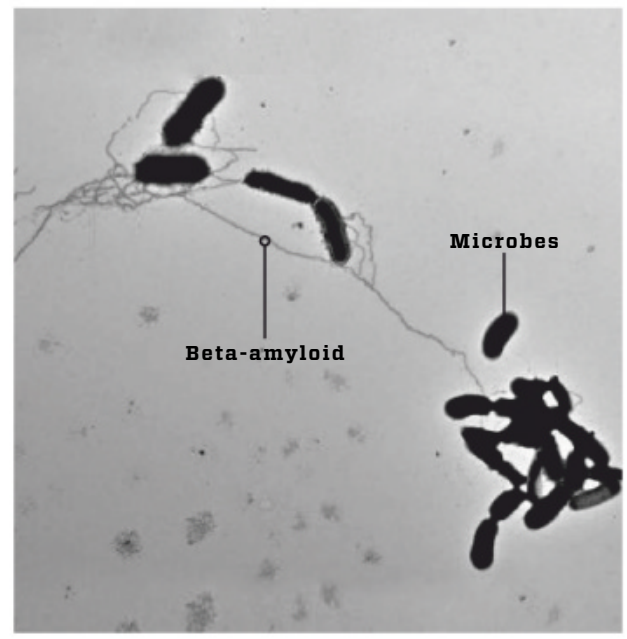
Alzheimer's affects our memory and our ability to solve problems; it can change our mood as well as our personality. The symptoms usually materialise when the patient is 60+ years old, but in some people they might emerge much earlier.

For decades, scientists have researched the cause of Alzheimer's, finding a long series of answers. First of all, brain scans reveal that several brain areas examined in Alzheimer's patients have shrunk as compared to normal sizes – particularly the hippocampus, which is important for our memory. Secondly, the disease has been linked to changes in the brain's proteins. Early in the course of the disease, the tau protein begins to clump together in the nerve cells. The tau protein is an important part of the nerve cell's internal skeleton, and the clumping destroys the cells' structure and their ability to send signals to each other; ultimately the cells die. Another protein, beta-amyloid, also plays a major role. The nerve cells normally only liberate this protein in small quantities, and it is usually cleared away as we are sleeping, but in Alzheimer's patients, large quantities are retained, getting tangled up as lumps known as plaque, which is toxic to nerve cells.

The major question is what causes the changes in the first place. Scientists now believe they have found the answer.

Self-defence injures the brain

The link between the beta-amyloid protein and Alzheimer's has been known since the

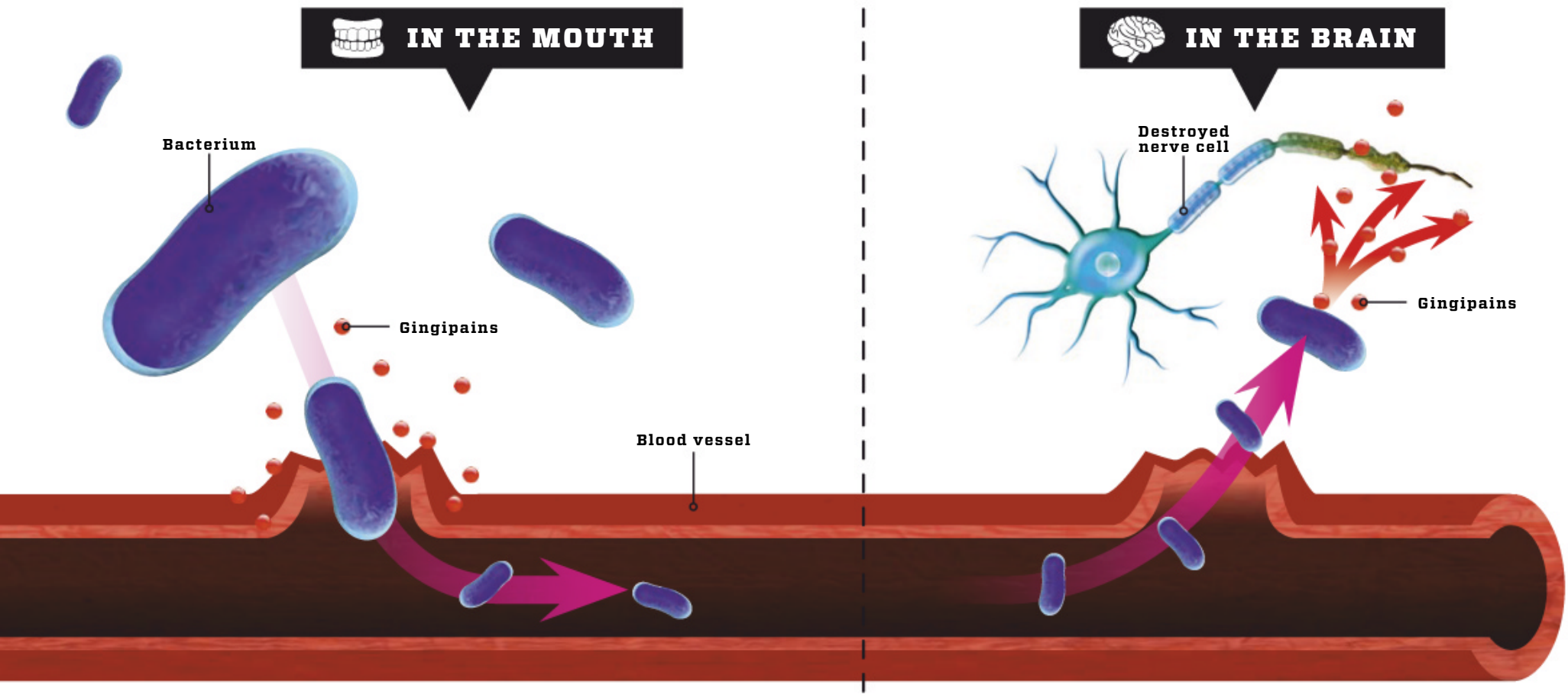


SCIENCE TRANSLATIONAL MEDICINE

Beta-amyloid produces long threads which make microbes clump together and prevent them from attacking your cells.

Gum bacterium attacks the brain

The bacterium that causes gingivitis can gain access to your brain. And if it does, it could break down nerve-cell skeletons and make the brain cells attack themselves.



Bacterium spreads from the mouth

1 The *Porphyromonas gingivalis* bacterium produces toxins known as gingipains. Some sit on the bacterium's surface, whereas others are liberated to the surroundings. The toxins are enzymes that can break down tissue and destroy gums. The injured gums open up to the blood stream, allowing the bacterium access to the rest of the body.

Toxin destroys nerve-cell skeleton

2 The bacterium infects the brain and bombards the brain's cells with toxins, which break down tau proteins inside the nerve cells. The tau proteins hold together cells' internal protein skeletons, and without those a cell's shape and ability to send signals is destroyed. Finally, the nerve cells die.

1980s, and scientists have been working to discover the function of the protein and to understand what causes its over-accumulation. But not until in recent years have they come close to this goal. In 2010, American and Swedish scientists showed that beta-amyloid curbs the growth of both bacteria and fungi in culture dishes. A few years later, several experiments concluded that the protein also curbs flu and herpes viruses' ability to release beta-amyloid, and that beta-amyloid binds to the bacteria. In combination, the results show that the protein plays an important role in the protection of the brain against microorganisms.

The function of beta-amyloid could very well have disclosed the underlying cause of Alzheimer's. Several scientists now consider that an accumulation of beta-amyloid in Alzheimer's patients is a direct result of bacteria or viruses in the brain. Intruders make the nerve cells release beta-amyloid in self-defence, but if the attack continues for years, then the protein over-accumulates and begins to harm the brain itself.

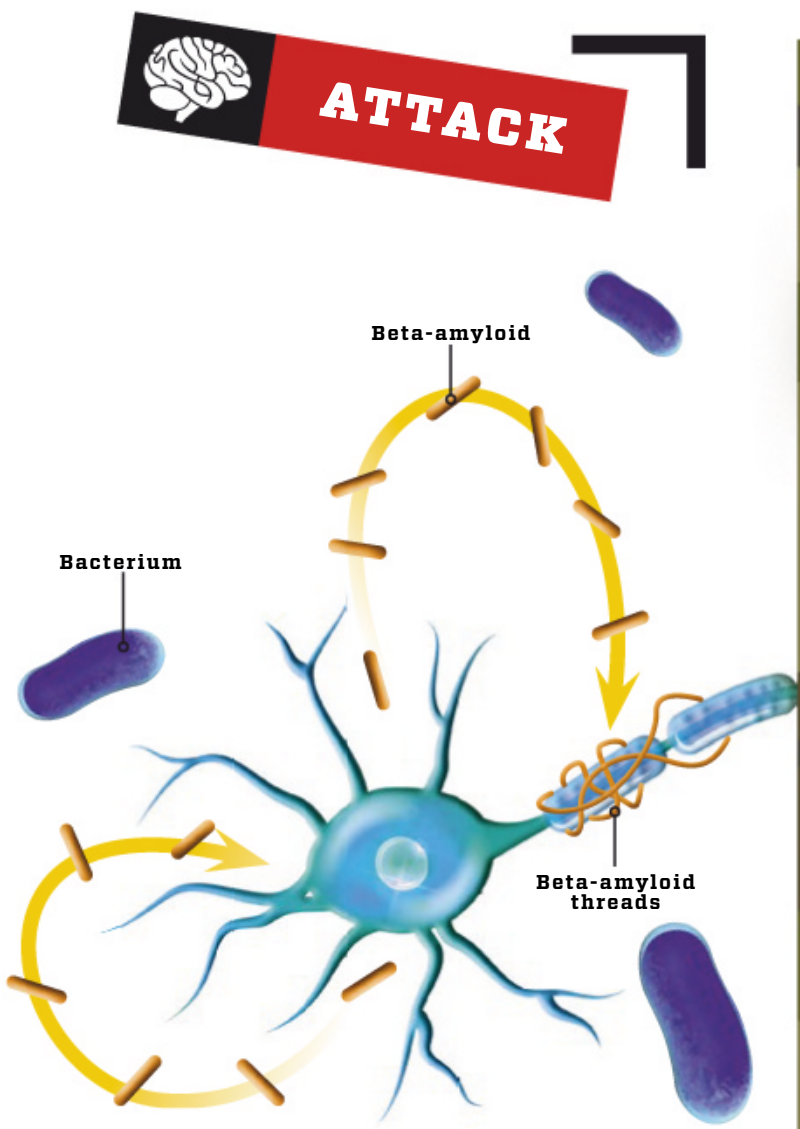
The new discoveries are consistent with other studies which have shown that infection with herpes virus increases the risk of developing Alzheimer's in people with a mutation of the APOE gene, which plays an important role in the immune system's struggle against microbes – and that this virus is highly concentrated in the lumps of beta-amyloid in brains of Alzheimer's patients.

In 2019 there was another major breakthrough. An international team of scientists headed by US doctor Stephen Dominy made a detailed map of the route from infection to Alzheimer's-like conditions in mice. But their focus was not the herpes virus. Instead, they found another microbe that was closely related to Alzheimer's – a microbe that normally attacks the gums.

Bacterium kills nerve cells

Porphyromonas gingivalis is the small bacterium that could soon become scientists' enemy no. 1 in the struggle against Alzheimer's. The bacterium has been known for a long time as one of the main causes of gum infection, a condition that affects up to half the world's population. It is also present in small quantities in the mouths of 25% of the people without gum infection.

Scientists have previously found a link between gum infection and Alzheimer's. A 2017 study found that chronic gum infec- ▶



KEN IKEDA MADSEN/SHUTTERSTOCK

Defence kills nerve cells

3 The nerve cells release beta-amyloid to defend themselves. But if the attack goes on for a long time, beta-amyloid could turn against the nerve cells themselves, perforating their cell membranes.

Alzheimer's costs billions

50 million people suffer from dementia, and the disease costs the world A$1.3 trillion a year. 100+ drugs have been tested, but only four have been approved.

50,000,000

people suffer from dementia, according to the World Health Organisation (WHO). The number will probably rise to 152 million by 2050.

60-80 per cent

of dementia cases are due to Alzheimer's. The second most common cause of dementia is reduced blood supply following a cerebral blood clot or other disturbance.

1,300,000,000,000
A$ is the estimated global cost of dementia in 2018 – which is more than 1% of the world's GNP.

Four drugs
have been approved for use against Alzheimer's. None of them slows the course of the disease, but they can relieve some symptoms.

SHUTTERSTOCK

tion can increase the risk of Alzheimer's by 70%, but it had not been proven that the infection causes Alzheimer's. However, that is exactly what Stephen Dominy and his colleagues have managed to do.

Dominy's team first found that the brains of patients with Alzheimer's contain much more gum bacteria toxins, also known as gingipains, than healthy brains – although most healthy brains also contained a certain quantity of gingipains. When the scientists took a closer look at the Alzheimer's brains, they realised that the toxins were located in the hippocampus memory centre and in the cerebral cortex, and that they were located closely together with accumulations of tau proteins and beta-amyloid.

Indeed the gum toxins destroyed healthy tau proteins – one of the first steps in the development of Alzheimer's. The toxin also killed nerve cells both in culture dishes and in the brains of mice. The scientists subsequently placed the bacterium in the mouths of mice, only to discover that it spread to the brain in a matter of six weeks. In the brain, it caused accumulation of beta-amyloid and the loss of brain cells in the hippocampus.

In combination, the results demonstrate the most well-documented link so far between micro-organism attacks and the development of Alzheimer's. Dominy and his colleagues have already gone one step further, developing a drug that efficiently curbs the toxins and kills the bacteria.

600

kilometres of blood vessels in the brain are protected by the blood-brain barrier.

New drug tested on patients

Scientists have focused on beta-amyloid for years in their search for a cure against Alzheimer's. In 2002 they tested a vaccine designed to make Alzheimer's patients' immune systems attack the accumulated beta-amyloid, but the experiment was halted due to severe side effects. The same thing happened in 2011, when scientists tested a drug that curbs the production of beta-amyloid. Other efforts to attack beta-amyloid have failed because they did not have the required effect.

Scientists have not yet given up going after beta-amyloid, but many now believe it is the wrong strategy. The growing proof of a link between infection and Alzheimer's has made microbes the obvious target of new treatments, and Stephen Dominy and his colleagues have developed the COR388 drug that binds to the toxins of gum bacteria, deactivating them. Dominy's experiments show that drugs resembling COR388 prevent the bacteria from killing nerve cells in culture dishes, and the drugs curb the growth of the bacteria – because the bacteria probably use toxins to break down their food. When the toxins are blocked out, the bacteria cannot spread from the mouth to the brain. In mice with infected brains, COR388 and a similar drug reduced the quantity of bacteria in the brain, preventing the loss of nerve cells in the hippocampus and curbing the accumulation of beta-amyloid.

The mysteries of Alzheimer's are far from solved, but COR388 gives reason for optimism; it has not caused any severe side effects in people, and is now being tested on more than 500 Alzheimer's patients. SCI

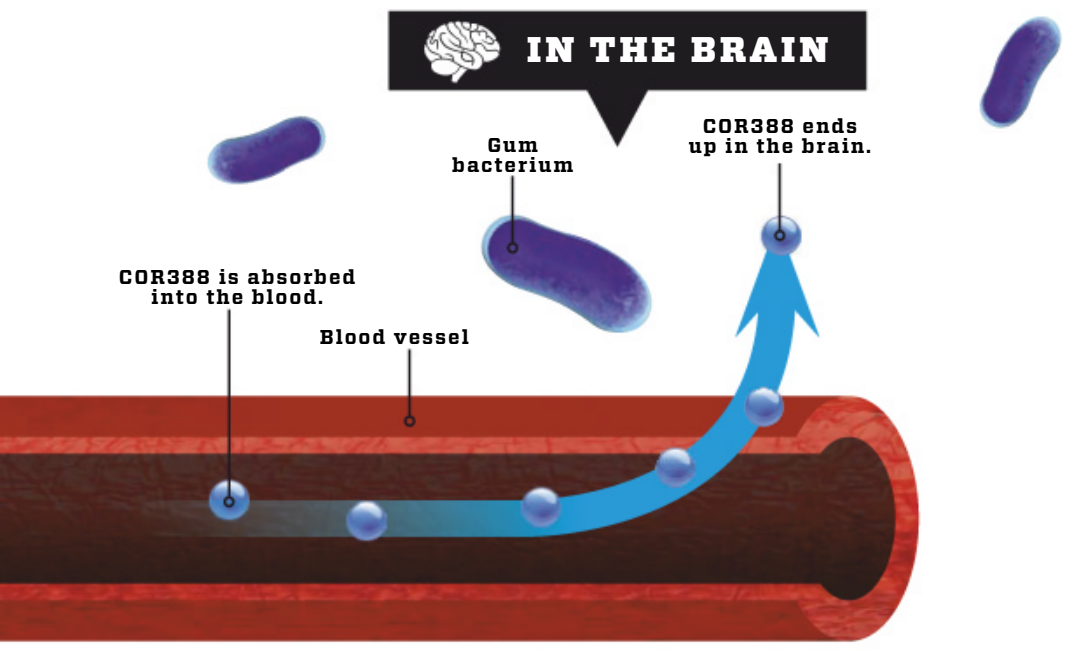
NO SMILING MATTER: The *Porphyromonas gingivalis* bacterium can make your gums bleed and your teeth fall out.

SCIENCE PHOTO LIBRARY

DEFENCE

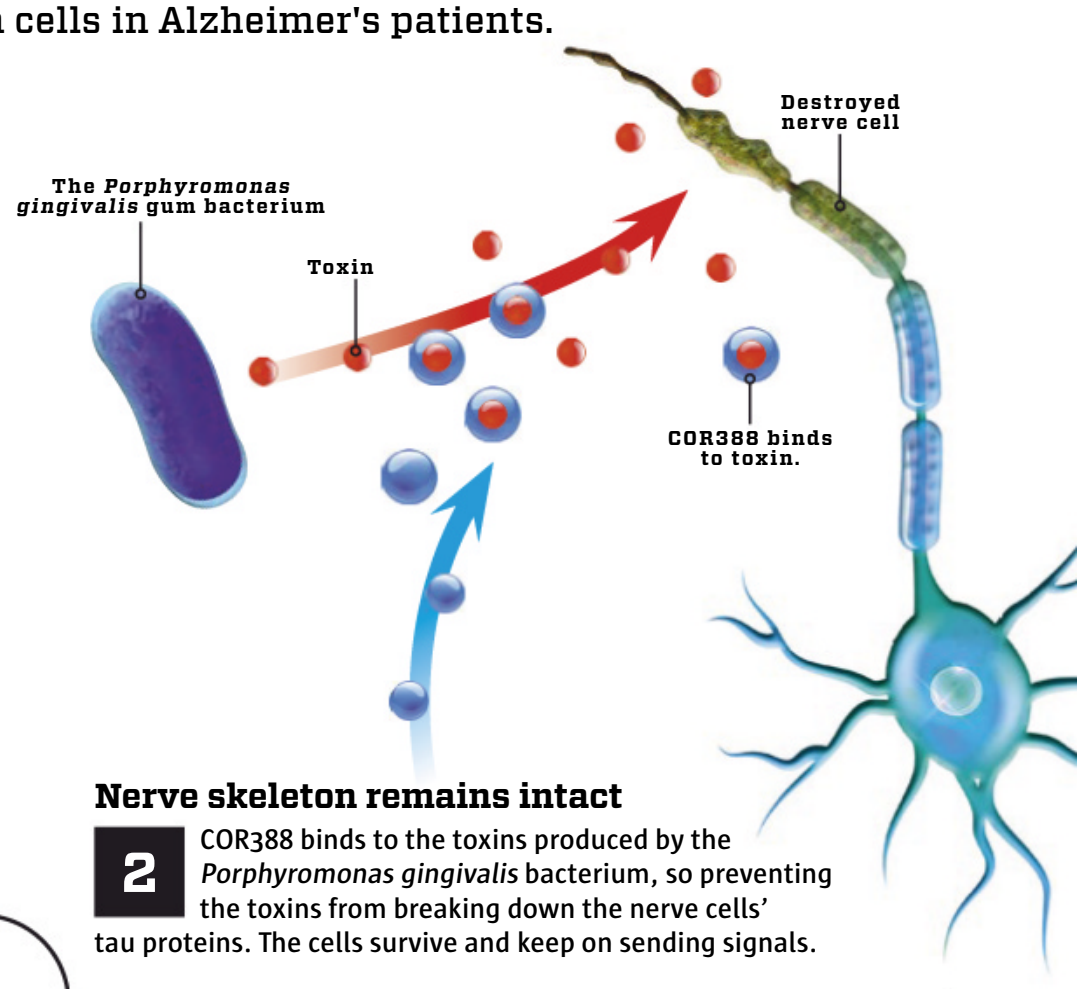
New drug to curb toxins

Gum bacteria are the most recent enemy identified in the struggle against Alzheimer's. Scientists have already developed a new antidote against the microbes that might for the first time allow us to curb the loss of brain cells in Alzheimer's patients.



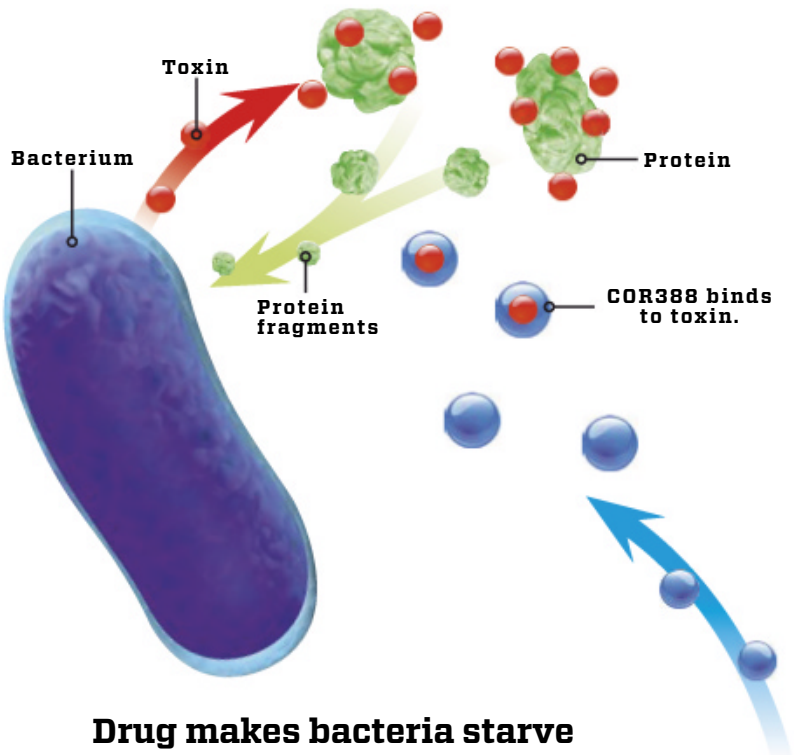
Antidote enters the brain

1 The patient swallows a capsule of COR388, which is dissolved in the intestines and absorbed into the blood. From the blood, it flows to the brain, where it is able to pass through the blood-brain barrier and reach the infected brain.



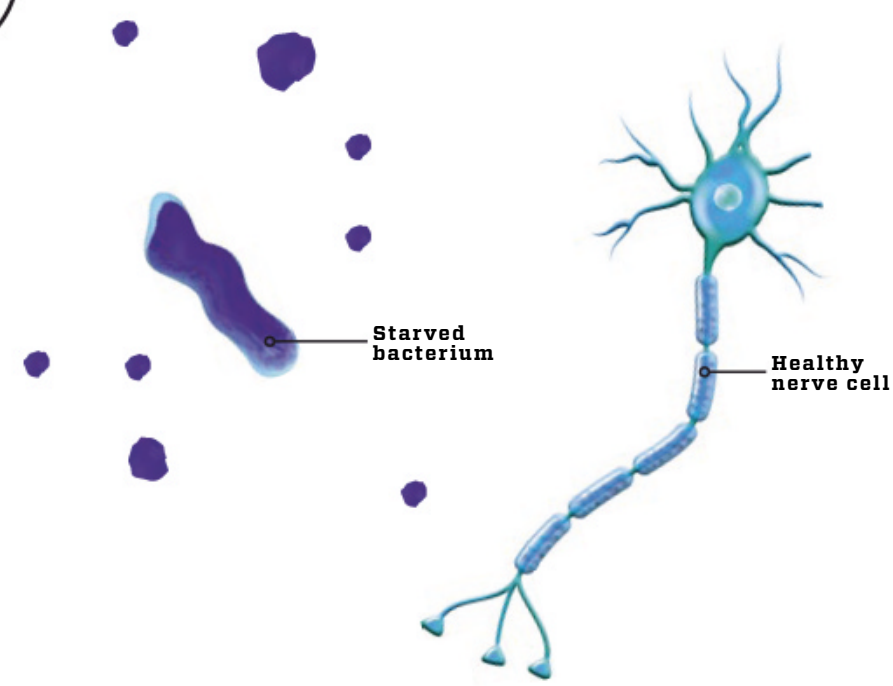
Nerve skeleton remains intact

2 COR388 binds to the toxins produced by the *Porphyromonas gingivalis* bacterium, so preventing the toxins from breaking down the nerve cells' tau proteins. The cells survive and keep on sending signals.



Drug makes bacteria starve

3 The bacterium usually uses its toxins to break down proteins around it to get iron and amino acids. COR388 prevents this, and so the drug cuts off the bacterium from a series of vital nutrients.



Infection disappears from the brain

4 The bacteria die due to starvation, and the infection in the brain disappears. The nerve cells stop the liberation of the beta-amyloid defence substance, and so the potentially harmful accumulation of beta-amyloid is curbed.

KEN IKEDA MADSEN/SHUTTERSTOCK

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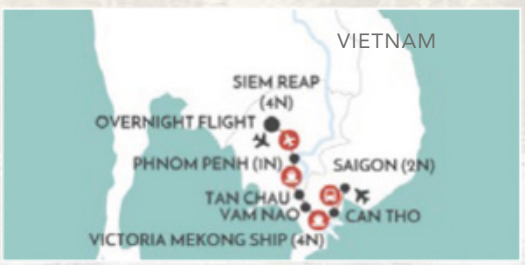

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CLAUS LUNAU

Models divide atmosphere into cubes

Scientists simulate the world's climate in computer models by dividing the atmosphere into cubes, and subsequently using various formulae to calculate the temperature, pressure, air humidity and so on in each cube. The bigger the cubes, the less accurate the predictions – but the smaller the cubes, the more computer power is required for the calculations.

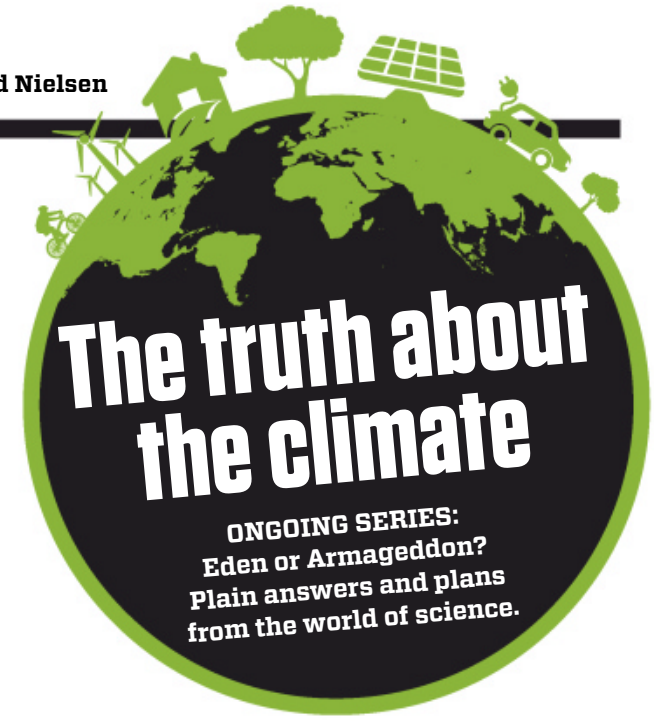
The models allow for the quantity of **sunlight** entering the atmosphere.

They simulate **weather phenomena** such as clouds, precipitation, and wind.

They calculate **evaporation and radiation** from different types of surfaces.

The atmosphere is divided into thousands of cubes, typically of size **100 × 100 kilometres**.

By **Rolf Haugaard Nielsen**



Clouds and ice reveal **the climate in 2100**

A scorching 3.5°C-degree rise or a moderate 0.5? Scientists are unable to predict how high temperatures will rise, but artificial intelligence and hidden satellite data patterns should give us a more accurate idea of future climate.

Is a disaster imminent, or do we have little to fear? Scientists have been processing huge quantities of data on the world's biggest supercomputers over recent decades. Their climate models have improved markedly, but the future is still uncertain, because the results of the models vary. They predict a temperature rise of between 0.5 and 3.5 degrees by 2100 – and the two outcomes would result in radically different scenarios.

If the world becomes 0.5 degree warmer, we will see some increase in the number and intensity of extreme weather phenomena such as torrential rain and heavy storms, but the situation is probably manageable. If it becomes 3.5 degrees warmer, we face a real climate disaster in which hundreds of millions of people will need to escape from draught, heatwaves, forest fires, flooding and storms.

Either scenario requires action, so the question becomes what action to take. Yet in order to determine the action required, we depend on climate models telling us exactly how the climate will change and where the changes will have the most severe effect.

New applications of artificial intelligence and the ability to find previously-hidden satellite data patterns are now helping scientists to simulate cloud formations and to reveal the drivers of Earth's melting ice. The results should provide a more accurate impression of the future world.

Supercomputers determine climate

The most sophisticated modern climate models are known as global circulation models; these include atmosphere, oceans, ice sheets, and ecosystems. The models are 'linked', in that they calculate how different parts of Earth's climate system affect each other. Rising air temperatures increase evaporation from the ocean, so increasing the water content of the atmosphere, so ▶

MAKE YOUR OWN CALCULATIONS

Answer:
255K or -18.15°C

The atmosphere holds on to heat

An extremely simplified climate model allows you to make simple calculations of the world's temperature.

$$T = \sqrt[4]{\frac{2 \times S \times (1 - \alpha)}{\sigma \times (2 - \varepsilon)}}$$

PROBLEM 1:

What would Earth's surface temperature be without the atmosphere?
Use this simple model to make your calculations. Withough an atmosphere ε would equal 0 instead of 0.76.

Key to symbols:

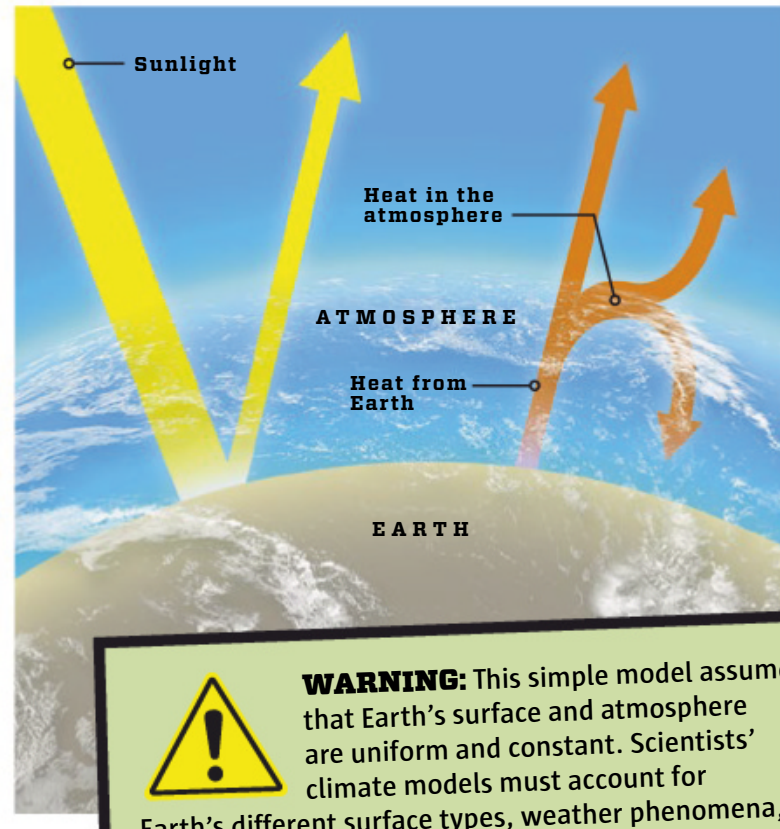
T is the temperature at Earth's surface measured in degrees Kelvin. (Convert into degrees Centigrade by deducting 273.15.)

S is the quantity of solar energy that hits Earth: 342W/m².

α is Earth's albedo value, the amount of total sunlight that Earth reflects back into space. Some 30% of the light is reflected, so α = 0.30.

σ is the Stefan-Boltzmann constant, which is $5.67*10^{-8}$ W/m²/K⁴.

ε is the emissivity of the atmosphere, the part of Earth's heat that is absorbed by the atmosphere. Half of the absorbed heat is sent back towards Earth, and the value of ε is approximately 0.76.



WARNING: This simple model assumes that Earth's surface and atmosphere are uniform and constant. Scientists' climate models must account for Earth's different surface types, weather phenomena, ocean currents, and many other factors.

JULIAN HERZOG

Global climate models require huge computing power, and are calculated by supercomputers such as this Cray XC40 in the University of Stuttgart, Germany. It can make 7.4 quadrillion calculations per second.

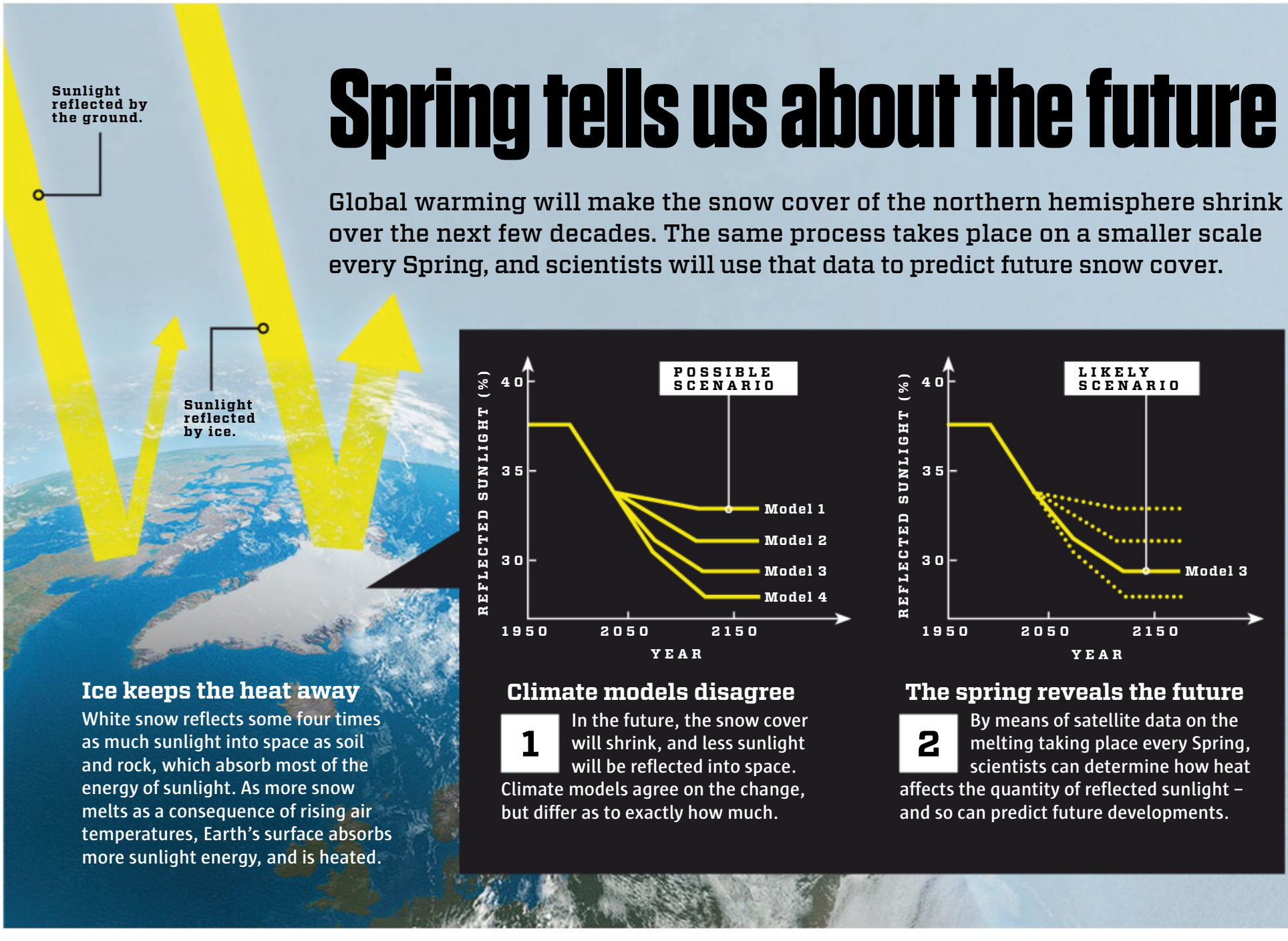
increasing the quantity of precipitation, and so on. The interaction between the different factors is described in extremely complex computer code, and the calculations require groups of supercomputers.

Specifically, the models describe Earth's climate system as a 3D network in which the atmosphere, the oceans and the land are all divided into cubes. In each cube, all the relevant climate variables – temperature, pressure, precipitation, clouds – are considered as the same throughout that cube. The cubes typically measure 100 × 100km horizontally and one layer of the atmosphere or the ocean vertically. The vertical layers are about 11km thick, and the models typically include about 30 layers of atmosphere and 20 layers of ocean. So each grid is an approximation, whereas in the real world one end of a cube might be covered in clouds while the sun shines in the rest of it.

Computers also divide time into steps which mark the flow from cube to cube of wind and ocean currents; these are typically calculated with intervals of 30 minutes.

Spring tells us about the future

Global warming will make the snow cover of the northern hemisphere shrink over the next few decades. The same process takes place on a smaller scale every Spring, and scientists will use that data to predict future snow cover.



Ice keeps the heat away

White snow reflects some four times as much sunlight into space as soil and rock, which absorb most of the energy of sunlight. As more snow melts as a consequence of rising air temperatures, Earth's surface absorbs more sunlight energy, and is heated.

Climate models disagree

1 In the future, the snow cover will shrink, and less sunlight will be reflected into space. Climate models agree on the change, but differ as to exactly how much.

The spring reveals the future

2 By means of satellite data on the melting taking place every Spring, scientists can determine how heat affects the quantity of reflected sunlight – and so can predict future developments.

CLAUS LUNAU

Ideally, both the time steps and the cubes would be infinitely small, or at least smaller, perhaps one cubic kilometre with steps of a few seconds. But such calculations would be too great for existing computer power. So with the main model, the results delivered by the application of the laws of physics are supplemented with a kind of rule of thumb, to allow for the uncertainty as best as possible. However, the rules are based on estimates, and different weightings from model to model are an important reason why different final results are delivered.

Testing the past

One important step on the way towards improved climate models is to test how accurate the models are, and then adjust them towards their best possible accuracy. We can't wait 50 years to see if the models get it right, so instead the models are tested by making them simulate the past climate.

Scientists have data about annual air temperatures back to the end of the ice age 11,700 years ago. The data comes from Greenlandic ice cores and from detailed data on tree ring thickness. Throughout this period there is reasonable agreement between the historic development and the results from today's climate models.

1500

quadrillion calculations per second is the aim of the new Frontier supercomputer.

Scientists also have global air temperature data from 1850 onwards. The climate models also simulate those accurately – but only when they include our emissions of greenhouse gases. If our emissions are left out, the models fail, as they do not reproduce the global temperature rise of 1.1°C that has occurred since 1880.

But on several counts, the models have so far under-estimated the consequences of global warming. The mass loss from the ice sheets of Greenland and Antarctica, for example, has been greater than predicted since the year 2000. In this case the models have since been improved by scientists incorporating the effect of warmer ocean water melting glaciers from underneath.

Ice-free sea intensifies warming

The Arctic sea ice has also receded faster than expected. Again an improvement has been made, in this case using the discovery of previously unrecognised patterns among decades of satellite data, which are helping scientists spot the errors in the models.

The retreating sea ice has global consequences because the white ice reflects sunlight into space, whereas dark, open sea absorbs most of the energy from sunlight, retaining large quantities of heat within the atmosphere. Calculations indicate that ▶

MAKE YOUR OWN CALCULATIONS

Answer: The temperature would rise from 14.1 to 15.4°C, an increase of 1.3°C.

Melted ice captures sunlight

When the ice melts, Earth will absorb more solar energy. The consequence is a considerably warmer planet.

$$T = \sqrt[4]{\frac{2 \times S \times (1 - \alpha)}{\sigma \times (2 - \varepsilon)}}$$

Key to symbols

α is Earth's albedo value, the amount of total sunlight that Earth reflects back into space. The value is calculated by finding the average albedo value of Earth's different types of surface, subsequently allowing for cloud albedo.

(The formula is explained under problem 1 on page 67.)

PROBLEM 2:

How much would the temperature increase if all ice in the world melted? Earth's average albedo value is 0.30. Assume that sea ice is replaced by ocean, terrestrial ice is replaced by grass, and the rest of the world remains the same. This makes the albedo 0.287.

WARNING: This climate model is extremely simplified. The problem does not account for rising sea levels nor all the consequences of the melting on weather systems, ocean currents, and more. Further, global warming could change the extent of deserts, forests, clouds...

When the ice disappears, a much darker surface is uncovered.

H. RAAB

» the melting has increased the absorption of solar energy so much that it has contributed to global warming an amount corresponding to 25% of the contribution from increased carbon dioxide in the atmosphere. It is vital that scientists can predict how quickly the sea ice is melting.

All climate models agree that the Arctic Ocean will be ice-free during summers if emissions of carbon dioxide continue at the present level. In some models this will happen within one or two decades; others predict the end of the century. To narrow down the uncertainty, American scientists have taken a close look back at satellite data collected since 1979.

Ice cover in early September has halved since 1979, from some 8 million km² then to less than 4 million today. At the same time, the ice volume has been reduced by 75% because of the increased quantity of thin first-year ice. American climate researcher Alex Hall and his colleagues have discovered that the change in the relationship between thin first-year ice and the thicker, older ice could explain the rapid melting. The UN climate panel has used this knowledge to narrow its predictions. The results indicate that the Arctic Ocean will become ice-free over summers by around the year 2050.

The cause of receding sea ice is the higher quantities of carbon dioxide in the atmosphere, and yet scientists still disagree over exactly how much carbon dioxide causes what level of global warming. The gas absorbs infrared heat radiation from Earth, which would otherwise disappear into space. But the radiation includes a spectrum of different wavelengths, and carbon dioxide does not absorb all wavelengths equally well.

Modern climate models are based on a weighted average of the absorption across wavelengths, but each model has its own method for calculating the average, and so they reach different results. New models will be able to calculate for individual wavelengths, reducing that uncertainty. On the other hand, such calculations again require immense computing power.

Clouds are tricky

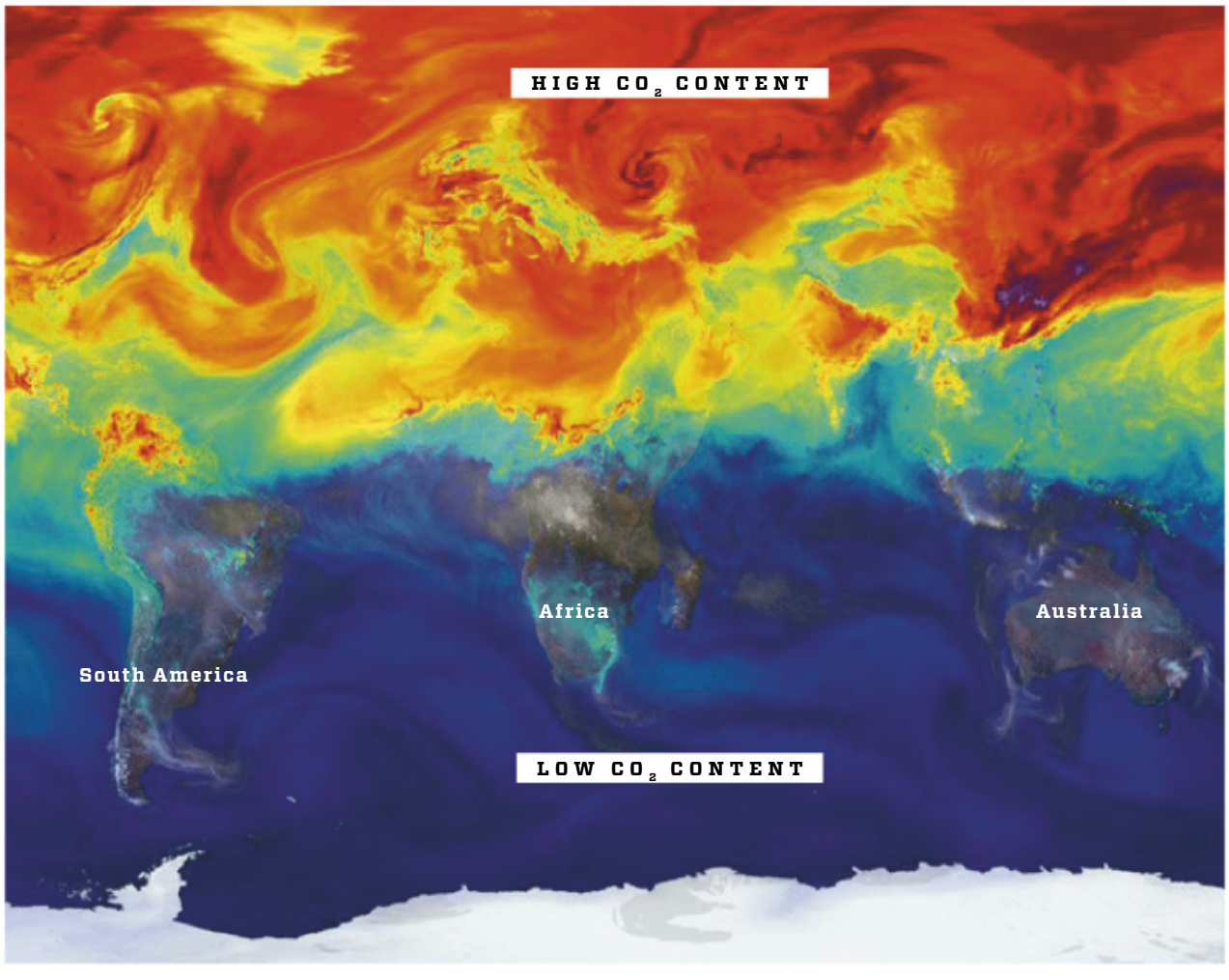
Scientists face even bigger challenges when they try to calculate the future of cloud cover, which greatly affects the results of the models, since clouds can either cool or heat. Dense low-lying clouds cool the world, because they reflect large quantities of sunlight into space. High-lying thin clouds, on the other hand, allow the light to pass, and at the same time they absorb heat from Earth's surface.

Dense low-lying clouds are the most common, and the net effect of cloud cover in the world today is cooling. But in a warmer atmosphere, both the existence of different types of clouds and their geographical distribution could change. The dense low-lying cloud cover is now primarily located above the tropics, but changing wind systems could push large quantities of low-lying clouds towards the poles. There they would reflect only the faint sunlight over these higher regions instead of the intense sunlight of the tropics. So in the future, cloud cover might heat the world instead of cooling it.

33.1

billion tonnes of carbon dioxide were emitted in 2018 – 1.7% more than in 2017.

Again climate models have difficulties supplying accurate predictions because clouds form in much smaller spaces than those large atmospheric cubes used by the models. American scientists now hope to develop methods using artificial intelligence which will use satellite data to simulate cloud formation within a more realistic volume of just a few cubic kilometres. These will then be included in the global models.



NASA

Based on detailed data about carbon dioxide emissions and atmospheric conditions, NASA has simulated the motion of carbon dioxide across the world in one year. This is the world in May 2006.

Models predict the near future

In recent years, models have become ever better at predicting Earth's climate for decades and even centuries ahead. But with climate change already taking place, increased accuracy is vital so that governments throughout the world can be more sure how their small parts of the world will be affected in the years to come.

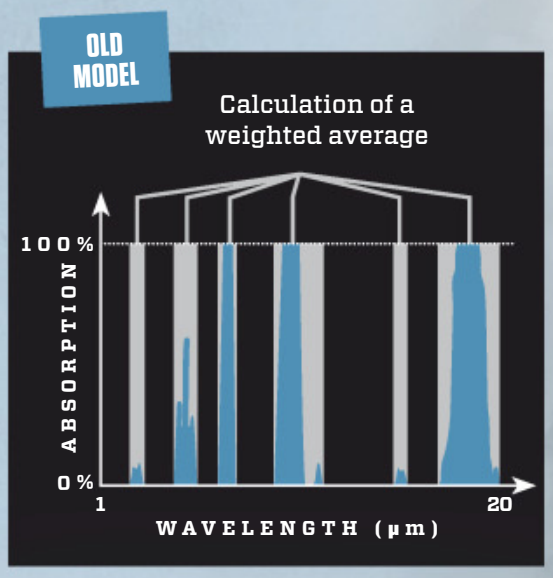
So scientists are developing localised models better at predicting local conditions, providing a clearer image of climate development within the next decade.

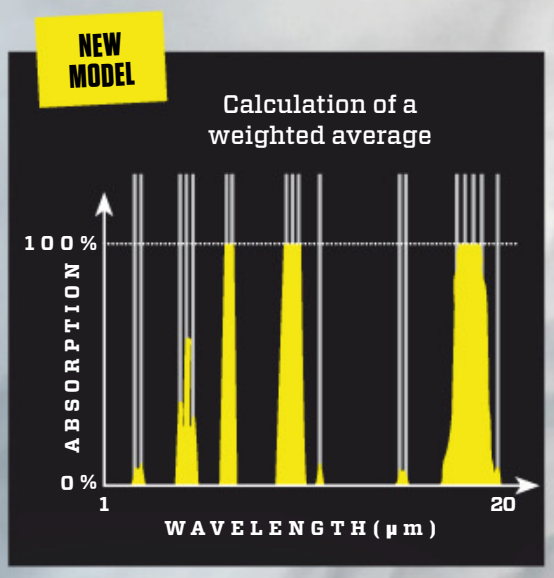
The UK is a leader in this field. In 2016, scientists drew up a major report about the risk of flooding in different parts of England and Wales within the following few years. The predictions mined decades of detailed weather satellite data, with the scientists predicting that the quantity of precipitation during intense winter downpours will probably increase by about 10% over the next 10 years – but with an increase up to 30% in south-east England. The detail provided a guide to the UK Government, which intends to spend £700m on improving the country's defences against flooding. SCI

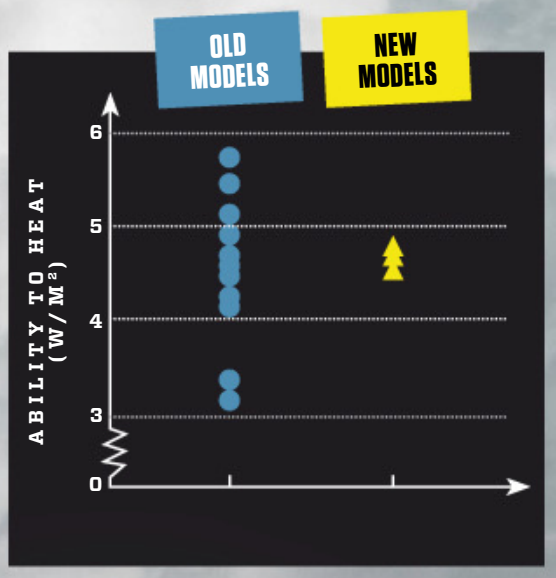
SHUTTERSTOCK

New models split radiation

Carbon dioxide heats Earth when it absorbs heat radiation of specific wavelengths and sends heat back towards Earth. However, scientists disagree about how much heating the gas causes. New climate models hope to reduce the uncertainty.







Wavelengths are added and a weighted average is used

1 When scientists currently calculate how much heat carbon dioxide absorbs, they use a weighted average of the absorption at all heat radiation wavelengths.

Scientists measure individual wavelengths

2 Scientists now aim to teach the models how to calculate carbon dioxide's absorption at each wavelength. The calculation requires more power, but the result is more accurate.

New models reduce uncertainty

3 In the old models, differences in the weighting of wavelengths caused uncertainty about carbon dioxide's ability to heat Earth. The new models avoid the problem and markedly reduce uncertainty.

MAKE YOUR OWN CALCULATIONS

Answer: In scenario 1, the temperatue is 15.1°C, and in scenario 2, it is 17.8°C.

Carbon dioxide heats Earth

Greenhouse gas emissions influence Earth's climate, and our efforts to reduce the gases will have a huge effect on future temperatures.

$$T = \sqrt[4]{\frac{2 \times S \times (1 - \alpha)}{\sigma \times (2 - \varepsilon)}}$$

$$\text{Rise in } \varepsilon = \frac{2F}{\sigma \times T_0^4} \times 1.7$$

PROBLEM 3:

What will the temperature in 2100 be in the two following cases?
1. We emit less carbon dioxide, and the radiation effect of the gas will be 2W/m².
2. We go on emitting higher quantities of carbon dioxide, and the number ends up being 7W/m².
Assume a stable albedo value of 0.30.

Key to symbols:

F is carbon dioxide's radiation effect, the quantity of heat that the gas reflects back towards Earth.

T_0 is Earth's present surface temperature: 287.2K.

The fraction of the bottom formula says how much the carbon dioxide contributes to the rise in emissivity, the atmosphere's ability to hold on to Earth's heat.

1.7 was inserted in the formula to allow for the temperature rise resulting in more water vapour in the atmosphere, increasing emissivity.

– The top formula is explained under problem 1 on page 67.

WARNING: This is an extremely simplified model. Carbon dioxide's radiation effect varies throughout the atmosphere, and scientists are still working on calculating the accurate numbers. Moreover, global warming triggers other processes such as evaporation, making it difficult to predict the emissivity of the future.

FROM THE SCIENTIFIC ARCHIVES

PRESENT STATUS

THE INTERNET CHALLENGES LIVE RADIO

Since 1906, people have been able to listen to the radio via amplitude-modulated (AM) electromagnetic waves, and since 1995 via DAB/DAB+ digital radio. The future probably belongs to internet radio, with 5G networks potentially facilitating space for new channels and better sound. People can customise their experience by mixing live radio, on demand services, and podcasts.

Italian physicist Marconi patented his radio system in England in 1897, and in 1904 was granted a further patent in the US.

SCANPIX/SCIENCE PHOTO LIBRARY

SHUTTERSTOCK

Some phones today include FM receivers, but many instead receive 'radio' as data.

BEEP. PAUSE. BEEP.

Over 100 years, the discovery of electromagnetism led to the development of wireless telegraphy and radio.

1820

Danish physicist H.C. Ørsted (1777-1851) discovers electro-magnetism, the relationship between electricity and magnetic fields.

1821

Michael Faraday (1791-1867) of England produces "electro-magnetic rotation" and electricity by means of a magnet. His discoveries are vital for modern electromagnetic technologies such as radio and television.

In 1820, Ørsted published his thesis on electricity and magnetism.

POLFOTO/CORBIS

By **Ulla Skovsbøl**

Struggles define the wireless age

Young Italian physicist Guglielmo Marconi was credited with the invention of the wireless telegraph and received the Nobel Prize. But his achievements were inspired by other people's work and were based on patents belonging to the brilliant Serbian scientist Nikola Tesla.

In the mid-1800s, it takes a long time to communicate across the Atlantic Ocean. News about revolutions in Europe or losses in the American civil war takes weeks to arrive via ship, while storms, shipwreck or piratical intervention sometimes mean that it is lost altogether.

This changes radically in 1866, when a cable is placed on the ocean floor from Great Britain to the US. Now it is suddenly possible to send telegrams between the continents. This new rapid link remains unstable, however, as the 3122km cable often breaks and requires repair.

Could messages be sent instead through the air? Visionaries, inventors and telegraph companies all imagine new ways of communicating without the cables. One of them is Nikola Tesla of Serbia. Another is young Italian Guglielmo Marconi, the son of an aristocratic landowner from near Bologna, Italy.

Wireless 'S' for success

On 12 December 1901 at 12.30AM, the dream comes true. A weak sound finally reaches 25-year-old Marconi, who has been waiting anxiously for days on a windy hill in Newfoundland, Canada, as his assistants 3500km away on the coast of Cornwall, England, have tried to get a signal through: "beep, beep, beep, pause" – the Morse signal for 'S'.

Marconi hands the earphones to his assistant George Kemp, who also hears the rhythmic sounds. The two men look at each other and know that they have made history. "For the first time, I felt positive that mankind would one day be able to send wireless messages not only across the Atlantic, but to the remotest corners of the world," Marconi subsequently writes in his records.

The Italian is celebrated for his ground-breaking feat. Though sceptics believe that he cheated and lied about the three beeps, the event dispelled any remaining doubt that sound could travel through the air over very long distances.

At the banquet for the young radio pioneer, a congratulations letter is read out. The sender is Nikola Tesla, an extremely gifted but eccentric scientist. The 56-year-old Tesla already holds patents for a series of inventions which become key for the development of the radio telegraph. He sent his first radio signal long before the young Marconi entered the scene, and one of his many then-current projects was to send a radio signal from Colorado to Paris.

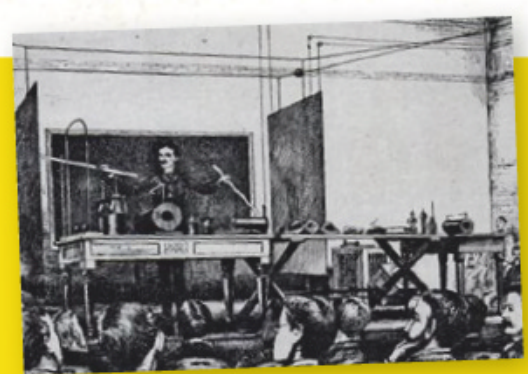
"Marconi seems to have outpaced you," one of Tesla's employees says, when they get the news of the trans-Atlantic radio signal.

"Marconi is a fine fellow – let him continue. He uses 17 of my patents," Tesla replies. Tesla perhaps does not have the imagination to foresee that he will get neither money nor recognition for his inventions. But that is what happens.

Marconi's invention of the radio makes him rich and famous, and in 1909 he is awarded the Nobel Prize. Yet his invention is based on Tesla's ideas.

Theory does not interest Marconi

Guglielmo Marconi grew up in Bologna as the son of an Italian father, Giuseppe Marconi, and an Irish mother. He was ▶



ELECTRICAL WORLD

Tesla's lectures were published in journals that Marconi read.

1886

Heinrich Hertz (1857-1894) of Germany detects electromagnetic waves. His experiments show that the waves can spread wirelessly through the air from a sender to a receiver.

1893

Nikola Tesla (1856-1945) of Serbia lectures about his discoveries and results in Philadelphia and elsewhere, showing that it is possible to send electric signals via radio waves.

1894

Tesla sends a radio signal from his lab in New York to West Point on the Hudson River – a distance of some 80km.

1894

British physicist Oliver Lodge (1851-1940) sends a radio signal across a distance greater than 32km.

1895

Guglielmo Marconi (1874-1937) sends his first outdoor radio signal across a distance of about 2km.

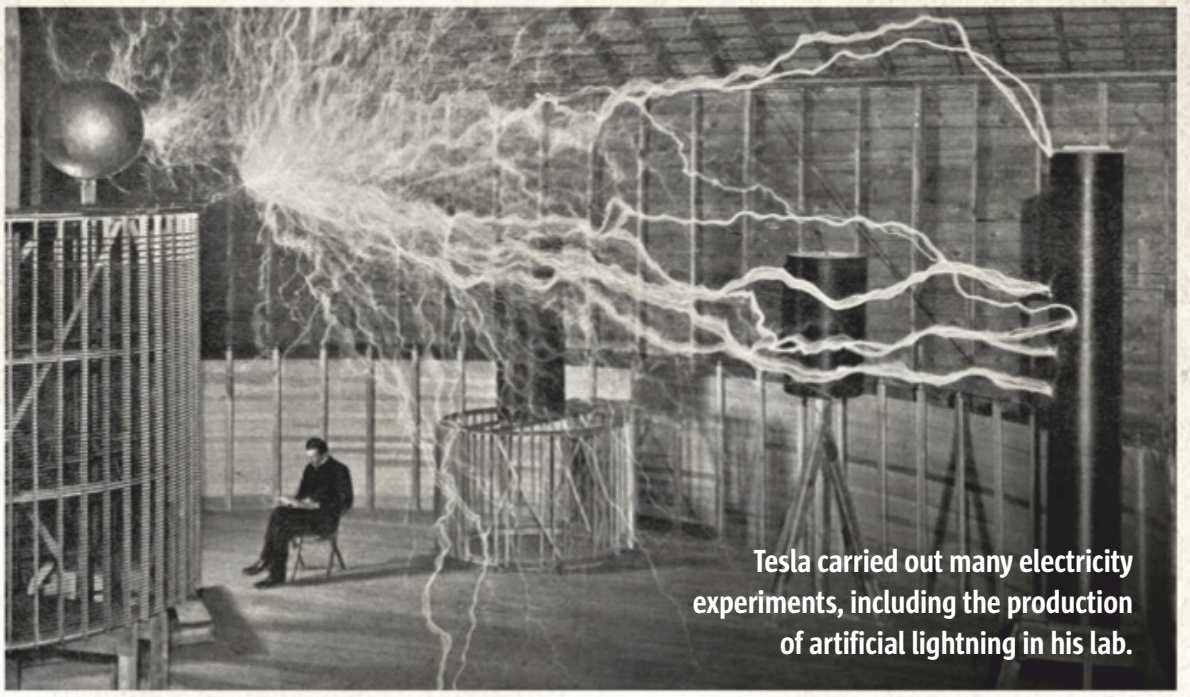
curious and inventive, but easily bored in school; he gets poor grades. Practical physics experiments are the only thing that really catch his attention. His mother Annie consequently employs a private physics teacher for him, and when Guglielmo fails to get into university, she sees to it that he is trained by physics professor Augusto Righi instead.

Righi specialises in electromagnetism and he is very interested in new theories about electromagnetic waves from Heinrich Hertz of Germany. Young Marconi loves what he is doing. Theory does not appeal very much to him, but he is very keen on using the new knowledge about radio waves in practice.

His experiments begin in the attic of his parent's house. Marconi copies Hertz' experiments and is further inspired by Nikola Tesla. In 1892 and 1893, Tesla gives a series of lectures about how electromagnetic waves can be used for communication, and his lectures and theories are published in a series of scientific journals that young Guglielmo Marconi most likely reads.

In the summer of 1895, Guglielmo Marconi makes his brother Alfonso carry a radio receiver a few kilometres away from the house. The two brothers agree that Guglielmo is to send a radio signal. If Alfonso receives it, he is to shoot his gun. Guglielmo sends the signal, and shortly afterwards he hears the gunshot. It works!

However, Guglielmo Marconi's transmission is no world first. Nikola Tesla had already sent a radio signal 80km up the American Hudson River, from New York to West Point, the year before. But the Marconi family is thrilled with their son's achievement and tries to interest the Italian mail and telegraph company in the invention. When this is unsuccessful, mother and son go to England, where they use their connections to develop interest in Guglielmo Marconi's device.



Tesla carried out many electricity experiments, including the production of artificial lightning in his lab.

POLFOTO/CORBIS

Tesla must dig trenches

While Guglielmo Marconi is born rich, Nikola Tesla, who is 18 years older, must fight his way through life. He was born in Austria-Hungary as the son of a Serbian priest, and after a single year in a university in Prague, the family's money runs dry. Tesla gives up his studies and moves to Paris to work for the Continental Edison Company, the European arm of Thomas Edison's energy company.

In 1884, Tesla emigrates to the US, taking with him a recommendation to Edison himself from one of his superiors in Paris, Charles Batchelor: "Dear Edison. I know two great men, and you are one of them. The other one is this young man."

The introduction was successful, and Tesla cooperates closely with Edison until wage disagreements see Tesla leaving in anger to found his own energy company. He works hard, and ideas keep coming. On the other hand, he has no talent for business. His progress stalls for want of money, and soon, the genius is forced to dig trenches at a pay of US$2 a day.

Luckily, a rich sponsor spots Tesla and helps him, so he can continue his radio experiments. In 1898, he demonstrates a remote-controlled boat to an amazed audience at Madison Square Garden, and he develops ideas for radio-controlled weapons which are not realised until 50 years later.

Marconi steals Tesla's patents

Back in England, young Marconi's substantial fortune and influential connections quickly bring success. In 1897, he takes out a patent for his radio in Britain, although it corresponds closely to a device that Nikola Tesla described in an article from 1893. A few years later when Marconi tries to patent the same equipment in the US, he is turned down due to Tesla's patents, although Marconi claims he knows nothing of Tesla's ideas.

The major public breakthrough comes in 1899, when he manages to send a radio telegram across the English Channel. The young Italian presents well as a great inventor and garners extensive press coverage. In 1901, when he receives his trans-Atlantic signal, his fame is assured.

The ultimate victory comes in 1904, when, for reasons unknown, the Ameri-

1897

Marconi founds the Wireless Telegraph & Signal Company in London.

FLICKR

Two years after Marconi founded his company, he sent a radio signal across the English Channel.

1900

Tesla is granted an American patent for a "system that can transmit electric energy" and another patent for an "electric transmitter". Marconi later abuses both patents in his radio.

1901

Marconi is the first to send a wireless signal across the Atlantic.

SCANPIX/SCIENCE PHOTO LIBRARY

Marconi used a kite as an antenna to receive the signal from England.

1904

For reasons unknown, Marconi is awarded US radio technology patents which had been turned down in 1903.

1906

Radio telegraphy is used to transmit the first radio programme with speech and music. The programme is broadcast in Massachusetts, USA, and heard in Virginia.

1921

2CM is usually regarded as Australia's first regular non-official radio station. From 1921 it broadcast classical music on Sunday evenings from the Wentworth Hotel, Sydney, on the long-wave band.

The golden age of radio: a Calstan 1960 radio dial packed with stations.

can patent office changes its mind and recognises Marconi as the inventor of wireless radio telegraphy.

Tesla dies before recognition

Nikola Tesla fights in vain to gain recognition for his contribution to the invention of the radio, and becomes increasingly eccentric, with contemporaries describing him with decidedly mixed praise as a "gifted madman" and as "a medieval practitioner of black arts." Although he usually keeps quiet publicly on his frustrations, one time he blurts out: "Mr Marconi is a donkey!"

Finally, in 1943, the US Supreme Court establishes that it was indeed Nikola Tesla who was the first to invent the radio, and that Marconi had lied when he claimed that he knew nothing about Tesla's scientific articles.

But neither adversary ever hears the verdict. Marconi dies of a stroke in 1937, aged 63. The hardy Nikola Tesla lives on to be 86 years old. But he dies alone in a hotel room in January 1943 – just nine months before the Supreme Court finally gives him the credit for his invention of the radio. SCI

The wireless telegraph

Marconi's radio transmitter and receiver converted electric Morse signals into radio waves and back.

SCANPIX/SCIENCE PHOTO LIBRARY

Marconi sent his first radio signal from a window in his parents' house.

The first 'radio' was not built to reproduce the sound of music and voices like modern radios. Instead, Marconi's device was a wireless telegraph, which was to send Morse signals by means of radio waves. For this purpose he needed a transmitter that could generate electromagnetic radio waves, a receiver that could register them, an antenna, a Morse code device, and a battery.

The heart of the transmitter was two copper electrodes separated by a few centimetres – the spark gap. When a spark sprang between the electrodes, it produced a radio wave.

To receive the radio waves, Marconi used a detector – an improved version of the coherer developed by British scientist Oliver Lodge. A coherer is a glass tube with two electrodes and metal filings inside it. When no electromagnetic waves is present, the coherer's metal filings are randomly distributed and carry no current. But when disturbed by radio waves, the filings attract each other and stick together. Their resistance is thereby reduced, and a current can flow through the metal filings to a set of earphones in which the radio signal is converted into sound.

Marconi's coherer consisted of an air-void tube with an internal diameter of 2.5mm. The electrodes were made of silver, and between them were the metal filings. It sounds simple, but he spent 1000 hours getting it to work.

5 ANTENNA PLATE: Via cables, the radio wave flows like a pulsating current into an antenna and is sent into the air at the speed of light.

3 CAPACITOR: The impulse's electric voltage is collected in a capacitor, until a spark springs in the spark gap.

1 TELEGRAPH KEY: When the button is pressed, an electric impulse is sent.

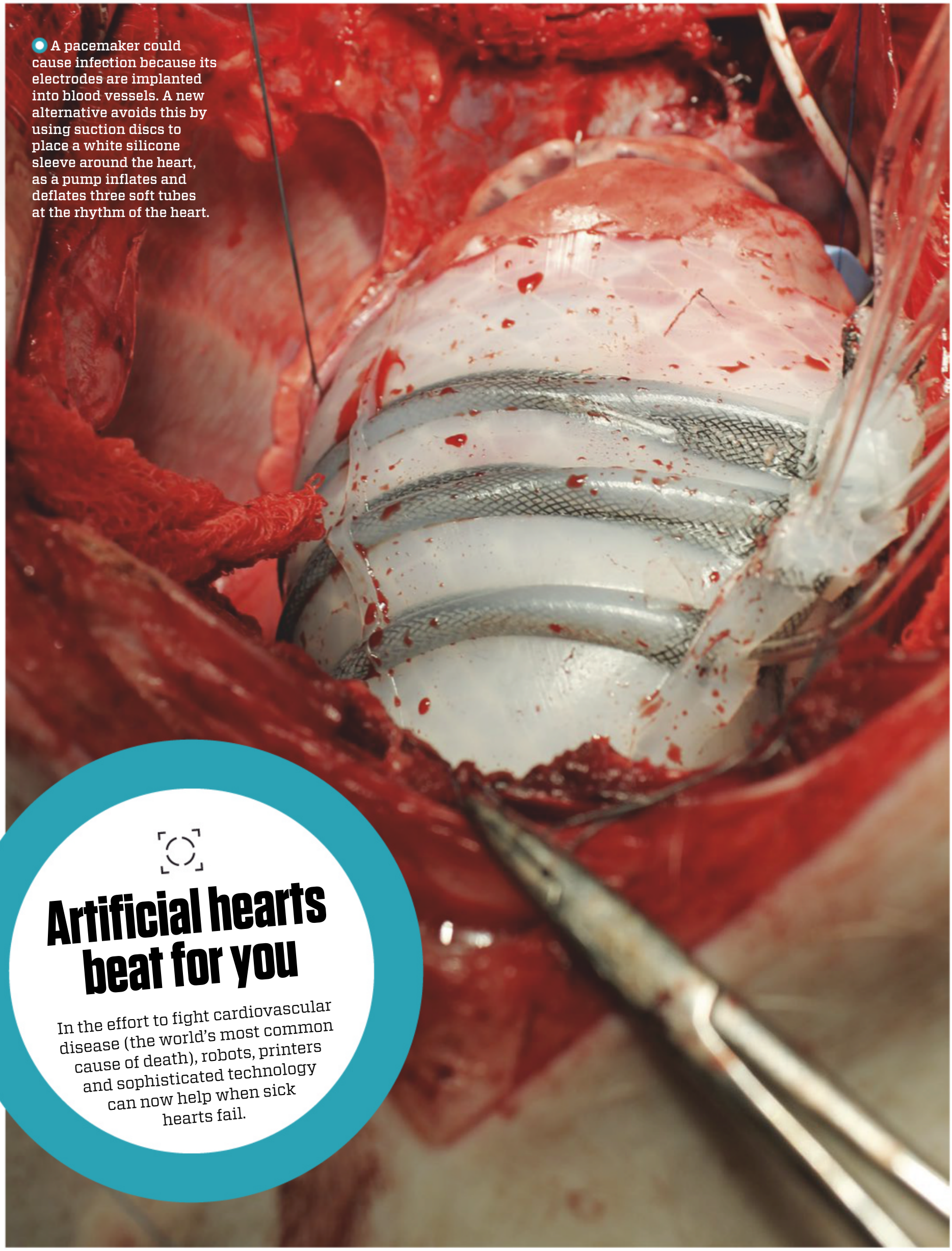
2 COIL: The impulse reaches the coil, which amplifies it.

6 TUNER CAPACITOR: The radio wave is detected by the receiver's antenna and is amplified by a tuner.

7 COHERER: By means of magnetic metal filings in the coherer, the radio wave is converted into a current that is delivered as audio via headphones.

4 SPARK GAP: The intense electric voltage makes a spark spring between two copper electrodes, producing an electromagnetic radio wave.

A spark gap produced Marconi's radio waves.



A pacemaker could cause infection because its electrodes are implanted into blood vessels. A new alternative avoids this by using suction discs to place a white silicone sleeve around the heart, as a pump inflates and deflates three soft tubes at the rhythm of the heart.

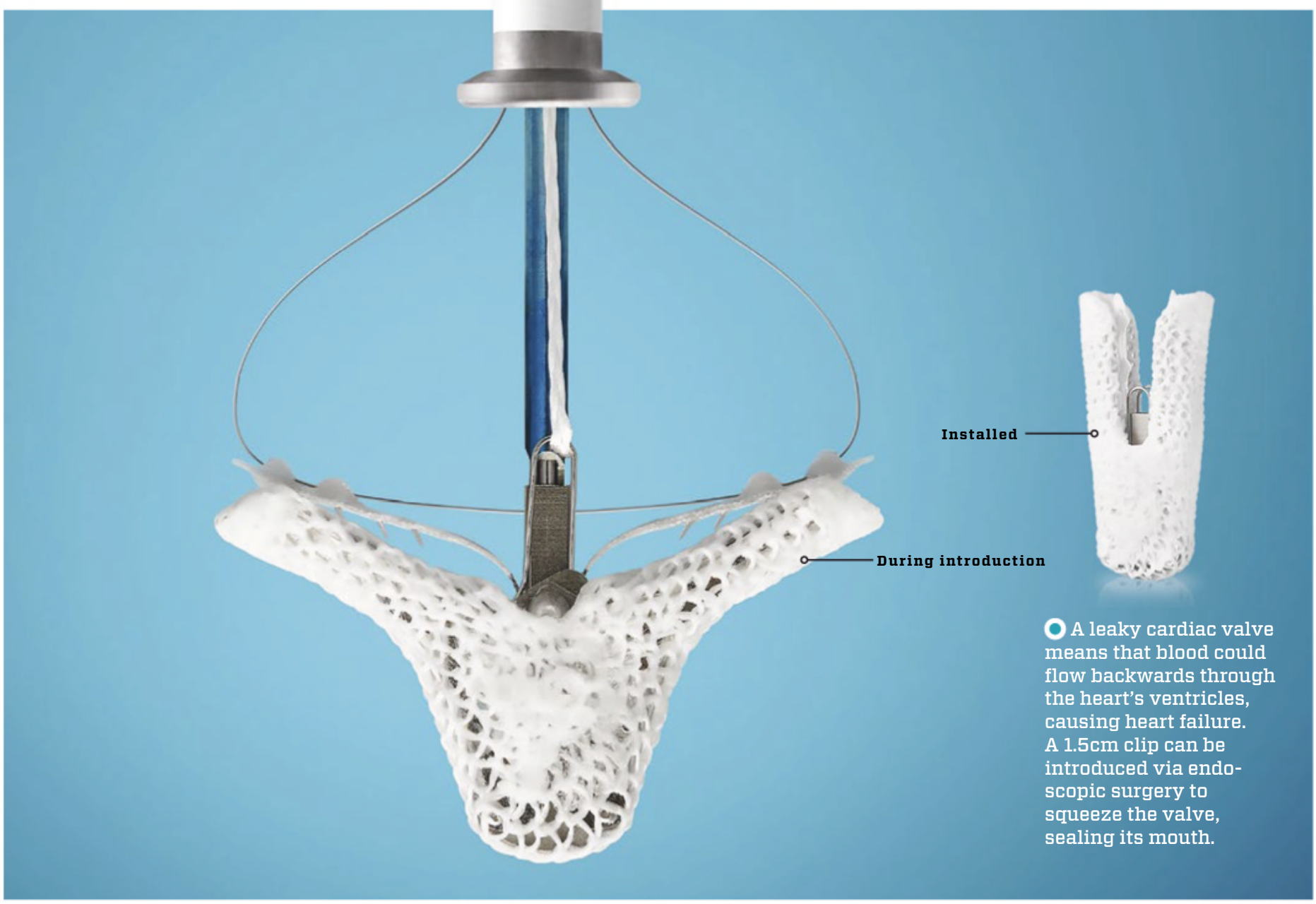
Artificial hearts beat for you

In the effort to fight cardiovascular disease (the world's most common cause of death), robots, printers and sophisticated technology can now help when sick hearts fail.

ELLEN ROCHE/HARVARD UNIVERSITY

| **SILICONE ROBOT** | Compressed air and gently-hugging tubes pump the cardiac rhythm.

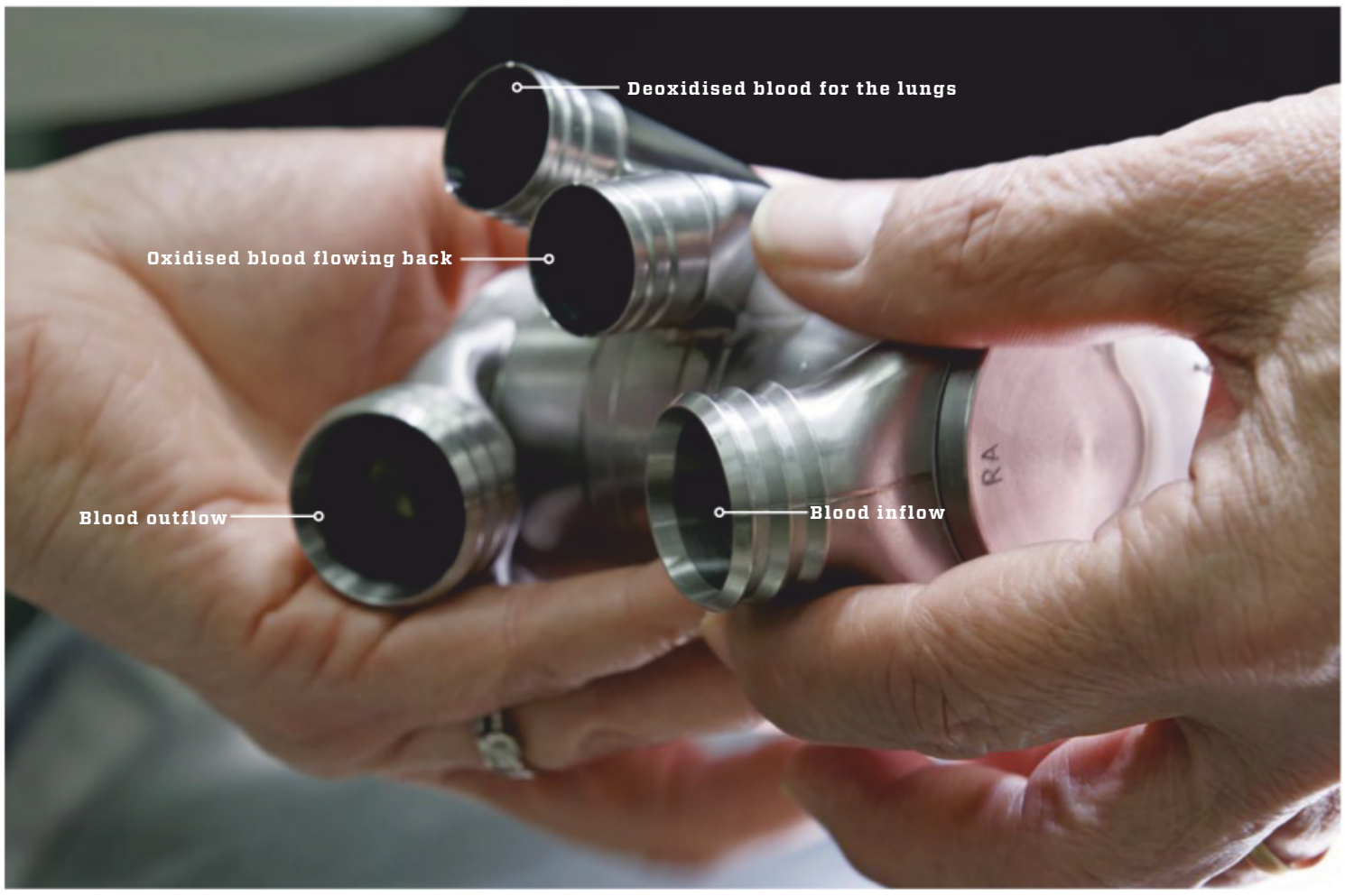
By **Lea Milling Korsholm**



ABBOTT

SMALL CLIP | A small clip staples defective cardiac valves.

A leaky cardiac valve means that blood could flow backwards through the heart's ventricles, causing heart failure. A 1.5cm clip can be introduced via endoscopic surgery to squeeze the valve, sealing its mouth.

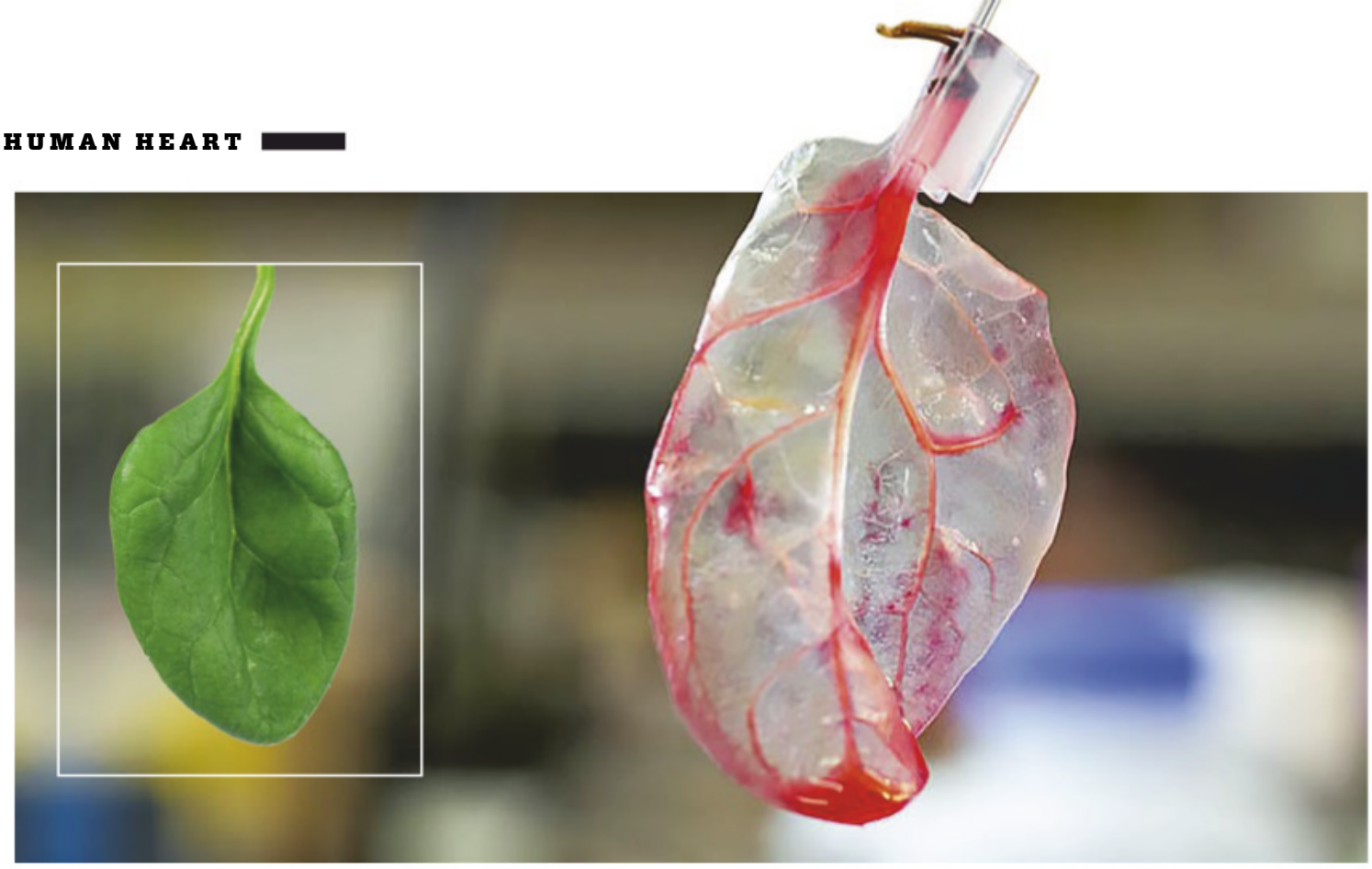


KRISTYNA WENTZ-GRAFF/OHSU

METAL HEART | Titanium tube mimics blood flow.

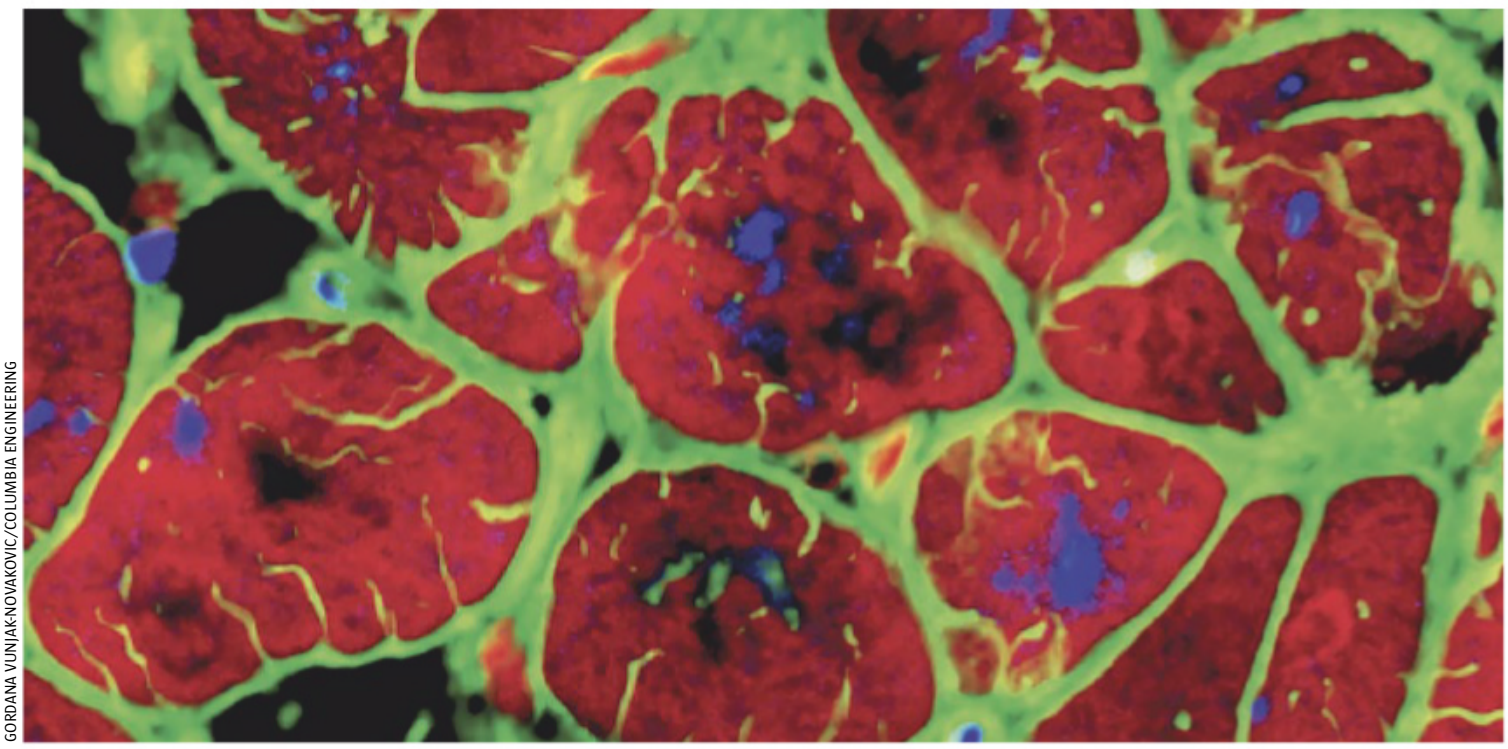
Artificial hearts must be robust enough to beat 115,000 times a day. US doctors have designed a metal heart with titanium tubes that absorb deoxidised blood at one end, before a flexible cylinder in the tube sends the blood into the lungs and back. At the other end, oxidised blood flows into the body.

In the future doctors might be able to insert small blood vessels into sick hearts. A new method produces the fine vessels by removing all plant cells from a leaf by means of a solvent, replacing them by blood vessel cells and stem cells. The leaf structure is made of cellulose, and can be implanted without causing infection.



WORCESTER POLYTECHNIC INSTITUTE/SHUTTERSTOCK

GREEN BLOOD VESSELS | Human cells grown on the structure of a leaf.

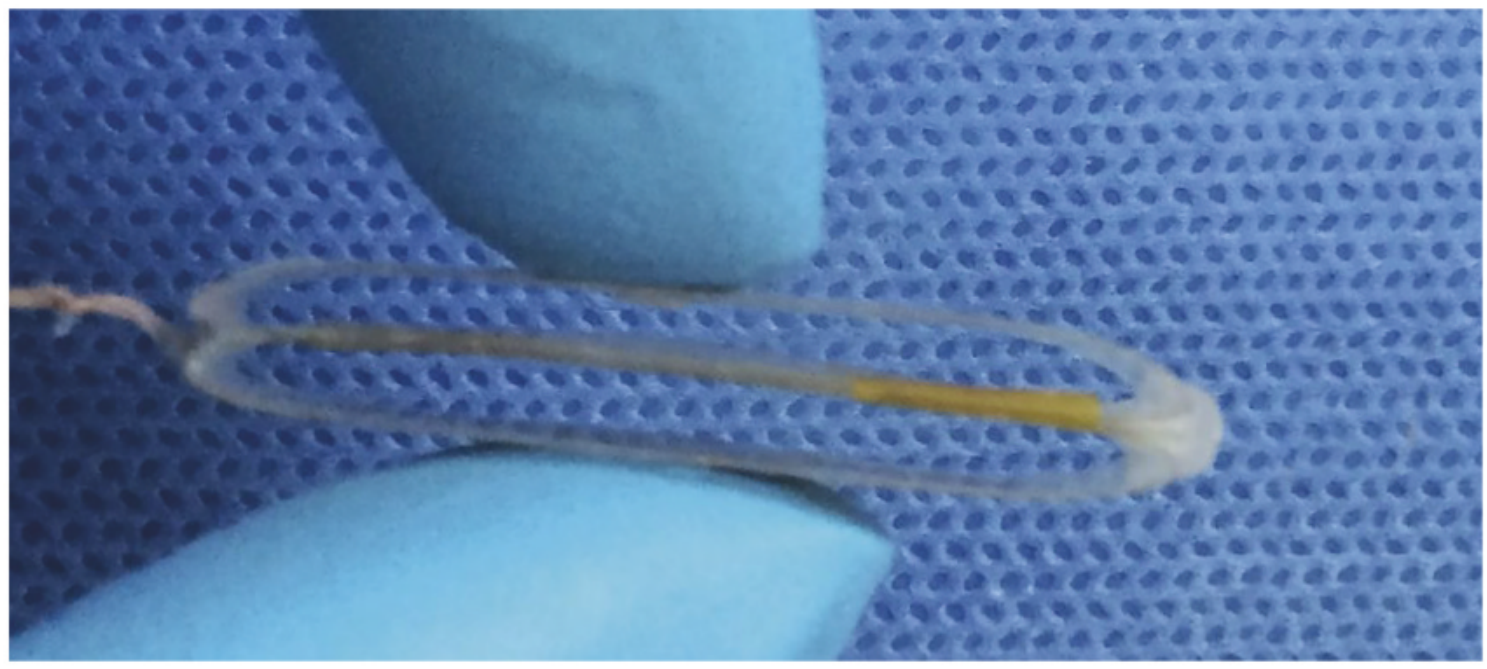


GORDANA VUNJAK-NOVAKOVIC/COLUMBIA ENGINEERING

Weak heart muscles are poor at pumping blood, and that could cause heart failure. So scientists are trying to revive weak musculature with cells from the heart's connective tissue that are forced back to the embryonic stages of heart stem cells. Subsequently, they become new muscle cells that can be inserted into patients.

REBOOTING | Stem cells strengthen slack heart muscles.

Pacemakers use batteries that must be surgically replaced after 5-10 years. Chinese scientists have developed the iPEG generator, which is placed under the patient's heart. A heart beat compresses the spring, and iPEG converts the energy into pacemaker power.



AMERICAN CHEMICAL SOCIETY

EVERLASTING BATTERY | A spring charges a pacemaker by means of heart beats.

DEBBIE HILL/UPI/RITZAU SCANPIX

A 3D printer can prevent the body from rejecting a transplanted heart. A fully functional new heart can now be 3D-printed by stacking stem cells of the patient's own fat tissue, which will later develop into muscles, blood vessels, etc. The heart copy is based on a CT scan of the patient's body.

PhotoDoc

SPRINGS, CLIPS, ROBOTS, AND PRINTERS KEEP THE HEART GOING.

ORGAN FACTORY | A 3D printer uses stem cells to build hearts.

NEW SERIES

RESISTANCE

When a bacterial infection remains unaffected by antibiotics, doctors talk about resistance. This makes it more difficult to treat diseases and increases the risk of pneumonia, childbirth and even minor injuries suddenly becoming potentially lethal.

"We will soon run out of antibiotics"

YES & NO

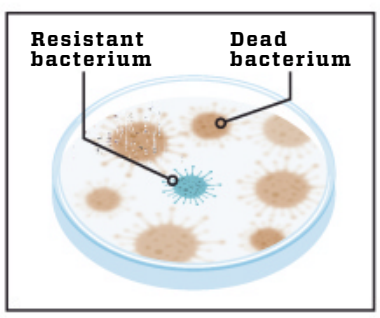
The pharmaceutical industry finds it difficult to develop new drugs as rapidly as bacteria develop resistance. Right now, the bacteria have the upper hand.

Before the 1950s, even skin scratches could be lethal if they caused infection. Since then, penicillin has saved more than 200 million lives, but bacteria have also become smaller and less receptive to treatment. The phenomenon of resistance originates when a bacterium develops an ability to pump antibiotics out through the cell wall, or it produces enzymes that break down the antibiotics into something harmless.

Over the past 50 years, only three entirely new classes of antibiotics have been discovered. During the same period, bacteria have developed resistance against all known drugs – except for the most recent one, odilorhabdin, which is not yet available. Some doctors are warning of a new 'medieval medical era' where infections go berserk and cannot be treated.

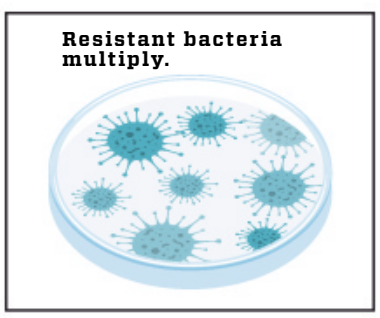
Scientists suggest that the search for new antibiotics should be internationally prioritised by bodies such as the UN. The potential rewards of tens of billions of dollars should motivate drugmakers to develop new antibiotics.

BACTERIA BECOME INVULNERABLE TO ANTIBIOTICS



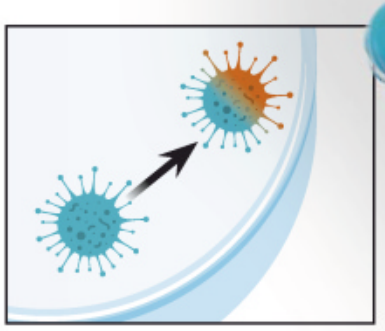
Resistance survives

1 Natural mutations make a bacterium resistant to an antibiotic that kills all other bacteria.



Bacterium multiplies

2 Without any competition, the resistant bacterium multiplies, so the entire colony becomes resistant.



Resistance spreads

3 The resistant bacteria share their DNA with other species of bacteria, spreading the resistance.

Only 2 in 7 antibiotics are efficient against this bacterium.

SHUTTERSTOCK

SHUTTERSTOCK & LOTTE FREDSLUND

"Resistance is not a problem in Australia"

FALSE

In a study of 19 Australian hospitals and 2767 patients between August and November 2018, presence of a multi-drug resistant organism was documented for 10.3% of patients.

Australians are still very high users of antibiotics, although AURA 2019 (the third in a series of antimicrobial use and resistance reports) found that overall use of antibiotics in the community fell between 2015 and 2017 – the first decline in 20 years. Nevertheless more than 10 million Australians had at least one antibiotic dispensed in 2017 and more than 26 million prescriptions for antimicrobials were issued, indicating prescribing rates that far exceed the recommended ranges set by the European Centre for Disease Prevention and Control.

Almost half the samples of enterococci tested across Australia were resistant to the antibiotic vancomycin – a level higher than seen in any European country.

According to the OECD, the number of people who die in Australia each year as the result of infections from eight drug-resistant bacteria is:

290

SHUTTERSTOCK

"Only bacteria become resistant"

FALSE

One of the most contagious multi-resistant organisms in the world is not a bacterium, but a yeast fungus. *Candida auris* was discovered in 2009 in the ear of a Japanese woman. *Candida auris* easily survives traditional fungicides, and even the most sophisticated ones in 20% of cases. Physician Tom Chiller, who heads the fungus research unit of the American Centers for Disease Control and Prevention considers *Candida auris* "more contagious than ebola".

By August 2019, 36 nations had recorded one or more *Candida auris* infection cases, including Australia.

Test Yourself

SEE THE ANSWERS ON PAGE 17. NO PEEKING!

MIND BOMBS!

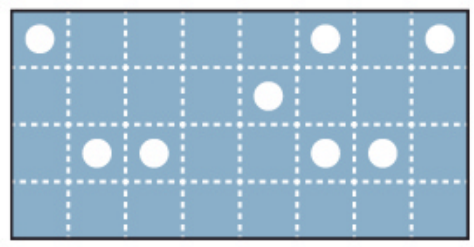
Solve problems designed for different types of intelligence and find out in which you excel.

Editor: **Jeppe Wojcik**
// Text & Art: **Anker Tiedemann**

VISUAL INTELLIGENCE

1 Which figure replaces the question mark?

2 Divide the rectangle along the lines into eight pieces of the same shape and size. Each piece must include a white dot (in any position).



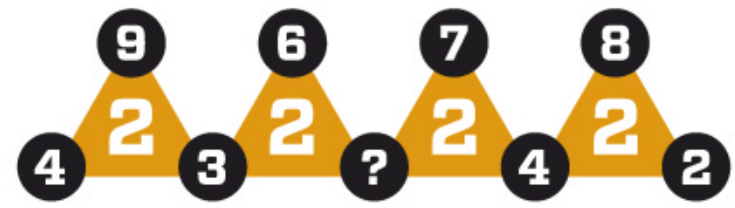
LOGIC

5 There are 65 pieces of candy. Adam is older than Eva, so he gets 1.5 times as many pieces. How many do they each get?

6 At a party, everyone drank something: half of the guests drank wine, 25% drank beer, one in six drank soda, and three people drank water. How many guests were there?

NUMERACY

3 What is the result of this calculation, if the frog colours represent 1, 2, 3, and 4?



4 Which number replaces the question mark?

Scientist in Focus

CREATIVE COMMONS

Name: Neil Armstrong
Life span: 1930-2012

The first man on the Moon became a scientist

After Neil Alden Armstrong took the first step on the Moon in 1969, he had a nine-year career as professor, teacher & researcher at the University of Cincinnati, exploring hypersonic flight and aerodynamic design.

7 As a professor, Armstrong cooperated with a famous doctor. Who was it?

A) Michael Crichton
B) Dr Virginia Apgar
C) Henry Heimlich
D) Dr Spock

8 Which wrecked space shuttle did Armstrong investigate in 1986 as part of the Rogers Commission?

A) Atlantis
B) Columbia
C) Challenger
D) Discovery

9 In which ocean did Neil Armstrong land when he returned to the Earth from the Moon?

A) The Mediterranean
B) The Atlantic
C) The Antarctic
D) The Pacific

10 What is the name of the landing module in which Armstrong and Buzz Aldrin landed on the Moon?

A) Albatross
B) Eagle
C) Birdie
D) Big Bird

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