

WHAT ARE PLANKTON?

HOW IT WORKS



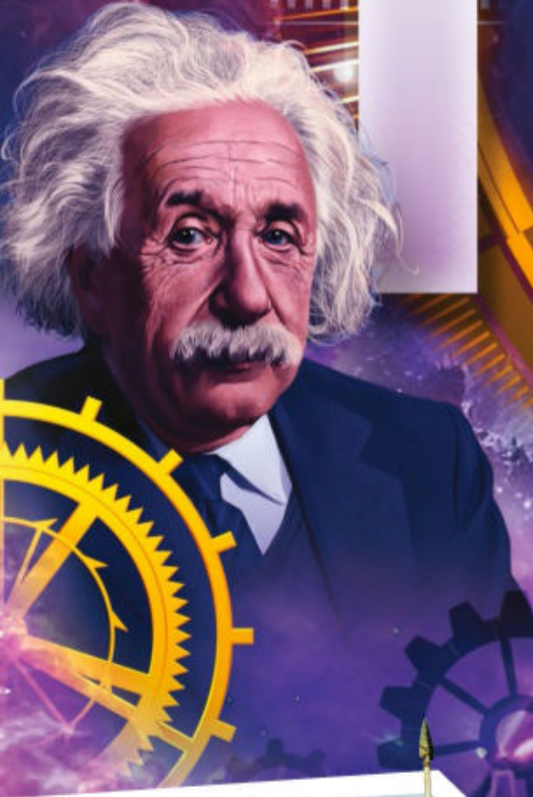
INSIDE THE BIGGEST NUCLEAR FUSION MACHINE

HOW TO SURVIVE THE AUSSIE OUTBACK

TIME

ATOMIC CLOCKS, ANCIENT MACHINES, BLACK HOLES AND THE CRAZY WAYS THIS FORCE OF NATURE AFFECTS US

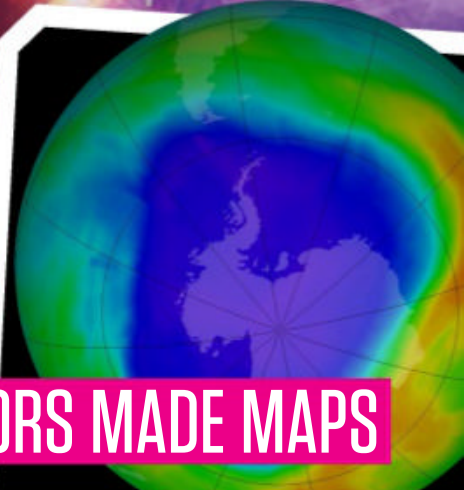
DISCOVER SEASONS ON OTHER PLANETS



WHO WERE THE FIRST AMERICANS?

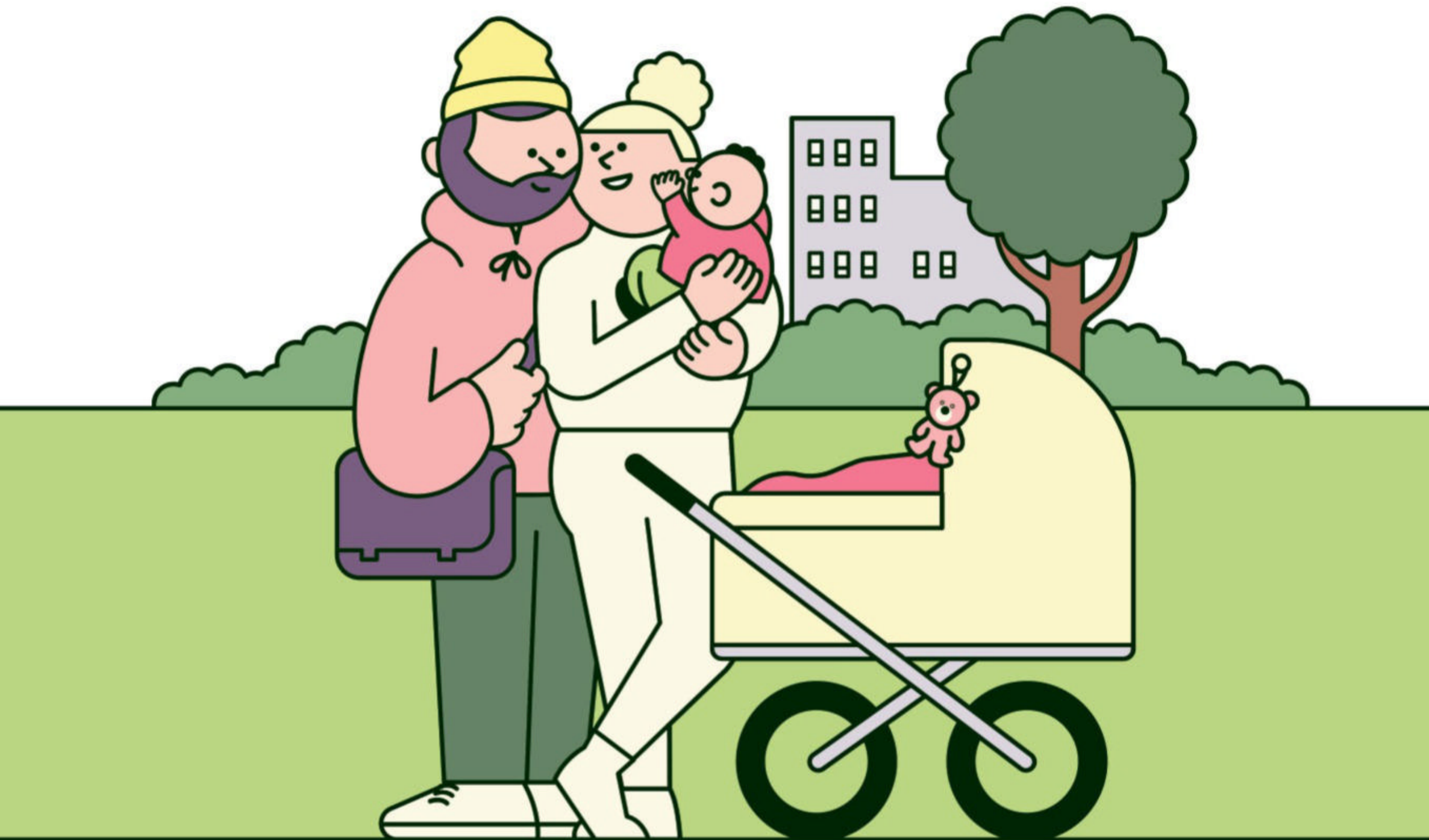
WHERE THE OZONE LAYER CAME FROM

FUTURE
ISSUE 187



+ WHAT ARE YOUR TONSILS FOR? / GIANT SOLAR BOAT / HOW OUR ANCESTORS MADE MAPS

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YOU MAKE
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INSIDE

Issue 187

SPECIAL

26 Time How we measure this unstoppable force of nature and its intimate connection with space

TRANSPORT

34 Aboard the world's largest solar boat
This catamaran runs on sunshine, powering its journey around the globe

36 Anatomy of a wrecked car
How a supersized hospital scanner is being used to look inside mangled cars and learn how to make them safer

HISTORY

38 The first map-makers
How did ancient cartographers calculate and draw the contours of their countries?

42 Who were the first Americans?
The first humans in the Americas may have arrived thousands of years before we thought

SPACE

46 Seasons in the Solar System
Do other planets have a spring, summer, autumn and winter?

50 Inside the asteroid belt
Any ideas this ring of debris had of forming a planet were wiped out by the Solar System's largest inhabitant

SCIENCE

52 Inside a giant fusion machine
JT-60SA will pave the way for making nuclear fusion a viable energy source of the future

56 What are your tonsils for?
You might not pay them much attention until you get sick, but these fleshy lumps can shield you from illness

58 Stem cells uncovered
How a change in approach may unlock their limitless potential

62 What is keratin?
Learn about the vital protein that helps hold your body together

ENVIRONMENT

64 How to survive the Australian Outback
From bush tucker basics to sourcing trapped water and battling crocodiles

70 Where did the ozone layer come from?
The invisible layer in the atmosphere that protects us from deadly radiation formed billions of years ago

72 What are plankton?
Drifting through the world's waters are tiny organisms that feed fish and trap carbon

TECHNOLOGY

76 Garden tool guide
These manual and electric implements are vital for growing vegetables and maintaining a perfectly manicured lawn

80 How a bowling alley works
Explore the inner mechanisms of ten-pin bowling and discover how pins and balls quickly resume position following a strike



80



34

Win
ONE OF TEN
BUILD YOUR OWN
MICROSCOPE
KITS
PAGE 82



64

REGULARS

06 Global eye
Science and tech news from around the world

22 Wish list
Movie night gadgets

84 Braindump
Your questions answered

90 Book reviews

92 Brain gym
Give your brain a workout with our puzzle pages

94 How to...
Make a water bridge with string

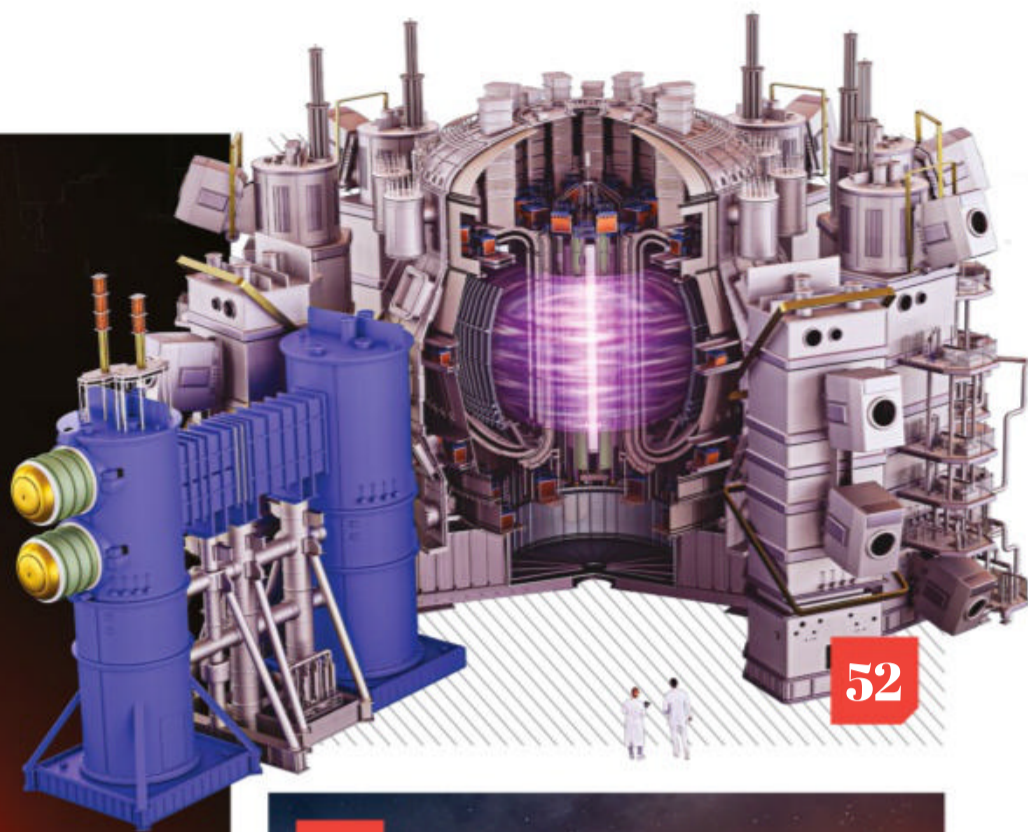
96 Letters
Have your say

98 Fast facts



72





52



46

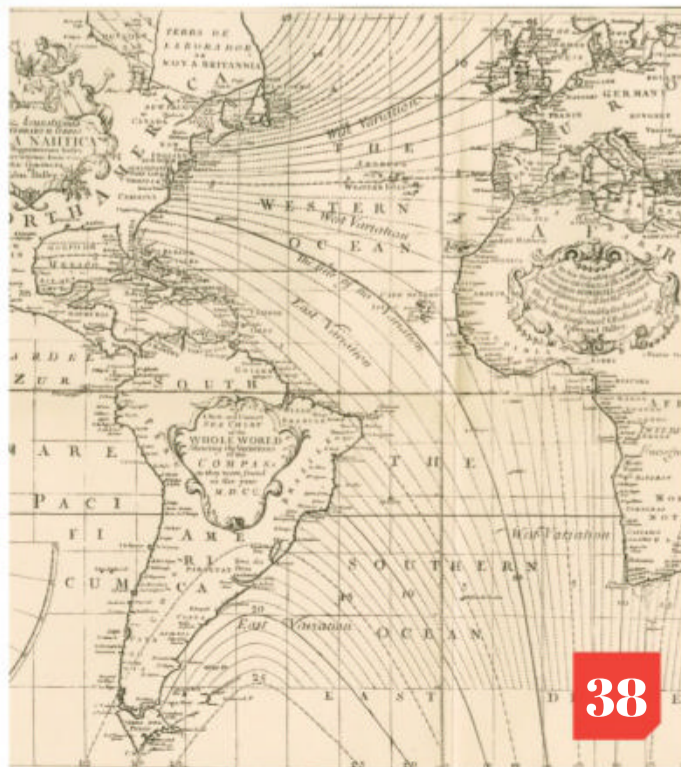


36

26



76



38

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Volcanic descent

In this image, an abseiler can be seen descending towards the eruption of one of the world's largest lava lakes. More than 1,000 miles off the east coast of Australia lies the country of Vanuatu, an archipelago of over 80 islands spanning almost 5,000 square miles. Within this archipelago is the island of Ambrym and Mount Marum, the crater of which forms the lake.



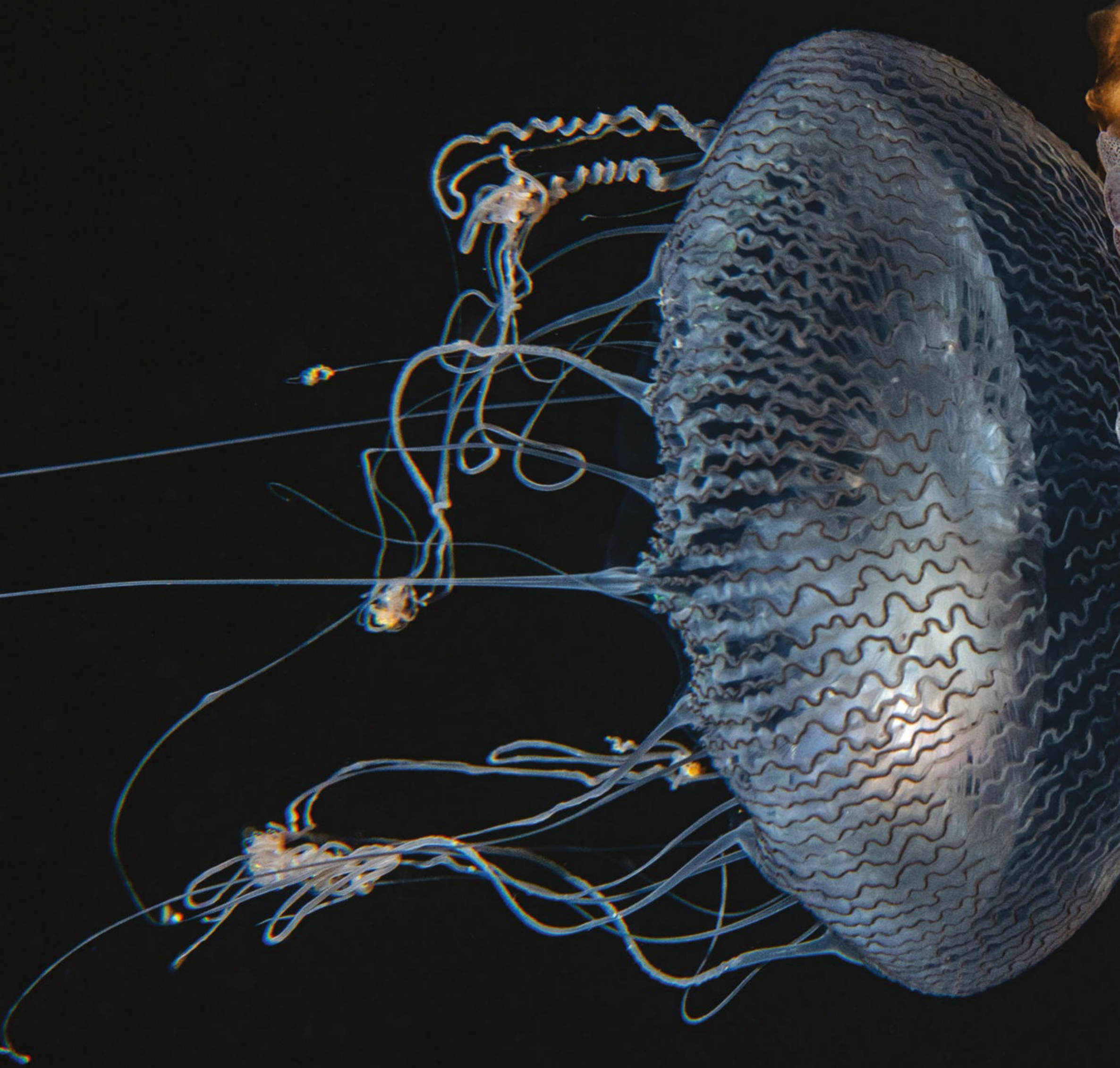




Amplified aphid

This imposing view of a green spruce aphid was captured using a scanning electron microscope. These sap-sucking insects are known to infest spruce trees, inflicting damage by secreting a toxin through their saliva while they feed. Using their pointed mouthparts, spruce aphids break through the exterior of the tree's leafy needles to drink the nutrient-rich sap stored within.







Jellyfish rides

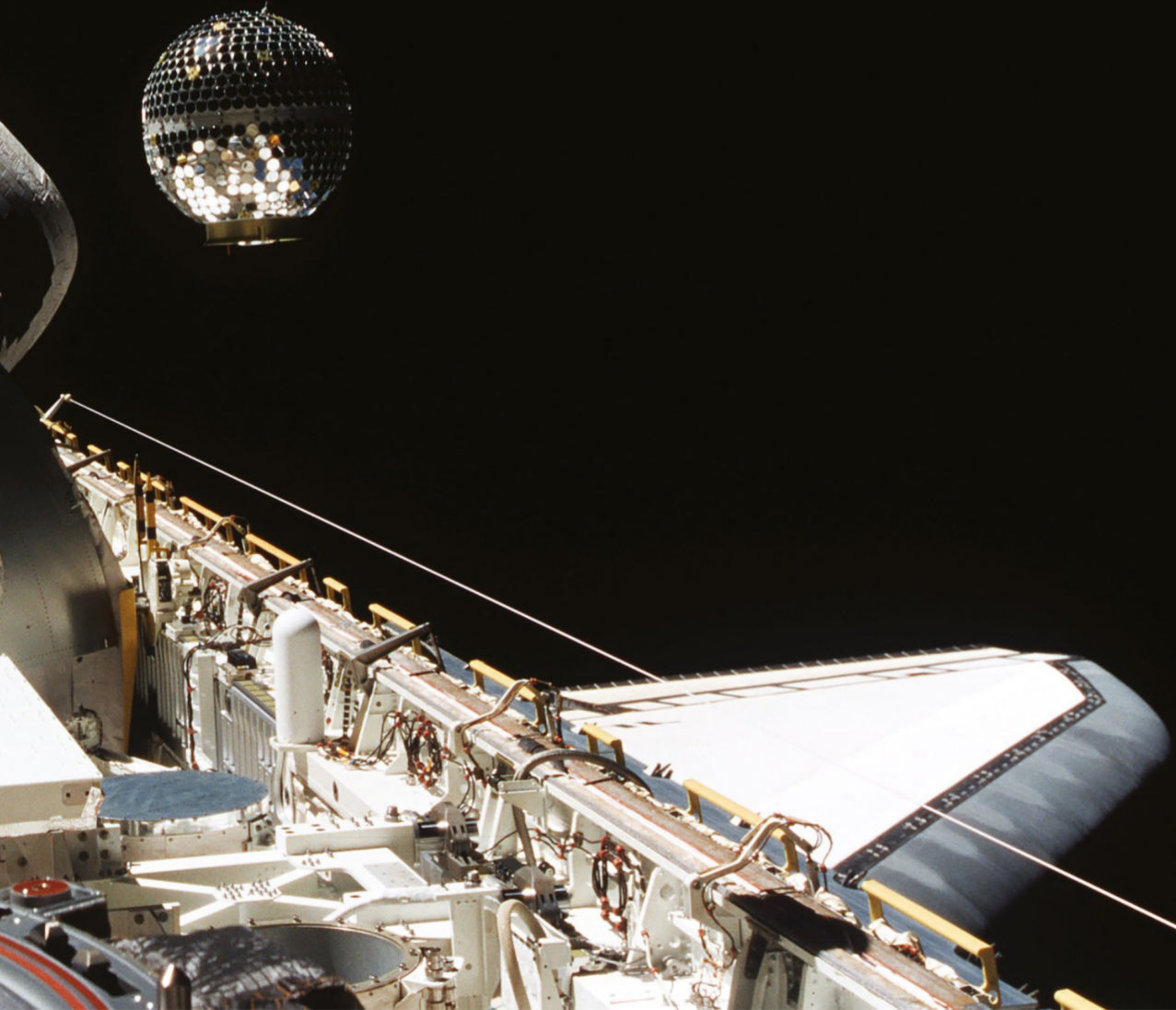
Sitting politely on top of a deep-sea jellyfish, this female argonaut was hitching a ride. They're often seen riding on driftwood or the occasional jellyfish, with the stinging cells protecting them from potential predators in transit. When female argonauts reach maturity, they fill their paper-thin shells with eggs before ejecting from the shell and leaving the eggs behind to incubate and hatch.





A disco ball in space

Although it might look like the astronauts aboard Space Shuttle Endeavour were throwing a disco in space in 2001, they were releasing a satellite with 858 mirrors called STARSHINE 2 into orbit around 230 miles above Earth's surface. While in orbit the spherical satellite collected and calculated data on the density of Earth's upper atmosphere before hurtling back to the surface in 2002.



SPACE

Five Earth-like worlds may lurk at the edge of the Solar System

WORDS DEEPA JAIN

Rocky planets captured by the Sun may reside in the outer Solar System, circling the Sun over tens of thousands of years

Most astronomers agree that there are only four terrestrial, or rocky planets in our Solar System, all of which lie close to the Sun. But new research suggests that up to five more may be lurking at the outer bounds of the Solar System. Free-floating planets are planet-sized objects that don't orbit a star. Also called rogue planets, free-floating planets either form from clumps of gas unconnected to any star or arise around stars but get flung out of their original orbits. The James Webb Space Telescope has identified hundreds of rogue planets in the Milky Way and beyond, including waltzing pairs of Jupiter-sized planets in the belly of the constellation of Orion. Simulations show that most free-floating planets are probably as big as Mars.

While some rogue planets are ejected by their stars, stars could also reel in these lonely wanderers with their gravity, making the planets permanent orbiting members of a solar system. In a recent study, researchers propose that our own Sun, in its infancy, may have lured rocky free-floating planets too. To determine the likelihood of this, researchers

used several previously developed models, or sets of equations, built on observations of free-floating planets. Assuming that our infant star had a 1-in-50 chance of trapping a rogue planet, researchers conducted 100 million simulations, tweaking factors like orbit shape to determine how many rocky worlds the Sun may have captured. The researchers also assumed the Sun's birth environment was pretty cramped to estimate the number in the worst-case scenario, as under such circumstances "planetary capture is more difficult," said Amir Siraj, a doctoral candidate in astrophysics at Princeton University.

The study found that two planets with a Mars-like mass, or three to five with a mass similar to Mercury's, may dwell roughly 1,400 astronomical units (AU) from the Sun – one AU being the distance between Earth and the Sun. That would place the trapped rogue planets in the Oort Cloud, a hypothetical giant bubble of billions of icy, mountain-size objects that cocoons the Solar System. The newly proposed planets are independent of Planet X, a yet-to-be-discovered hypothetical Neptune-like world hypothesised to orbit about 43 AU from the

Sun. Unlike the new study, which relies on theory, scientists have predicted Planet X's existence based on observations of the strange trajectories of objects in the Kuiper Belt – a doughnut-shaped region of icy bodies that extends from Neptune to the Oort Cloud.

Even though the captured terrestrial worlds would likely be more Earth-like than Planet X, their suitability as habitable real estate remains speculative. While water may exist as icy sheets, sunlight would be "very faint, comparable to the brightness [of] moonlight here on Earth," Siraj said. But because the theorised planets come from other star systems, and are thus exoplanets, future space missions investigating exoplanets may target them. Yet finding the newly proposed planets will be even trickier than identifying Planet X, as they're much smaller and more distant than that proposed planet. Siraj believes that the Vera C. Rubin Observatory in Chile, slated to go live in 2025, could identify a former free-floating planet lying closer than 700 AU, but only if "it's in the southern sky and close enough to us, with a high enough albedo," the ability to reflect light that illuminates it.



Bottlenose dolphins have been observed attacking manatee calves near Belize

ANIMALS

Dolphins are bullying baby manatees

WORDS MELISSA HOBSON

Dolphins are mysteriously attacking manatee calves, and this hostile behaviour may be a regular occurrence. In a recent study, researchers documented ten aggressive interactions by bottlenose dolphins towards Antillean manatee calves that targeted orphans as well as youngsters that were with their mothers. The attacks occurred near Belize over a 21-year timespan, from 1999 to 2020, with the majority of instances occurring between 2015 and 2020. “Dolphins don’t eat manatees, and why they act this way with another species is unclear,” said Eric Angel Ramos, a scientist at the Fundación Internacional para la Naturaleza y la Sustentabilidad. “It’s likely they are quite curious when they encounter manatees, and because dolphins are often aggressive with each other, they display this behaviour to other species like manatees.”

The researchers observed dolphins attempting to separate calves from their mothers and harassing, ramming and biting them. In each case, the dolphins initiated the interaction. Researchers believe the attacks were intentional. “I’m confident in saying that I think they want to inflict death,” said Jérémy Kiszka, a biological science professor at Florida International University. The researchers also found tooth rake marks with spacing that indicated dolphin teeth on orphaned calves

during health checks, providing further evidence of these violent assaults. Although scientists don’t fully understand what’s going on, dolphins are known to display similar behaviours with their own young and calves from other species. They have previously been recorded biting other dolphins, and are known to attack and kill harbour porpoises.

Dolphins might act aggressively towards manatees and other marine animals because they perceive them as competitors for food, space or resources. And if these animals’ ecosystems degrade due to climate change and human activities, there’s a chance it could cause the species’ habitats to overlap

further, resulting in an increase in these hostilities, Kiszka said. The aggressive interactions between manatees and dolphins took place over many years, so they’re likely more common than scientists previously thought and could impact the survival of the species. Antillean manatees are threatened across their range; this subspecies of the West Indian manatee can be found in marine, brackish and freshwater environments from southeastern Texas to northeastern Brazil. Even around Belize, which has a relatively healthy population, they’re threatened by vessel collisions. Understanding what’s going on could help conservationists protect calves and the wider manatee population, Kiszka said.

Did you know?

There are 42 species of dolphin and seven porpoise species

HISTORY

RARE ROMAN ARMOUR WAS PIECED TOGETHER LIKE A JIGSAW PUZZLE

WORDS JENNIFER NALEWICKI

Conservators at National Museums Scotland have reconstructed a 1,800-year-old segment of Roman armour that was broken into more than 100 pieces. Over several weeks, conservators painstakingly pieced together what they’re calling an ancient jigsaw puzzle. The second-century brass armour was shattered into pieces, discovered in 1906 scattered throughout Trimontium, a former Roman fort located southeast of Edinburgh. The fragments have been in the museum’s collection ever since, with the upper portion on display for the past 25 years.

“This is an incredibly rare object, and it’s great that this exhibition gave us the opportunity to rebuild it,” said Fraser Hunter, principal curator of prehistoric and Roman archaeology at National Museums Scotland. Researchers thought the artefact was part of a thigh guard used by a cavalryman. But as conservators worked out the arduous puzzle, they realised it was an armguard inspired by similar equipment worn by gladiators. The piece would have stretched from the shoulder to the hand and protected the wearer in battle. The rebuilt artefact will be on display until 23 June 2024.



The reconstructed brass armguard will be on display as part of an exhibition at National Museums Scotland

An image of the galaxy UGC 5189A, taken by the Hubble Space Telescope

Did you know?

A supernova occurs somewhere in the universe every ten seconds



SPACE

Hubble observes a supernova 2.5 billion times brighter than the Sun

WORDS ROBERT LEA

A new Hubble Space Telescope image shows the tiny galaxy UGC 5189A, located about 150 million light years away in the constellation of Leo, in stunning detail. The space telescope, which has been observing the universe since 1990, has been studying this galaxy since 2010, with scientists using this investigation to learn more about a supernova that occurred in this galaxy over 150 million years ago. Over just three years, this supernova, called SN 2010jl, emitted at least 2.5 billion times more visible energy than the Sun released over the same time frame across all wavelengths.

SN 2010jl is a Type II supernova, meaning that it marks the death of a massive star that during its life would have had a mass of at least 40 to 50 times that of the Sun. These explosions occur when these massive stars have run out of the fuel for nuclear fusion, and the energy that for millions or billions of years supports them against the inward push of gravity ceases.

While studying supernovae themselves is of immense value to scientists, examining the wreckage that these cosmic explosions leave behind can be equally fruitful. For example, studying the environments around detonated stars can show the conditions needed to drive a supernova and how that supernova changes its

surroundings. This interest means Hubble has found itself directed at UGC 5189A many times. This new picture is created from data collected during the long-serving space telescope's last three observation periods of the distant galaxy, which is just 36,000 light years across, making it diminutive compared to our 100,000-light-year-wide galaxy, the Milky Way.

The image shows UGC 5189A as a flat, somewhat misshapen disc with a warped upward curve. The right-hand side of the galaxy is marked by 'blue fizz' that represents plumes of bright gas and dust. The left side of UGC 5189A is less dramatic and striking, slightly dimmer with patchier coverings of gas and dust. Outside the main bright disc of the galaxy, a dark coffee-coloured trail of gas underlines UGC 5189A and leads up away to the top left-hand corner of the image. While the background of the galaxy is mostly dark, a few small galaxies can be seen punctuating the inky blackness, and one star is clearly visible in the top right-hand corner of the Hubble image.

Hubble hasn't just been studying UGC 5189A to zoom in on supernova wreckage. The space telescope has also examined several other supernova-hosting galaxies located around 1,000 million light years away that saw stellar explosions in their recent pasts – at least as we see them.

SPACE

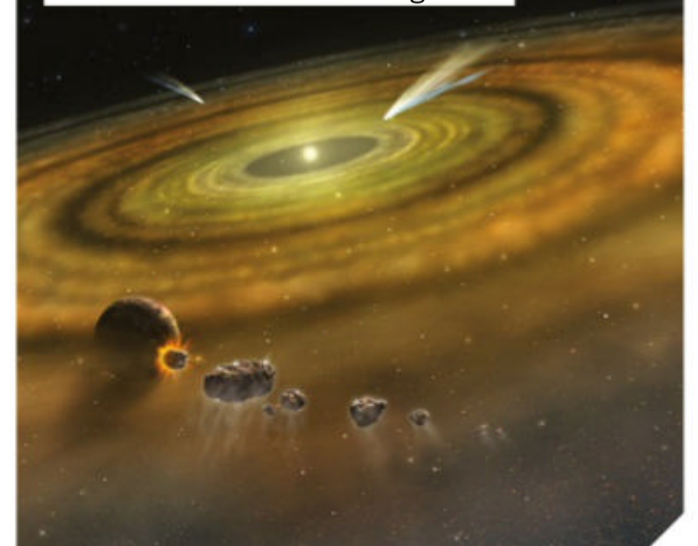
EARTH'S WATER MIGHT HAVE COME FROM ANCIENT SPACE ROCKS


WORDS RAHUL RAO

The Solar System's rocky planets are the products of tiny planetesimals, pebbles of primordial cosmic dust that assembled themselves more than 4 billion years ago. Now, a new analysis suggests those planetesimals already contained water. Researchers tested samples from meteorites they say are just as ancient as those planetesimals, and they found the fingerprints of chemical reactions known to occur in the presence of water.

There's no water in these samples today, but scientists can trace water they once held. Over time, if water is in the presence of other elements, the water molecules' oxygen atoms will separate and join up with those elements – water and iron will beget iron oxide, the substance that colours Mars' surface rust-red. Even iron oxide is now long gone in the meteorites, but when it faded it would have taken a bit of the meteorites' iron content away with it. Scientists can test for ancient water by measuring a meteorite's iron level in comparison to the space rock's other elements. Researchers expected to find about as much iron as nickel and cobalt. But instead they found quite a lot of missing iron in comparison, implying the presence of oxygen, and by extension water.

An artist's depiction of planets forming from a disc of material surrounding a star





The scientists behind the new model hope it will aid research into some of the most common eye conditions

HEALTH

Scientists develop a ‘crying’ model of human eye tissue

WORDS EMILY COOKE

Scientists have created the first 3D model of the human conjunctiva, the clear protective outer membrane of the eye, in the lab, and it even produces its own tears. The researchers say the new model could be used to study diseases that affect millions of people, such as conjunctivitis. The replica conjunctiva is an ‘organoid’, a lab-grown mass of cells made to resemble 3D, miniature versions of full-size tissues in the body. Organoids are typically grown from stem cells and enable scientists to recreate the structure and function of human organs. Because of this, the models are emerging as promising alternatives to using animals for drug testing.

Until now, there have been no realistic lab models of the human conjunctiva, which has limited research in the field. To make the new model, the researchers collected stem cells from conjunctival tissue provided by organ donors and patients who were undergoing eye surgery. Using chemicals called growth factors, the scientists coaxed the cells into 3D structures that mimicked the human conjunctiva. These organoids contained all the cells normally found in the conjunctiva, including mucus-producing cells, such as goblet cells and keratinocytes, which enable the tissue to make mucus-rich tears that protect and lubricate the surface of the eye. However, the researchers found that the latter cells also secreted antimicrobial proteins.

“We discovered that the conjunctiva makes antimicrobial components and therefore contributes to tear production in more ways than by simply making mucus,” said Marie Bannier-Hélaouët, a postdoctoral researcher in developmental biology and stem cell research at the Hubrecht Institute in The Netherlands. The new model

mimicked all the major features of the human conjunctiva, including its ability to produce mucus-rich tears. In addition to revealing these antimicrobial properties of keratinocytes, the model helped the scientists identify tuft cells, a type of cell not previously known to be in the conjunctiva. These are epithelial cells found in tissues that cover different surfaces of the body and have previously been linked to allergies. “Similar cells have been discovered in other tissues, but not in the human conjunctiva,” Bannier-Hélaouët said.

Researchers experimented with the new organoids by applying inflammatory chemicals called interleukins to the models to imitate what would happen during an allergic reaction. “The organoids started to produce completely different tears: there was more mucus, but there were also more antimicrobial components,” Bannier-Hélaouët said. The newly discovered tuft cells also became more abundant within the organoid, suggesting they may influence how our eyes respond to allergies.

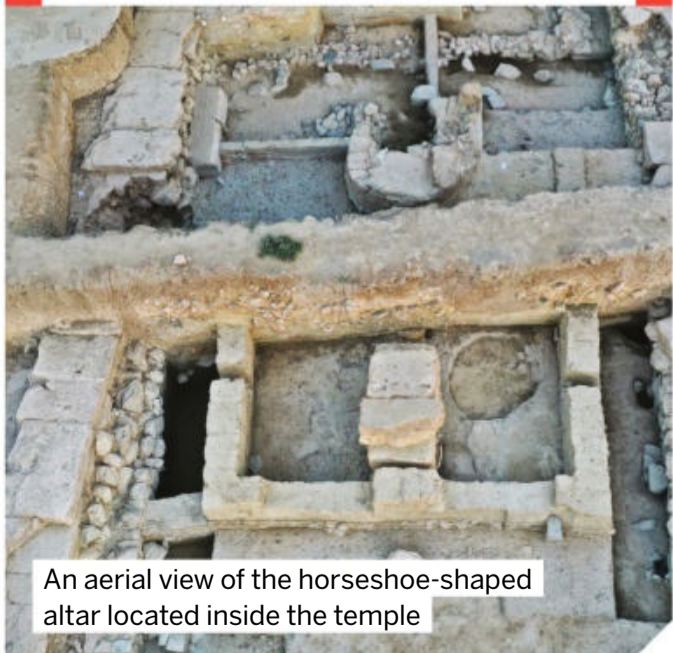
Researchers intend the model to be used to test new drugs to treat diseases of the conjunctiva, including dry eye, which is caused by a poor quantity or quality of tears, and pink eye, or inflammation triggered by an infection, allergies or irritants. In the recent study, the researchers infected the organoids with various viruses that are known to cause viral conjunctivitis and then treated the infections with drugs. For example, infection with herpes simplex virus 1 – which is mainly responsible for oral and genital herpes but can also cause conjunctivitis – was reversed using antiviral medications. More research is needed, but the researchers hope to one day use this approach to make replacement conjunctivae for people with eye burns, cancer or genetic disorders.

HISTORY

ANCIENT ALTAR COVERED WITH PRECIOUS GIFTS UNEARTHED IN GREECE

WORDS JENNIFER NALEWICKI

Archaeologists in Greece have discovered a 2,700-year-old temple that houses a horseshoe-shaped altar overflowing with offerings. Made of brick, the temple is 30 metres long and is located next to the Temple of Amarysia Artemis, a sanctuary dedicated to the Greek goddess Artemis, which researchers found in 2017. During excavations in 2023, archaeologists found the second temple. Structures included several hearths located in the temple's nave, including the ash-caked altar stacked with offerings. Some of its pottery pieces predate the newfound temple and were fired during the late 8th century BCE, leading researchers to suspect the altar may have once resided outside the temple and was moved indoors. In the 6th century BCE, brick partitions were placed at the sanctuary's heart for added support, leading researchers to think the temple was partially destroyed by a fire. Beneath the temple, they found several dry stone walls from a different building that once stood at the site, along with several bronze figurines shaped like bulls and a ram. They also unearthed remnants of buildings from the 8th and 9th centuries BCE next to the first temple.



An aerial view of the horseshoe-shaped altar located inside the temple

PLANET EARTH

Nearly 75 per cent of the US is at risk from earthquakes

WORDS BEN TURNER

Nearly 75 per cent of the US could be struck by damaging earthquakes, the US Geological Survey (USGS) has discovered. The new finding, made by a model used to build a colour-coded earthquake map, reveals that millions of Americans live in areas with a high earthquake risk. That includes known earthquake hazard zones such as Los Angeles, San Francisco, Portland and Seattle, but also locations like Salt Lake City and Memphis.

According to the new model, 37 US states have experienced earthquakes greater than magnitude 5.0 in the last 200 years. The new information helps update the odds of harmful earthquakes in the seismically active regions of Alaska and California and highlights the possibility of more damaging earthquakes along the central and northeastern Atlantic coastal corridor, which includes the cities of Washington DC, Philadelphia, New York and Boston. "Earthquakes are difficult to forecast, but we've made great strides with this new model," said Mark Petersen, a geophysicist at the USGS. "The update includes more faults, better characterised land surfaces and computational advancements in modelling that provide the most detailed view ever of the earthquake risks we face."

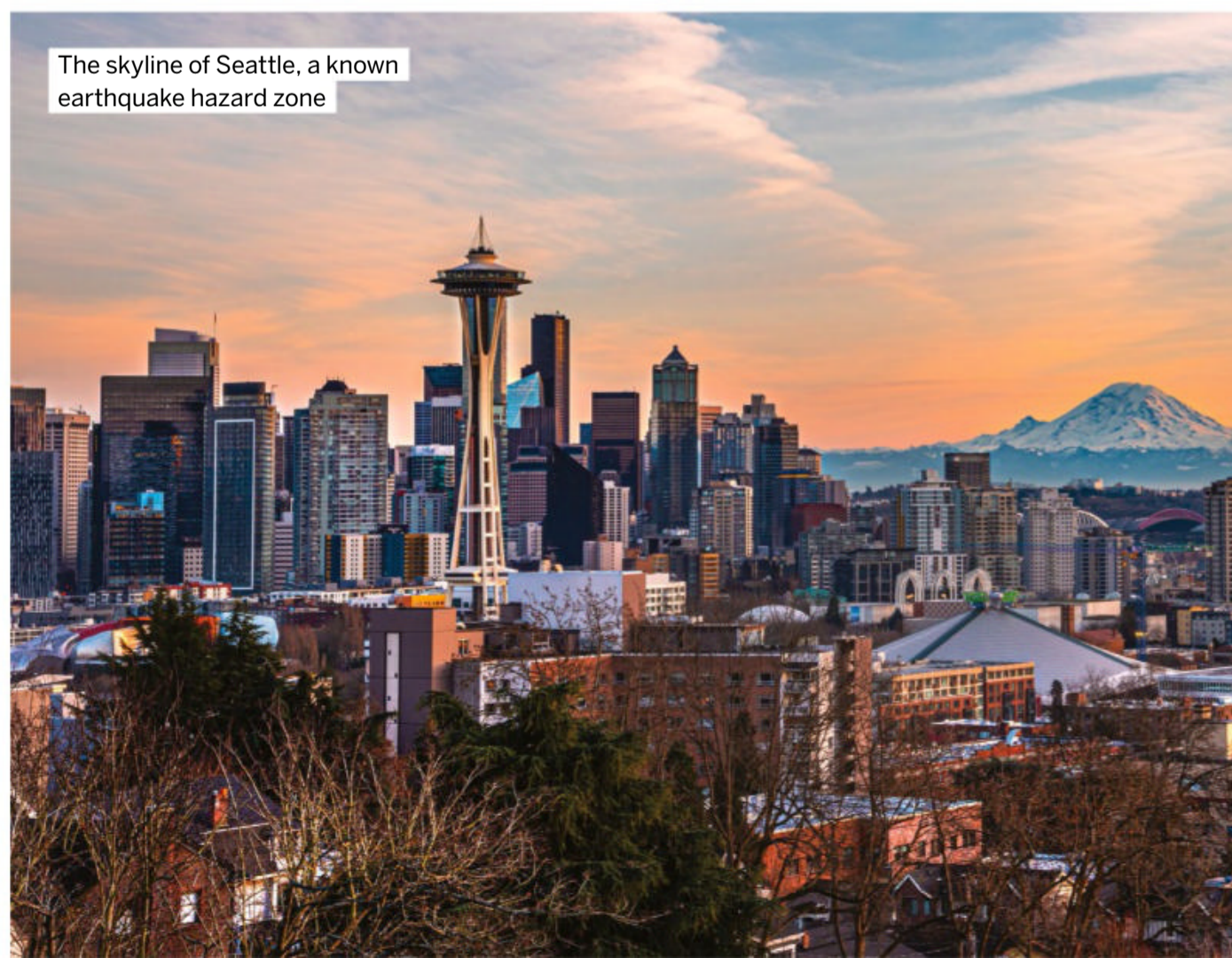
Earthquakes occur because tectonic plates get locked together as they move over the mantle. The forces that caused them to collide continue to build up until the plates suddenly shift. This creates a gigantic rupture, releasing energy in the form of potentially devastating seismic waves that violently shake the ground. Scientists have searched for patterns that could forecast major earthquakes for decades, but without a precise map of Earth's

subterranean crust, these efforts have come up short. Instead, geophysicists collate data on past earthquakes' locations and magnitudes to create risk maps indicating where the strongest and most frequent temblors could hit.

The new map is the first National Seismic Hazard Model to chart this risk across all 50 states, and is the result of a collaborative effort between federal, state and local officials. Notably in the new model, the strength of the earthquakes in Hawaii have been upgraded – a consequence of increased volcanic activity witnessed in recent years in the region. "This was a massive, multi-year collaborative effort between federal, state and local governments and the private sector," Petersen said. "The new seismic hazard model represents a touchstone achievement for enhancing public safety."

Did you know?

Around 20,000 earthquakes occur each year around the globe



The skyline of Seattle, a known earthquake hazard zone

New technology may cut electric vehicle charging times and boost their range

WORDS VICTORIA ATKINSON

A technology that could dramatically increase the range and decrease the charging time of electric vehicle (EV) batteries could soon be in many more cars. The technology swaps the graphite normally used on the negatively charged anodes of lithium-ion EV batteries for silicon. Panasonic recently announced a partnership with Sila Nanotechnologies, which makes the silicon anodes, to integrate the technology into the company's existing battery production line in 2024.

Over 14 million electric vehicles were sold in 2023, and their popularity is expected to increase in the coming years. Currently, these vehicles use high-performance lithium-ion batteries. While these batteries are getting better every day, some obstacles still limit their usability and convenience. "The capability of a battery to store energy in relation to its size and weight, known as energy density, is a key factor for electric vehicles, as it affects the distance they can cover on a single charge," said Azin Fahimi, chief scientific officer at Sienza Energy, who leads a team working on a different silicon anode implementation than Sila. "Another crucial aspect is power density, which refers to how quickly a battery can supply energy." In other words, if a car can't go very far between charges, it's a nonstarter for many consumers. So why does the new silicon anode have such a dramatic impact on the range and charge time?

Batteries rely on the movement of charged particles, known as ions, between the electrodes, or two electrical conductors. During charging, lithium ions move from the positive electrode, called the cathode,

through a conducting solution called the electrolyte and into the negative electrode – the anode – where they are stored until power is needed. "When the battery is providing power to a device, the lithium ions move back from the anode to the cathode," Fahimi said. "This movement of ions allows electrons to flow through the external circuit, generating an electric current that powers the device."

Because the ions are stored on the anode until they're needed to power the car, the anode material plays a critical role in a battery's performance. "A good anode should possess a high lithium storage capacity to ensure high energy density, good electrical conductivity to facilitate efficient electron flow and fast ion transport for rapid charging capabilities," Fahimi said. The anode also needs a stable structure that doesn't change in volume when ions are flowing in and out of it, as this can damage the surface.

Conventionally, lithium-ion batteries have used graphite anodes. The layered structure of this conducting material means ions can move into and out of the anode without it changing much in volume. However, due to its chemistry, silicon can hold more than tenfold more energy per gram. "This higher capacity means that silicon can store more lithium ions, resulting in a higher energy density," Fahimi said. "A higher energy density translates to a longer range for electric vehicles on a single charge." Unfortunately, silicon swells to three or four times its original size when filled with lithium ions, leading to "mechanical stress and eventual degradation of the anode material." Careful nanoscale design of the silicon anode is crucial to overcoming this challenge.

The circular DNA of mitochondria contains key genes implicated in Parkinson's

HEALTH

Gene variant guards against Parkinson's disease

WORDS NICOLETTA LANESE

People who carry a rare gene variant are about half as likely to develop Parkinson's disease than people who carry a different version of the gene, a new study has found. Researchers have started to unravel exactly how this genetic quirk might protect against Parkinson's by preserving the function of a crucial enzyme needed for cells' metabolism and survival. A better understanding of the protective mechanism could lead to new treatments for the disease. "This study advances our understanding of why people might get Parkinson's and how we might develop new therapies for this devastating disease," said Dr Pinchas Cohen, dean of the University of Southern California Leonard Davis School of Gerontology.

Parkinson's disease emerges when movement-controlling cells in the brain die off over time. The loss of these neurons causes the well-known movement symptoms of the disease, such as tremors, muscle stiffness and impaired balance, as well as lesser known symptoms including emotional changes, sleep disturbances and cognitive decline. Scientists don't yet fully understand what triggers the neuron loss in Parkinson's, but the dysfunction of

mitochondria, the powerhouses of cells, has long been considered a hallmark of the disease. The gene variant uncovered in the new study is related to the function of mitochondria, underscoring the importance of this connection.

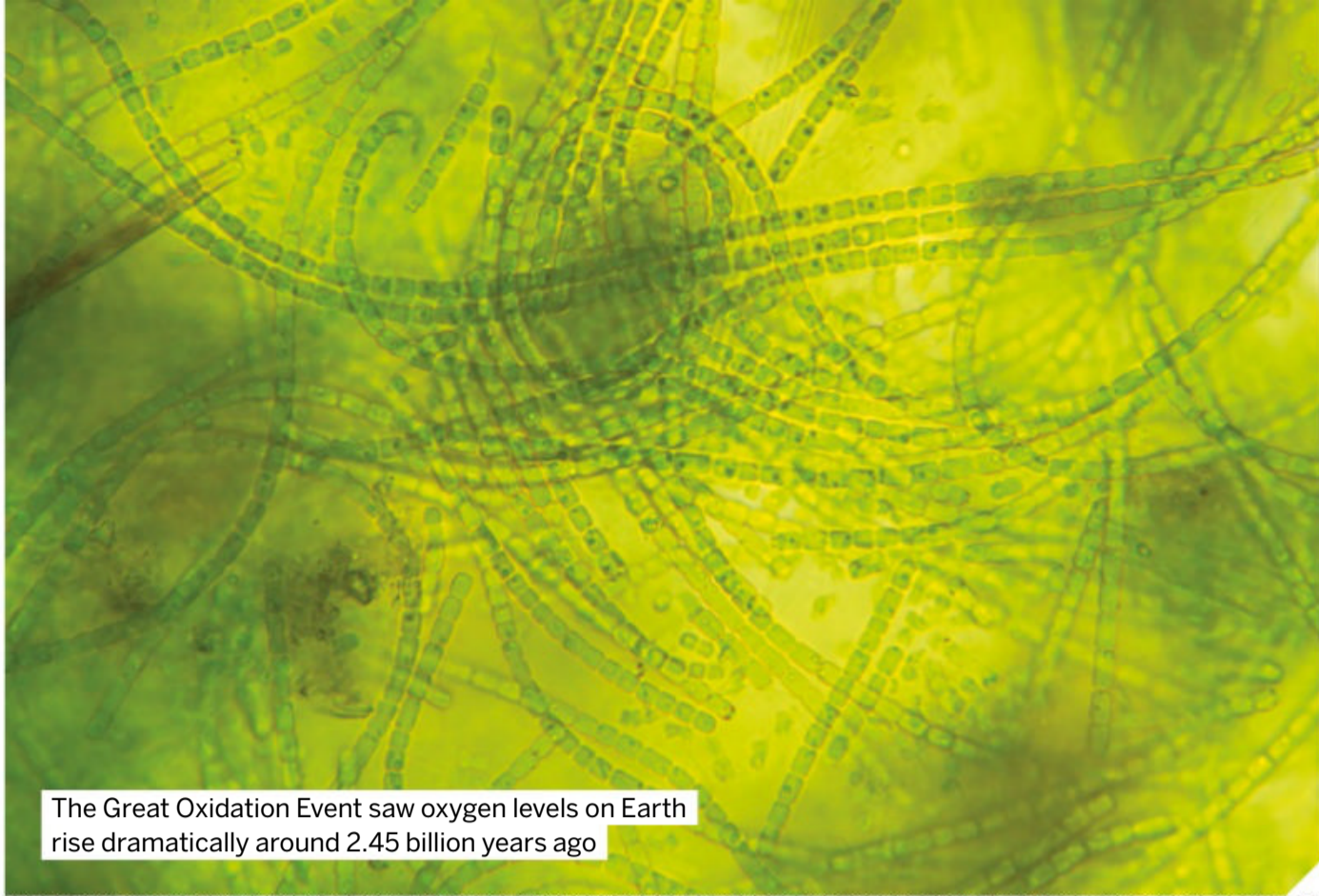
The majority of our DNA lies tucked away in cells' control centres, or nuclei, but mitochondria actually carry their own set of DNA that's passed down from mother to offspring. In previous research, Cohen and his colleagues found that a tiny protein made in the mitochondria, called SHLP2, appears key to their function and declines with age. Later, other researchers found that certain versions of the gene for SHLP2 are tied to a lower Parkinson's risk, but it wasn't clear why. So Cohen and his collaborators zoomed in on the SHLP2 gene. First they screened for different versions of the gene in the mitochondrial DNA of thousands of people who participated in three large, long-term studies: the Health and Retirement Study, the Cardiovascular Health Study and the Framingham Heart Study. The protective version of SHLP2 appeared in one per cent of these individuals, all of whom were of

European ancestry, and it was associated with half the chance of Parkinson's disease compared with other versions of the gene. Through experiments with human cells in lab dishes and additional tests with mice, the researchers found that the gene variant likely boosts both the stability and the prevalence of the SHLP2 protein. In turn these changes prevent dysfunction in a key enzyme in mitochondria.

Together, the researchers' results suggest that a potential treatment strategy for Parkinson's could involve supplying cells with this super-stable protective SHLP2 protein to help keep their mitochondria working. But this idea will require much more research to confirm. "Our data highlights the biological effects of a particular gene variant and the potential molecular mechanisms by which this mutation may reduce the risk for Parkinson's disease," said Su-Jeong Kim, an adjunct research assistant professor of gerontology at the USC Leonard Davis School. "These findings may guide the development of therapies and provide a roadmap for understanding other mutations found in mitochondrial microproteins."

Did you know?

Genetics are responsible for 10 to 15 per cent of Parkinson's cases



The Great Oxidation Event saw oxygen levels on Earth rise dramatically around 2.45 billion years ago

PLANET EARTH

1.75-billion-year-old fossils provide evidence of photosynthesis

WORDS JACKLIN KWAN

The earliest direct evidence of photosynthesis has been discovered in fossils dating back to 1.75 billion years ago. Scientists collected fossils from Australia, Canada and the Democratic Republic of Congo and found that the samples from Australia and Canada contained evidence of cyanobacteria, the oldest known life form on Earth. Scientists believe that cyanobacteria first emerged 2 to 3 billion years ago before evolving to be capable of oxygen-producing, or oxygenic, photosynthesis. In a recent study, researchers revealed these cyanobacteria fossils featured photosynthetic structures, known as thylakoid membranes, which contain pigments like chlorophyll that convert light into chemical energy via photosynthesis. The cyanobacteria were preserved in a mud clay that was compacted over time to become rock. The researchers used a technique called transmission electron microscopy (TEM) to see the membranes and other tiny details preserved in the fossils.

Instead of using light to image objects, TEM uses electrons, which have a much smaller wavelength than light, allowing us to see much finer details down to the atomic level. To achieve this, scientists bombard a sample with an electron beam. Some electrons will pass through, while some will be absorbed or scattered off more dense parts of the object. "Finding these membranes tells us that [these cells] are indeed cyanobacteria that are performing oxygenic photosynthesis," said Emmanuelle Javaux, a palaeobiologist from the University of Liège in Belgium. "This pushes back the fossil record of such

membranes by 1.2 billion years," Javaux said. Identifying the exact time in which cyanobacteria evolved the ability to produce oxygen is an important milestone in Earth's natural history.

The concentration of oxygen in Earth's atmosphere rose dramatically around 2.45 billion years ago in what is known as the Great Oxidation Event. The rise in atmospheric oxygen transformed life on Earth. It unlocked aerobic respiration for many life forms and increased the rate at which minerals weathered and provided nutrients to different environments. However, scientists don't know whether the Great Oxidation Event was triggered by the evolution of oxygenic photosynthesis or whether other ecological or geological events occurred first. The exact biological and physical drivers of the Great Oxidation Event are still deeply debated among scientists. Though cyanobacterial photosynthesis is generally accepted as the key reason why oxygen concentrations increased, drivers like volcanic eruptions or a decreased level of iron in the oceans may have also played a part.

"If oxygenic photosynthesis evolved very early, but oxygen levels only accumulated in the atmosphere much later, that suggests that there are other processes at work, like the burial of organic carbon," said Greg Fournier, a geobiologist at the Massachusetts Institute of Technology. The researchers' use of electron microscopy has the potential to pave the way to reanalysing older, existing fossil samples with the same imaging technique to identify exactly when cyanobacteria first evolved thylakoid membranes.

SPACEFLIGHT

BLUE ORIGIN JOINS TWO STAGES OF ITS NEW GLENN ROCKET

WORDS MIKE WALL

Blue Origin's powerful new rocket is starting to come together. The company, founded by Jeff Bezos, announced on 21 January that it has mated the two stages of its New Glenn heavy lifter for the first time. The milestone, which occurred at Launch Complex 36 (LC-36) at Cape Canaveral in Florida, will enable Blue Origin "to exercise our tooling and stage interfaces in preparation for our first launch later this year." The two-stage New Glenn will stand 98 metres tall and be able to haul 45 tonnes to low-Earth orbit – that's about twice the payload capacity of SpaceX's workhorse Falcon 9.

Like the Falcon 9, New Glenn's first stage is designed to be reusable. The booster will be powered by seven of Blue Origin's BE-4 engines, which flew for the first time earlier in January on the debut flight of United Launch Alliance's new Vulcan Centaur rocket. That launch went well, though the payload, Astrobotic's Peregrine Moon lander, suffered problems of its own in deep space and ended up crashing back to Earth. New Glenn has been in development for more than a decade. The heavy lifter's debut was originally targeted for 2020, but it has been pushed back multiple times.



The two stages of Blue Origin's first New Glenn rocket have been brought together for the first time

WISH LIST

The latest **MOVIE NIGHT GADGETS**

ROKID AR JOY PACK

\$499 (APPROX. £393.85) GLOBAL.ROKID.COM

For those who want to watch a movie solo or on the go, the Rokid Max AR Glasses are a completely new way to enjoy them. Through the power of augmented reality, simply place the glasses on your head and navigate through all your favourite streaming services using the control companion, the Rokid Station. While looking through the lenses, movies appear in 1080p full high definition on a virtual cinema screen from around ten metres away. The Rokid Max Glasses can do so much more than project movies though. For example, the glasses can be used alongside almost every gaming console and can be used as your desktop screen for remote working.



HALO+

£749 / \$849
GLOBAL.XGIMI.COM

For a more cinematic movie night, projectors, such as the Halo+ by XGIMI, can be a more immersive experience than traditional TVs. This projector provides a super-bright 1080p full high-definition picture along with dual Harman Kardon speakers for clean and distortion-free sound. Portable and compact, this travel-sized projector comes with a two-and-a-half hour battery life for a movie night away from home. The Halo+ also comes with advanced screen adaptation technology to autofocus and adjust its display and provide the same image quality from different positions around the room.



CHILLFACTOR

£10.99 (APPROX. \$13.95)
THECHILLFACTOR.COM



For some, no trip to the cinema is complete without getting your hands on a slushy for a brain-freezing start to any film. Home slushy makers such as the ChillFactor provide all the enjoyment of a cinema slushy in the comfort of your home. In a matter of seconds, your favourite flavour slushies can be made without the use of ice or blenders. Simply pre-freeze the ChillFactor, then add your favourite chilled drink and squeeze. Slushies can be created from all sorts of ingredients, including fruit juices, yoghurts and milk. There's plenty for children to enjoy, as well as frozen cocktail classics to make adult-only slushies.

THE POPCORN MAKER

£40 (APPROX. \$50.70)

JOEANDSEPHS.CO.UK

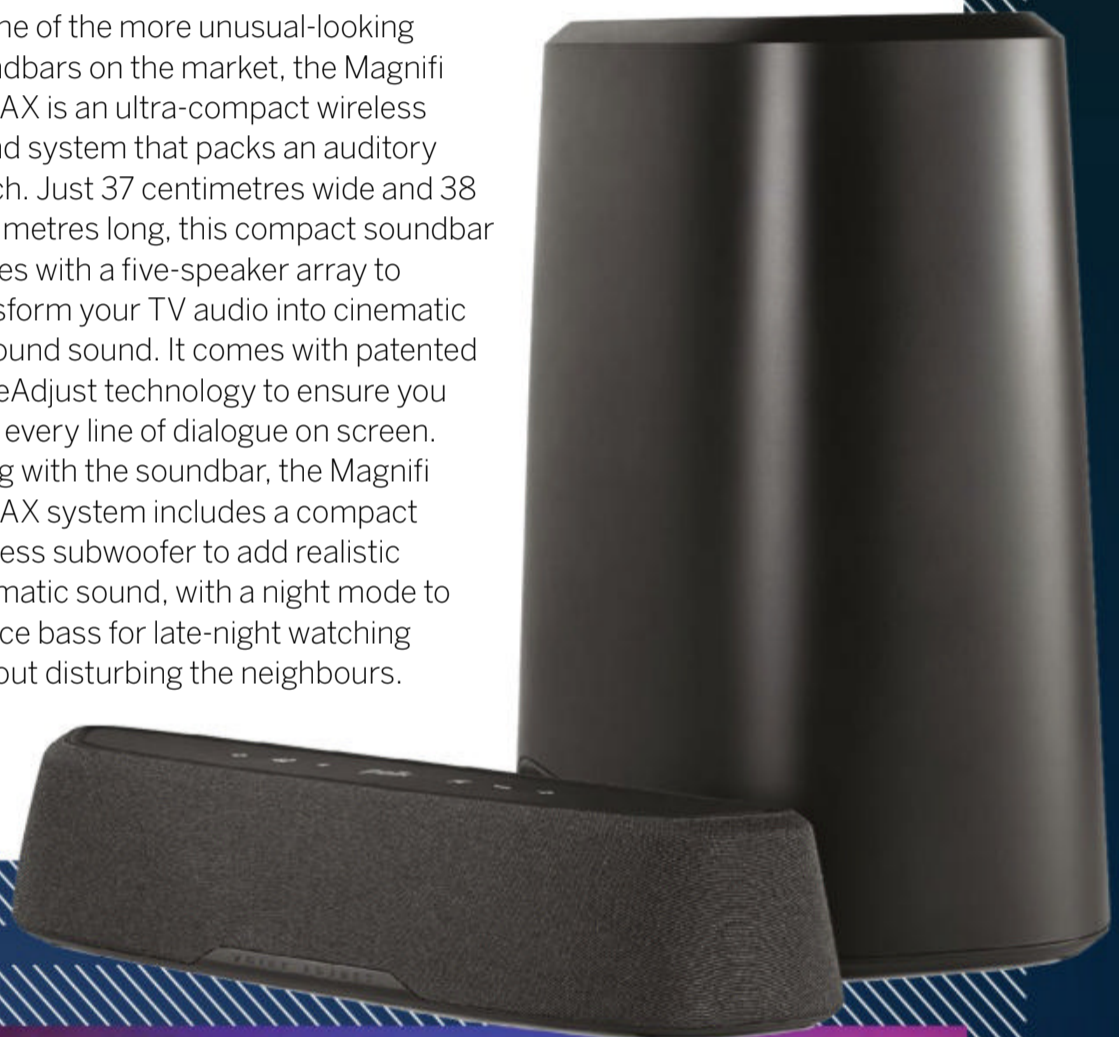
No movie night is complete without popcorn. Created by gourmet popcorn makers Joe & Seph's, the machine lets you pop your own corn in just two and a half minutes. The Popcorn Maker circulates hot air in its central chamber to heat unpopped corn. Once the kernel has popped, the hot air lifts it from the heating compartment and out through vents that drop it straight into a snacking bowl. There's no need to use any oils, fats or butters, although there are heaps of Joe and Seph's seasonings and sauces to try, such as salted caramel and cappuccino.



MAGNIFI MINI AX

£429 / \$499 POLKAUDIO.COM

As one of the more unusual-looking soundbars on the market, the Magnifi Mini AX is an ultra-compact wireless sound system that packs an auditory punch. Just 37 centimetres wide and 38 centimetres long, this compact soundbar comes with a five-speaker array to transform your TV audio into cinematic surround sound. It comes with patented VoiceAdjust technology to ensure you hear every line of dialogue on screen. Along with the soundbar, the Magnifi Mini AX system includes a compact wireless subwoofer to add realistic cinematic sound, with a night mode to reduce bass for late-night watching without disturbing the neighbours.



PHILIPS HUE SYNC BOX AND LIGHTSTRIP

FROM £309.98 / \$549.98 PHILLIPS-HUE.COM

One way to transform your room into a dynamic and immersive home cinema is to use smart backlighting, such as the Philips Hue Lightstrip and Sync Box combo. In a similar way to how surround sound immerses you in the world that's on screen, surround lighting extends it beyond your TV. Once the Philips Hue Sync Box and Lightstrip are connected to your TV, they will analyse the colours on the screen and extend them from behind the TV in real time. The companion app also lets you customise the ways your lights react with your TV, such as adjusting brightness and intensity.



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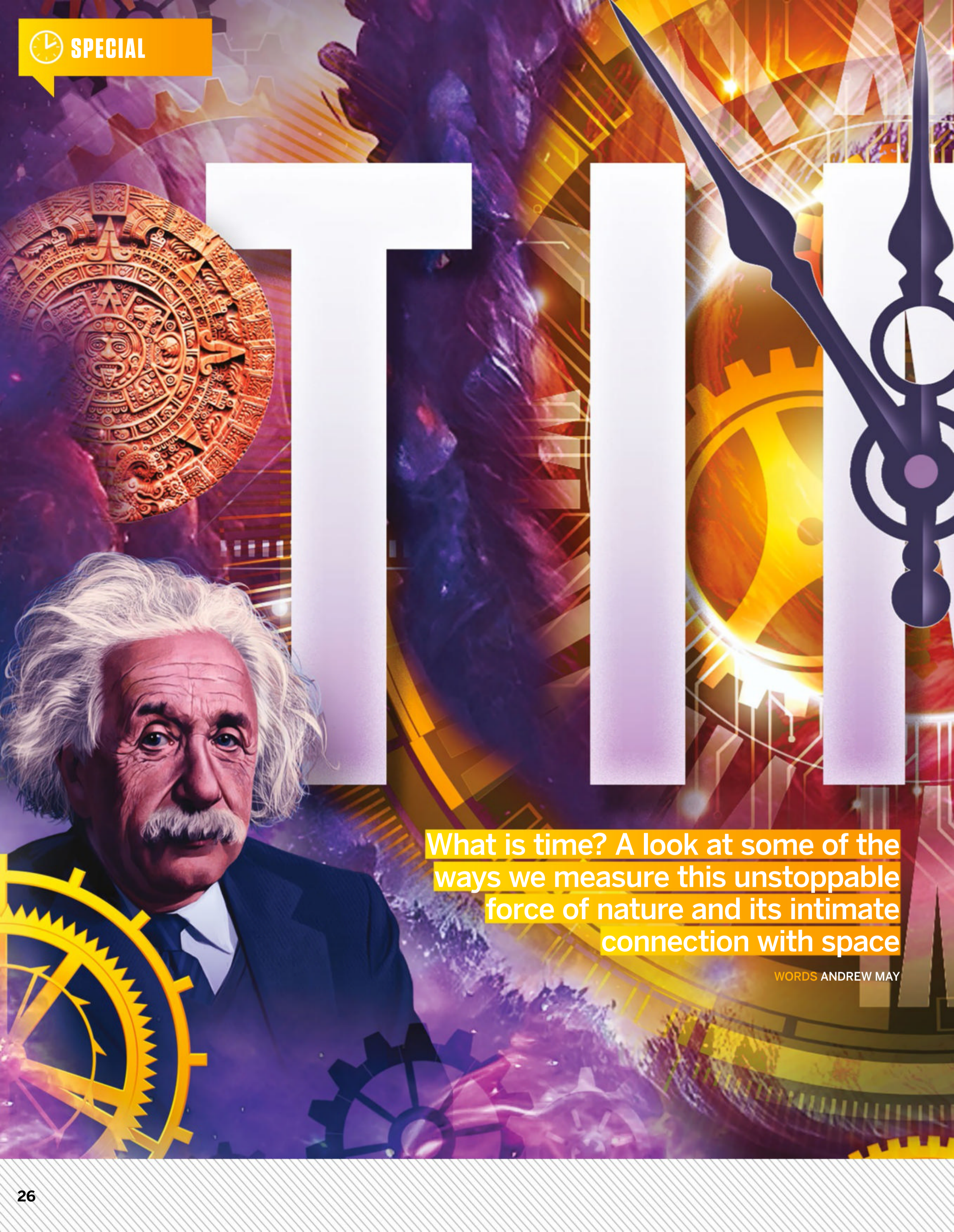
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What is time? A look at some of the ways we measure this unstoppable force of nature and its intimate connection with space

WORDS ANDREW MAY

DID YOU KNOW? In ancient times, an hour was a 12th the duration of daylight, varying in length with the seasons

W E

Time is something we all take for granted, yet it can be very difficult to grasp when we think hard about it. As long ago as 400 CE, Saint Augustine remarked that he knew exactly what time was, except when he tried to explain it. Many of us might say the same thing today, and the world's philosophers are still arguing with about the exact nature of time and how we perceive it. Fortunately, there are some aspects of the subject that we're now able to pin down much more precisely, thanks to super-accurate timepieces and sophisticated mathematical theories. The next few pages are a guided tour of some of the most fascinating highlights. We'll

start by looking at the way our measurement of time has evolved over the centuries, from ancient sundials and megalithic calendars like Stonehenge, through the earliest mechanical timepieces to the ubiquitous quartz-driven electronic clocks and watches of today. Then we'll take a dip into Einstein's mind-bending theory of relativity, which shows how space and time are intimately interconnected, and how different observers can see time passing at different rates. Finally, we'll come bang up to date with the latest generation of high-tech atomic clocks, some of which are so accurate that they wouldn't lose so much as a second in the entire lifetime of the universe.



The Aztec calendar seen here is a more recent relative of the ancient Mayan calendar

4 REAR DIALS

Two large dials and three smaller ones display additional astronomical data, plus dates of the Olympics and other games.

GOING BACK IN TIME

For prehistoric people, keeping track of the time of year was much more important than knowing the time of day. As a result, their most sophisticated attempts at timekeeping were not so much clocks as calendars. They watched the Sun and Moon changing position in the sky in order to keep track of the seasons, and several of their most striking monuments are built around solar or lunar alignments for this purpose. The summer solstice alignment of Stonehenge is the most famous of these, although Newgrange in Ireland – which is aligned with the winter solstice – is equally impressive and even older.

As for the time of day, the oldest and simplest method of working it out also used the Sun. This is the sundial, which does have the disadvantage that it won't work at night or on a cloudy day. A more reliable alternative, which emerged in ancient Egypt, is the water clock. This may be less familiar today than the

hourglass, a somewhat later invention, but it works on the same basic principle, just using flowing water instead of sand grains.

The first mechanical clocks appeared in the latter part of the 13th century. A European invention, these were based around a system of weights, levers and gears – 'clockwork' in other words. The earliest such mechanisms didn't have familiar clock faces, but simply struck a bell every hour. They were the first devices to actually bear the name 'clock', from the Latin word *clocca*, which means 'bell'.

Over the following centuries, timepieces were gradually refined and improved in two directions: towards greater precision and greater practicality. A major leap forward in accuracy came in the latter part of the 17th century, with the introduction of pendulum clocks. This allowed precise minutes and even seconds to be shown as well as hours. In regard to practicality, clocks gradually

Did you know?

The oldest known sundial dates from 1500 BCE



4

1

1 ADJUSTMENT KNOB

This hasn't survived, so we don't know what it looked like, but it was used to input the desired date.

ANCIENT GREEK COMPUTER

Sometimes called the world's oldest computer, the Antikythera mechanism is a complex calendrical device made some time around 100 BCE. It gets its name from the fact that it was found in a shipwreck off the Greek island of Antikythera, although it probably originated on another island, Rhodes. Made of bronze and roughly the size and shape of a shoebox, it's badly corroded but intact enough for scientists to see how it must have

worked. Turning a knob on the side would set the desired date, which via a complex set of gears inside the box would operate a number of display dials on the front and rear faces. The front one showed the positions of the Sun, Moon and planets relative to the zodiac, while the rear dials showed things like solar and lunar eclipses – and possibly of more interest to some of its users, the timing of various sports tournaments.



Parts of the Antikythera mechanism are displayed with other bronze items at an Athens museum

DID YOU KNOW? A pendulum clock will run slower if raised from sea level to a mountaintop, where gravity is weaker

INSIDE THE ANTIKYTHERA MECHANISM

This sophisticated device from the ancient world was a multifunction calendar

“They watched the Sun and Moon changing position in the sky”



3

3 GEARS

The inside of the box contains over 30 precision-engineered gears that drive the front and rear displays.

2

2 FRONT DIAL

This is the main output of the device, showing planetary movements and other astronomical data.

KEEPING TIME

Although hourglasses are rarely used today, they have become a familiar computer icon



3200 BCE

Prehistoric people made a kind of calendar at Newgrange, which fills with sunlight at just one moment each year.

450 BCE

The Mayan calendar of Central America was one of the most sophisticated timekeeping systems in the ancient world.

685 CE

A sundial showing the correct times for prayer was installed outside Bishopstone Church in East Sussex.



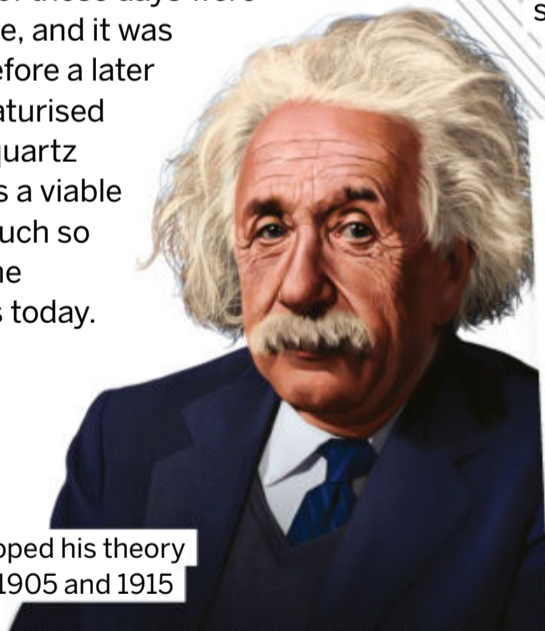
1270

The first mechanical clocks, with bells but no hands or dials, appeared in northern Italy and southern Germany.

became smaller, with pocket-sized watches making their first appearance as early as 1574, followed by the first wristwatch in 1812. Also around the early 1800s, the first mass-produced clocks hit the market, making them much more widely available than before.

Prior to the 19th century, knowing the exact time had been more a matter of curiosity than necessity. With the growth of rail travel, however, people suddenly had a much stronger motive for knowing what the time was. Trains ran to strict timetables, and you could miss your connection if you were a few minutes late. In the early days of rail travel, different parts of the country even had their own local time standards, which caused considerable chaos before national time zones – such as Greenwich Mean Time in the UK – were introduced.

Although traditional ‘clockwork’ clocks and watches dominated for several centuries, it’s quite likely you don’t have a single one in your home today. This is due to a discovery that was made early in the 20th century concerning a common mineral called quartz. If a crystal of it is incorporated into an electronic oscillator circuit, it produces a signal with a very precisely defined frequency. This discovery made it possible to construct timepieces that were at least ten times more accurate than the best traditional clocks. The first such ‘quartz clock’ was built in 1927, but it didn’t create an immediate revolution. This was because the electronic devices of those days were bulky and unreliable, and it was several decades before a later generation of miniaturised electronics made quartz clocks and watches a viable proposition – so much so that they’ve become virtually ubiquitous today.



Albert Einstein developed his theory of relativity between 1905 and 1915



Did you know?
TV tube designers had to allow for time dilation

EGYPTIAN WATER CLOCK

This simple-but-effective timepiece has been around for at least 3,400 years

1 FILL POT WITH WATER

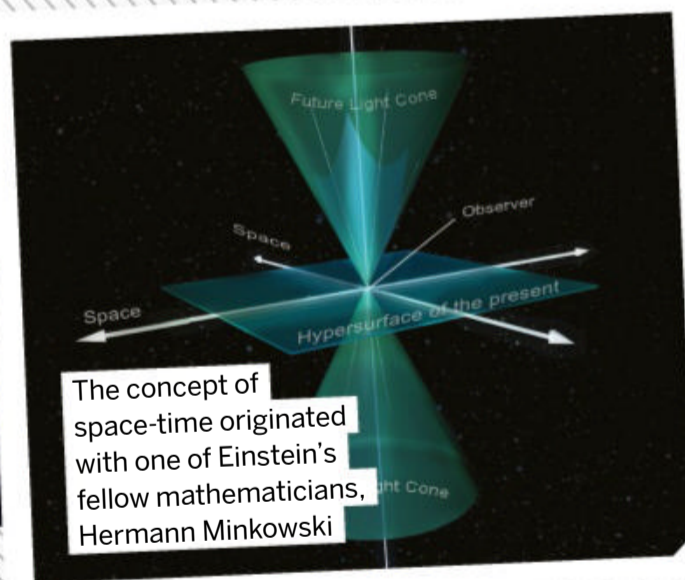
To start the clock, pour water into the funnel-shaped pot until it’s filled to the brim.

2 LET WATER DRIP OUT

After the inflow stops, water continues dripping at a steady rate from a small hole in the bottom.

3 READ OFF TIME

As the water level drops, compare it with the graduated markings to see how much time has passed.



“It works on the same basic principle, using flowing water instead of sand”

1656

Dutch scientist Christiaan Huygens designed the first pendulum clock, and had it built by a local clockmaker.



1847

Greenwich Mean Time (GMT) was adopted as the official ‘railway time’ throughout Britain.

1915

Einstein published the final part of his theory of relativity, which revolutionised the way physicists view time.

1967

Electronic wristwatches based on quartz-crystal oscillators were demonstrated for the first time.

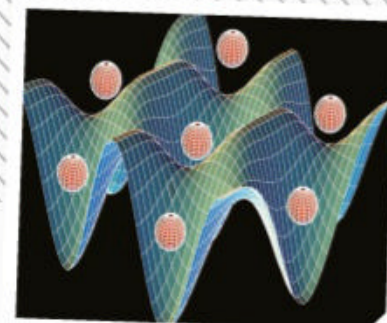


1989

Physicist Norman F. Ramsey was awarded the Nobel Prize for his role in the development of atomic clocks.

2018

An optical lattice clock at America’s National Institute of Standards and Technology set a new world record for precision timekeeping.

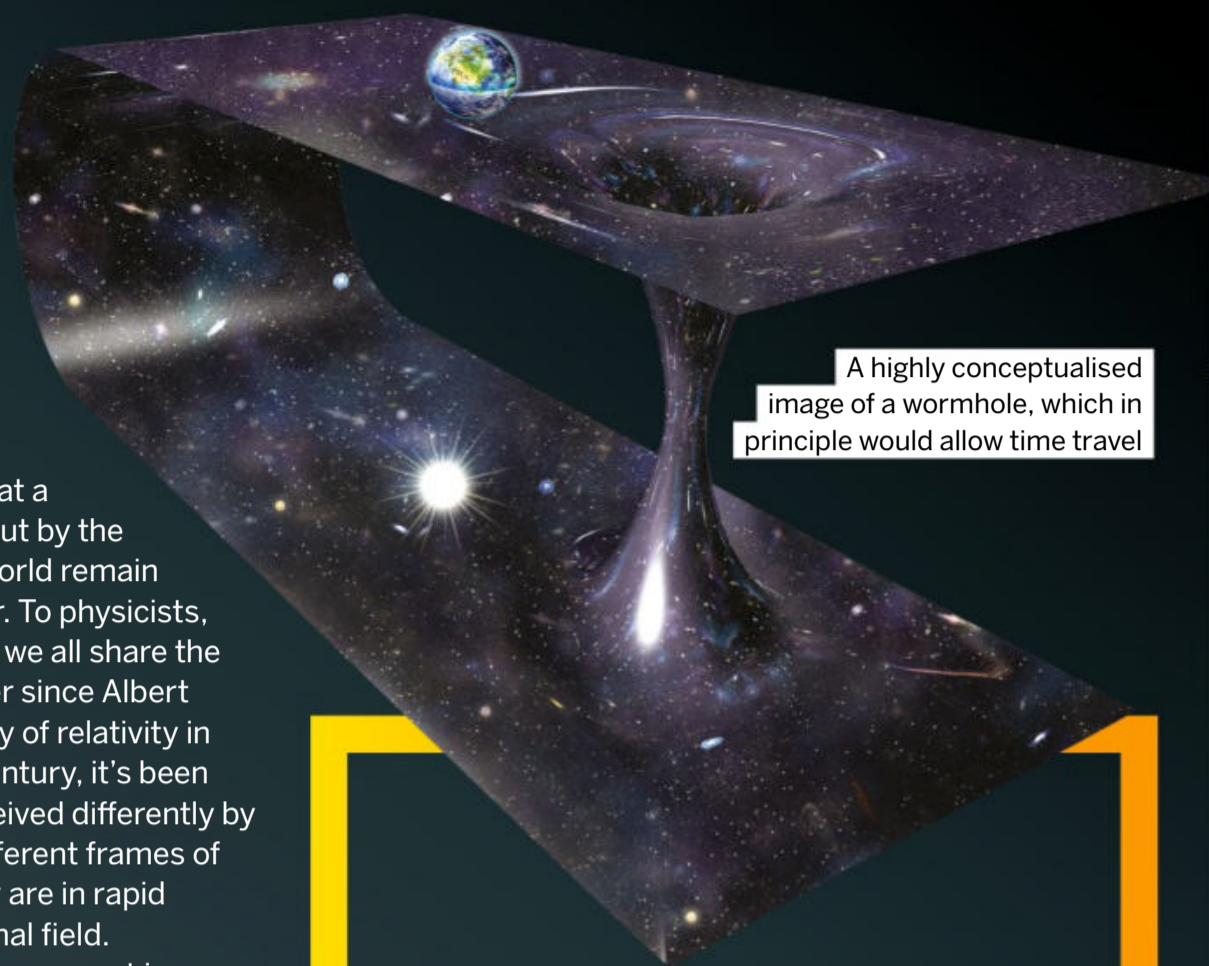


DID YOU KNOW? Tipler cylinders are a more practical hypothetical method of time travel than wormholes

THE RELATIVITY OF TIME

In everyday life, we take it for granted that time ticks away at a constant rate. This is borne out by the fact that clocks all over the world remain synchronised with each other. To physicists, however, this is only because we all share the same frame of reference. Ever since Albert Einstein formulated his theory of relativity in the early years of the 20th century, it's been known that time can be perceived differently by observers in substantially different frames of reference, for example if they are in rapid motion or a strong gravitational field.

One notion that has to be thrown out in Einstein's theory is the idea of simultaneity. An observer on Earth might perceive two astronomical events as happening simultaneously, while the pilot of a fast-moving spaceship would see them occurring at different times. Similarly, the space-travelling and Earthbound observers might obtain different answers when measuring the duration of an event at a third location. Known as time dilation, this effect occurs in two distinct situations: if the two observers are moving relative to each other, or if one of them is in a stronger gravitational field. These 'relativistic' effects aren't quite as weird as they sound, because they only relate to the way observers see time passing at some location other than their own. For the observers themselves, time always passes at its normal rate.



A highly conceptualised image of a wormhole, which in principle would allow time travel

IS TIME TRAVEL POSSIBLE?

One of the oddest consequences of relativity is that it allows the possibility of time travel. The immensely strong gravitational fields surrounding black holes can distort space-time so much that it folds back on itself. The result is a 'wormhole'. Like its fictional counterpart, a real-world wormhole acts like a shortcut between different points in space-time – and it's perfectly possible for the wormhole's exit to lie at an earlier time than its entrance. A path through space-time that loops back into the past is known as a 'closed timelike curve', and physicists have worked out several ways of creating them. Unfortunately, these all require impossible feats of engineering, so time travel remains a purely theoretical, rather than practical, possibility.

5 FACTS ABOUT TIME DILATION

1 SLOWED DOWN MUON DECAY

Super-fast muon particles are created by cosmic rays hitting the upper atmosphere, and they're so short-lived they should never reach ground level – but they do, thanks to time dilation.

2 CLOCKS ON A PLANE

Even at ordinary speeds, time dilation has measurable effects at the sub-microsecond level. This was demonstrated in 1971 when scientists took atomic clocks on round-the-world flights.

3 RELATIVITY AND GPS

To provide metre-level navigational accuracy, GPS satellites need nanosecond-accurate timing. They can only achieve this by taking the effects of relativistic time dilation into account.

4 LARGE HADRON COLLIDER

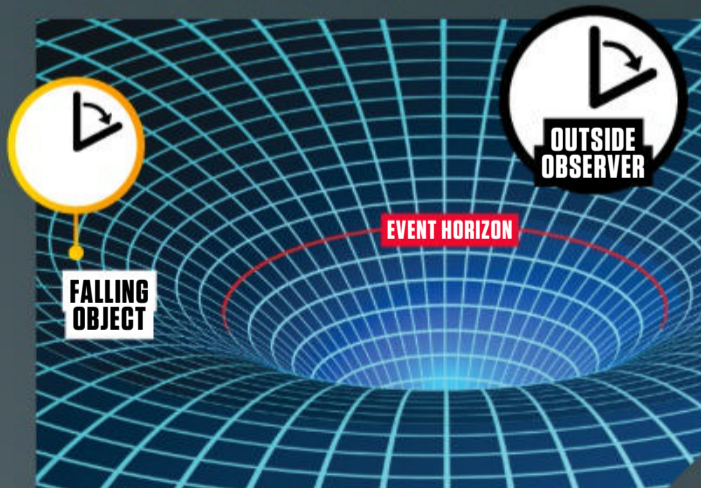
Protons whiz around the collider so rapidly that if they continued for two hours by an external clock, they would experience little more than a second of their own time.

5 NASA'S TWINS

When astronaut Scott Kelly did a stint on the International Space Station, time dilation meant he aged approximately five milliseconds less than his twin brother Mark, who remained on Earth.

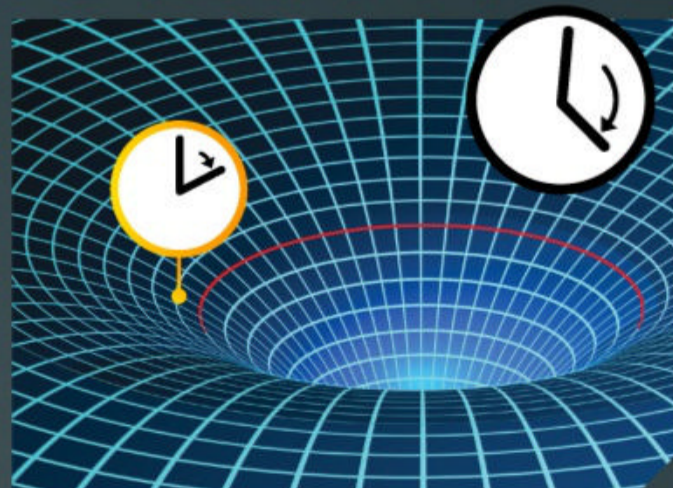
BLACK HOLE TIME DILATION

This is what you'd see if you watched a spaceship falling into a black hole



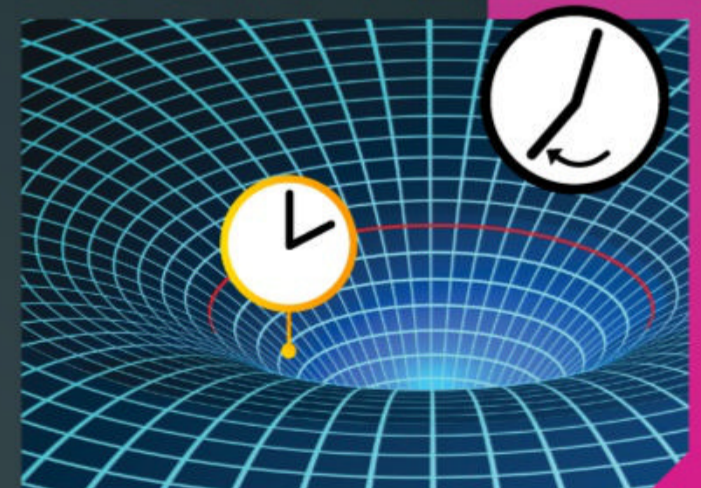
1 SPACESHIP APPROACHES A BLACK HOLE

As long as the ship is still a safe distance from the black hole's event horizon, the distortion of space-time is relatively small, and events are seen to occur at the same rate by an outside observer and by the ship's crew.



2 SPACESHIP FALLS IN TOWARDS THE EVENT HORIZON

From the perspective of the crew, nothing has changed – they're still travelling at the same speed. But an outside observer sees the ship slowing down – and if they could see inside, the ship's clock would be slowing down too.

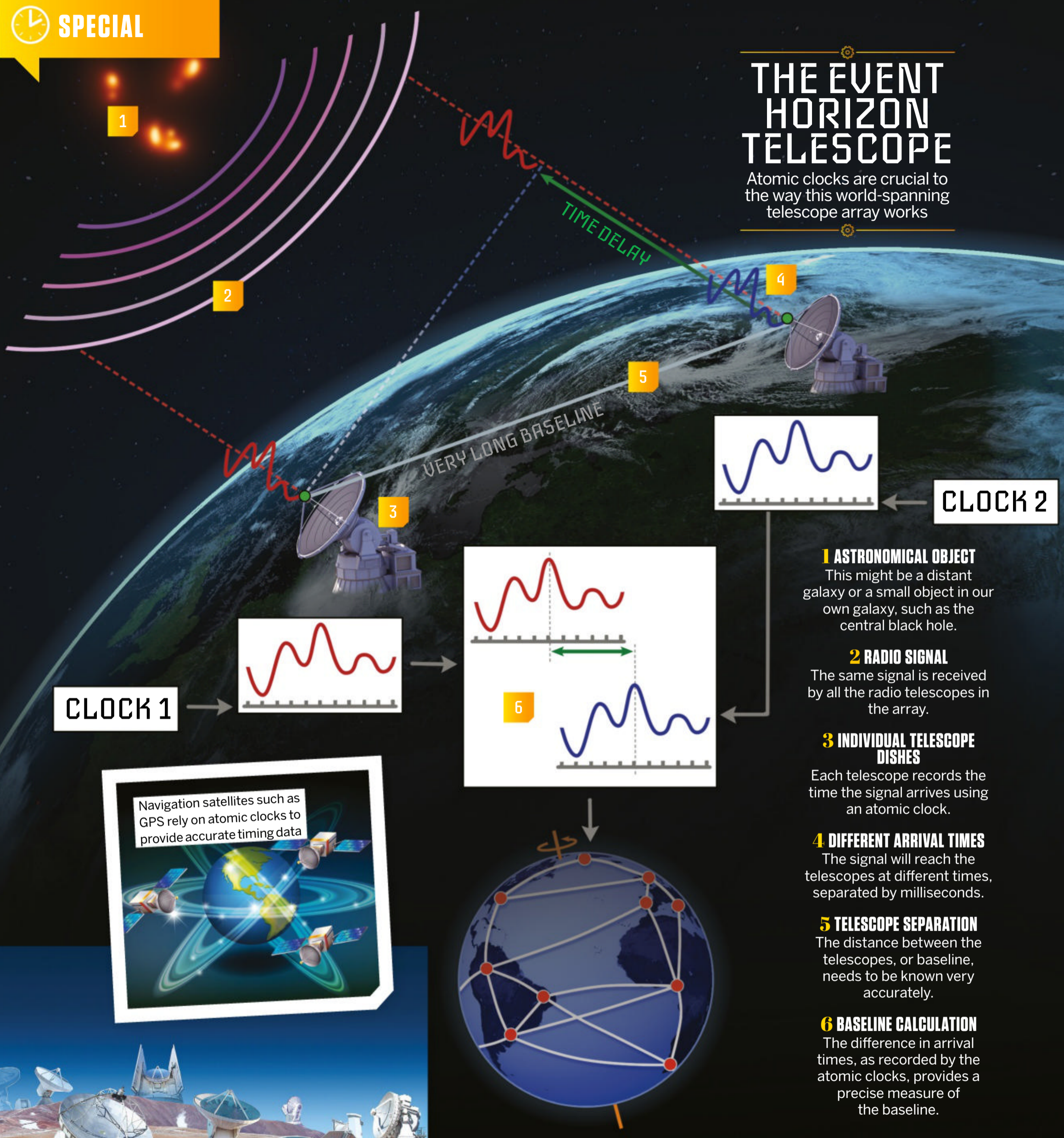


3 SPACESHIP REACHES THE EVENT HORIZON

As far as the passage of time is concerned, the crew would see nothing special at this point. But for the external observer, the ship grinds to a halt and becomes frozen in position on the event horizon.

THE EVENT HORIZON TELESCOPE

Atomic clocks are crucial to the way this world-spanning telescope array works



CLOCK 1

CLOCK 2

1 ASTRONOMICAL OBJECT
This might be a distant galaxy or a small object in our own galaxy, such as the central black hole.

2 RADIO SIGNAL
The same signal is received by all the radio telescopes in the array.

3 INDIVIDUAL TELESCOPE DISHES
Each telescope records the time the signal arrives using an atomic clock.

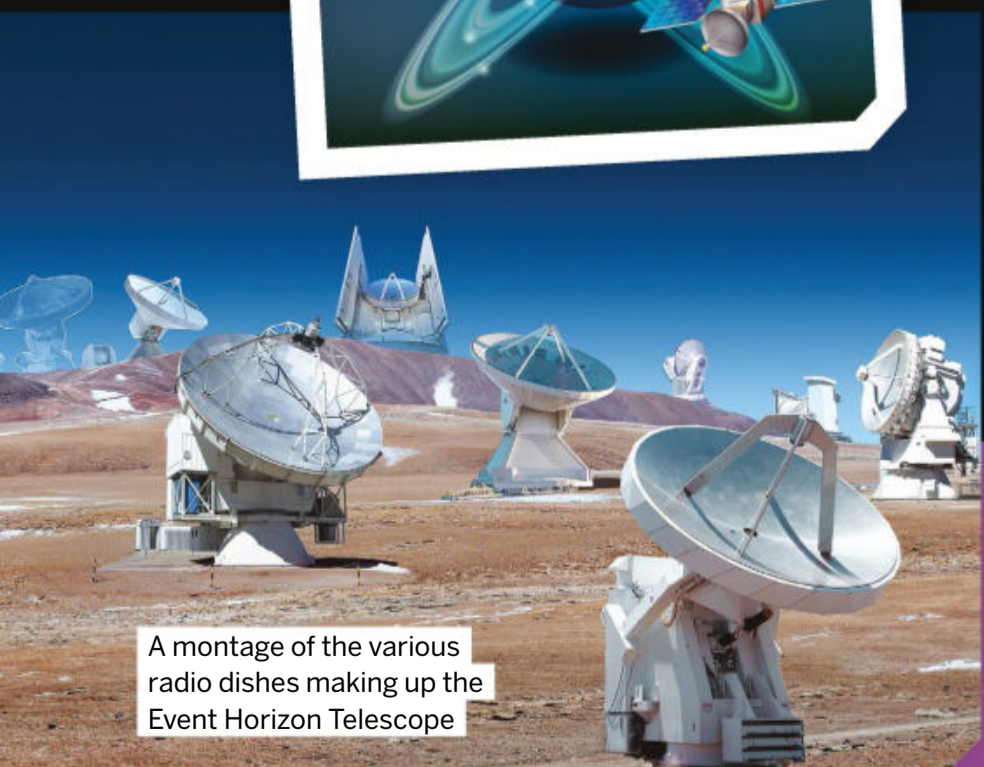
4 DIFFERENT ARRIVAL TIMES
The signal will reach the telescopes at different times, separated by milliseconds.

5 TELESCOPE SEPARATION
The distance between the telescopes, or baseline, needs to be known very accurately.

6 BASELINE CALCULATION
The difference in arrival times, as recorded by the atomic clocks, provides a precise measure of the baseline.



Navigation satellites such as GPS rely on atomic clocks to provide accurate timing data

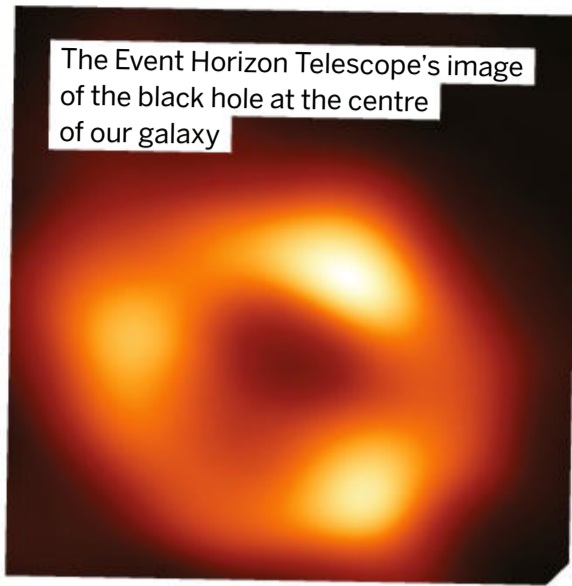


A montage of the various radio dishes making up the Event Horizon Telescope

“This technique requires an extremely precise knowledge of a signal’s time of arrival at different dishes”

DID YOU KNOW? Nuclear clocks could be ten times as accurate as the best atomic clocks

The Event Horizon Telescope's image of the black hole at the centre of our galaxy



OBSERVING BLACK HOLES

Many people will be aware of the spectacular images of supermassive black holes produced by the Event Horizon Telescope. What may be less well known is the key role played by atomic clocks in obtaining these pictures. To achieve the incredibly high resolution needed to see the region around the black holes, astronomers ideally needed an enormous radio telescope the size of Earth. What they actually used was the next best thing – individual dishes located in Spain, Arizona, Hawaii, Chile and Antarctica, all connected up in such a way as to act like a single giant instrument. Technically known as very-long-baseline interferometry, this technique requires an extremely precise knowledge of a signal's time of arrival at different dishes. In the case of the Event Horizon Telescope, this was provided by state-of-the-art atomic clocks called hydrogen masers.



The world's first atomic clock was built at the UK's National Physical Laboratory in 1955

ATOMIC CLOCKS

The world's most accurate timepieces, atomic clocks exploit the relationship between time and the frequency of electromagnetic waves. Expressed in hertz, frequency simply means the number of wave cycles per second. So if we know a wave's precise frequency, and can count the number of cycles, we can work out exactly how long a second is.

The first step is to create a wave of precisely known frequency – and that's where the atoms come in. The electrons inside an atom respond preferentially to certain frequencies, which cause them to jump from one energy level to another. To give a specific example, a frequency of 9,192,631,770 hertz triggers an important energy transition in caesium atoms. So if we fire a radio wave at a collection of

caesium atoms and fine-tune its frequency until they all make this transition, we know we've got the frequency spot on. Add an electronic counter to count the number of wave cycles and tick off a second every time this reaches the magic number of 9,192,631,770, and we have our atomic clock.

The earliest atomic clocks focused on caesium for purely practical reasons, because that frequency of 9,192,631,770 hertz – or a little over nine gigahertz – was right at the upper limit of what was technically possible at the time. Today, however, it's possible to achieve much higher frequencies, and a whole new generation of atomic clocks is emerging that use elements such as strontium and ytterbium.

Did you know?
Caesium is the softest of all the solid elements

SUPER-ACCURATE TIMEKEEPING



RUBIDIUM CLOCK

ACCURATE TO

One second in 300 years

The smallest and cheapest atomic clocks are based on the element rubidium. They are widely used in mobile phone towers and TV transmitters.



HYDROGEN MASER

ACCURATE TO

One second in 300,000 years

Hydrogen masers are specialised atomic clocks used in certain applications, such as the European Space Agency's Galileo satellites.



CAESIUM CLOCK

ACCURATE TO

One second in 100 million years

When scientists require high-precision timekeeping, they use caesium atoms. Caesium clocks have steadily improved in accuracy since their invention.



OPTICAL LATTICE CLOCK

ACCURATE TO

One second in 15 billion years

Powered by a laser and using strontium atoms on a 3D optical lattice, this is by far the most accurate timekeeping technology in use today.

ABOARD THE WORLD'S LARGEST SOLAR BOAT

This catamaran runs on sunshine, powering its journey around the globe

WORDS SCOTT DUTFIELD

In 2010, hundreds of people gathered at a dock in Kiel, Germany, to witness the unveiling of the MS Tûranor PlanetSolar, a solar-powered catamaran that was set to be the first of its kind to circumnavigate the globe. It took one year, seven months and seven days for Tûranor PlanetSolar to cross more than 37,296 miles to circumnavigate the globe, docking in six continents along the way and setting the record for the longest journey made by a solar-powered boat. In place of a traditional fossil-fuelled engine, this catamaran runs solely on the power of the Sun. Spread across the entire upper portion of the vessel is an array of photovoltaic cells covering 512 square metres. These power cells convert sunlight into electrical energy to charge over eight tonnes of lithium-ion batteries stored in the catamaran's hull. These batteries supply four motors attached to two rotary propellers that ferry the Tûranor PlanetSolar through the ocean.

A single charge of the onboard batteries can last 72 hours, and with a

continuous supply of energy from the photovoltaic cells, the vessel can sail non-stop around the world. However, due to the limitations of the human crew, food and supply pickups were undertaken in many countries along its route. All of the onboard facilities, such as showers, lights and kitchen appliances, are powered by sunlight, not just the motors.

After completing its pioneering journey around the world in 2012, Tûranor PlanetSolar has been involved in many scientific expeditions – such as the Terra Submersa expedition in 2014 to investigate prehistoric landscapes engulfed by water around Greece – and global travel to spread the word about sustainable alternative energy sources.

Did you know?

'Tûranor' means 'power of the Sun' in Tolkien's Elvish

60 PEOPLE

PlanetSolar can house over seven Olympic rowing teams

38,000 PHOTOVOLTAIC CELLS

A lot of cells make up the solar array

35 METRES LONG

The vessel is almost as long as two cricket pitches

89 TONNES

The PlanetSolar weighs almost as much as a blue whale

THE CATAMARAN'S MAX SPEED IS AROUND 16 MILES PER HOUR

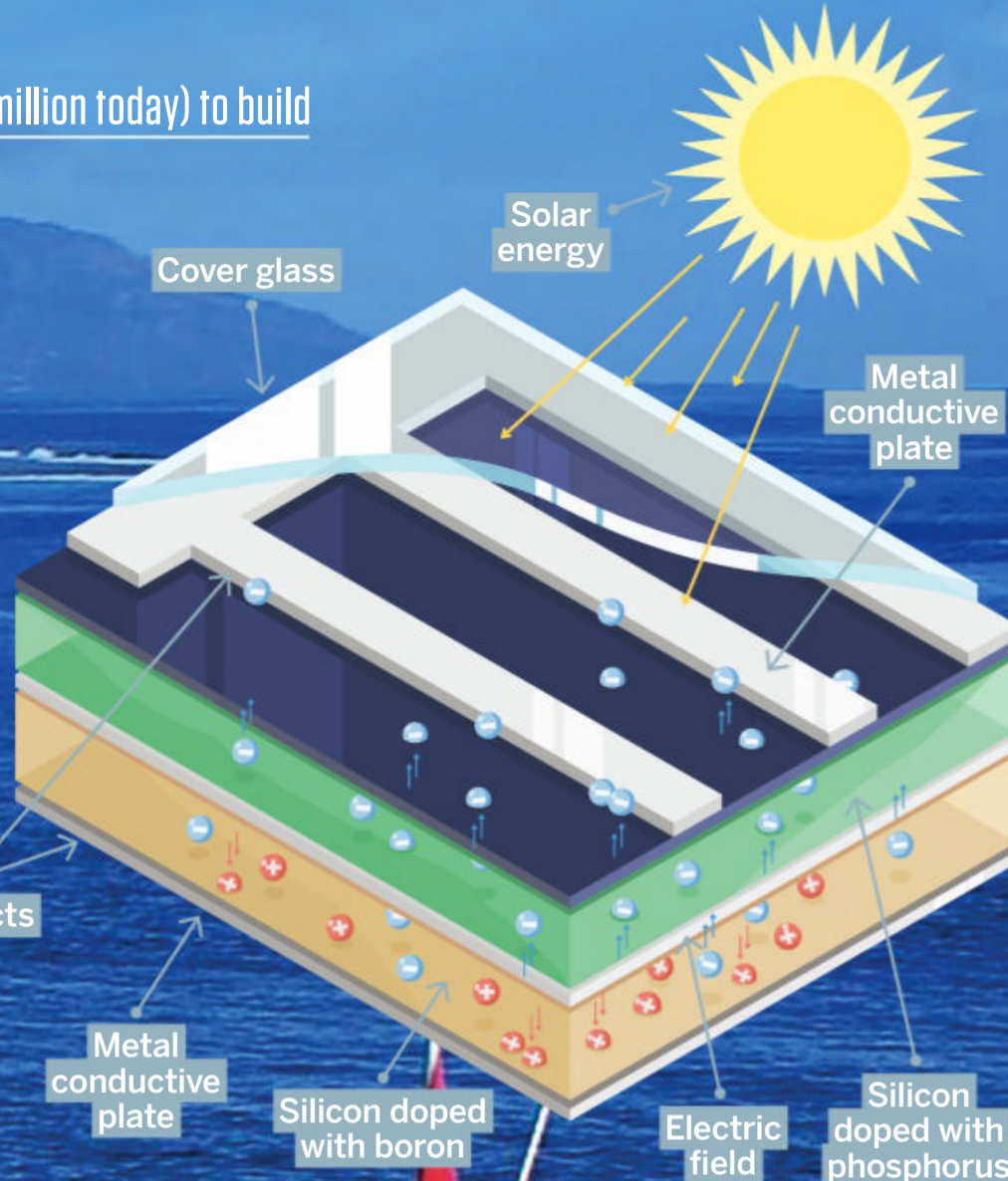
DID YOU KNOW? Tûranor PlanetSolar cost about \$17 million (around £20 million today) to build

TURNING SUNLIGHT INTO ELECTRICITY

To generate solar energy, photovoltaic cells work using a material called a semiconductor, which absorbs light energy and passes it on to negatively charged particles within the material called electrons. As these electrons move around the semiconductor, they create a current of electricity. The current is then extracted from the semiconductor to a conductive metal, which forms the grid on a

photovoltaic cell, and is transported to a connected battery. The amount of energy a photovoltaic cell generates compared to the amount of sunlight it's exposed to is referred to as its efficiency percentage. In the case of PlanetSolar, the photovoltaic array has an efficiency of 22.6 per cent.

The anatomy of a photovoltaic cell as electrons move through a semiconductor



120 KILOWATT HOURS

PlanetSolar's engine has a maximum output double that of a Tesla Model 3 car

THE VESSEL IS PROPELLED BY TWO PROPELLERS SPINNING AT UP TO 600 REVOLUTIONS PER MINUTE



23 METRES WIDE

The vessel's width is two-and-a-half times the length of a London bus

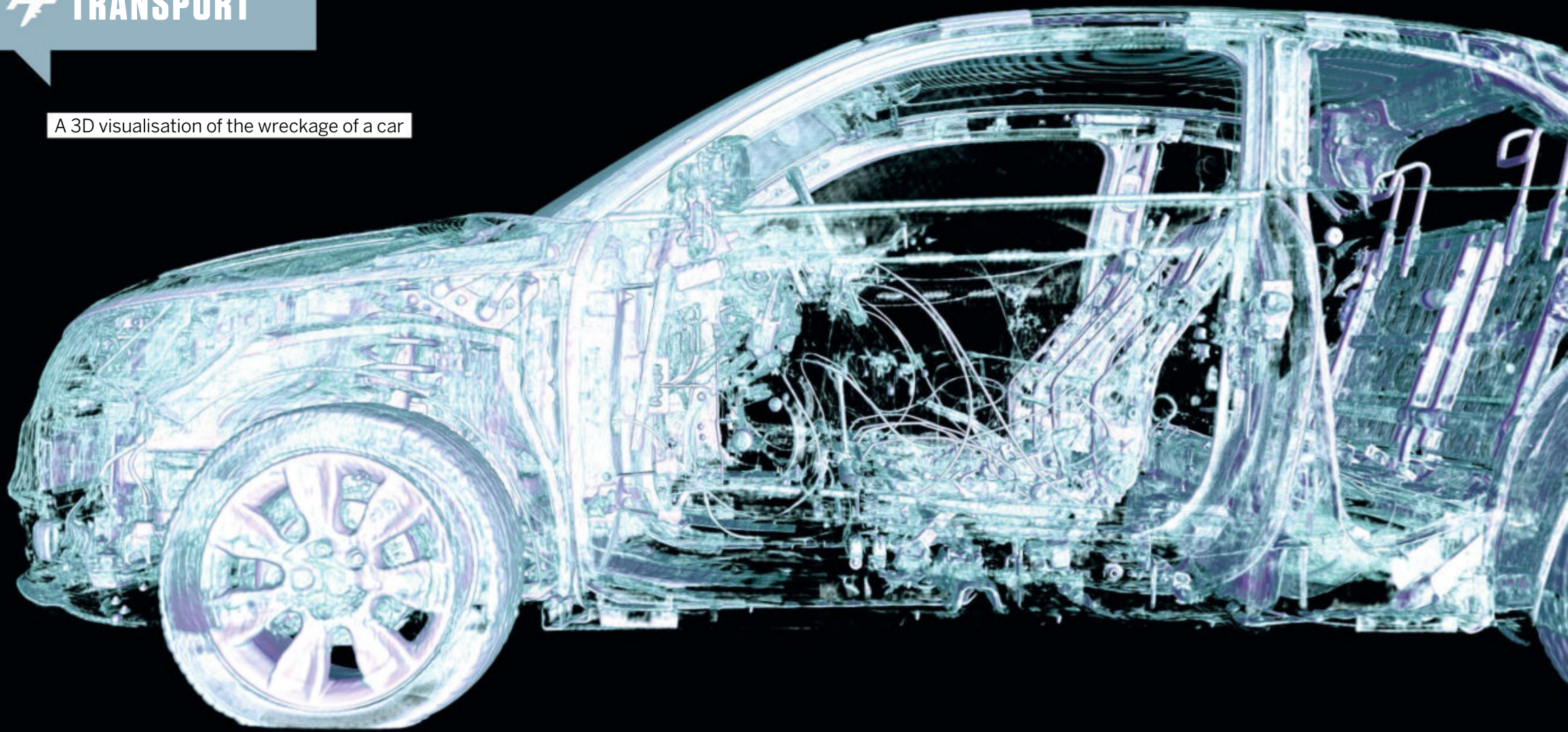
FROM SEA TO SKY

Having conquered the sea, PlanetSolar creator Raphaël Domjan has since turned his attention to the skies and founded another solar project called SolarStratos. Using the same solar principles as the Tûranor PlanetSolar, this two-seater aircraft uses 22 square metres of photovoltaic cells on its wings to soar through the sky. Domjan's plan for SolarStratos is to set new altitude records of over 15,000 metres in the stratosphere and touch the edge of space using only the power of the Sun as fuel. Thus far, SolarStratos has climbed more than 1,500 metres, showcasing the power of solar energy and its potential use in the aviation industry.

Domjan piloting the SolarStratos on a test flight over Switzerland



A 3D visualisation of the wreckage of a car



ANATOMY OF A WRECKED CAR

The humble hospital scanner has been supersized to look inside mangled car wrecks and learn how to make cars safer

WORDS JEM STANSFIELD

The internal components of a modern car can be tricky to pinpoint at the best of times – and once they've been subjected to a high-speed impact, the task becomes even more difficult. That's a problem if you're a crash researcher who wants to examine the wreck to find out how each element has fared. There's a risk of compromising the evidence as you pick apart the wreckage.

If only there was a giant version of the kind of X-ray scanners we use to look at bones, it would be possible to get a detailed look inside the vehicle without disturbing it. The Fraunhofer Society in Germany has such a scanner – one so big it can accommodate cars, aeroplane wings and dodgy shipping containers. This giant scanner enables users to observe the insides of a mangled car in

3D, pinpointing internal structures to within less than a millimetre. This research is vital, as in the event of an impact, a car's structure typically has less than one-tenth of a second to save the occupants. This detailed knowledge on how all elements perform could be vital in designing safer vehicles.

Did you know?
'Tomography' is Latin for 'drawing from slices'

Although this may seem like another story of phenomenal German engineering, the technology at the heart of it was started by a Nobel Prize-winning Englishman working at a record company in the early 1970s. Godfrey Hounsfield was a researcher for EMI. He figured out that by X-raying an object from several angles, a computer could be used to build an accurate 3D model of its interior. One of his early tests was on a pickled brain, using a lathe to provide a slow rotating action. It took nine days, but started an imaging revolution.

COLLISION FORCES

30 MILLISECONDS

Air bags will deploy a fraction of a second after a frontal impact with sufficient force

1991 Volvo introduced its side impact protection, which spreads the force of impact

30 G

A 70-kilogram person in a crash with a fixed object at 30 miles per hour experiences 2.1 tonnes of force

150 G

If the same person isn't wearing a seat belt, they can experience 10.8 tonnes of force

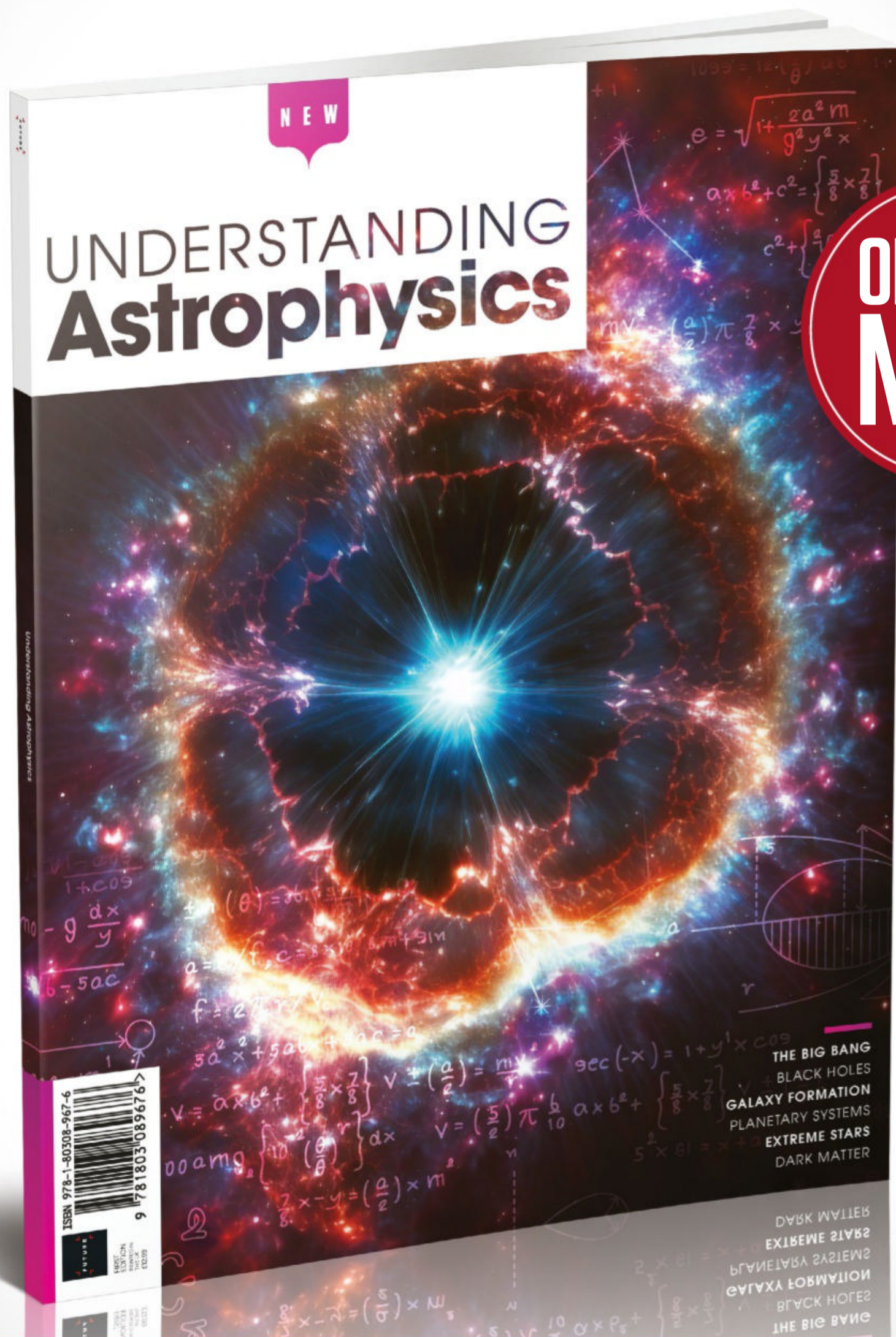
FORCE OF IMPACT IS CALCULATED USING A NUMBER OF VARIABLES THAT INCLUDE WEIGHT OF VEHICLES, THE SPEED THEY WERE TRAVELLING AND ANGLE OF IMPACT

These computerised tomography (CT) X-ray scanners have become invaluable for doctors.

Realising that their mechanical specimens didn't need the same delicate treatment and exposure limits of living tissue, engineers ramped up the power and increased the scanning times to obtain phenomenally accurate internal views and measurements. And now that the Fraunhofer Society has taken all that and supersized it, there's a good chance that X-rays will be preventing broken bones as well as detecting them.

DISCOVER THE WONDERS OF THE UNIVERSE

New from the makers of *All About Space*, this special edition reveals the science that governs our incredible universe and delves into the fascinating theories behind curious cosmic mysteries.



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THE FIRST MAP-MAKERS

How did ancient cartographers calculate and draw the contours of their countries?

WORDS AILSA HARVEY

Today you can virtually visit almost any street or landmark in the world, viewing an accurately mapped layout of its placement on the planet. When navigating new roads, real-time updates about weather and traffic conditions can keep us constantly in the know. This combines satellite and street-level imagery, incorporating huge amounts of data quickly and accurately. But before computers and satellites could lend a hand, the work of cartographers and surveyors was far more laborious and less accurate.

Maps have long been an essential tool for human civilisation, helping our ancestors

piece together the world around them, document borders and navigate new landscapes. The first maps of 600 BCE were carved into chunky clay tablets. As human understanding of the world grew beyond local territories, maps escalated from local representations to attempts to envisage the entire planet. For a map to hold any real navigational benefit, mountain ranges and roads have to be drawn to scale.

Before the assistance of advanced technologies like GPS, cartographers took considerable time to manually calculate and plot each observable distance. The invention of the compass made for more precise

map-making, helping surveyors orientate themselves. Meanwhile, large areas could be mapped quickly using triangulation. This technique involved dividing the landscape into triangular segments for plotting and meant that significant distances could be calculated without needing to manually measure all sides of each triangle. Trigonometry and three distinct reference points were used to achieve this. These time-consuming data-collection tasks proved successful in the production of history's first accurate large-scale maps.

Did you know?
Medieval European world maps are called 'mappa mundi'

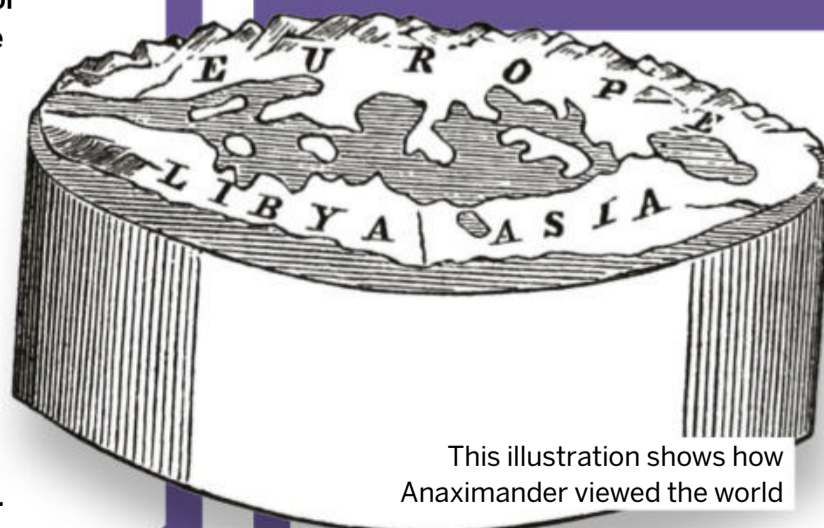


The remaining pieces of the Severan marble plan in the Forma Urbis Museum

ROME'S OLDEST MAP

Comprising 150 marble slabs, the Severan marble plan was a giant carved map of Rome displayed on the wall of the city's Temple of Peace. The detailed engraving measured 18 by 13 metres and had an orientation opposite to today's common practice, with the northernmost points at the bottom. Only about 10 to 15 per cent of the original map is still preserved today, broken up into 1,186 parts. Carved across these substantial slabs is a plan of all the monuments and every ground-floor room of buildings in the centre of Rome. Some buildings are even mapped with interior details such as staircases and columns. The exact purpose of the map is still debated. Due to it being on display next to government offices, some historians believe it was used for administrative purposes. However, the scale and impractical hanging of the map makes others doubt this theory.

The map was created under the orders of emperor Septimius Severus between 203 and 211 CE. Unlike the maps of today, in which areas are plotted based on geographical and political borders and onto readily available paper, the boundary of this map was determined by the limits of accessible marble. Sadly, in the Middle Ages, the map was partially destroyed in order to use the material for building. Putting together the pieces of this hefty stone jigsaw raised significant challenges. However, in 1999 the Digital Forma Urbis Romae project was launched, which digitised the fragment carvings and the pieces that were preserved only as drawings. The project enables people to view a complete version of this map.



This illustration shows how Anaximander viewed the world

TRIANGULATION TECHNIQUE

How early surveyors used the angles of a plotted triangle to map precise points and distances

1 HILLY BENEFITS

Triangulation surveying involves the tracing of triangles over an area. Hilly regions work best for mapping large areas as reference points can be viewed across greater distances.

3 UNKNOWN LENGTHS

The distance between the castle and the two other points are unknown. When determined, these lines will become new baselines for the adjoining triangular areas to be mapped.

2 BASELINE

To calculate the other distances, one length of the triangle is a known distance that has been measured.

6 UNKNOWN ANGLE

The angle at the distant or unreachable location can be calculated using the two known angles. All three angles in a triangle add up to 180.

5 THEODOLITE MEASUREMENTS

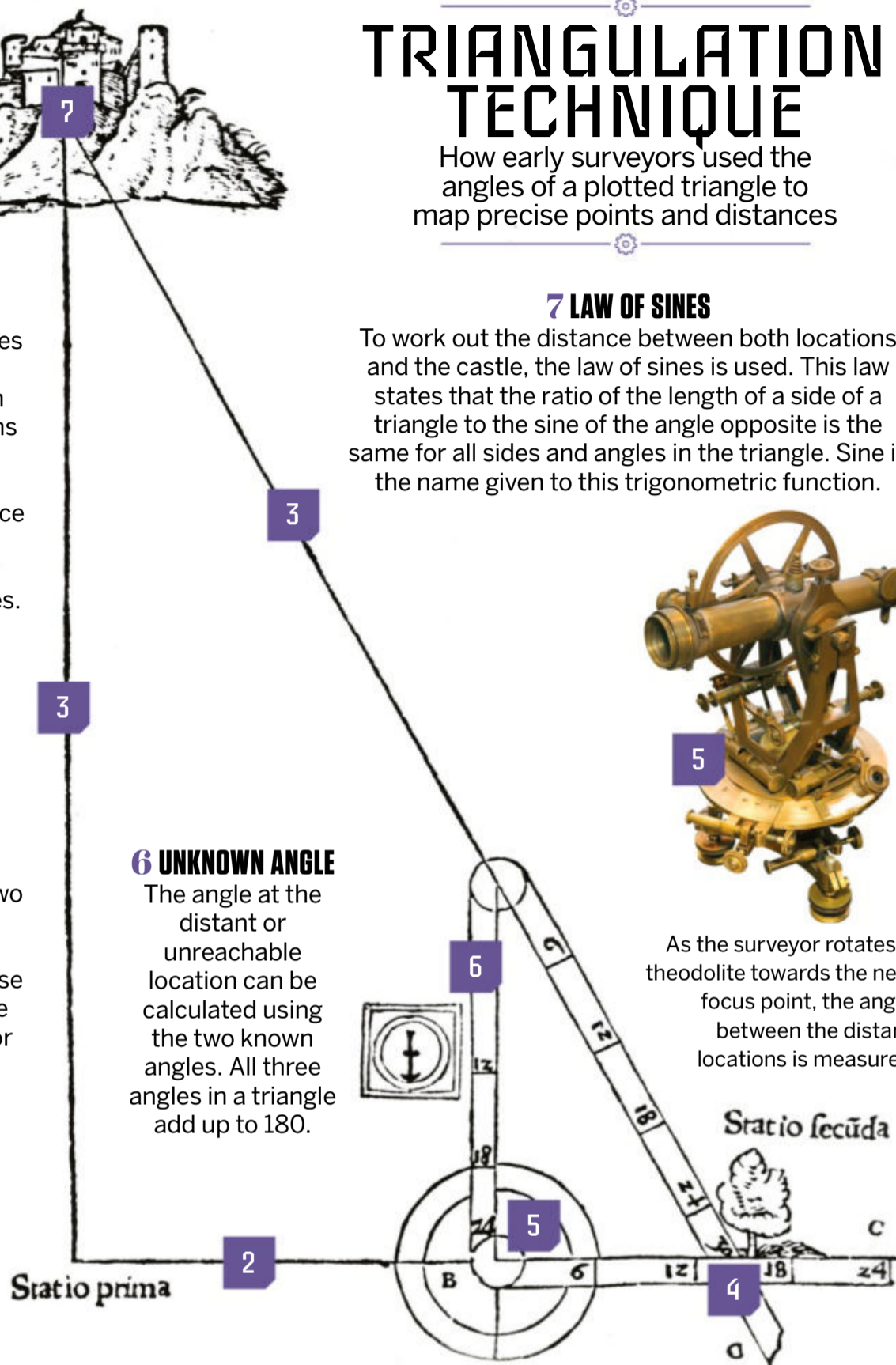
The two angles between the distant point and the two ends of the baseline are measured using an instrument called a theodolite – a movable telescope that rotates along axes marked with angle degrees.

7 LAW OF SINES

To work out the distance between both locations and the castle, the law of sines is used. This law states that the ratio of the length of a side of a triangle to the sine of the angle opposite is the same for all sides and angles in the triangle. Sine is the name given to this trigonometric function.



As the surveyor rotates a theodolite towards the new focus point, the angle between the distant locations is measured

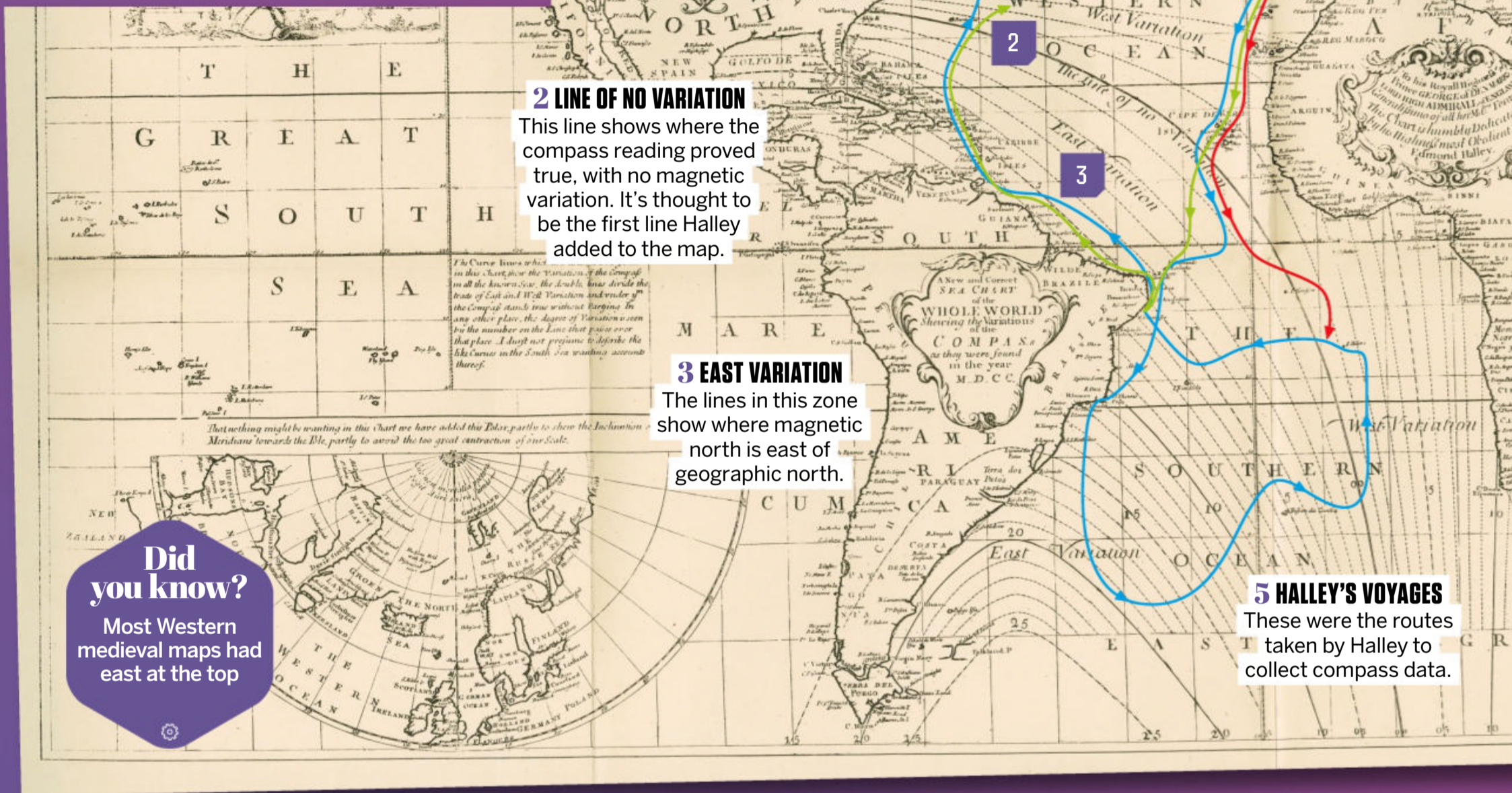


FROM TABLET TO PAPER

Paper maps were first produced by the ancient Greeks. The scholar Anaximander was the first person to publish a map of the world and is widely regarded to be the first cartographer. His map placed Greece at the centre of the world and was circular, as Anaximander assumed the planet was cylindrical and the land was surrounded by a ring of ocean. It didn't show the whole world we know today, but depicted all the parts that the ancient Greeks were aware of at the time: Europe, Asia and Africa.

MAP OF MAGNETIC DECLINATION

From 1698, Edmond Halley completed Atlantic voyages to measure Earth's magnetic variation. This was the first magnetic survey of the ocean, and his maps were some of the first to include such data



1 ISOGONS

Halley plotted lines called isogons that connect the points on Earth where magnetic declination – the angle between magnetic north and true north – is the same.

4 WEST VARIATION

West magnetic variation is described as negative variation.

2 LINE OF NO VARIATION

This line shows where the compass reading proved true, with no magnetic variation. It's thought to be the first line Halley added to the map.

3 EAST VARIATION

The lines in this zone show where magnetic north is east of geographic north.

5 HALLEY'S VOYAGES

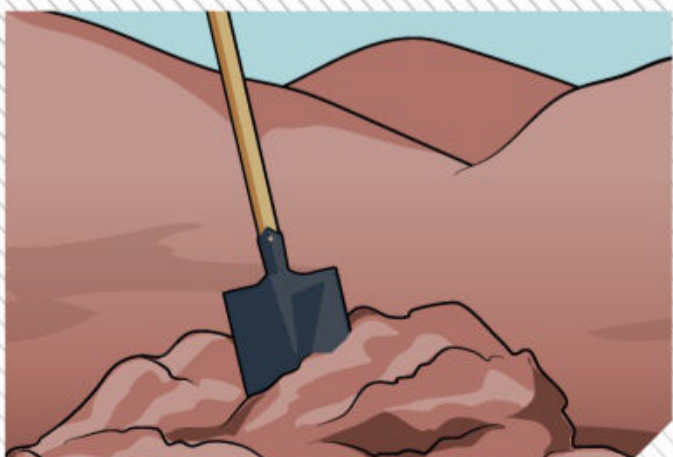
These were the routes taken by Halley to collect compass data.

Did you know?

Most Western medieval maps had east at the top

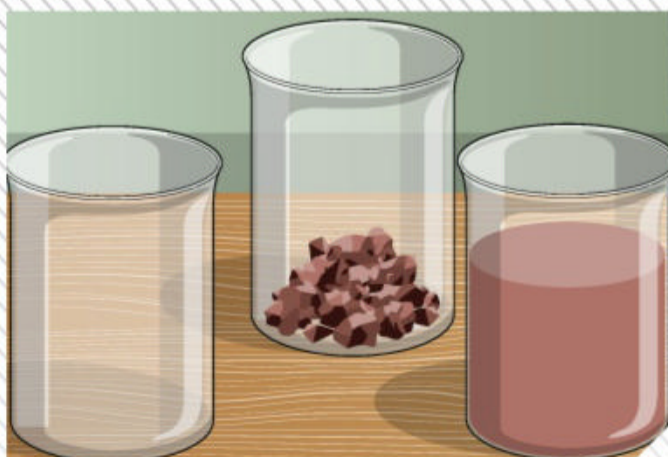
HOW BABYLONIAN CLAY TABLETS WERE MADE

From finding optimal materials to precise inscriptions, the first maps were elaborate projects



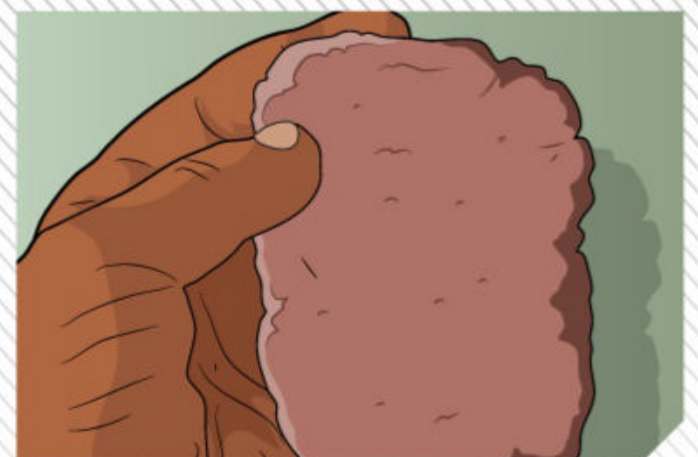
1 CLAY SOURCING

Clay was abundant across vast floodplains and in riverbanks. The plains, called Eden, were located just north of the city of Babylon and contained enough clay to build temples and most of the architecture of the civilisation.



2 REFINING

When mixed with water, the clay became liquid. This was left to settle so that any sand impurities sank to the bottom and separated from the clay, while the clay remained wet and sculptable.



3 TABLET SHAPING

Clay was first kneaded to make the consistency constant. When the clay was dry enough but still mouldable, it could be manipulated to any map shape and thickness.



WIDESPREAD PRODUCTION

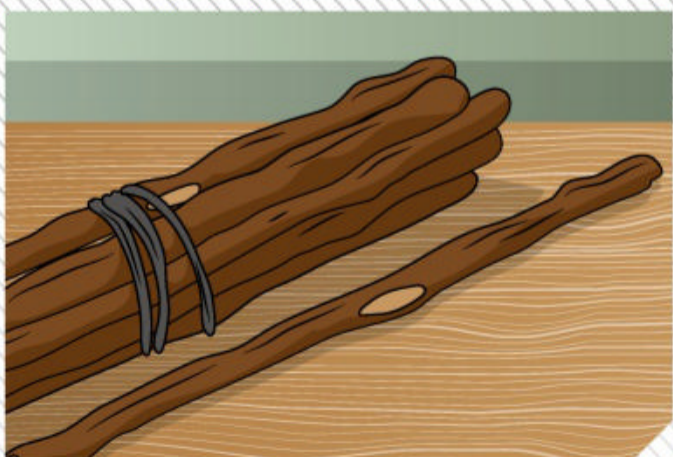
It was a technique called woodblock or woodcut printing that enabled maps to be distributed more widely. Beforehand, each map was a one-off work of art. They could be relatively bulky productions and were reserved for one location or group of people to use. Woodblock printing involved carving a map's design into wood so that the useful details were protruding from the wood. The wood's surface was then coated in ink and transferred onto any map material. This meant the map's design could be reprinted as many times as needed. Although woodblock printing made maps more widespread, the marked areas of the map appeared less detailed than standard line drawings, as fine and accurate lines were more difficult to carve into wood.



This is an example of a printed woodblock map

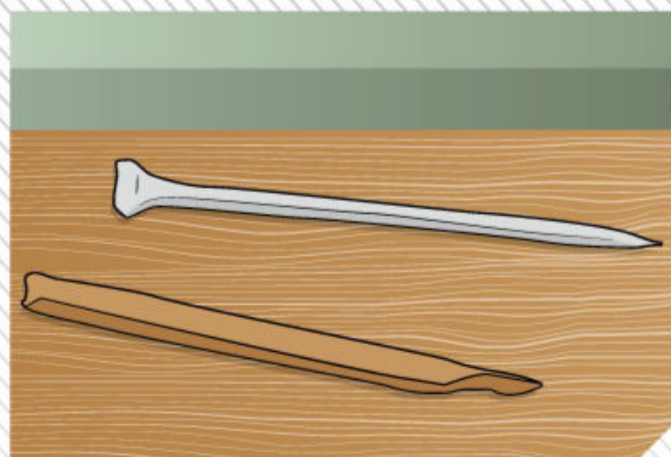


The Madaba Map decorated the floor of a 6th century CE church in modern-day Jordan



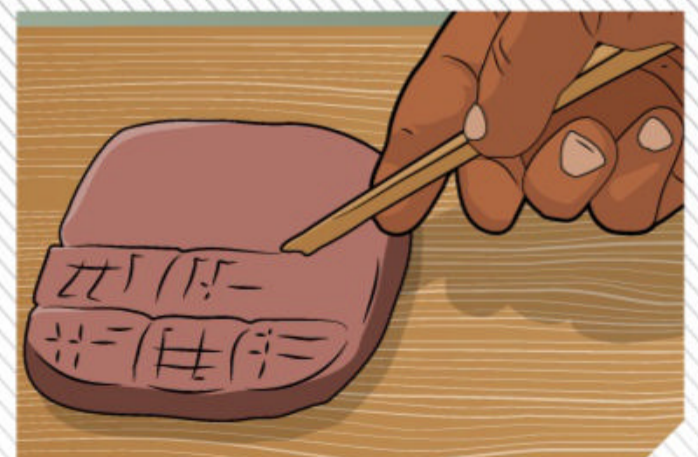
4 REED SELECTION

Many reed species were used to make styluses for ancient map carving. However, giant reed was ideal, with its tough stalk and waterproof coating.



5 CUNEIFORM CREATION

Wedge-shaped styluses carved unique, blocky characters in the clay, called cuneiform. Both reed and bone tools were common, and the triangular-shaped points made drawing on clay easy and efficient.



6 MAP MARKING

Many points on these ancient maps are marked as triangles due to the stylus designs. Inscription needed to be carried out once the clay had stiffened to keep its shape but was still soft enough to engrave into.

WHO WERE THE FIRST AMERICANS?

The first humans in the Americas were thought to have travelled across a land bridge from Asia 13,000 years ago, but new evidence suggests otherwise

WORDS LAURA GEGGEL AND BEN BIGGS



DID YOU KNOW? One theory claims that the first Americans arrived by boat from across the Atlantic

During the last ice age, humans ventured into two vast and unknown continents: North and South America. For nearly a century, researchers thought they knew how this wild journey occurred. The first people to cross the Bering Land Bridge, a massive swath of land that connected Asia with North America when sea levels were lower, were the Clovis, who made the journey shortly before 13,000 years ago. According to the Clovis First theory, every Indigenous person in the Americas could be traced to this single inland migration. But in recent decades, several discoveries have revealed that humans first reached the so-called New World thousands of years before we initially thought, and probably didn't get there by an inland route. Who were the first Americans, and how and when did they arrive?

Genetic studies suggest that the first people to arrive in the Americas descended from an ancestral group of Ancient North Siberians and East Asians that mingled around 20,000 to 23,000 years ago. They crossed the Bering Land Bridge sometime between then and 15,500 years ago. But some archaeological sites hint that people may have reached the Americas far earlier than that. For instance, there are fossilised human footprints in White Sands National Park in New Mexico that may date to 21,000 to 23,000 years ago. That would mean humans arrived in North America during the Last Glacial Maximum, which occurred between about 26,500 and 19,000 years ago, when ice sheets covered much of what is now Alaska, Canada and the northern US.

Other more equivocal data suggests the first people arrived in the Western Hemisphere by 25,000 or even 31,500 years ago. If these dates can be confirmed, they would paint a much more complex picture of how and when humans reached the Americas. Almost all scientists agree, however, that this incredible journey was made possible by the emergence of Beringia – a now-submerged 1,100-mile-wide landmass that connected what is now Alaska and the Russian Far East. During the last ice age, much of Earth's water was frozen in ice sheets, causing ocean levels to fall. Beringia surfaced once waters in the North Pacific dropped roughly 50 metres below today's levels; it was passable by foot between 30,000 and 12,000 years ago.

From there, the archaeological picture gets muddier. The older version of the story originated in the 1920s and 1930s, when Western archaeologists discovered sharp-edged, leaf-shaped stone spear points near



Mammoths, like this well-preserved baby mammoth found in Alaska, were still roaming the Arctic islands 4,500 years ago



Petroglyphs, prehistoric rock carvings like these in Utah, are found in numerous sites across the Americas

Clovis, New Mexico. The people who made them, now dubbed the Clovis people, lived in North America between 13,000 and 12,700 years ago, based on a 2020 analysis of bone, charcoal and plant remains found at Clovis sites. At the time, it was thought that the Clovis travelled across Beringia and then moved through an ice-free corridor, or a gap between the continental ice sheets in what is now part of Alaska and Canada. Once they left the corridor, they spread quickly throughout the Americas, bearing a signature stone tool known as the Clovis spear point. This was likely used to hunt megafauna, such as mammoths and bison, as well as smaller game. For decades, it was challenging to suggest that the first Americans arrived any earlier than 13,000 years ago.

Slowly, new discoveries began turning back the clock on the first Americans' arrival. In 1976, researchers learned about the site of Monte Verde II in southern Chile, which radiocarbon dating showed was about 14,550 years old. It took decades for archaeologists to accept the dating of Monte Verde, but

soon other sites also pushed back the date of human arrivals in the Americas. The Paisley Caves in Oregon contain human coprolites, or fossilised poo, dating to about 14,500 years ago. Page-Ladson, a pre-Clovis site in Florida with stone tools and mastodon bones, dates to about 14,550 years ago. And Cooper's Ferry – a site that includes stone tools, animal bones and charcoal – dates to around 16,000 years ago. Then, in 2021, scientists announced much more ancient traces of human occupation: fossilised footprints in White Sands, New Mexico, dating to between 21,000 and 23,000 years ago.

There are dozens more sites, although some of the older ones are controversial. For instance, some archaeologists said 31,500-year-old rocks in a remote Mexican cave were stone tools made by humans, but there was an argument against that theory that suggested the rocks got their shapes naturally. Another site in Brazil holds giant sloth bones that may have been modified by humans at least 25,000 years ago, but a narrow hole in the bones could also have occurred naturally. And 50,000-year-old stone tools at Pedra

Furada in Brazil may have actually been made by capuchin monkeys. Sites such as White Sands and Cooper's Ferry have big implications for how the first people arrived in the Americas. It's thought that the ice-free corridor through North America didn't fully open until about 13,800 years ago. If humans were in the Americas long before then, they likely travelled there along the Pacific Coast. That coastal journey could have been made by

Did you know?

Today there are around 381 million people living in North America

WHAT'S NEXT

Archaeologists would like to find more sites from all of these genetic branches, especially any remains that could explain the genetics behind the people at White Sands between 23,000 and 21,000 years ago. But when they do uncover exceptionally preserved sites, they find that over 90 per cent of what people made and used was perishable: plant fibres, feathers, animal skins and the like. These organic artefacts and remains typically preserve well only in rare circumstances – extremely wet, dry or cold places such as caves, rock shelters or water-logged sites.

Even if there are other sites, many scientists aren't looking for them. They are stuck in a Clovis mindset, hunting for the stone tools ancient people crafted. But evidence of these long-lost people can also be found in the remains of the animals they butchered, the charcoal they burned, the tools they crafted and the loved ones they buried... even fossilised footprints these ancient individuals left behind. The field can only move forward when more archaeologists focus on this kind of evidence.

foot, by watercraft or both. But no fossil or archaeological evidence of this journey has been unearthed. No boat nor submerged site has been found on a 16,000-year-old shoreline in British Columbia. Still, the coastal route isn't outlandish. A lot of evidence suggests that people were capable of large ocean crossings. For instance, people were using boats to reach Australia by around 50,000 years ago.

Despite these uncertainties, researchers have ruled out some of the wildest theories. For instance, the first Americans weren't Pacific Islanders who boated across the open ocean, because people didn't migrate to Polynesia until around 3,000 years ago and genetic evidence shows that the first Americans are only very distantly related to Polynesians. Likewise, genetic studies rule out the 'Solutrean hypothesis' that suggests that Paleolithic Europeans came across the Atlantic around 20,000 years ago.

Geneticists studying the first Americans tend to paint a more consistent picture than archaeologists do, mainly because they're using the same human remains and genetic datasets. Genetic analyses have found that Ancient North Siberians and a group of East Asians paired up around 20,000 to 23,000 years ago. Soon after, the population split into



A prehistoric human coprolite, or fossilised poo. One of 700 such examples found at Paisley Caves

two genetically distinct groups: one that stayed in Siberia, and another, the basal American branch, which emerged around 20,000 to 21,000 years ago. Genetic data suggests the descendants of this basal American branch crossed the Bering Land Bridge and became the first Americans.

The basal American branch then split into three groups: unsampled population A, a mysterious genetic 'ghost' that has only been detected indirectly from the genomes of the Mixe people of what is now Mexico; Ancient Beringians, who have no known living descendants, and Ancestral Native Americans, whose descendants live on today. All three of these groups ultimately made it to North America, but their diverging genetics suggest that they crossed in separate movements. Some didn't make it very far – the Ancient Beringians entered Alaska but never made it south of the continental ice sheets. The last known Ancient Beringian, known as the 'Trail Creek individual', died around 9,000 years ago in Alaska.

Did you know?
Giant beavers lived in North America when humans arrived there

Meanwhile, the Ancestral Native American lineage underwent several splits, suggesting that these people settled in different areas of North America as they had limited gene flow between them. There was one split that took place between 21,000 and 16,000 years ago and then a second one around 15,700 years ago. During this second split, the Northern Native Americans – whose living descendants include speakers of the Algonquian, Salishan, Tsimshian and Na-Dené language groupings – separated from the Southern Native Americans, who spread southward and whose descendants include the Clovis. According to this theory, every known living and deceased Indigenous individual south of Canada belongs to the Southern Native Americans.



Mastodons were shorter than elephants, but were stockier and covered with thick hair

PREHISTORIC MIGRATIONS WORLDWIDE

First humans

Migration: **Africa to the Arabian Peninsula**
Date: **150,000 BCE**

First Europeans

Migration: **Arabian Peninsula to Europe**
Date: **50,000 BCE**

First Australians

Migration: **Timor to Australia**
Date: **70,000 BCE**

Beringia migration

Migration: **Siberia to Alaska**
Date: **25,000 BCE**

South America inhabited

Migration: **North America to Chile**
Date: **12,500 BCE**

OLDEST HUMAN SITES IN THE AMERICAS

These archaeological sites show how prehistoric humans spread across the continent

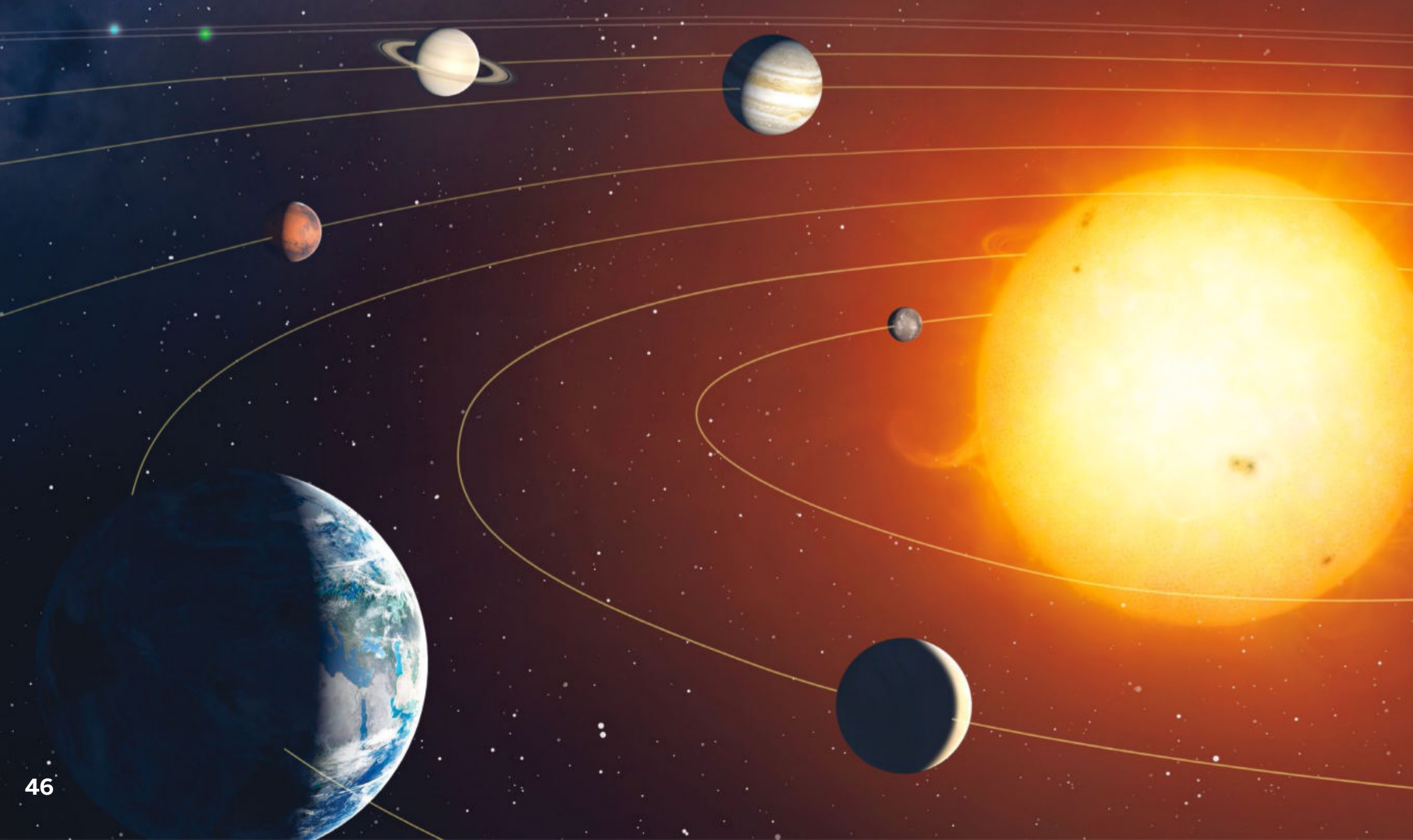




SEASONS IN THE SOLAR SYSTEM

Do other planets have a spring, summer, autumn and winter?

WORDS SCOTT DUTFIELD



Every three months or so, Earth shifts from one of its four seasons into the next. This can mean a shift from summer sunshine to a colder autumn. But wherever you are in the Solar System, the seasons change in line with the planet's movement around the Sun. As Earth zips along its 365-day solar orbit, it also spins on a fixed axis which is slightly tilted, at 23.5 degrees. Known as its obliquity, a planet's degree of tilt determines the exposure of

sunlight that reaches each of its hemispheres as it orbits the Sun. It's measured using the planet's axis, which runs through its poles, and an imaginary vertical line that runs through it perpendicular to the Sun's equator, referred to as the orbital plane.

When a planet is tilted, either its northern or southern hemisphere is angled more towards the Sun than the other. This difference in exposure to sunlight is what shapes the planet's seasons. During summer Earth's

Northern Hemisphere is facing sunward, while the Southern Hemisphere is tilted away from the Sun and experiences winter. As Earth orbits, the Sun-facing hemisphere shifts through the spring and autumn months, when both hemispheres bask in sunlight. Earth's tilt also results in the creation of seasonal weather patterns. When a hemisphere is exposed to more sunlight it increases the temperature on the surface and within the atmosphere, which in turn causes pressure fluctuations and

FROM SUMMER TO WINTER

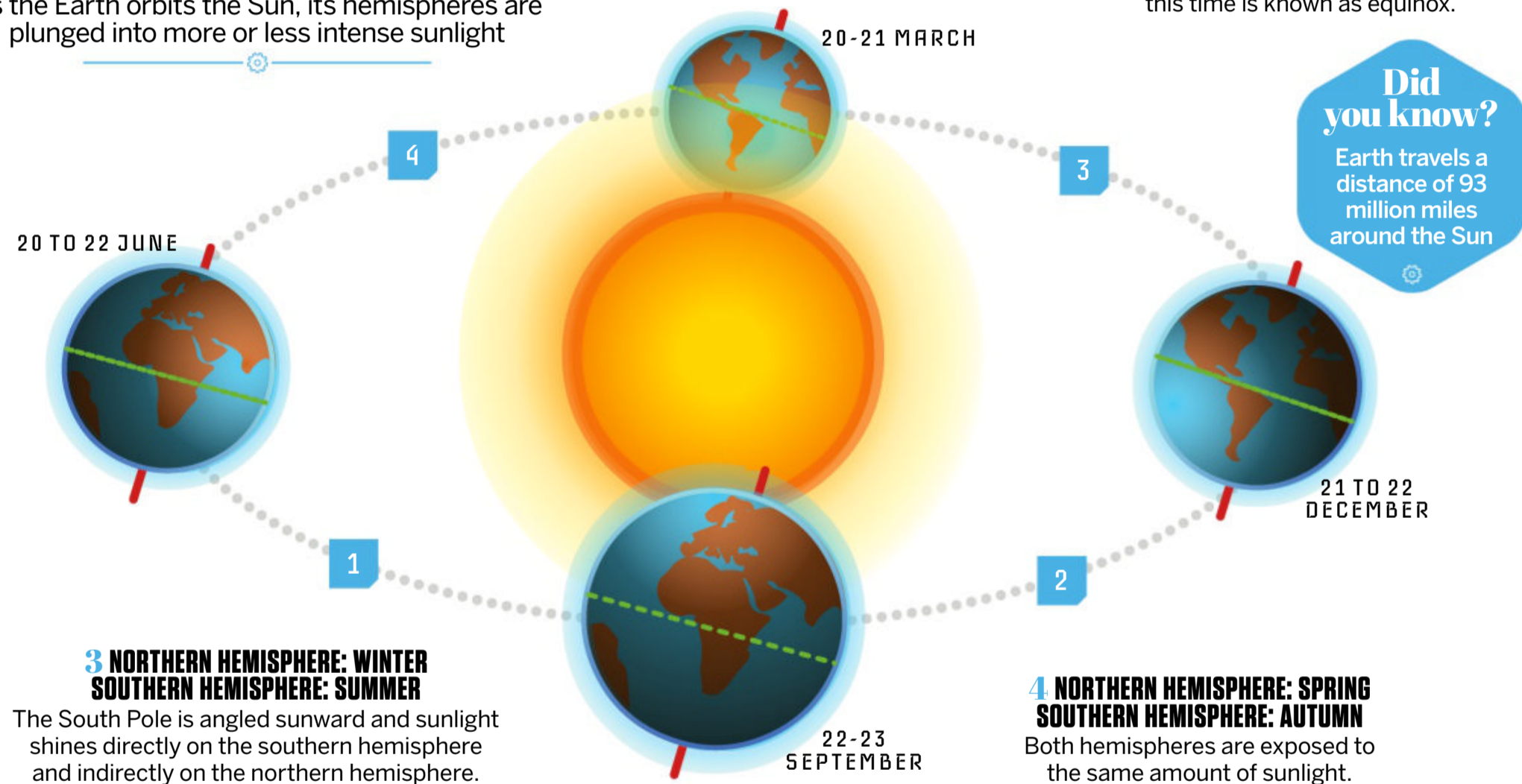
As the Earth orbits the Sun, its hemispheres are plunged into more or less intense sunlight

1 NORTHERN HEMISPHERE: SUMMER SOUTHERN HEMISPHERE: WINTER

The North Pole is angled sunward and sunlight shines directly on the northern hemisphere and indirectly on the southern hemisphere.

2 NORTHERN HEMISPHERE: AUTUMN SOUTHERN HEMISPHERE: SPRING

The sun shines equally on both hemispheres. The point at which the length of day and night is equal during this time is known as equinox.



3 NORTHERN HEMISPHERE: WINTER SOUTHERN HEMISPHERE: SUMMER

The South Pole is angled sunward and sunlight shines directly on the southern hemisphere and indirectly on the northern hemisphere.

4 NORTHERN HEMISPHERE: SPRING SOUTHERN HEMISPHERE: AUTUMN

Both hemispheres are exposed to the same amount of sunlight.

More than 20 years after its launch, the Hubble Space Telescope is still snapping images of planets and their changing seasons



WATCHING PLANETS SPIN

To keep tabs on a planet's seasonal changes NASA and the European Space Agency (ESA) use data collected by the trusty Hubble Space Telescope, which was launched back in 1990. Over the years, Hubble's onboard cameras have captured images of seasonal activities in the Solar System, particularly on Jupiter and Uranus. In 2022 Hubble captured a thick, high-altitude photochemical haze, similar to the smog of a bustling city, created during the planet's stormy spring. Scientists

hope that the haze will return even brighter when the planet enters its summer solstice in 2028. Back in 2014 during the planet Uranus's spring, Hubble snapped an image of the clouds of methane ice-crystals that painted the planet's atmosphere a light cyan colour. This telescope has also been used to help identify changes in wind speed, which dropped from 1,000 miles per hour to 800 miles per hour at Saturn's equator as it transitioned from summer to autumn.



A Hubble telescope image of Uranus' photochemical haze during the planet's spring in 2022



seasonal weather patterns. However, the outer planets beyond Mars don't have a solid surface and receive less sunlight to drive circulation in their atmospheres – factors which govern the seasonal weather changes on Earth.

While there are some planets that are tilted in a similar way to Earth, and thus have similar seasonal changes, not every planet or celestial object in the Solar System does. The Moon has a small tilt of around 1.5 degrees, meaning it doesn't experience different seasons. However, many moons in the Solar System do, such as Saturn's Titan, which shares roughly the same tilt as its parent planet, meaning it also shares its seasonal changes.

As for trying to explain why a planet tilts, scientists have several theories. Planets like Earth and Venus may have been impacted by another celestial object at some point in their history, causing them to be knocked from a vertical axis. Mars, on the other hand, got its axial tilt around 3.5 billion years ago thanks to an enormous volcanic structure known as Tharsis. Under the mounting mass of Tharsis' colossal dome, which is thought to span more than 3,000 miles, the planet's axis shifted by around 20 degrees. For the Solar System's favourite dwarf planet, Pluto, a 600-mile-wide region known as Sputnik Planitia may have been the cause of its dramatic tilt. When the region filled with ice and gained enough mass, it's believed to have caused the dwarf planet's axis to shift.



Due to its 119.5-degree tilt and 248-year orbit, Pluto's seasons last for over a century

SUMMER IN THE SOLAR SYSTEM

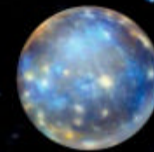
How the seasons shift for each planet as it orbits around the Sun

NO SEASONS

Three of the planets within our Solar System aren't subjected to seasonal changes. Mercury, Venus and Jupiter all have a fairly vertical rotating axis, meaning their exposure to sunlight while they orbit the Sun remains fairly uniform and they don't experience much in the way of seasons. However, there is something a bit odd about the way Venus spins. Even though its axis is only a few degrees from being completely perpendicular to its orbit, the planet appears to spin upside down and in the opposite direction to all the other planets in the Solar System. Scientists think a sizable collision with an object during Venus' history caused it to flip. This upside-down orientation

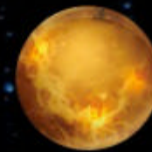
means that if you were to stand on its surface you would see the Sun move in the opposite direction to how it's viewed on Earth, rising in the Venusian sky in the west and then setting in the east.

NO-SEASON PLANETS



MERCURY

Orbit: 88 days
Tilt: 2.0 degrees



VENUS

Orbit: 225 days
Tilt: 177 degrees



JUPITER

Orbit: 12 years
Tilt: 3.1 degrees



EXTREME-SEASON PLANET

URANUS

Orbit: 84 years
Tilt: 97.8 degrees
Spring: 21 years
Summer: 21 years
Autumn: 21 years
Winter: 21 years

EXTREME SEASONS

Around 1.8 billion miles from the Sun is lop-sided Uranus, spinning almost horizontally. Like many of the other planets, Uranus is thought to have been impacted by a long-lost moon that threw it off its axis, causing it to ultimately lay on its side. However, other theories suggest that Uranus entered into a gravitational dance with a neighbouring moon, shifting the planet's axis before

the moon impacted it. Due to its oddball axis, seasons on Uranus are extreme: for the entirety of the 21 years of its summer the planet is constantly illuminated by sunlight. But in winter the planet is plunged into complete darkness, which also lasts 21 years. During the transitional seasons of spring and autumn, Uranus experiences a day-to-night cycle every 17 hours.

EARTH-LIKE SEASONS

With Earth-like tilts, Mars, Saturn and Neptune follow a similar seasonal pattern, but for much longer periods. Due to Neptune's 165-year orbit around the Sun, each of its seasons lasts more than 40 years. Not every planet has the same roughly circular orbit around the Sun as Earth. Mars has an elliptical

orbit that alters the length of its seasons. Mars passes its closest point to the Sun during summer in the southern hemisphere. A summer day in the southern hemisphere on Mars can be as warm as 20 degrees Celsius. The higher summer temperatures can lead to more of the planet's dusty

surface being whipped into its atmosphere, creating larger dust storms than any other time. Also during its summer, Mars' carbon dioxide ice caps melt away almost entirely and reform in the next frigid winter, which can plummet the poles into temperatures of -80 degrees Celsius.

EARTH-LIKE-SEASON PLANETS



EARTH

Orbit: 365 days
Tilt: 23.5 degrees
Spring: 92 days
Summer: 94 days
Autumn: 89 days
Winter: 90 days



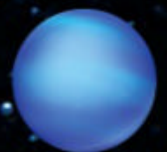
MARS

Orbit: 687 days
Tilt: 25 degrees
Spring: 199 days
Summer: 183 days
Autumn: 146 days
Winter: 159 days



SATURN

Orbit: 29.4 years
Tilt: 27 degrees
Spring: 7 years
Summer: 7.5 years
Autumn: 7 years
Winter: 7.5 years



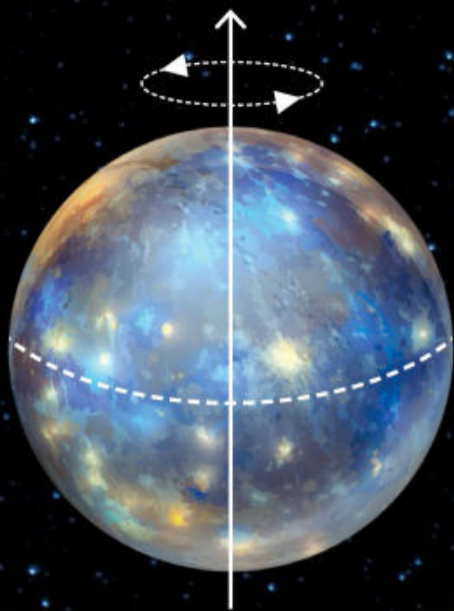
NEPTUNE

Orbit: 165 years
Tilt: 28 degrees
Spring: 40 years
Summer: 40 years
Autumn: 40 years
Winter: 40 years

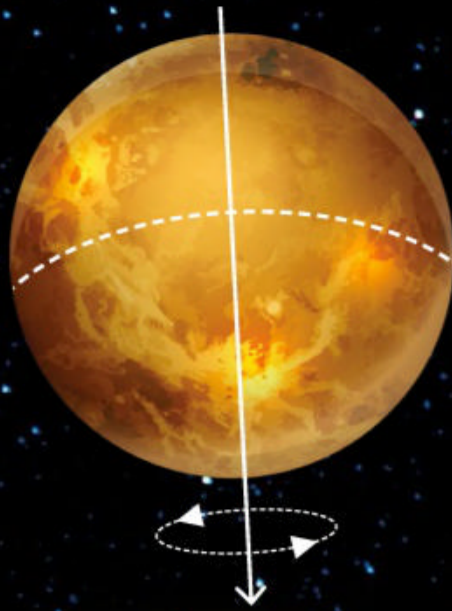
DID YOU KNOW? On Mercury, it takes 176 days for the Sun to rise, set and then rise again in the sky

Did you know?

Neptune's summer started in 2005 and ends in 2045



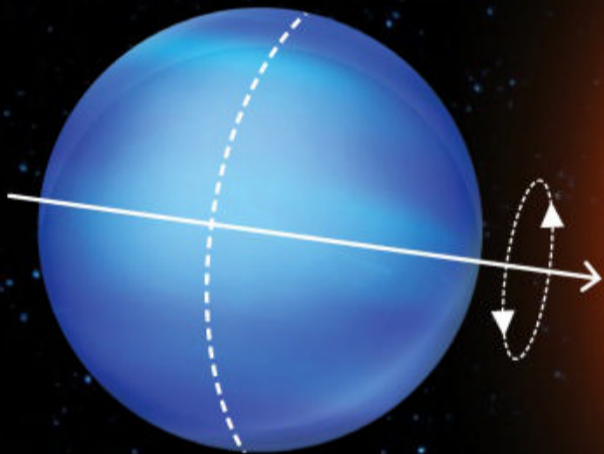
MERCURY
2.0 DEGREES



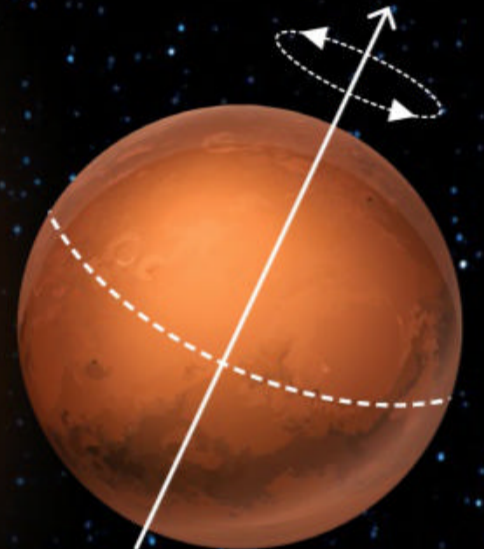
VENUS
177 DEGREES



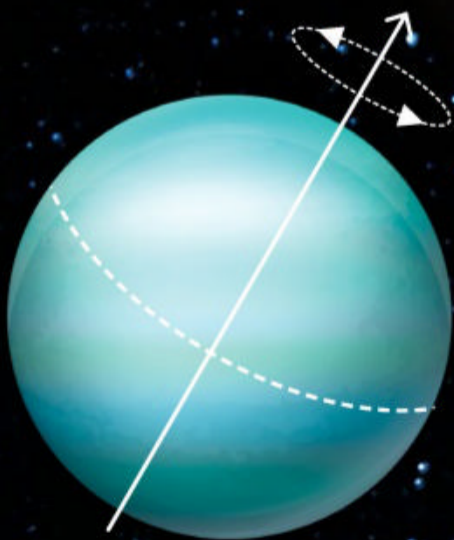
EARTH
23.5 DEGREES



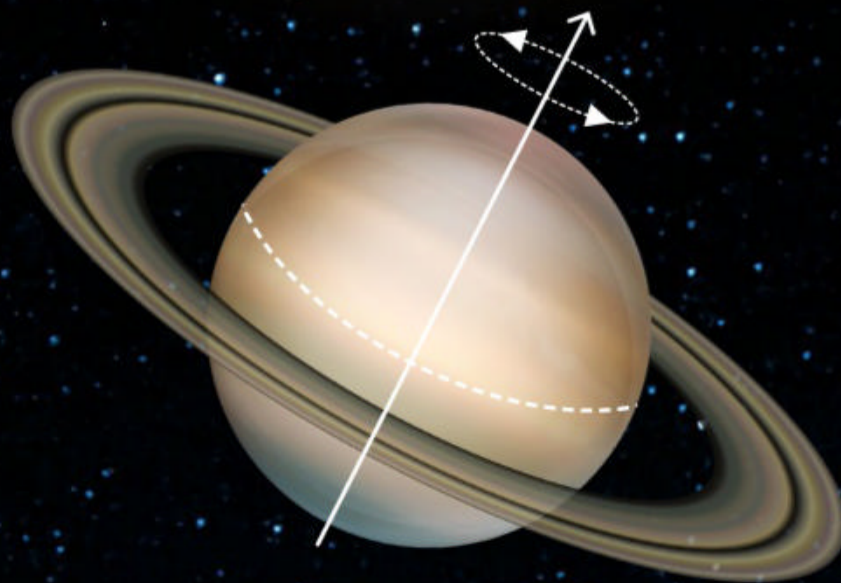
NEPTUNE
28 DEGREES



MARS
25 DEGREES



URANUS
97.8 DEGREES



SATURN
27 DEGREES



JUPITER
3.1 DEGREES

INSIDE THE ASTEROID BELT

Any ideas this sprawling ring of debris orbiting the Sun had of forming a planet were wiped out by the Solar System's largest inhabitant

WORDS ALAN DEXTER

If the asteroid belt is indeed a planet that didn't get the chance to form properly, you could be mistaken for thinking that it wouldn't have made much of a planet in the first place. The asteroid belt stretches from just past Mars beyond the orbit of Jupiter, and although it consists of millions of asteroids, many of those are tiny, dust-like particles. The belt's overall mass is just four per cent that of our Moon. Almost half that mass is contained in just four asteroids: Ceres, Vesta, Pallas and Hygiea. With a diameter of 591 miles, Ceres – officially classified as a dwarf planet – is by far the belt's largest object. This means that the belt is a much emptier area than we're generally led to believe, so much so that spacecraft can navigate safely through it without incident. But it wasn't always this way. Computer simulations suggest that the main belt originally had a mass closer to that of Earth in the earliest days of our Solar System.

Unlike the inner planets, the asteroid belt's fragments never fused together to become a fully formed planet. Its proximity to our Solar System's largest planet, Jupiter, is likely to have proved its undoing. The gas giant's huge gravitational pull gave these fragments too much orbital energy to form planets. Instead of joining together when they collided, they simply shattered into ever-smaller fragments. Jupiter continues to influence the asteroid belt to this day, its colossal mass disturbing the path of some asteroids and causing gaps to appear in the belt; these are known as Kirkwood gaps after Daniel Kirkwood, the 19th-century American astronomer who first described them.

Jupiter might also answer the question of where the rest of the belt's mass ended up. The abundance of nitrogen and argon on Jupiter leads many scientists to conclude that the planet formed much further out and migrated to its current position over time. As Jupiter shifted closer towards the Sun, much of the mass in the asteroid belt would have been thrown outwards by the influence and movement of the gassy planet. Jupiter's gravity still has implications for us here on Earth today. While Jupiter does to some extent act as a shield, its gravity deflecting dangerous debris such as comets out of our Solar System, it's thought to send just as many dangerous objects our way.

Did you know?

Over 640,000 asteroids have official designations

ROOM TO MOVE

The spaces between large objects in the asteroid belt are large enough for spacecraft to safely pass through.

1

WHAT ARE ASTEROIDS MADE OF?

The composition of asteroids varies because they are mostly the debris from collisions between objects in the early days of the Solar System. C-type asteroids are composed mostly of carbon, S-type asteroids mainly of silicates and M-types of metal. Generally, asteroids contain rock, metals and water ice in varying proportions.



“Unlike the inner planets, the asteroid belt’s fragments never fused together to become a fully formed planet”

4 DUST BAND

Dust with a radius of a few hundred micrometres is produced in part through asteroid collisions. It slowly spirals in towards the Sun.

4

2

2 MAKING CONTACT

Collisions between asteroids can form an ‘asteroid family’ – a group of rocks with similar orbits. In slower collisions, two asteroids may join.

3 SHAPING UP

Most asteroids are irregular in shape. Only the largest have enough gravity to pull them into a spherical, planet-like form.

3

ASTEROIDS OF NOTE

The belt’s biggest attractions

1 CERES

DISCOVERED: 1 JANUARY 1801

This was the first asteroid to be identified. With a diameter of 591 miles, it accounts for 30 per cent of the main belt’s total mass and is classed as a dwarf planet.

87 SYLVIA

DISCOVERED: 16 MAY 1866

Lying beyond the core of the main asteroid belt, this was the first asteroid known to have two orbiting satellites: Sylvia I Romulus and Sylvia II Remus.

1950 DA

DISCOVERED: 23 FEBRUARY 1950

The asteroid that’s most likely to collide with Earth. We’re safe until March 2880, and even then there’s only a 0.044 per cent chance of an impact occurring.

3200 PHAETHON

DISCOVERED: 11 OCTOBER 1983

The first asteroid to be discovered by a spacecraft, it has an unusual orbit that brings it closer to the Sun than any other asteroid of its size.

2005 YU55

DISCOVERED: 28 DECEMBER 2005

This 360-metre-diameter asteroid came within 201,900 miles of Earth on 8 November 2011 – one of the closest encounters in modern times.

2008 TC3

DISCOVERED: 6 OCTOBER 2008

This 80-tonne asteroid entered Earth’s atmosphere on 7 October 2008 and exploded into around 600 meteorites 23 miles above the desert in Sudan.

2013 TV135

DISCOVERED: 12 OCTOBER 2013

This near-Earth asteroid came within 4.2 million miles of Earth on 16 September 2013. But the odds of it ever hitting us are only 1 in 63,000.



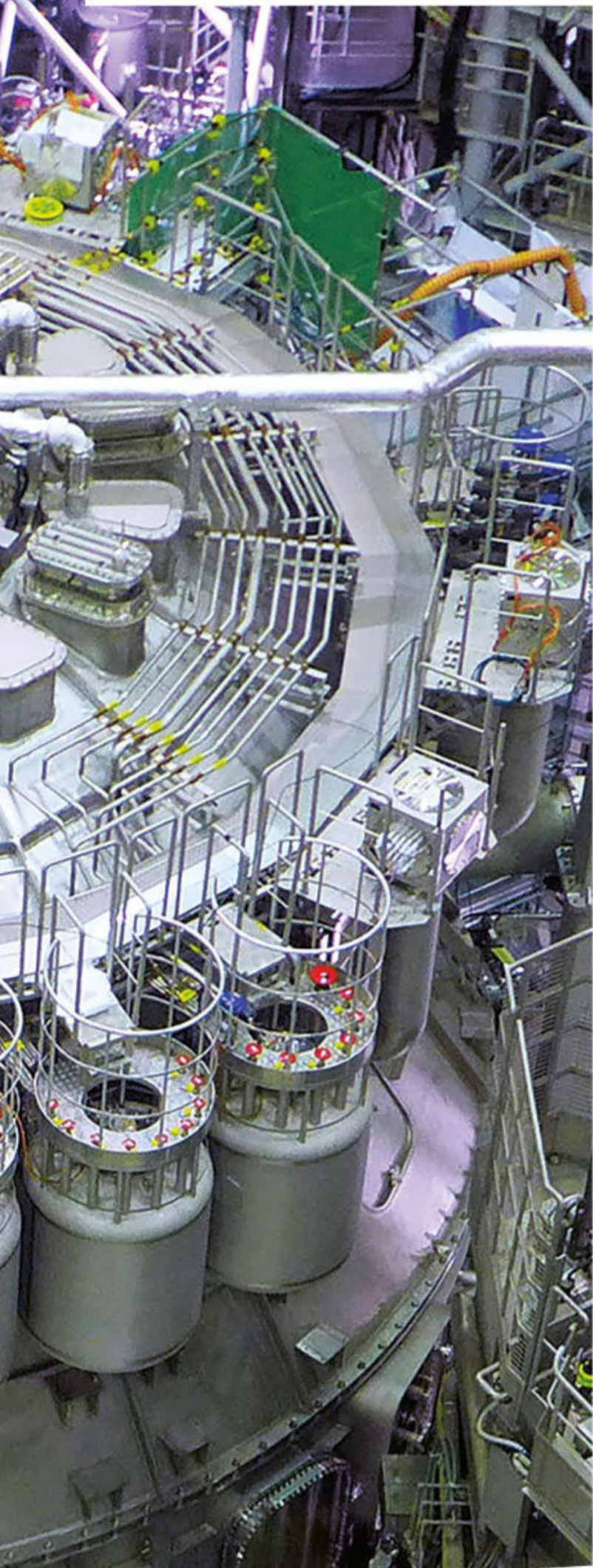
INSIDE A GIANT FUSION MACHINE

WORDS SCOTT DUTFIELD

JT-60SA will pave the way for making nuclear fusion a viable energy source of the future

DID YOU KNOW?

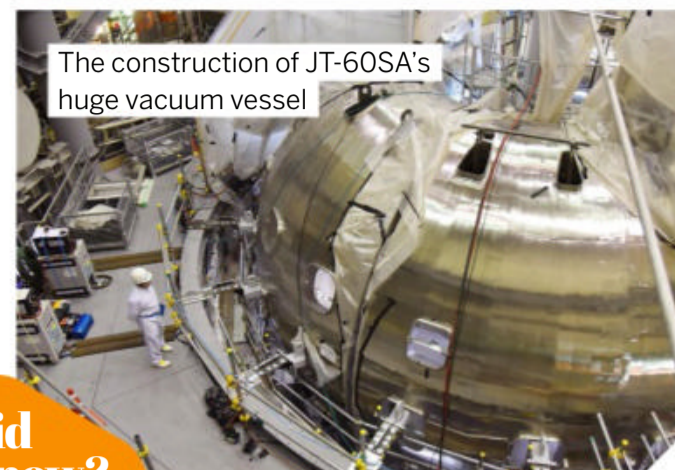
Every second the Sun converts around 550 million tonnes of hydrogen into 515 million tonnes of helium



5

Scientists have taken the next big stride in nuclear fusion technology with the switch-on of the Japanese Torus-60 Super Advanced (JT-60SA), the current record holder for the world's largest tokamak. Situated at Japan's National Institutes for Quantum Science and Technology (QST), the tokamak has produced plasma volumes up to 135-cubic-metres and has been created in a collaboration between the European Union's Fusion for Energy and QST. The word 'tokamak' comes from the Russian acronym for 'toroidal chambers with magnetic coils', and like others of its kind, JT-60SA generates energy by harnessing the power of nuclear fusion reactions. To achieve this, a fuel of superheated deuterium and hydrogen is injected into the doughnut-shaped vacuum chamber at the core of the machine, which is controlled by coils of superconducting magnets. A powerful magnetic field causes the fuel to swirl in a hot ring, known as plasma, around the core. The two elements are forced together until their atomic magnetic fields break apart, and the atoms fuse to form a new atom of helium. This is also how the Sun converts hydrogen into helium as it burns.

Along with the new helium atoms, the production of plasma also generates an enormous amount of energy as a byproduct, in the form of light and heat. The JT-60SA is capable of confining a ring of plasma up to temperatures of 200 million degrees Celsius. When the heat produced by the plasma exceeds the energy cost of causing the fusion reaction, that's when nuclear fusion becomes a viable source of energy. Tokamaks haven't yet been able to achieve this feat, but scientists think that it's possible to produce terajoules



The construction of JT-60SA's huge vacuum vessel

Did you know?

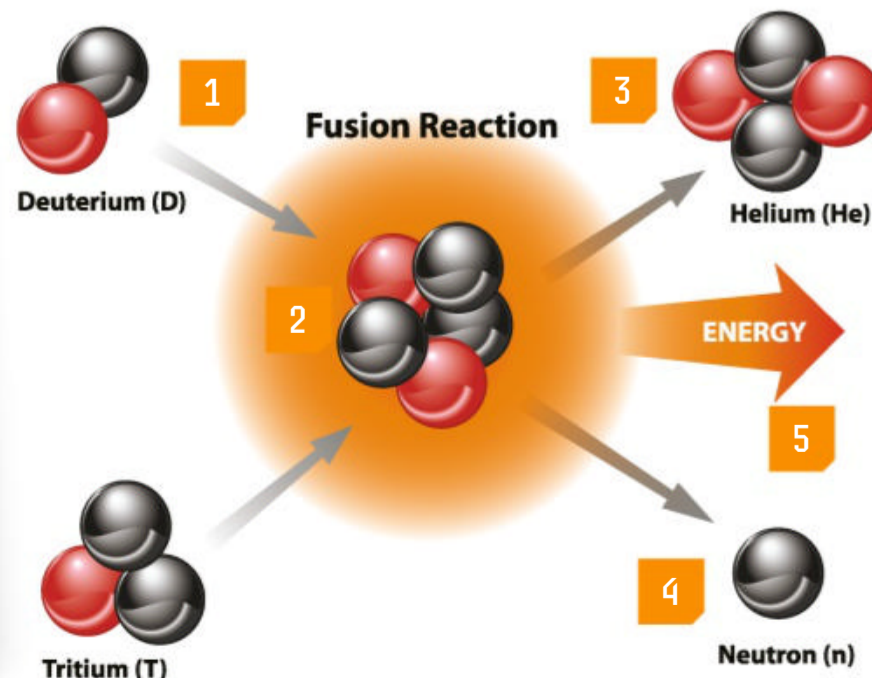
JT-60SA generates a plasma ring three metres wide

(trillions of joules) of energy from just a few grams of fuel. For comparison, 60 kilograms of fusion fuel can provide the same amount of energy as 250,000 tonnes of oil.

Construction on JT-60SA started in 2007 and was completed in 2020. On 23 October 2023, scientists announced that the tokamak had generated its first successful plasma current. With much more plasma current to generate and power to be produced, the work of JT-60SA is one of discovery, paving the way for an even larger tokamak – the International Thermonuclear Experimental Reactor (ITER). Unlike JT-60SA, ITER will use an alternative fuel combination of deuterium and tritium. Deuterium is sourced from salt water, and while tritium can be sourced from the atmosphere, it's in limited supply. However, it can also be harvested from lithium when it's exposed to a rogue neutron, which just so happens to be emitted from nuclear fusion. That's why ITER engineers will construct a lithium 'blanket' within the tokamak to 'breed' more tritium fuel while plasma is flowing. Currently under construction, ITER will have an 850-cubic-metre volume to pack with plasma. Its design and operation will be heavily influenced by the outputs of JT-60SA.

FUSING ATOMS

How to create white-hot plasma for nuclear fusion



1 ATOM INGREDIENTS

Deuterium and tritium are exposed to intense heat and pressure.

2 PLASMA

The two atoms combine and fuse together to create a superheated and electrically charged plasma.

3 HELIUM

When deuterium and tritium fuse, they become a helium atom.

4 NEUTRON

A high-energy neutron is released as a byproduct of the fusion reaction.

5 ENERGY

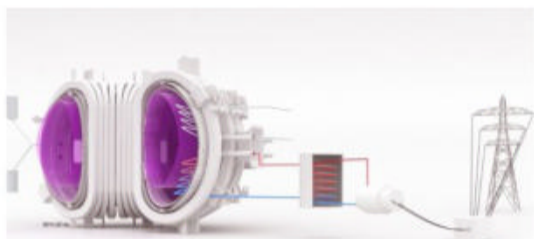
The mass of the helium atom is less than the two atoms that fuse together to make it, so the difference in mass becomes energy.

An illustration of the 30-metre-tall ITER Tokamak currently being built in France



THE ROAD TO DEMO

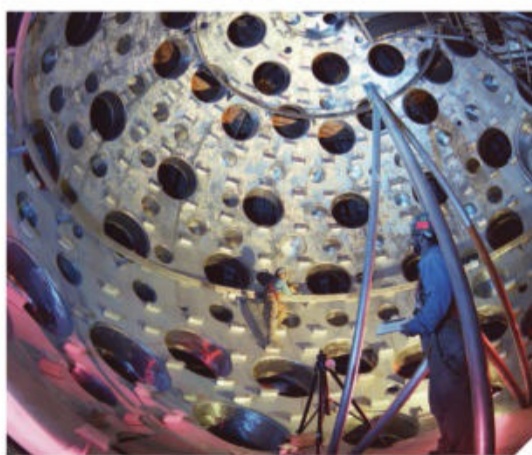
JT-60SA and ITER are designed to help scientists understand more about nuclear energy and how we can make it viable for energy production. If and when that day comes, a nuclear power plant will be needed to collect fusion energy and distribute it. That power plant will come in the form of DEMO, which will build on the lessons learned in harvesting energy from nuclear fusion. To generate a supply of electricity, DEMO will use the heat energy produced from nuclear fusion to boil water. The steam from this turns turbines and generates electricity. A DEMO reactor could be built and operating by 2050.



An illustration of a DEMO power plant connected to the grid

THE NUCLEAR BREAKTHROUGH

Nuclear fusion was first achieved in experiments by Australian physicist Mark Oliphant in 1932. However, it wasn't until 2022 that the first signs nuclear fusion could one day become a feasible source of energy were seen. On 5 December 2022, the US National Ignition Facility carried out a nuclear fusion experiment that used up 2.05 megajoules of energy but generated 3.15 megajoules, meaning that 1.5 megajoules were gained. Although this isn't much, it showed that in principle it's possible to extract more energy from fusion than you put in.



The interior of the ten-metre-wide target chamber of the National Ignition Facility

PRODUCING PLASMA

These high-tech components make it possible to control and harvest energy from nuclear fusion reactions

1 NEUTRAL-BEAM INJECTION

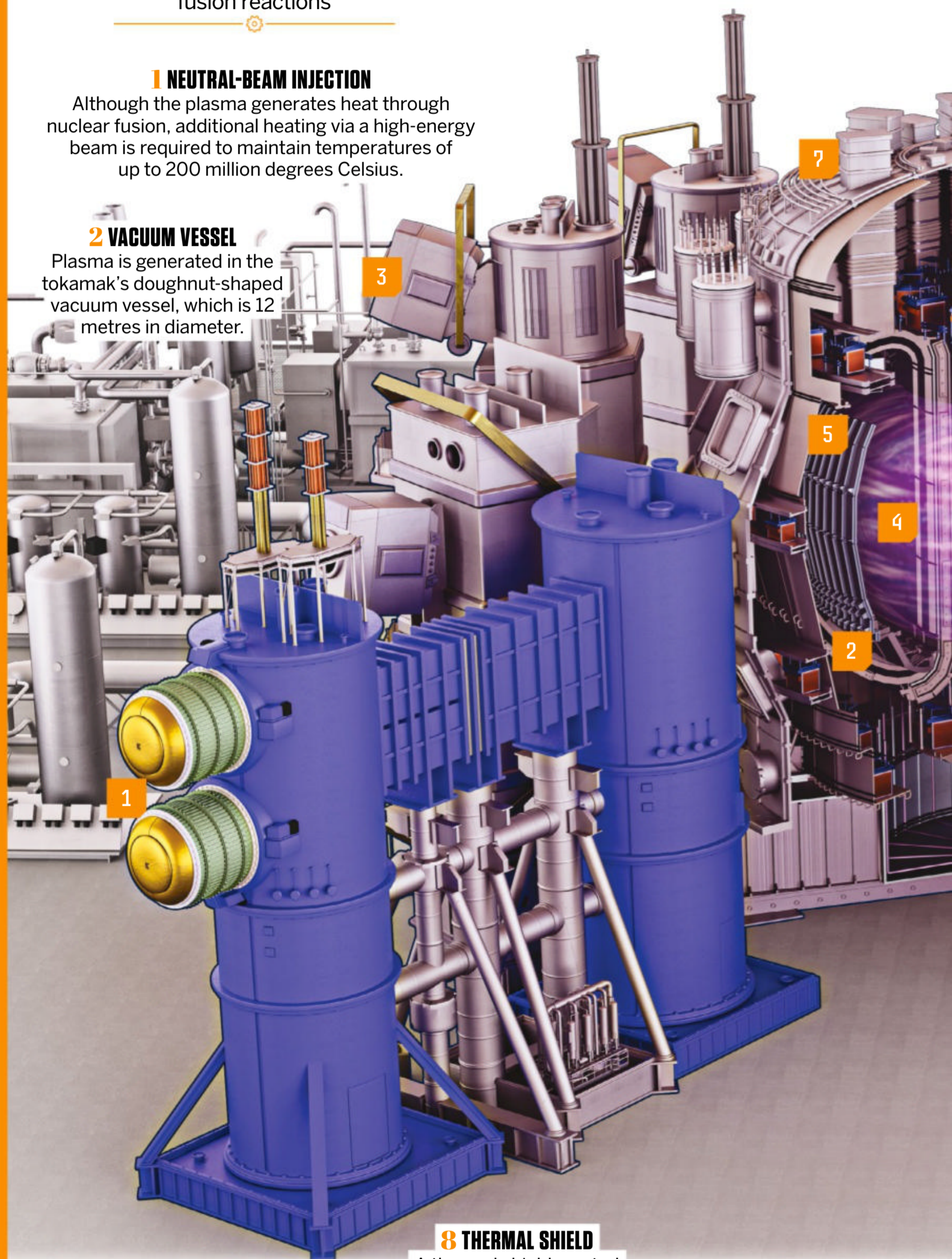
Although the plasma generates heat through nuclear fusion, additional heating via a high-energy beam is required to maintain temperatures of up to 200 million degrees Celsius.

2 VACUUM VESSEL

Plasma is generated in the tokamak's doughnut-shaped vacuum vessel, which is 12 metres in diameter.

7 CRYOSTAT

Made from three-centimetre single-walled stainless steel, the cryostat creates a vacuum around the magnets to minimise their chance of being exposed to the extreme heat that's generated.



4 PLASMA

Magnetic fields strip electrons from the deuterium and tritium fuel to produce energised plasma particles, which collide and fuse together.

8 THERMAL SHIELD

A thermal shield, coated with a thin layer of silver, helps prevent heat from the vacuum chamber transferring to the magnetic coils.

5 MAGNETS

28 superconducting magnet coils are used to confine plasma for up to 100 seconds.

DID YOU KNOW? A total of 500 researchers from Europe and Japan were involved in creating JT-60SA

3 VACUUM PUMPING SYSTEM

Before any plasma is generated, the contents of the chamber are pumped out, leaving a vacuum for the fusion reaction to occur in.



GUY PHILLIPS

Fusion for Energy's head of unit for JT-60SA tells us more about the challenges of nuclear fusion and its future



How did it feel to see the first JT-60SA plasma?

It was an amazing moment for us. After 15 years of working on this machine, we signed an agreement with the Japanese in 2007, and in 2023 we actually started operating the machine for the first time. It's a huge achievement and we're really proud and happy to have got to that point.

What have been the biggest challenges in constructing JT-60SA and in developing nuclear fusion energy?

Probably the biggest thing is the materials for construction. It's not well understood how different materials will react under the neutron loads that they will have in a device that would be manufactured for power production. Within Fusion for Energy, we have a group looking after a linear accelerator. This is being built so that we can study the material behaviours and we can better understand how the materials would behave without actually having a fusion device to study materials. At the moment it is in the prototyping stages, so there's a lot of work that needs to be done on this before we get to the point of understanding more about the materials, but it's a critical step.

How long will JT-60SA conduct experiments and help other tokamaks like ITER?

I would say there's not really a life span. It's something which we intend to develop over the years. At the moment we have operation plans well into the 2030s and into the future. The intention is that JT-60SA remains as a support device for ITER, so when things come up on ITER we should be there and ready to be able to react and adjust things accordingly, and experiment accordingly. There's no intention to shut the device down and stop everything, so it's indefinite at the moment.

Did you know?

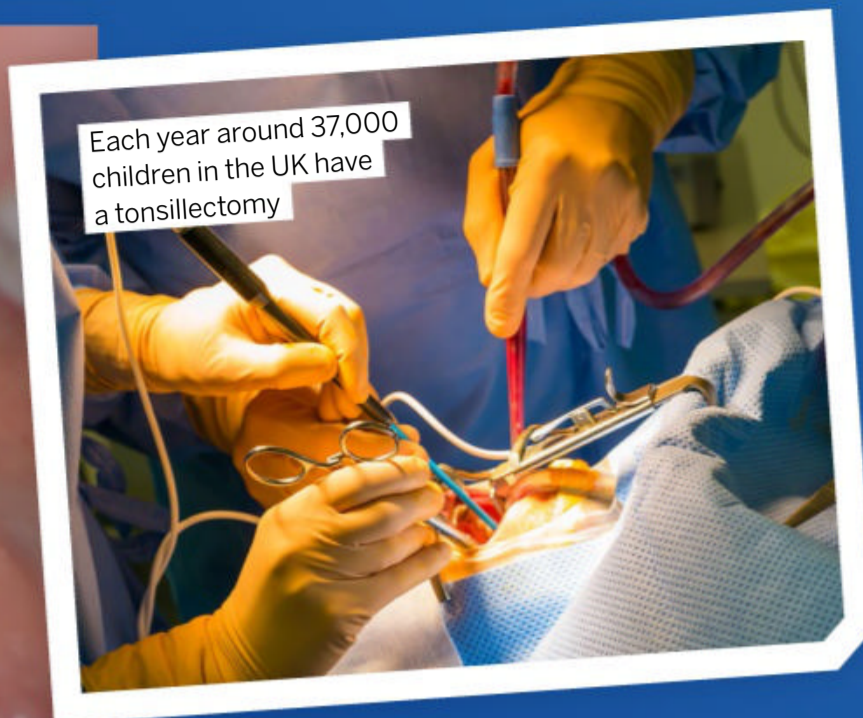
The total weight of JT-60SA is 2,600 tonnes



6 SUPERCOOLED

Magnet coils are cooled to around -268 degrees Celsius, turning them into superconductive magnets generating a strong enough magnetic field to form and contain the plasma.

Want to know more?
FUSIONFORENERGY.EUROPA.EU



WHAT ARE YOUR TONSILS FOR?

You might not pay them much attention until you get sick, but these lymph nodes at the back of the mouth can shield you from illness

WORDS AILSA HARVEY

If you stand in front of a mirror and open your mouth wide, at the back of your throat you should be able to see two pink lumps of tissue poking out from the flesh at the sides. These are your tonsils, which are vital tools of the immune system. Tonsils work to defend the body from infection by trapping, detecting and fighting bacteria, viruses and other harmful intruders. The trapping of these infection-causing cells is assisted by the structure of the organs, as they are covered in crevices called crypts. When bacteria and viruses enter the mouth or nose, they are likely to come into contact with the tonsils.

Immune cells called lymphocytes are activated in the tonsils, launching an attack before an infection can take hold. When the

tonsils fail to destroy the bacteria or viruses they come into contact with before they can multiply, the tonsils become red and inflamed with infection. This infection is called tonsillitis and causes a sore throat, difficulty swallowing and swollen glands in the neck. Sometimes you can see white specks on the tonsils. This is a sign that the tonsils are fighting back. The white spots are usually pus that has accumulated as white blood cells undergo their immune response. Some people are much more prone to tonsillitis than others, and if the infection is serious enough, it's possible to remove the tonsils in a procedure called a tonsillectomy. Doctors will only suggest this surgery if they believe the tonsils are creating more infections in the body than they are reducing.

Did you know?

Swollen tonsils can cause snoring

PRODUCING STONES

When food, mucus and dead cells get trapped around the tonsils, calcium from saliva in the mouth can be deposited and hardens around it. This calcification of the debris is what produces tonsil stones. Usually, these aren't much larger than a grain of rice, but in some instances they can grow to the size of a grape and can obstruct breathing or eating. These stones are quite common, but if they're a relatively rare occurrence in an individual they don't pose much risk to health. However, they can have a strong smell and aren't the most pleasant items to discover in your mouth. To prevent lingering debris around the tonsils, make sure you stay hydrated, gargle water and mouthwash and brush your teeth regularly. However, this doesn't completely eliminate the possibility of finding these stones. Some people are simply more prone to producing them, even with exceptional oral hygiene.



Tonsil stones usually fall out themselves without needing treatment

DID YOU KNOW? Tonsils in adults grow to be about 2.5 centimetres long, 2.1 centimetres wide and 1.2 centimetres thick

TONSIL ANATOMY

Take a look behind the tongue to explore your tonsils' structure

1 LINGUAL TONSILS

These tonsils at the base of the tongue contain white blood cells that are activated when harmful bacteria arise.

2 PALATINE TONSILS

Palatine tonsils are the ones most people know about, which noticeably swell when you have tonsillitis. It is this type that can be fully removed during a tonsillectomy.

3 EPIGLOTTIS

This elastic cartilage assists in swallowing food. Being in a similar position to the tonsils, inflammation of this tissue causes similar pain to tonsillitis.

4 PHARYNGEAL TONSIL

This tonsil is located in the top part of your throat, called the pharynx. It releases lymph fluid to flush away infections.

5 FACTS

REASONS FOR A TONSILLECTOMY

1 ENLARGED TONSILS

After numerous infections, tonsils can swell in size. This can make it difficult to breathe during the day and night. When sleeping, enlarged tonsils can cause sleep apnea and snoring.

2 RETURNING INFECTION

Tonsil removal may be recommended to a patient who suffers from recurrent and severe throat infections – if tonsillitis significantly impacts their life and they suffer from it at least seven times a year.

3 PERSISTENT TONSILLITIS

Also called chronic tonsillitis, this form of the infection is more severe and difficult to treat, causing tonsil stones. It can be prevented by performing a tonsillectomy.

4 BAD BREATH

Some people suffer from halitosis, a condition caused by debris building up in the tonsils' crevices. One main symptom is bad-smelling breath, which can cause insecurities in daily life.

5 ABSCESS ISSUES

People who experience regular abscesses of the tonsils can get their tonsils removed. Pus builds up near the tonsils and can make the area more of a threat to the body.

STEM CELLS UNCOVERED

Long billed as the next big thing in medical treatment, a change in approach may unlock stem cells' limitless potential

WORDS LAURA WALKER

Stem cells are the 'parent' cells from which all other cells in our bodies arise. They are nature's building blocks, with the potential to become any type of cell – from the skin on the soles of our feet to photoreceptors in our eyes. While scientists suggested their existence as far back as 1908, it wasn't until 1978 that they were finally discovered in umbilical cord blood. Stem cells quickly became the focus of a scientific and media frenzy. There was much speculation about their potential to solve all sorts of medical issues – from curing diseases such as Alzheimer's to creating whole new organs – thanks to their ability to change into any cell type and therefore replace those that have been damaged or lost.

But this excitement was swiftly followed by debate and controversy, most of which has centred on the source of the stem cells. Most controversial are embryonic stem cells. They are harvested five to seven days after the fertilisation of a human embryo, while it's still a tiny ball of cells. Embryonic stem cell research is only permitted in certain US states and is allowed, subject to tight controls, in the UK. But researchers have also turned their attention to adult stem cell research.

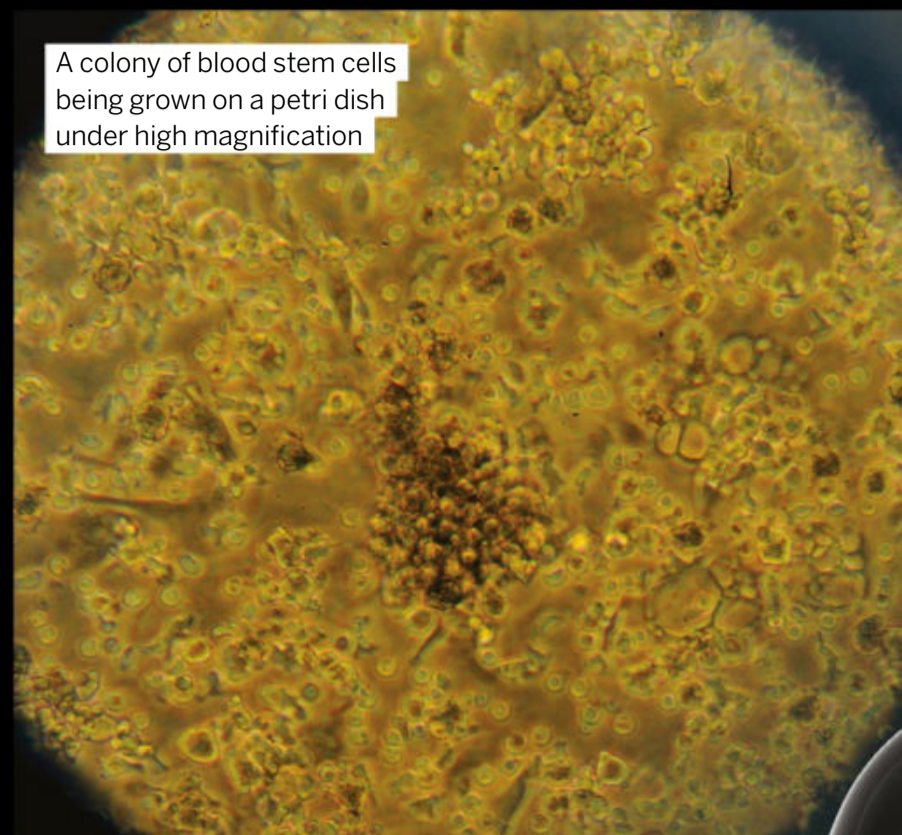
Stem cells found in adults are left over from foetal development. They remain in specific tissues, such as bone marrow and fat tissue, and replace old, dying cells. While they are not able to turn into as many cell types as embryonic stem cells, they still hold a lot of therapeutic potential and are at the cutting edge of stem cell research. In 2006, scientists found they could reprogram normal adult cells, such as skin cells, to a stem-like state. Skin cells have already reached their

end goal, but they can be 'rewound' to become stem-like by being treated with specific proteins. These cells were named induced pluripotent stem cells, or iPS cells. IPS cells are not without their problems, however. Their genes are regulated in a different way to those of naturally derived stem cells, and researchers are not yet sure how this might affect their behaviour. Nonetheless, iPS cell research has rocketed in the past two decades.

One advantage of this change in approach, aside from avoiding the ethical issues of using embryonic cells, is the potential adult stem cells and iPS cells have for autologous therapy. This is where cells are removed from and given back to the same person. The reimplanted cells don't cause the immune system to respond in the same way that 'foreign' cells would. Adult stem cells and iPS cells are offering new, accessible and varied approaches to regenerative medicine. And while research into embryonic stem cells continues, these newer methods also provide hope for curing diseases such as Huntington's and cancer.

“Stem cells found in adults are left over from foetal development”

A colony of blood stem cells being grown on a petri dish under high magnification

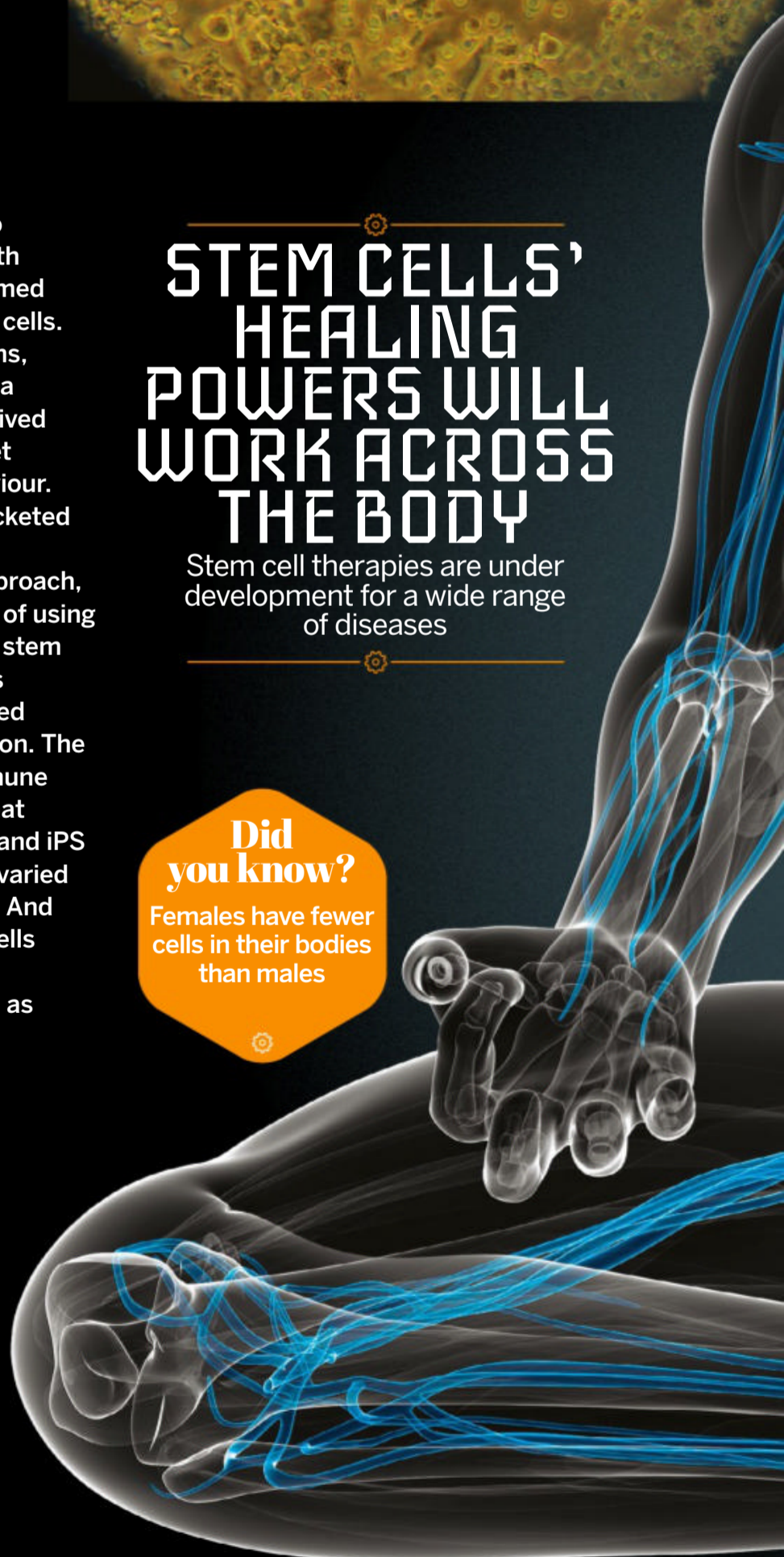


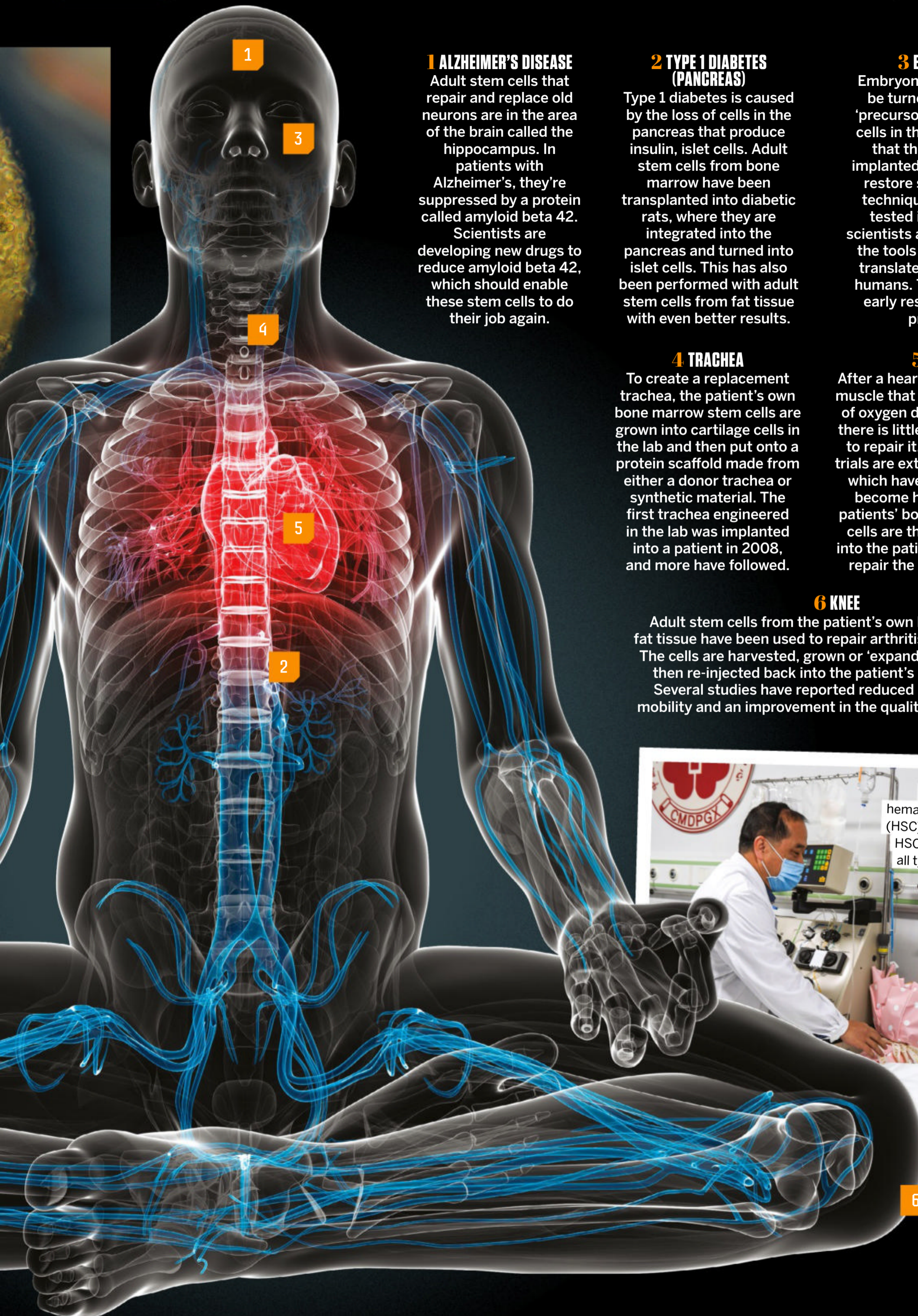
STEM CELLS' HEALING POWERS WILL WORK ACROSS THE BODY

Stem cell therapies are under development for a wide range of diseases

Did you know?

Females have fewer cells in their bodies than males





1

1 ALZHEIMER'S DISEASE

Adult stem cells that repair and replace old neurons are in the area of the brain called the hippocampus. In patients with Alzheimer's, they're suppressed by a protein called amyloid beta 42. Scientists are developing new drugs to reduce amyloid beta 42, which should enable these stem cells to do their job again.

3

3 EYE DAMAGE

Embryonic stem cells can be turned into early, or 'precursor', photoreceptor cells in the lab. The idea is that they can then be implanted into the retina to restore sight. So far the technique has only been tested in rodents, and scientists are still developing the tools and protocols to translate this research to humans. This is costly, but early results in mice are promising.

4

2 TYPE 1 DIABETES (PANCREAS)

Type 1 diabetes is caused by the loss of cells in the pancreas that produce insulin, islet cells. Adult stem cells from bone marrow have been transplanted into diabetic rats, where they are integrated into the pancreas and turned into islet cells. This has also been performed with adult stem cells from fat tissue with even better results.

5

4 TRACHEA

To create a replacement trachea, the patient's own bone marrow stem cells are grown into cartilage cells in the lab and then put onto a protein scaffold made from either a donor trachea or synthetic material. The first trachea engineered in the lab was implanted into a patient in 2008, and more have followed.

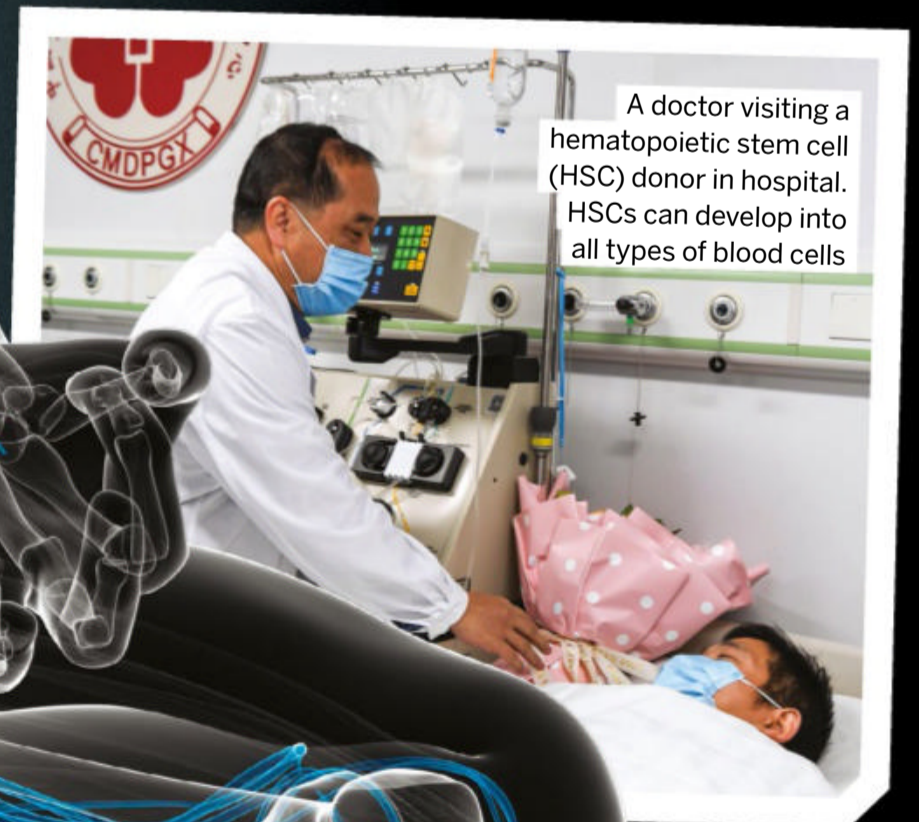
5 HEART

After a heart attack, the heart muscle that has been deprived of oxygen dies, and currently there is little that can be done to repair it. Ongoing clinical trials are extracting stem cells, which have the potential to become heart cells, from patients' bone marrow. These cells are then injected back into the patient's heart to help repair the damaged tissue.

2

6 KNEE

Adult stem cells from the patient's own bone marrow or fat tissue have been used to repair arthritis in the knee joint. The cells are harvested, grown or 'expanded' in the lab and then re-injected back into the patient's damaged knee. Several studies have reported reduced pain, increased mobility and an improvement in the quality of the cartilage.



A doctor visiting a hematopoietic stem cell (HSC) donor in hospital. HSCs can develop into all types of blood cells

6

REPAIRING THE HEART WITH STEM CELLS

Blocked or damaged blood vessels around the heart can cause heart disease, and must be replaced during heart surgery. Stem cells cultivated from your own body can be used to repair the damage

1**GATHERING**

Stem cells are isolated and treated with proteins to induce them to become the types of cells needed to form blood vessels. Stem cells from the patients themselves are less likely to trigger the immune system.

2**INCUBATING**

The appropriate scaffold material on which to grow the cells is selected. It must be able to withstand high blood pressures, be elastic so it can stretch and contract with variations in blood flow and have the potential to degrade over time.

3**GROWING**

The cells are grown on the cylindrical scaffold inside a bioreactor – a specially designed incubator. The bioreactor also allows scientists to grow one type of cell on the inside of the scaffold and another on the outside.

4**IMPLANTING**

Once the scaffold is coated with cells, it is implanted into the patient to replace the damaged blood vessel. If the cells are from the patient's own body, it's unlikely that the graft will be rejected.

5**HEALING**

As the patient heals, the engineered vessel is assimilated into the body. The cells break down the scaffold and lay down their own, leaving a totally biological vessel.



STEM CELLS by numbers

200 40%

The estimated number of specialised cells in the human body

of unrelated stem cell transplants are international – the donor is living in a country different to that of the recipient

ONE MILLION

haematopoietic (bone marrow or blood) stem cell transplants had been carried out worldwide by December 2012

1 MILLION

Americans were treated with their own stem cells in the mid-1980s

Did you know?

The EU has banned patents on embryonic stem cell research

96 MILLION

cells are created by an adult male per minute

96 MILLION

cells are lost by an adult male in a minute

3.72×10^{13}

cells make up an average male human body

WHAT IS KERATIN?

Did you know?

Hair keratin loses pigment with age, turning white

Learn about the vital protein that helps hold your body together

WORDS AILSA HARVEY

Keratin is a protein that adds strength to many of your body's hard and soft external tissues. It is predominantly found in the hair, nails and outer layer of skin, but is also in many other glands and organs. The molecule is much tougher than others in the body, being more resistant to tearing and scratching. Keratin is also waterproof and isn't dissolved by acids, alkalis or most of the body's natural chemicals.

Your body produces keratin itself, but relies on you consuming enough protein as part of your diet. If you aren't eating enough, your body struggles to make an adequate supply of keratin and you might experience brittle nails, thinning hair and dry or flaking skin. Keratin keeps your many millions of skin cells connected and working together as the largest organ in the body. To achieve this, the proteins form long strands inside the cells, which anchor to each other to form a strong skin shield.

The two broad forms of keratin are alpha-keratin and beta-keratin. Mammals usually produce alpha-keratin structures, and birds and reptiles the latter form of keratin. The structure of mammalian keratin molecules is twisted into a coil, while beta-keratin is in the form of stacked sheets. Unlike the hair, nail and skin structures of keratin in the human body, beta-keratin produces scales, feathers, beaks and claws. Reptiles, for example, benefit from the more rigid skins this keratin provides.

POWER IN THE PROTEIN

Keratin is found in a diverse range of tissues, delivering elasticity in hair strands and hardness to nails. For the different functions there are 54 different forms of this protein, which can be categorised into two types. Type I keratins are mostly acidic, low-weight proteins – 17 of this type are found in skin cells, while 11 are produced in the hair. Type II keratins are generally larger structures. 20 of this type are put to work in the cytoplasm of epithelial cells – the gelatinous liquid inside skin cells. The remaining six are in hair follicles. While the first type protect cells from internal forces, type II keratins support cells from external stress, such as scrapes and extreme cold and heat.

The red strands in this skin cell show type II keratin

DID YOU KNOW? 95 per cent of hair is made of keratin, giving it its waterproof properties

Under a microscope, a fingernail (brown) emerges from the nail bed

5 KERATIN

Dispersed throughout the hair's width are strands of keratin. These are twisted into a coil called a helix for extra strength.

4 MICROFIBRIL

Tightly packed keratin molecules create small bundles to increase hair durability.

3 MACROFIBRIL

These thick bundles are made up of multiple units of intertwining keratin to make the hair more rigid.

2 CORTEX

The cortex is the main body of the hair, with increased strength through layering. Long keratin filaments are held together by disulphide and hydrogen bonds.

2

1 CUTICLE

The outer layer of hair looks like scales close up. These are hardened layers of keratinocytes, which work as a protective shield.

1

INSIDE A HAIR STRAND

How this protein is packed into bundles to achieve hierarchical strength

5 FACTS

KERATIN DISORDERS

1 EPIDERMOLYSIS BULLOSA (EB)

Due to protein mutations, including those of keratin, this genetic disorder gives a person fragile and easily blistered skin.

2 ICHTHYOSIS

This condition is caused by an overproduction of keratin. Skin cells accumulate and create a scaly appearance over the body.

3 PACHYONYCHIA CONGENITA

Keratin loses its strong structure and network of filaments. Nails grow to become very thick and sore calluses form on the soles of the feet.

4 CURLY HAIR SYNDROME

The keratin in a person's hair is unable to maintain its elasticity and strong shape. As a result, hair forms unusually tight curls.

5 STEATOCYSTOMA MULTIPLEX

The symptoms of this genetic disorder include multiple cysts in the skin. The keratin 17 gene is impacted, preventing a strong skin cell network and altering the growth of skin gland cells.

A human hair is around 0.01 millimetres wide



HOW TO SURVIVE THE AUSTRALIAN OUTBACK

From bush tucker basics
to sourcing trapped water
and combating crocodiles

WORDS AILSA HARVEY

Around 40 lives are lost in the Australian Outback every year. It's a land that only some of the most resilient of Earth's plants and animals are capable of calling home. Aboriginal tribes have mastered survival in the Outback over the course of 65,000 years, learning to live in the unique environment and source meals from sparse and poisonous vegetation. Most tribes respect the power of nature in the Outback to give and take life, and have become wiser through each generation. Their innovative methods that utilise the resources around them include extracting parts of plants as medication for illness and animal-inflicted injuries. For example, the leaves of the emu bush are used to wash cuts, and have demonstrated similar natural strength to modern antibiotic medication. Meanwhile, the bright-orange desert mushroom works to treat oral thrush when held in the mouth.

Many people who visit the Outback each year are foreigners to the unforgiving landscape. Despite covering 2.1 million square miles – more than 70 per cent of Australia – only five per cent of the country's population live there. Often visitors fear the animals that have claimed the land, but heat and dehydration are the two biggest killers in the Outback. Your body can use up more than four times as much water during summer there, as daytime temperatures usually hover around 40 degrees Celsius. Being dehydrated in this environment can lead to death in a matter of hours. And any other safety precautions you may be taking lose effectiveness when dehydration diminishes your ability to think clearly. Without the extensive knowledge of Australia's ancestors, visitors should enter the Outback as equipped as possible, both mentally and physically.

Did you know?

In winter, Outback temperatures drop below freezing



DID YOU KNOW? In the Northern Territory there are 0.16 people per 1,000 square metres

ESSENTIAL EQUIPMENT

When exploring the Australian Outback's expansive desert landscape for long periods of time, possessing a few key survival items can make the difference between life and death. Your survival toolkit should include navigation devices, water purification appliances, emergency communication technology and protective camping items. Portable water filters are vital for situations when you run out of clean drinkable water. The Outback is known for its arid conditions, so being able to remove dirt and germs from the limited natural water reduces the chances of severe dehydration.

With few large geographical landmarks, GPS devices will be your saviour, keeping you travelling in the right direction. If this fails, a compass is also reliable. Large areas of the Outback don't have mobile phone network coverage, so satellite phones are useful for emergency communications. Finally, protection from the weather and animals should be considered. You will need a weather-resistant tent and moisture-wicking clothes to protect your skin from the Sun and keep you cool. Incorporating many thin layers is an effective way to regulate temperature.



Fire-starting gear is useful for cooking food, boiling water and as a light source



Outback soil is rich in iron, giving it a reddish hue



WHERE'S THE WATER?

The Great Artesian Basin is a 650,000-square-mile underground freshwater resource

1 EULO

An outflow of the basin's water can be found near this small town in the form of mud springs. Mud and water are forced upwards through fissures in the ground. The mud is thermally heated and mineral-rich.

2 WARREGO BORE

This bore, or well, was drilled in 1890 as part of 541 that were completed by 1897 to access the basin's water. Today there are over 50,000 bores.

3 GREAT DIVIDING RANGE

This mountain range is a recharge area for the Great Artesian Basin. Mountains intercept precipitation and water is able to seep into the basin through the soil.

4 LAKE EYRE

Covering 3,668 square miles, this lake is the biggest in Australia and lies directly above the Great Artesian Basin

5 COOPER CREEK

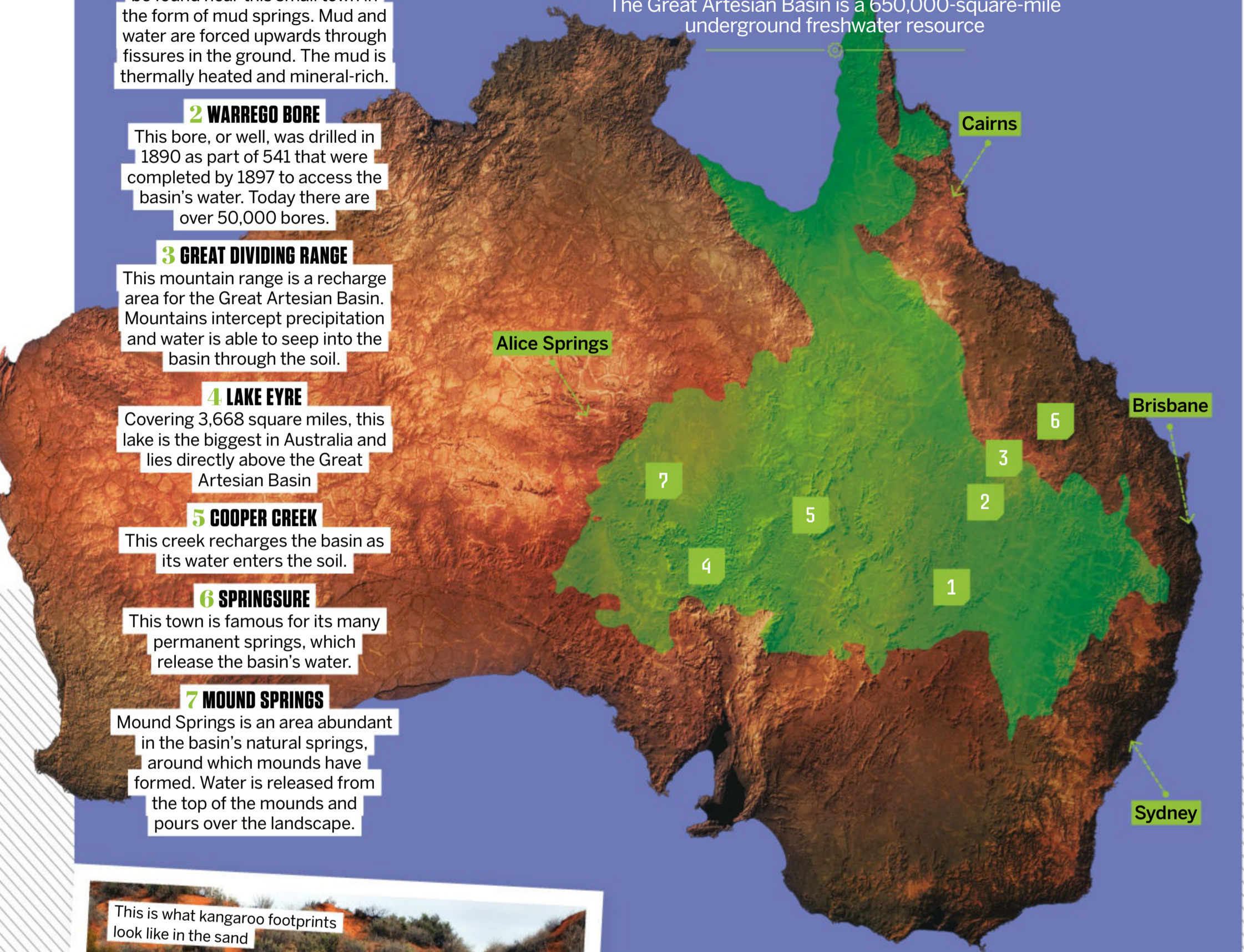
This creek recharges the basin as its water enters the soil.

6 SPRINGSURE

This town is famous for its many permanent springs, which release the basin's water.

7 MOUND SPRINGS

Mound Springs is an area abundant in the basin's natural springs, around which mounds have formed. Water is released from the top of the mounds and pours over the landscape.



This is what kangaroo footprints look like in the sand



FOLLOWING FOOTSTEPS

If you ever lose your way in the Australian Outback, it's worth examining the ground. If you come across the tracks of humans or animals, this can lead you to civilisation, or at least to hydration. Following previously trodden paths can return you to established routes, while some animal tracks will inevitably guide you to a water source. The tracks of wild pigs and kangaroos will lead to water, as they need to drink regularly. These trails should be followed downhill if you're in search of water. For unknown animal tracks, those that appear to have been regularly trodden are most likely to be water routes.

BUSH TUCKER BASICS

7 TOOLS AND MATERIALS

The gum inside the plant has been used as glue, and the branches and bark utilised for firewood.

6 FRAGRANT FLOWERS

The wattle plant's flowers can be eaten straight from the tree, and are often used to make flower fritters.

WATTLE LOT OF USES

For over 50,000 years, the golden wattle plant has aided Australians' survival as food, medicine and tools

1 POD POUNDING

The seed pods can be ground into flour and used to make dough.

2 BUSH POPCORN

Roasting raw wattle seeds over a fire until they pop gives the seeds a light texture and sweet flavour.

5 GREEN SEEDS

When green, golden wattle seeds can be cooked like peas.



4 BARK

The bark is high in tannins, which can be used as a remedy for indigestion.

3 RESILIENT GROWTH

Golden wattle is a widespread food source, as it can survive droughts and favours hot climates.

Did you know?

Witchetty grubs live on the roots of the witchetty bush



their abundance and high fat content. They carry out seasonal migrations and are easy to collect in large numbers as they typically rest on each other. Traditionally, these moths are cooked and ground to a paste.

In contrast to the larger, juicier creatures, ants seem like a strange meal choice for survival. However, as they are found in all areas of the Outback, they make a reliable meal. Ants are a good source of protein, relatively easy to catch and have unique flavours among species. Green ants have a citrus flavour, while honey ants have filled their stomachs with honey and taste sweet.

EDIBLE INSECTS

It might not be everybody's first meal choice, but when food is scarce you can look to creepy crawlies for energy and nutrients. Insects have been a bush tucker delicacy for thousands of years, but it requires knowledge of which animals are edible. The main groups of edible insects are witchetty grubs, bogong moths and honey ants.

Witchetty grubs are the caterpillars of the giant wood moth, and were historically a staple food in Aboriginal communities due to their impressive energy content. By weight, the insects have 15 per cent protein and 20 per cent fat. Witchetty grubs are generally eaten raw or lightly roasted. They have a creamy texture and nutty, egg-like taste when raw, but when cooked they taste more meaty.

In New South Wales, large bogong moths have long been used for culinary purposes because of

5 FACTS TOXIC FOODS

1 BUSH TOMATO

The fruits of the bush tomato can be a tasty snack, but make sure they are ripe. When they are still green they are poisonous, as they contain the toxin solanine.



2 STRYCHNINE FRUIT

The small, orange spheres that hang from this tree may look like an appetising juicy fruit, but contain highly poisonous seeds. Eating these can cause paralysis or death.



3 FINGER CHERRY

Eating this fruit has been linked with permanent blindness. Some people still eat these without any ill effects, but it is recommended to stay away from this fruit.



4 KANGAROO APPLE

All parts of this plant are poisonous when green and unripe. However, when they are ripe they are soft and edible.



5 BURRAWANG

This cycad is poisonous until it undergoes thorough treatment. Aboriginal Australians learned that the plant is made edible after the seeds are pounded and soaked in regularly changed water for weeks.





DEADLY COMPANY: OUTBACK ANIMAL GUIDE

1 SALTWATER CROCODILES

Saltwater crocodiles aren't fussy when it comes to their prey, and will take the opportunity to launch their powerful jaws in your direction if you get too close. They inhabit the coastal waters of Australia, but also venture inland to swamps, marshes and lakes. They're expert ambush hunters and are well-camouflaged in the muddy waters, lurking just below the surface. As they are difficult to see in a landscape, avoid swimming in waters of unknown risk – especially in Northern Australia, where these crocodiles are most common.

LIFE-SAVING LESSON

The jaws of a crocodile are near-impossible to escape from. But if a crocodile has hold of you, your best chance of survival is to aim for vulnerable body parts like the eyes and head. If you are dragged underwater and are spun in a move called a 'death roll', you should try to roll with the crocodile to prevent your limbs from being damaged. If you survive a crocodile bite, the immediate first-aid response is to stop the bleeding and remove infection through antibiotics.

3 WIDESPREAD ARACHNIDS

The redback spider is one of Australia's most poisonous spiders. They can be encountered in urban areas as well as the extreme climates of the Outback. Distinguished by the red stripe stretched over its back, the spider is responsible for around 2,000 reported bites annually. The females are capable of the nastiest bites, but they don't typically cause death in adults. Instead, the venom attacks the nervous system and causes intense and long-lasting pain.

LIFE-SAVING LESSON

The bite of a redback has more severe consequences for children, so younger victims need to seek medical attention with more urgency. The bitten individual should lie down and rest, while another person can apply a cold object to soothe the pain. Antivenom is given by doctors to treat this bite.

2 DEADLIEST SNAKE

The inland taipan is the most venomous snake in the world, trawling the Australian Outback for its next prey. This hardy reptile is well-adapted to high temperatures and dry landscapes. Beware of small cracks and crevices in the ground and rocks, as they shelter in these spaces, away from the sunlight and your gaze. Just one bite from the inland taipan releases enough venom to kill 100 people. To identify this snake, look out for large to medium-sized snakes of yellow or brown colour, a rectangular-shaped head and large, dark eyes.

LIFE-SAVING LESSON

Despite their deathly reputation, the inland taipan doesn't typically approach humans. However, if you get bitten, remain as calm as possible and at rest. This prevents venom from travelling quickly around the body. Apply tight bandages to the bite site or firm pressure if the site can't be bandaged.

4 AGGRESSIVE STINGERS

The desert scorpion is one of the most aggressive scorpions in Australia. They measure around 8 to 11 centimetres long and are widespread in the central Outback regions of the country. The scorpion makes deep burrows in the sand to protect itself from the Sun and emerges mostly after nightfall. If provoked, this animal is known to be highly aggressive towards humans, unleashing a sting from its tail and causing inflammation that remains for many hours. Signs of a defensive scorpion include standing upright, a high tail and open pincers, ready to snap.

LIFE-SAVING LESSON

Scorpion stings in Australia don't typically cause death, but it's possible for them to instigate a deadly allergic reaction. You should wash a sting straight away and apply antiseptic to prevent any infection. A cold pack and painkillers can be used to reduce the pain, though you should seek medical assistance if the pain doesn't subside.



1



3

Redback spiders are native to Australia

DID YOU KNOW? 30,000 people go missing in Australia every year – the equivalent of one person every 18 minutes

Did you know?

Saltwater crocodiles emerged 240 million years ago



An adult saltwater crocodile has an average of 66 teeth

Inland taipans can kill a person in 45 minutes



2

WATCH THE WEATHER

The Australian Outback is a vast expanse of mostly flat, dry terrain. Being inland, the ocean can't help moderate temperatures and weather changes. Meanwhile, lying relatively close to the equator means the environment receives intense direct sunlight and long periods of high temperatures. Some of the most dangerous weather conditions experienced in the Outback are wildfires, heat waves, dust and sandstorms, sudden rainfall in the northern regions and droughts.

You can spot an incoming dust storm by observing the sky's colour. If it changes colour and adopts a red hue, this is an indication that a dust storm may be approaching. Changes in animal behaviour can also alert you to incoming weather. Many animals have heightened senses to give them a better chance of survival. If all the surrounding animals take shelter, it's unlikely to be coincidental.



When dust is in the atmosphere, blue light is scattered and the sky appears redder

4

Desert scorpions can live for up to 20 years





WHERE DID THE OZONE LAYER COME FROM?

The invisible layer in the atmosphere that protects us from deadly radiation formed billions of years ago

WORDS SCOTT DUTFIELD

Between 10 and 25 miles above our heads in the stratosphere, there is a layer of oxygen dedicated to blocking dangerous forms of solar radiation, called the ozone layer. Along with visible light, the Sun also emits rays of radiation in the form of ultraviolet (UV) light. Within UV are three different wavelengths of light, commonly referred to as UVA, UVB and UVC, each of which has different levels of energy. UVA is the least energetic light, while UVB sits in the middle and UVC is the most energetic. On their journey from the Sun and into Earth's atmosphere, the high energy of the UVC rays is absorbed by the oxygen molecules that form the ozone layer. The lower energy wavelengths of UVA and UVB, however, can pass through ozone and reach Earth's surface. Around 95 per cent of the UV that reaches Earth's surface is UVA, and the remaining five per cent is UVB.

Before Earth was protected by the ozone layer, life was limited to the oceans in water deep enough to shield it from the Sun's harmful UV rays. It's thanks to tiny multicellular organisms called algae that life was able to leave the water and venture onto land. For billions of years, algae have been dumping oxygen into the atmosphere through the process of photosynthesis, where sunlight is used to convert carbon dioxide into food, as well as producing oxygen as a waste product. By around 600 million years ago, during the Precambrian era, the concentration of oxygen was around just ten per cent of modern-day levels, and a layer of ozone – made up of three oxygen molecules – had formed in the stratosphere. Around 150 million years later, thanks to the UV protection of the ozone layer, the world's first terrestrial plants emerged, pumped even more oxygen into the atmosphere and started life's journey on land.

Without the ozone layer to absorb the majority of UV radiation, our planet would

be exposed to high-energy rays, wreaking havoc on all life on Earth. Unprotected exposure to UVA and UVB, for example when someone doesn't use sun cream, results in sunburned skin, but can also cause mutations in skin cell DNA, leading to the formation of cancer. When a pair of scientists from the University of California revealed in 1974 that commonly used chemicals called chlorofluorocarbons were destroying the

ozone layer, the world began to phase them out. Chlorofluorocarbons (CFCs) were widely used in refrigerators and as propellants in aerosol cans. When released into the atmosphere, CFCs can break apart the oxygen molecules that make up the ozone layer, leading to the formation of colossal holes in this layer of the atmosphere and subsequently paving the way for harmful UV rays to reach Earth's surface.

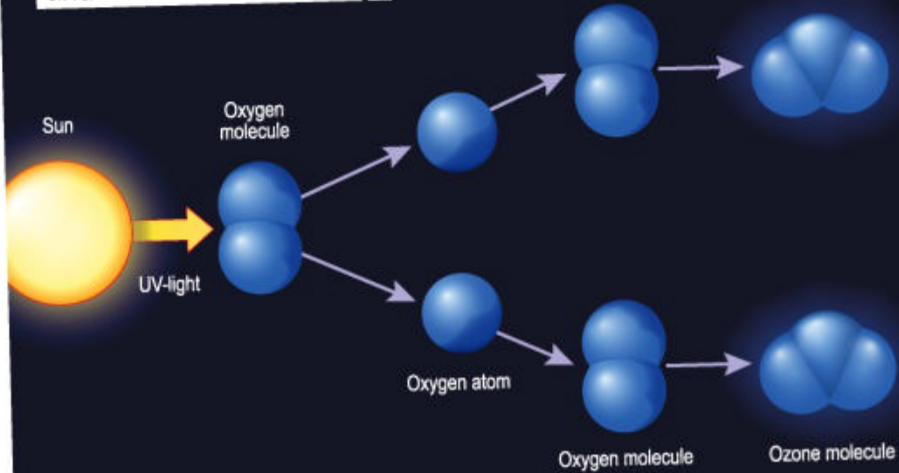


Did you know?
The ozone layer is just two to five millimetres thick



DID YOU KNOW? The ozone layer was discovered in 1913 by French scientists Charles Fabry and Henri Buisson

The Sun's UV rays provide the energy to break apart atmospheric oxygen (O_2) and reform it as ozone (O_3)

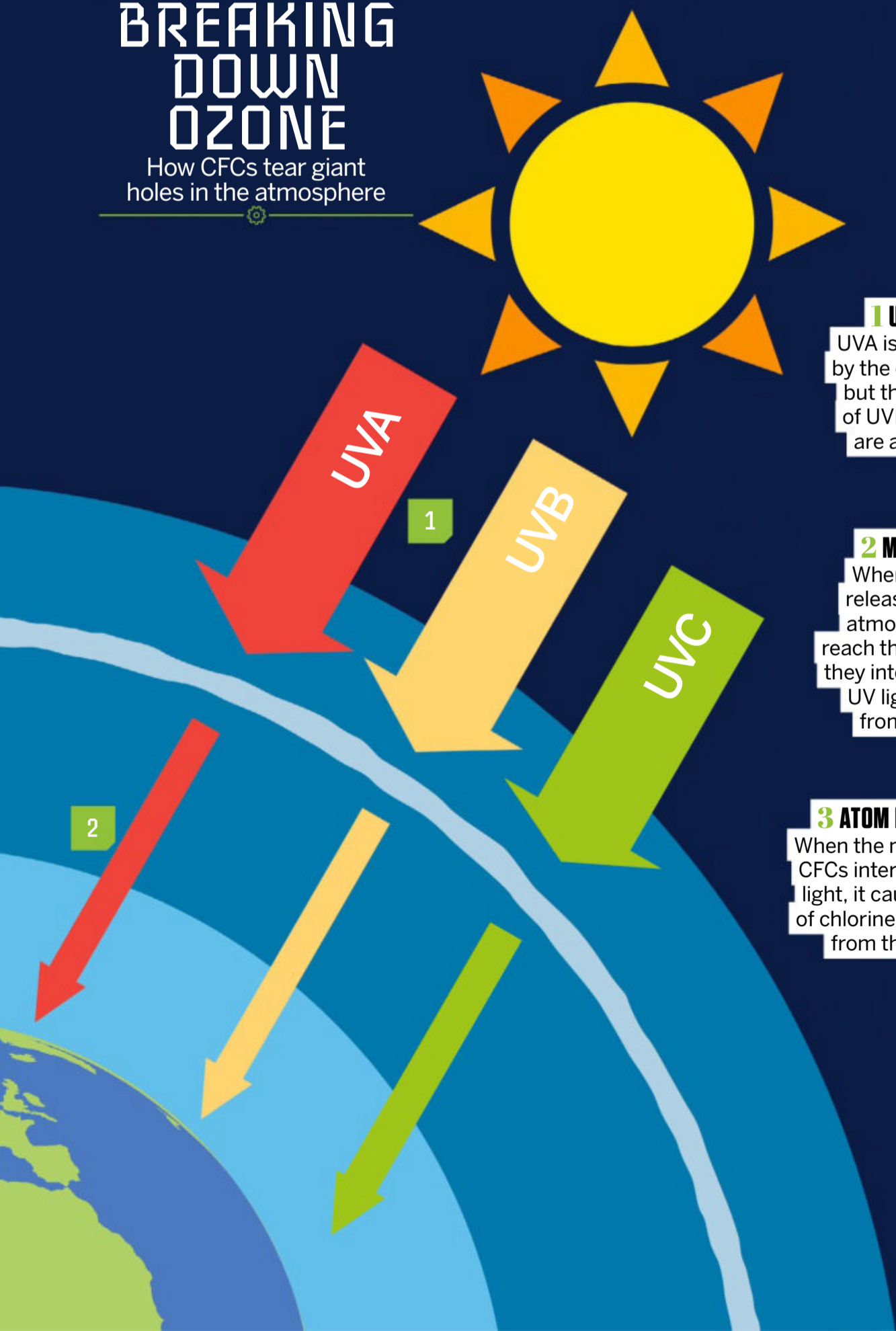


FORGING THE SHIELD

The ozone layer's relationship with UV radiation is twofold. On one hand, the atmospheric shield works to block the harmful rays, but on the other, it needs UV to build or repair itself. As wavelengths of solar radiation interact with atmospheric oxygen, which holds two molecules of oxygen, it breaks them apart. The two lonely atoms quickly find a molecule of atmospheric oxygen and bind with, forming three bonded oxygen atoms. Several natural processes, such as sunspots, stratospheric winds and even volcanic eruptions, deplete the ozone layer, maintaining a cycle of formation and depletion. However, when the balance is interrupted, such as with the release of CFCs, more ozone is lost than the Sun's UV rays can build, and holes are formed.

BREAKING DOWN OZONE

How CFCs tear giant holes in the atmosphere



1 UV LIGHT

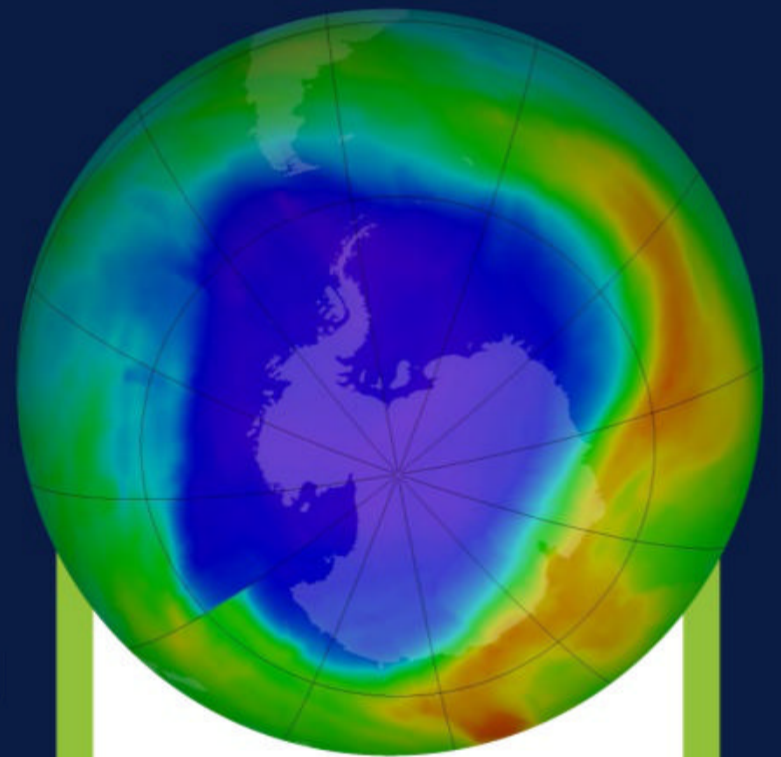
UVA isn't blocked by the ozone layer, but the majority of UVB and UVC are absorbed.

2 MEETING UV

When CFCs are released into the atmosphere and reach the ozone layer, they interact with the UV light emitted from the Sun.

3 ATOM BREAKAGE

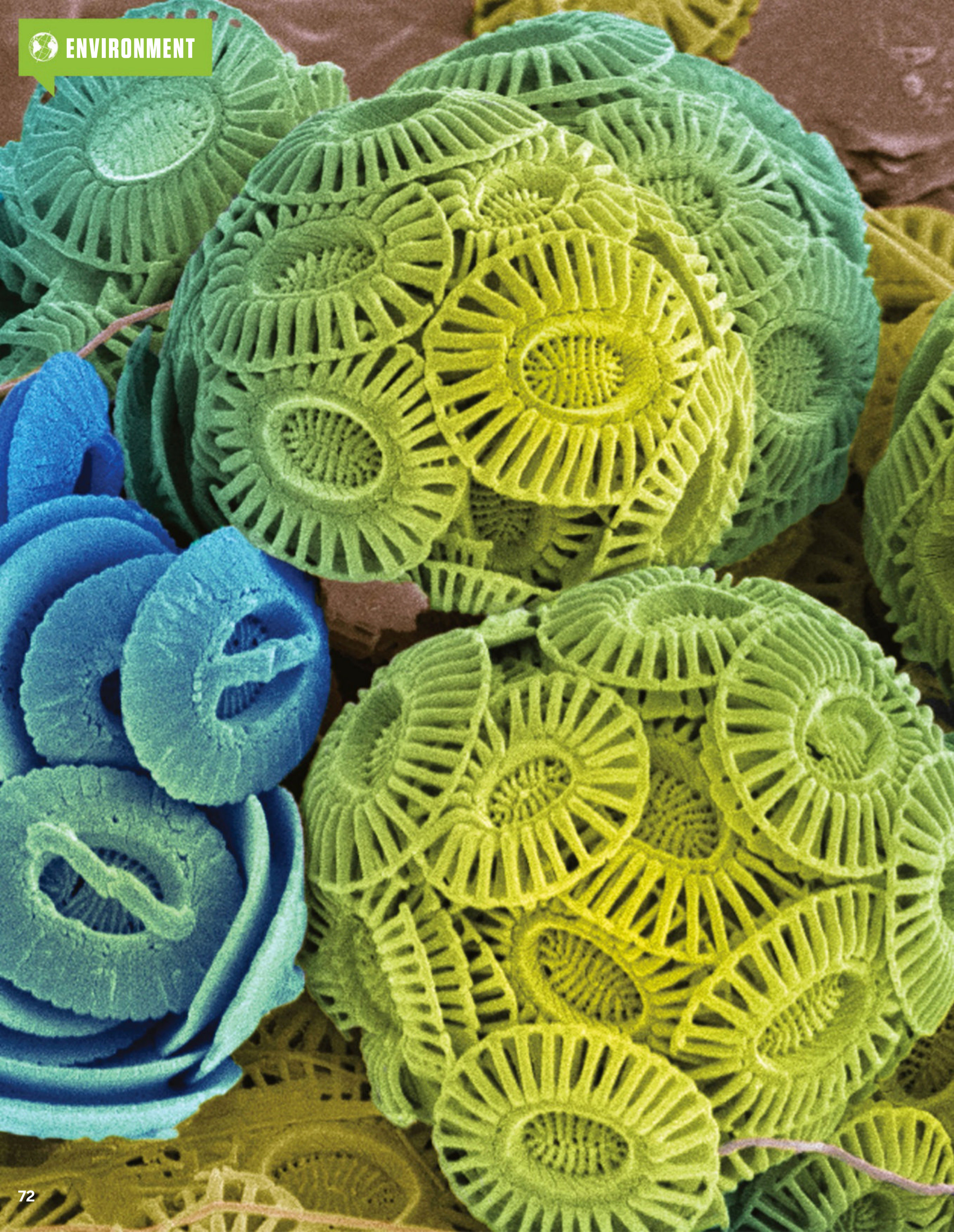
When the molecules of CFCs interact with UV light, it causes atoms of chlorine to separate from the CFCs.



The ozone hole (blue) over Antarctica in 2013

REPAIRING HOLES IN THE OZONE

Since the introduction of the 1989 Montreal Protocol, an international agreement to rid the world of ozone-depleting chemicals such as CFCs, giant holes over the polar regions are set to close as soon as 2045. An assessment by the United Nations has found that the ozone hole over the Arctic could heal in the next 11 years, and the layer above Antarctica will close by 2066. By simply eliminating the use of ozone-depleting chemicals, the natural process of ozone formation has gradually been able to reverse the thinning of the ozone layer and patch up holes. At present, the ozone hole over the Antarctic has a maximum area of around 10 million square miles. Its largest size was reached in 2000, when the hole peaked at around 11 million square miles.



DID YOU KNOW? The word 'plankton' comes from the Greek meaning 'drifter' or 'wanderer'

Phytoplankton under a scanning electron microscope

WHAT ARE PLANKTON?

Drifting through the world's waters are tiny organisms that feed fish and trap carbon

WORDS SCOTT DUTFIELD

In seawater worldwide, microscopic organisms called plankton are bobbing along with the current. Plankton are vital for maintaining balance, not only in marine ecosystems, but also in regulating the global climate. Plankton can be divided into two different categories: phytoplankton and zooplankton. Phytoplankton, also known as microalgae, are chlorophyll-packed organisms that operate in the ocean in a similar way to how plants live on land. To obtain their food and energy, phytoplankton perform photosynthesis. These tiny invertebrates convert sunlight and carbon dioxide dissolved in the water into energy, releasing oxygen as a byproduct. Their requirement for sunlight means that plumes of phytoplankton are found drifting near the surface, moving around the world at the mercy of ocean currents.

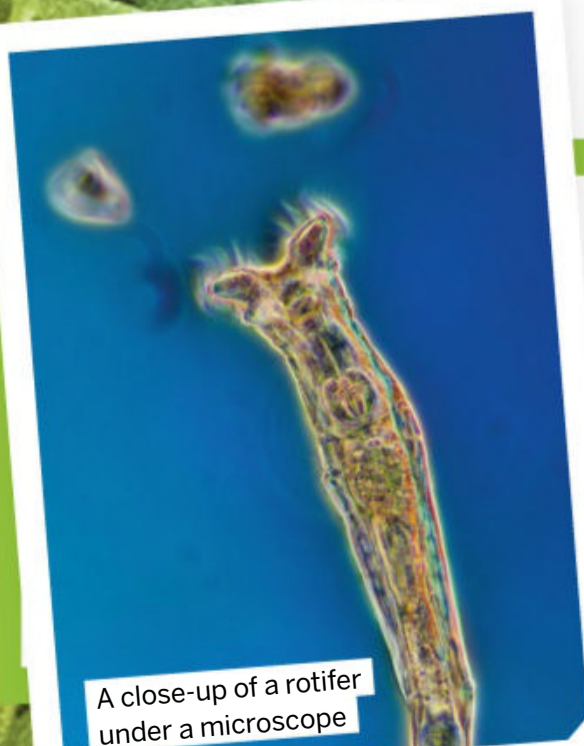
Zooplankton, on the other hand, are microscopic organisms made up of many

different animals, including fish larvae, worms and even snails. One of the best-known creatures categorised under the zooplankton umbrella is krill. As the preferred meal of many penguin and fish species, along with the world's largest animal, the blue whale (*Balaenoptera musculus*), krill, and all other zooplankton, serve as an important food source in marine ecosystems.

Another way that plankton play a vital ecological role is within Earth's global carbon cycle. As a carbon sink, the ocean is one of the many places where carbon is plucked from the atmosphere and stored. Plankton act as a kind of carbon conveyor belt, moving different forms of this chemical element from the surface and transforming it through various means, such as by defecating or dying, in a process known as the biological carbon pump. Phytoplankton transform carbon dioxide that has dissolved into seawater through photosynthesis into organic carbon to build their bodies and

Did you know?

Blue whales eat four tonnes of krill each day



A close-up of a rotifer under a microscope

AIDING THE PLASTIC PROBLEM

On the face of it, you might think that zooplankton with the ability to chow down on plastic would be a game changer in the fight against the world's plastic problem. However, Researchers at the University of Massachusetts Amherst have discovered that zooplankton called rotifers are making the problem worse, not better. When these tiny organisms encounter a piece of plastic, they break it down into smaller microplastics, some pieces smaller than a micron wide, which is one-thousandth of a millimetre. Researchers estimate that each rotifer can create up to 366,000 pieces of microplastic each day. Along with the potential initial toxic effects of microplastics, they can also affect the ability of some marine species to reproduce and respire.



skeletons. When those bodies are eaten or die, the carbon is moved along marine food chains until it eventually descends to the ocean floor, where it's stored. It's estimated that each year around 11 gigatonnes of carbon is stored within the ocean.

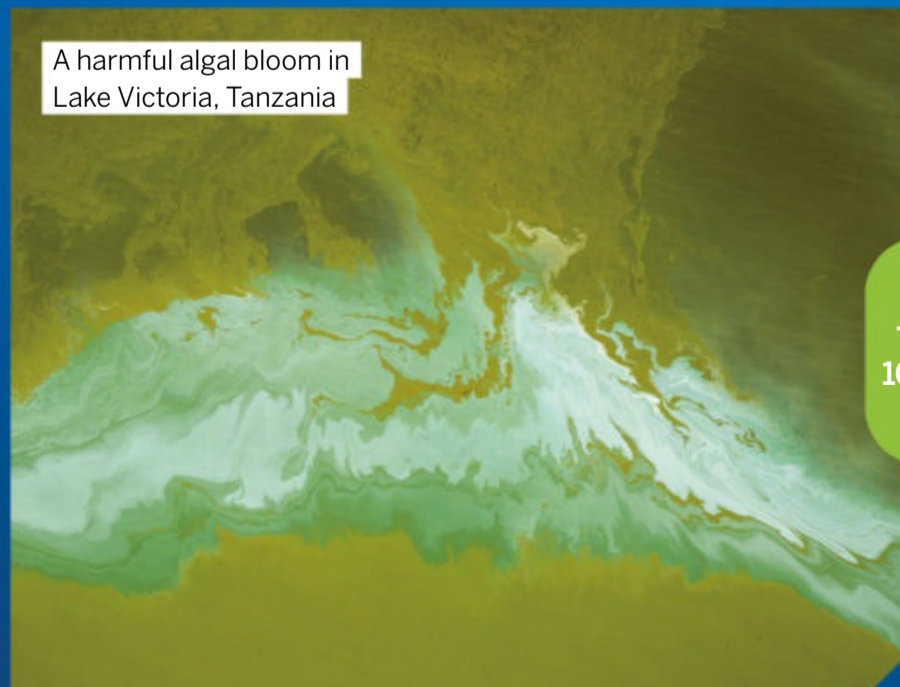
Despite all the benefits to the environment phytoplankton bring, there are also some potential negative side effects. When it comes to plankton, there can sometimes be too much of a good thing. While these incredible organisms can maintain balance in marine ecosystems, when their population numbers become too great, the balance shifts, with potentially catastrophic consequences. When phytoplankton numbers erupt, it can lead to the formation of what's known as a harmful algal bloom (HAB). Some algal species produce toxins; when produced in large numbers, this can kill many fish and marine mammal species. Similarly, some HABs choke the oxygen out of the water, leading to severe oxygen depletion, known as hypoxia. HABs are also responsible for clogging the gills of many fish species, leading to their eventual death.

In the last 20 years, half of the world's oceans have changed colour thanks to plankton. Along with a rise in surface temperature, climate change might be affecting the way nutrients in the water are disturbed, which is affecting phytoplankton populations. Researchers at the Massachusetts Institute of Technology have suggested that rising ocean temperatures reduce marine nutrients' ability to mix through the many levels of the ocean, leaving plankton to feast nearer the water's surface and giving blue waters a green hue.

“When it comes to plankton, there can sometimes be too much of a good thing”



A group of copepods swimming in water



A harmful algal bloom in Lake Victoria, Tanzania

THE POWER OF THE BIOLOGICAL PUMP

How plankton play a vital role in creating the world's largest carbon sink

5 CARBON FIXING
Through photosynthesis, phytoplankton use carbon dioxide that has dissolved into the water from the atmosphere.

CARBON DIOXIDE

5

6 PHYTOPLANKTON LUNCH
Herbivorous zooplankton consume phytoplankton, and the carbon stored in the phytoplankton is passed onto the zooplankton.

PHYSICAL MIXING

CARBON UPTAKE

1 DINOFLAGELLATES
Single-celled phytoplankton characterised by hair-like appendages called flagella.

2 DIATOMS
These phytoplankton are the only organisms that have cell walls made of a material called biogenic silica, also known as opal.

9 DECOMPOSITION
Bacteria in ocean water decompose the bodies and release the carbon, as carbon dioxide, back into the deep ocean.

DISSOLVED ORGANIC CARBON

9

DECOMPOSITION

Did you know?
There are around 100,000 species of phytoplankton

DID YOU KNOW? Plankton make up about one per cent of Earth's biomass

3 COPEPODS

Among the many zooplankton species are copepods, a distant relative of shrimp; they can be found in almost every ocean and freshwater habitat on the planet.

7 CARBON RELEASE

Zooplankton release some of the carbon as carbon dioxide back into the water through respiration.

Antarctic krill (*Euphausia superba*) live in the Southern Ocean



5 FACTS HUMAN USES FOR PLANKTON

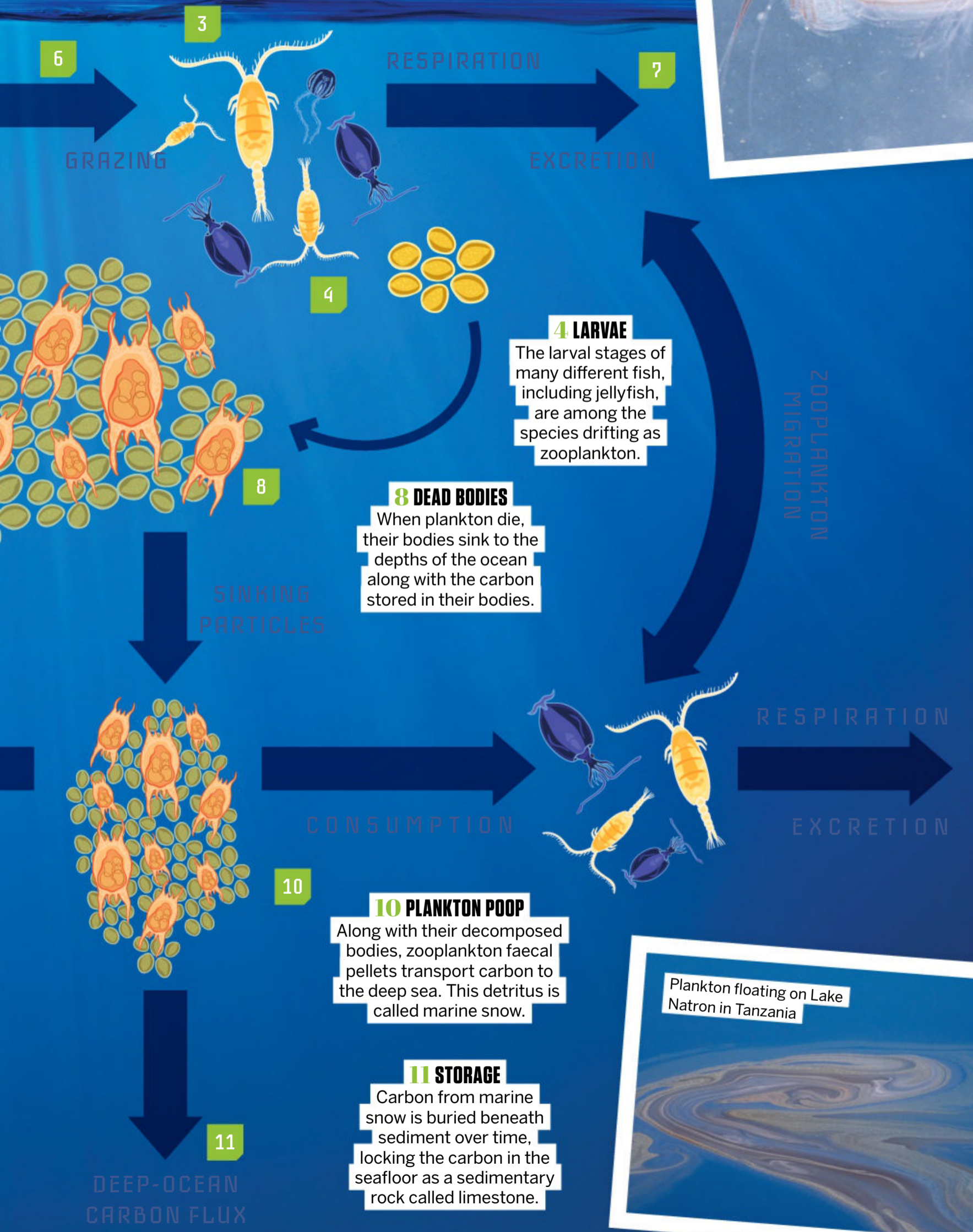
1 BIOFUEL
Since the early 2000s, plankton has been studied as a possible biofuel. Through the process of fermentation, phytoplankton can produce a type of alcohol for fuel. However, the science is not yet productive enough to replace other fuel sources.

2 COSMETICS
Plankton extract, often in the form of fats and proteins, is commonly found in several different cosmetic products, such as sunscreen and anti-ageing serums, for its moisturising qualities.

3 FUTURE MEDICINES
Some toxins released by phytoplankton are currently being researched for their ability to treat many chronic conditions and disorders, such as diabetes, obesity, cancer and Alzheimer's disease.

4 SUPPLEMENTS
Along with fish food, plankton are found in food supplements that can provide health benefits, including certain properties that reduce inflammation in the body.

5 POLLUTION MONITORS
Researchers at the University of California San Diego School of Medicine have used plankton samples collected since 1931 to compare chemical ocean pollutant concentrations and identify areas where pollution is greatest.





GARDEN TOOL GUIDE

WORDS
AILSA
HARVEY

These manual and electric implements are vital for growing plants and maintaining a perfectly manicured lawn

For around 12,000 years, humans have been deliberately sowing seeds to grow plants for our species to benefit from. It's a practice that enables communities to settle in one place and claim a patch of land as their home. Stone, bone and wood were first crafted to make digging and raking tools for agricultural purposes, and the essential pieces of equipment that most gardeners use today haven't changed much. However, the use of stronger materials, like steel for blades, and today's electric appliances have changed the gardening game.

The average European gardener uses three powered gardening tools. As modern technology advances, more efficient garden tools reduce the time and effort required by gardeners to carry out simple gardening tasks. For example, before lawn mowers were invented in 1830, individuals would cut entire lawns by hand using simple shears. The latest lawn mowers have almost completely cut out human assistance aside from setting up the machines: autonomous lawn mowers can be scheduled to begin cutting a lawn without the direction of a gardener, then return to the charging port to prepare for their next shift.

ESSENTIAL TOOLS

What equipment is most common for keeping a garden in check?



1 SPADE

This digging tool moves soil and can cut through tougher material such as roots.

2 SHOVEL

Shovels are pointier than spades, which makes them a better choice for creating deeper and more precise holes in compacted ground.

3 HAND RAKE

Moving this three-pronged tool through the soil breaks it up and makes the ground more even and smooth.

4 HOE

As you pull this utensil through the soil, it pulls out weeds from the garden. It is also used to efficiently shape the soil.

5 FORK

This tool is used to loosen soil and can be pushed through the earth more smoothly than a spade. However, forks won't cut as easily through roots and tough material.

6 SHEARS

Hedge shears are used like scissors, but with both arms, to cut branches and shape large plants.

Did you know?

Leaf blowers blow out air at 200 miles per hour

SMART GARDENING

Although it's possible to grow healthy blooms with core gardening knowledge and the power of nature alone, with new technology there are ways to produce optimal results with much less effort. This is thanks to smart gardening technologies, which can keep tabs on your garden and automatically provide any necessary treatment. For example, smart irrigation systems monitor the moisture levels in soil and transmit this data to a device controller. Based on the readings, the system starts and stops water flow by automatically controlling pumps and valves, eliminating temporary or long-term plant dehydration. More advanced machines use robotics to carry out gardening tasks using robotic arms.

Other tools can be found on smartphone applications. Using artificial intelligence, simply taking a photograph of a plant's condition can reveal the type of plant and what it needs to return to full health. These applications use a database of thousands of images of unhealthy plants and information from crop experts to match the photograph with useful gardening tips.

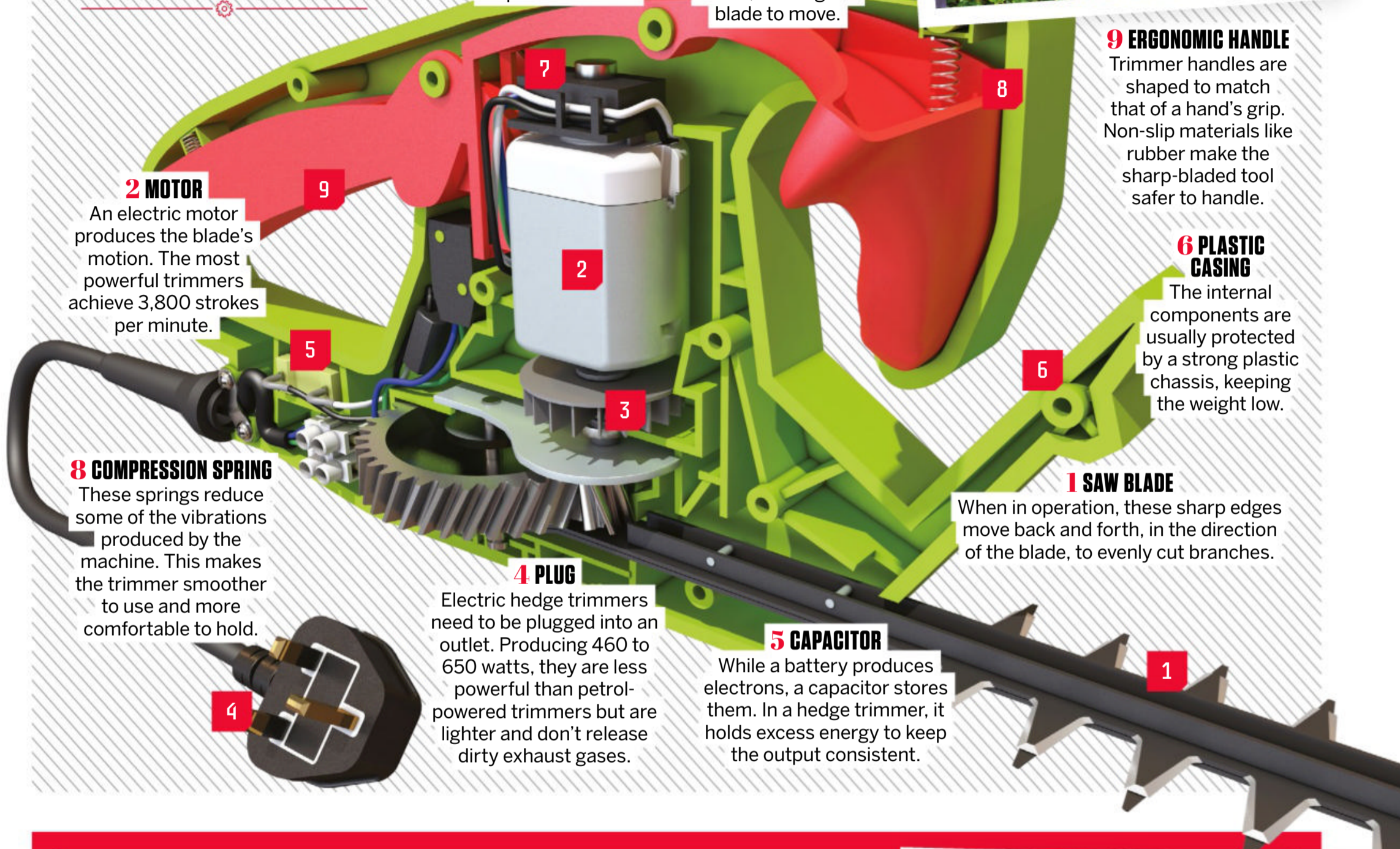
Simply taking a photograph of a plant can tell you the species, how often to water it and other caregiving tips





TRIMMER TECHNOLOGY

The electric saw in this device drastically reduces pruning time



3 COOLING FAN

As this fan turns, it creates airflow, cools down the internal components and helps clear debris.

7 CARBON BRUSH

This component conducts electricity to the rotating sections of the motor, causing the blade to move.

2 MOTOR

An electric motor produces the blade's motion. The most powerful trimmers achieve 3,800 strokes per minute.

9 ERGONOMIC HANDLE

Trimmer handles are shaped to match that of a hand's grip. Non-slip materials like rubber make the sharp-bladed tool safer to handle.

6 PLASTIC CASING

The internal components are usually protected by a strong plastic chassis, keeping the weight low.

8 COMPRESSION SPRING

These springs reduce some of the vibrations produced by the machine. This makes the trimmer smoother to use and more comfortable to hold.

1 SAW BLADE

When in operation, these sharp edges move back and forth, in the direction of the blade, to evenly cut branches.

4 PLUG

Electric hedge trimmers need to be plugged into an outlet. Producing 460 to 650 watts, they are less powerful than petrol-powered trimmers but are lighter and don't release dirty exhaust gases.

5 CAPACITOR

While a battery produces electrons, a capacitor stores them. In a hedge trimmer, it holds excess energy to keep the output consistent.



Trimming hedges is made quick and easy

REMOVING DEBRIS

Why do you need to sweep your garden if the fallen leaves and other debris are all natural products? Although this lawn covering can benefit different plants and creatures, they might not be the ones you want to attract to your outdoor space. Leaf debris creates covered spaces where extra insects and small creatures like rodents can breed. As the leaves decompose, the damp that results makes these hiding spaces more appealing to pests. In this decaying matter, microorganisms and plant diseases thrive.

Some of the tools that help remove natural garden debris are leaf blowers, leaf mulchers and lawn sweepers. Leaf blowers are machines that create a powerful stream of air, using long pipes to direct the air and

push the debris into a neat pile. These machines are worn like a backpack to allow gardeners to easily move around the garden and accumulate leaves in piles ready for mulching. Leaf mulchers suck in leaf matter and tear leaves into small pieces.

Did you know?

Leaf mulchers massively reduce leaf volume

Once shredded, these leaves are more easy to dispose of or can be used for composting.

To pick up loose items from the garden quickly, lawn sweepers are pushed across lawns. Twigs, leaves and other items are picked up in the machine's rotating brushes and released into the collection compartment. Tools like rakes and handheld brushes perform similar roles to these machines, but require more manual labour and time.



A leaf-mulching machine can also turn wood into wood chips

DID YOU KNOW? The first lawn-cutting tool was the scythe, which had a curved blade



5 FACTS IRRIGATION TYPES

1 SOAK
The soil is slowly saturated. Plants with deep root systems benefit from this method as this form of irrigation helps water seep deeper into the ground.

2 DRIP
Tubes carry water to the base of individual plants. This prevents it being caught on leaves during watering.

3 SPRAY
This watering method releases water that falls as mist, sprayed through nozzles with small gaps. This benefits a garden that has a range of crop types.

4 SPRINKLE
Sprinkle irrigation is similar to spray irrigation, but imitates rainfall. Droplets fall over the plants instead of misting around them.

5 FILL
Trenches in the soil around the plants are filled with water. Water permeates the soil gradually towards the roots.

MOWING ROBOT

How automatic lawn mowers map and cut your lawn

- 1 AREA SENSOR**
Positioned at the front of the mower, this sensor detects boundary markers such as physical wires or magnetic strips that are placed at the garden's perimeter.
- 2 OBSTRUCTION SENSOR**
Using infrared sensors, this component spots upcoming obstacles, such as trees, and sends a signal to the machine to change direction to avoid collisions.
- 3 LIFT SENSOR**
The lift sensor tracks the mower's orientation. When it detects the device lifting off the ground, the blades automatically stop to prevent injury.
- 4 ELECTRONIC CONTROL UNIT (ECU)**
The ECU works as the lawn mower's brain. This central computer receives signals from sensors and relays responses to the appropriate components.
- 5 BLADE MOTOR**
This motor turns the blade when the mower is in operation.
- 6 WHEEL MOTOR**
Each wheel often has its own motor to control how it turns and accurately position the lawn mower on programmed paths.
- 7 LITHIUM-ION BATTERY**
These batteries are lightweight, small, energy efficient and quick-charging.
- 8 CONTROL PANEL**
This panel has buttons that the user can press to interact with the mower. It includes operations such as 'stop' and 'return home'.
- 9 BLADE DISC**
The sharp, circular blade rotates at around 2,000 to 4,000 rotations per minute for efficient cutting, and its height can be adjusted to cut the grass to different lengths.



HOW A BOWLING ALLEY WORKS

Explore its inner mechanisms and discover how pins and balls quickly resume position

WORDS AILSA HARVEY

Many sports in which you throw, aim or knock down objects also require you to collect the items and reset the playing zone. But anyone who has tried their hand at indoor bowling will have seen the mechanical efficiency in which a strike is cleaned up and the lane reset.

A sophisticated robotic system cycles the pins and sets them up with precision for another game.

Bowling dates back over 5,000 years to the ancient Egyptians, who used stones as balls and various materials for pins. Since then, the game has evolved drastically. Before this machinery was perfected, the role of pinsetter was held by a person who stood just beyond the firing line at the back of each lane. The mechanical pinsetter that replaced this job was invented in 1936 and has become increasingly

efficient with the invention of new autonomous functions and data-collecting sensors. Infrared sensors on the bowling lane flag up any player who steps past the foul line, while bowling pin detection sensors can be used in some lanes to track the movement and position of pins for rapid automatic scoring.

Did you know?

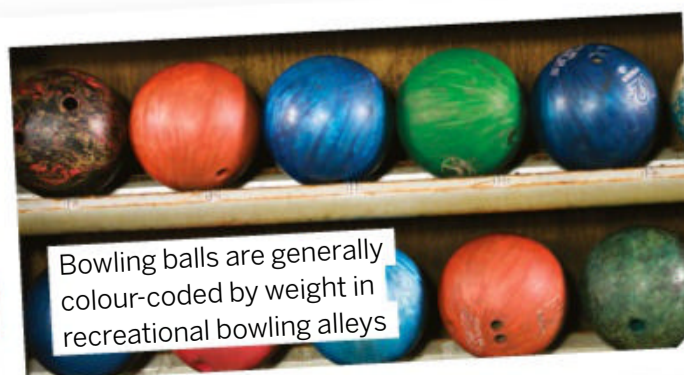
Pins that are knocked over are called 'deadwood'

Another adaptation to the pin-setting machine is an energy-saving function, which shuts off the pin distribution system if there is a gap in play for a minute or longer. This saves power and reduces the wear and tear on a machine that would otherwise be on a continuous and unnecessary cycle. With the efficiency of the new technology systems found in the alleys, bowling has advanced to create a game of high skill and ease of play while maintaining the core elements of the ancient sport.

BALL BASICS

Balls have different weights, finger grip positioning and subtle adaptations for different lanes and bowling styles. The balls you use when playing recreationally will be between three and seven kilograms. Professional bowling balls are custom made, with manufacturers measuring a player's hand to achieve an optimal design. They're also designed to achieve 'hooking' of the ball, which makes the ball roll in a curved shape to attack pins from a sharper angle. House balls generally aren't as capable of hooking as custom-made balls. The centre of a ball is usually made with different percentages of metal oxides and resin. This core gives the ball its weight and determines its ability to roll

down the lane. Materials are poured into a mould and left to harden. Once solid, the outer layer, or coverstock, is added. The materials for this are generally polyester, urethane or resin. The coverstock makes contact with the lane and can impact performance. Plastic is ideal for beginners as it produces less friction. Urethane offers more friction, while resin is reserved for more advanced players.



Bowling balls are generally colour-coded by weight in recreational bowling alleys

PIN POSITIONING

Between throws, machinery restores pin configurations. This illustration shows what occurs behind the scenes

1 SWEEP

After each roll, this lowers in front of the pins and moves towards the back of the lane to clear all knocked pins.

2 PIN ELEVATOR

There are more than 20 pins in the machine, so there are always some pins readily available at the setter. This elevator consists of two pulleys and trays that each hold one pin. When the trays reach the top, the pin is released and the empty tray returns to the bottom for collection.

3 PIN DISTRIBUTOR

When the pin table has fully risen after a player's second roll, the pins that have climbed the elevator are released into the ten free slots, ready for the next player.

4 PIN TABLE

This holder has enough slots for each pin. It's lowered onto the lane and clamps around the top of each remaining pin. As it does this, it relays the points scored to the automatic scoring software. The pin table lifts the standing pins out the way of the sweeper and lowers them to resume play.

5 SENSOR

A sensor lies slightly in front of the pins. When it detects the

movement of a rolling ball, it will trigger the pinsetter's actions after two seconds have passed and the bowl is complete.

6 CONVEYOR BELT

This belt is constantly moving towards the back of the lane. It rolls swept pins onto the pin elevator. It is tilted slightly so that the ball rolls towards the ball return tunnel underneath the lane.

7 FILTERING BARRIER

This component is set at a specific height to work as a filter. It makes a gap big enough for the pins to roll through to the elevator, but not the ball.

8 PIN FEED DEFLECTORS

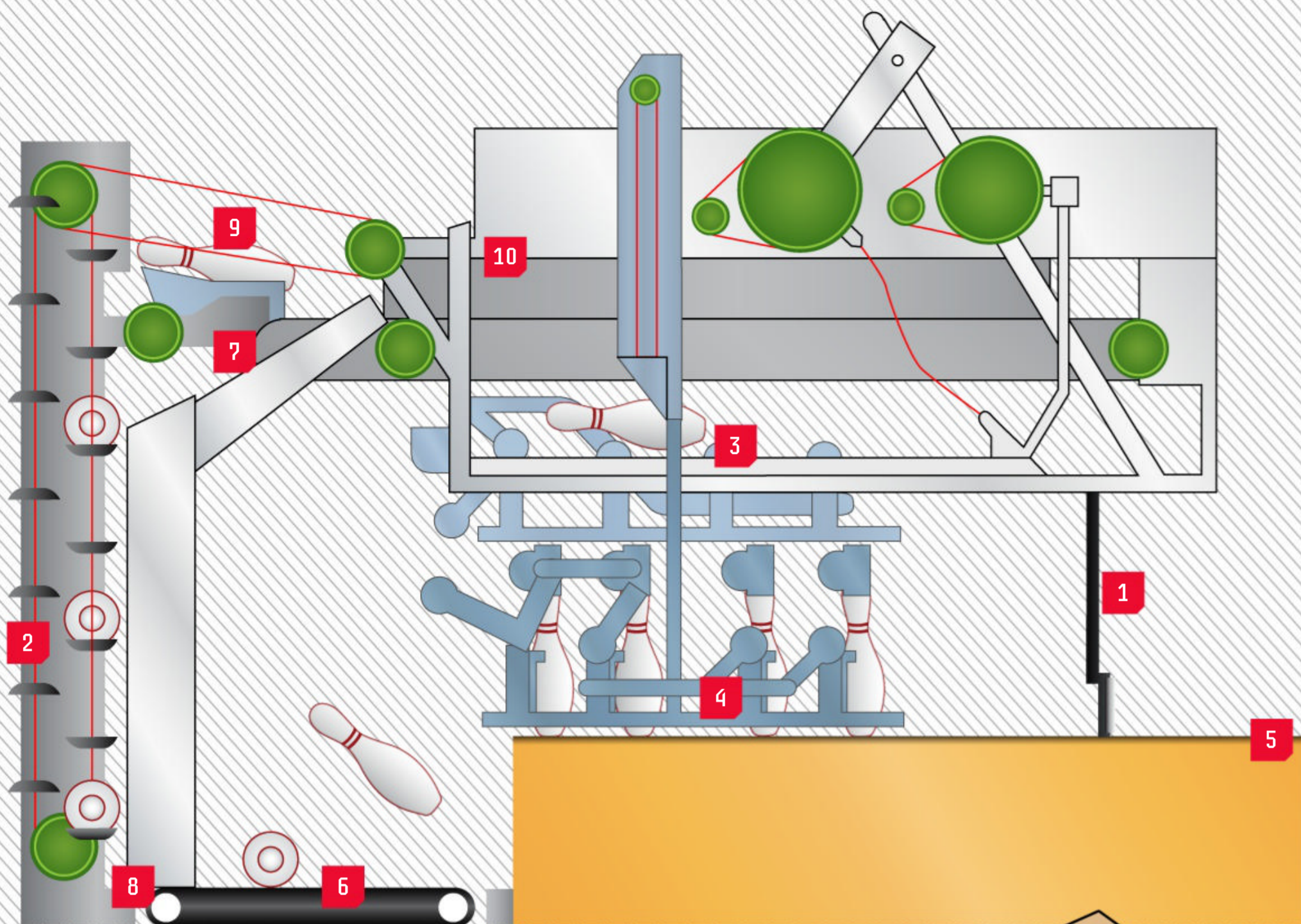
The sides of the elevator are angled to guide the pins to the centre of the lane. This lines them up perfectly to enter the pin elevator.

9 PIN COUNT SWITCH

As pins roll off the elevator, they move a switch. Each movement is relayed to the next part of the machine to record how many pins are returning.

10 OVERFLOW CHUTES

If all the spaces in the pin distributor are filled, the pins fall down these chutes to the base of the elevator, ready to rise back to the top.

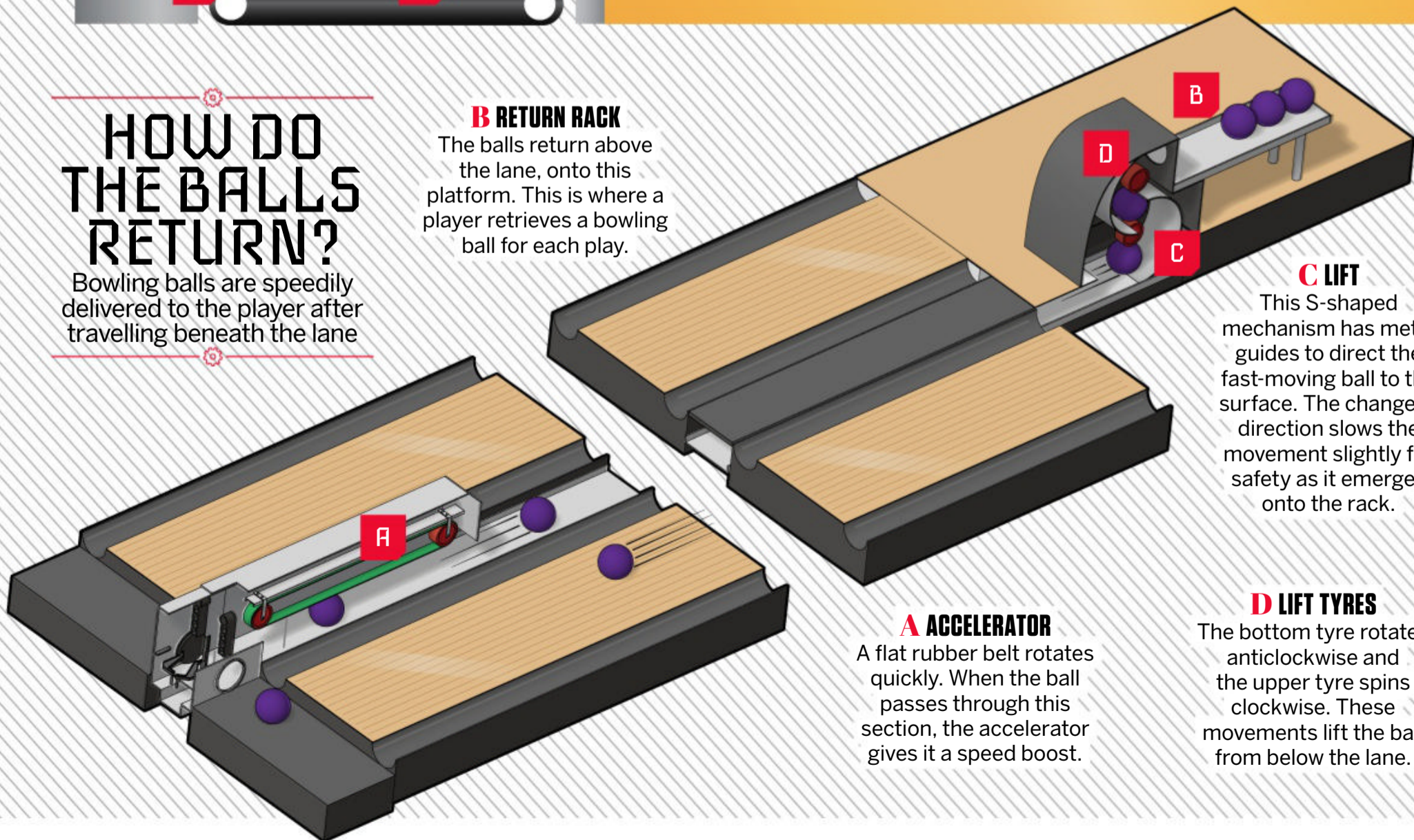


HOW DO THE BALLS RETURN?

Bowling balls are speedily delivered to the player after travelling beneath the lane

B RETURN RACK

The balls return above the lane, onto this platform. This is where a player retrieves a bowling ball for each play.



A

A ACCELERATOR

A flat rubber belt rotates quickly. When the ball passes through this section, the accelerator gives it a speed boost.

C

C LIFT

This S-shaped mechanism has metal guides to direct the fast-moving ball to the surface. The change in direction slows the movement slightly for safety as it emerges onto the rack.

D LIFT TYRES

The bottom tyre rotates anticlockwise and the upper tyre spins clockwise. These movements lift the ball from below the lane.

Win!

ONE OF TEN BUILD YOUR OWN MICROSCOPE KITS

In celebration of British Science Week 2024, we're giving you the chance to win a microscope kit from buildyourownkits.com. This fun family project is easy to assemble, without the need for messy adhesives or glue. Simply press out the pre-cut parts and slot them together to build your own microscope. The fully functional microscope has a 30x magnification lens that children can use to investigate all kinds of things, such as insects, leaves and feathers



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Why doesn't NASA take parts into Earth orbit and build a spaceship to go to Mars up there, like the ISS?

There are a few reasons why we haven't sent a manned flight to a planet like Mars yet. The distance is one. At their closest Mars and Earth are still 50 million miles away, or about seven months travel time. They'll need supplies on board for all that time. Even if advances in rocketry can reduce the time, once on Mars astronauts will have to wait up to a year and a half to return, when the orbits of the planets align just so. A spaceship big enough to contain all the necessary supplies would be

too big to launch from Earth's gravity given our current technology, so we could theoretically build on the Moon or in orbit. But launching parts up over time like that could get expensive. Beyond these issues, astronauts going to Mars would be exposed to high levels of radiation, as well as suffering the effects of microgravity, losing about one per cent of their bone mass each month. There would be psychological fallout from being so far from home too.



WHY DO PERSIAN CATS HAVE FLAT FACES?

Not all Persian cats do – the doll-faced Persian actually has a muzzle. In the late 1950s, some cat fanciers decided a spontaneous mutation was a desirable trait, and began breeding Persians to have shorter muzzles until they had high noses and flat faces. This ultra-typed cat became the breed standard. At its most extreme, a Persian cat with these features runs the risk of having deformed tear ducts and perpetually runny eyes, so some are calling for a return to the traditional breed.

WHAT MAKES THE WIND BLOW?

Wind is the movement of large bodies of air. Air is made up of gas molecules, and those molecules are already whizzing around – that's what makes air a gas instead of a solid. But the motion of individual molecules is chaotic. They are constantly bouncing off one another and changing direction. When you add all the trillions of tiny collisions together, you get an overall pressure that increases as the temperature rises, because the molecules are moving faster. Air at the equator gets heated by the Sun more than air at the poles, so it exerts a greater pressure and pushes the colder air out of the way. Because Earth is also rotating, the atmosphere gets pulled into huge vortices. These rotating pressure systems move across the planet, and we feel the result as wind. The exact pattern of the wind is further complicated by differences between the temperature of the land and sea, obstructions from mountains and buildings and even the energy released when water vapour condenses as rain. This is why predicting weather is so hard.

WHY ARE THERE SO FEW WAVES IN THE ARCTIC?

The Arctic Ocean is already the smallest of the oceans, and it is tightly contained by the landmasses of Russia, Alaska, Canada and northern Europe. This means that large ocean swells from storms around the world don't penetrate the Arctic. In winter, virtually the entire surface is frozen, and even in summer ice covers all the deep water in the centre. Without a central landmass like Antarctica, the Arctic has little temperature variation throughout the year and thus relatively calm weather. The only waves in the Arctic are raised by local winds and generally don't travel very far.



What is pareidolia?

Do you ever think you can see your best friend's face in the clouds? What about the 'Man in the Moon'? This is an incompletely understood phenomenon called pareidolia. Many theories exist to explain it, including religious, scientific, evolutionary and psychological explanations. The most likely is that the complex human brain attempts to make patterns out of random data as it tries to interpret it. Evolutionary theories suggest we are preprogrammed to recognise faces, both for protection and defence. Religious theories suggest these patterns come from higher sources. This includes a woman who saw the face of Jesus on a tortilla in 1978; thousands trekked to rural New Mexico to worship it.

WHY DO SLOTHS GENERALLY HANG UPSIDE DOWN?

Sloths eat leaves with very little nutritional value; in fact, it takes up to a month for their food to digest. To compensate, they have a metabolic rate about half that of other mammals their size. Since they can't run away from predators or fight them off easily, they hide instead. Hanging below branches makes them less visible to harpy eagles, and their claws can grip branches without using any energy – indeed, sloths won't fall from a tree even if they're asleep. Sloths spend so much time upside down that their fur lies the opposite way to most mammals, growing from the paws up to the body.



IF I TOUCH SOMETHING REALLY HOT, WHY IS THERE A NOTICEABLE DELAY BEFORE I FEEL IT, AND WHY DOES IT FEEL COLD AT FIRST?

The spinal cord runs in two directions: towards the brain (receptors) and down to the muscles (effectors). An upwards-running pathway called the spinothalamic tract detects pain and temperature. There are both hot and cold receptors in the skin. When you touch something extremely hot, it can cause 'over-stimulation', meaning that both hot and cold receptors are activated, as well as pain receptors. If the cold message travels back to your brain first, it will get there moments before the hot sensation. However, this phenomenon certainly doesn't affect everyone. No matter what you sense, a reflex arc will stimulate your muscles and force you to withdraw your limb from danger in under a second.

Can we eat ostrich eggs?

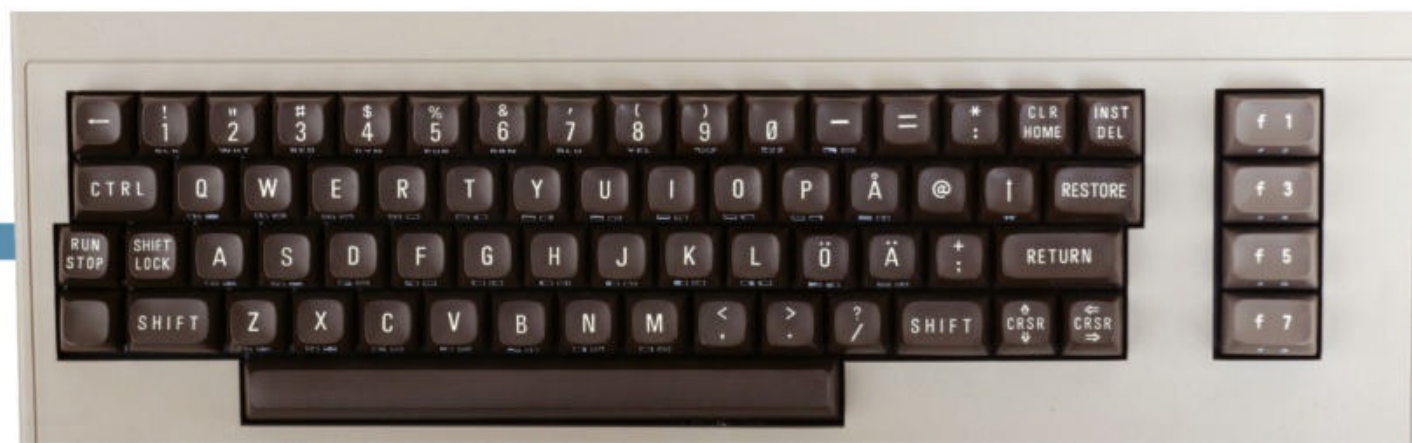
Not only can you eat them, but they're delicious, surprisingly healthy and available online or even in certain supermarkets. Ostrich eggs contain more magnesium and iron, a lot less cholesterol and a little less saturated fat than the equivalent serving of chicken eggs. They provide less vitamin A and E and less zinc, but that's not really the problem with adding them to a balanced diet – it's the practicality. Ostrich eggs typically weigh around 1.4 kilograms, the equivalent of two dozen chicken eggs. They also take up to 90 minutes to hard boil, and at 2,000-plus calories per egg will need 15 very peckish adults to finish. You'll probably need a chisel or electric drill to break into the shell too.



WHO MADE THE FIRST QWERTY KEYBOARD?

Modern keyboards are based on the system devised for the very first typewriter, patented in 1873 by Milwaukee printer Christopher Latham Sholes. His model used a piano-style keyboard of two rows of keys arranged alphabetically. This ran into problems when the metal typebars linked to the keys jammed if pressed too quickly. The solution was to separate commonly used letter pairs like 'th' so the typebars jammed less often. This system was called QWERTY, after the first letters of the top row. Contrary to popular myth, it

wasn't intended to deliberately slow down typists, but rather help them work more efficiently. After Remington picked up the manufacturing rights to Sholes' typewriter, the QWERTY system was continually modified, shifting the position of less important keys and adding new ones. The whole QWERTY system took on a new life with the advent of electronic typewriters before IBM adopted it in the 1960s for its first PC keyboards. Since then, there have been many improvements, such as the addition of function keys.



What's stopping us from building a tower that goes up to space?

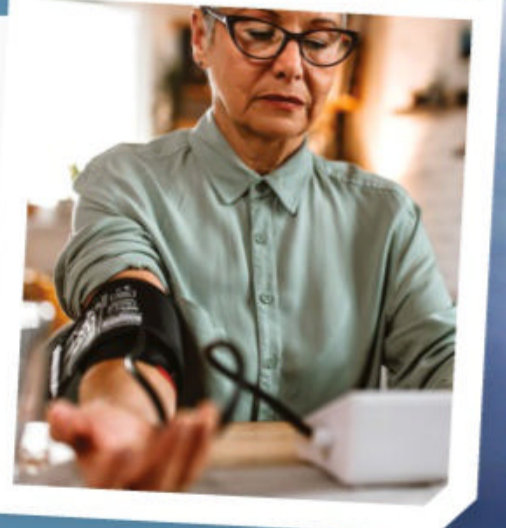
The main challenge in building a tower which extends past the upper reaches of Earth's atmosphere is that there are currently no known materials that would be strong enough not to buckle under their own weight. However, this hasn't stopped many scientists and engineers devising ways that it could be possible, along with high-profile bodies such as NASA investing in research into how it could be done. The accepted view of how this might work involves building from the top down, where the top would be a large mass in geosynchronous orbit around Earth, orbiting the planet yet staying in the same position at all times. The 'tower' would most likely be a thin-yet-strong cable or tether that could be climbed by mechanical means to deliver payloads into space. Building from the top down would need to be balanced by building up from Earth, where the upwards building would act as a counterweight to keep the geosynchronous orbit in check. Exciting developments in the manufacture of new materials such as carbon nanotubes could be the perfect candidate. However, finding the huge amount of carbon that we would need is the next hurdle to overcome.



DO OTHER MAMMALS HAVE DIFFERENT TYPICAL BLOOD PRESSURES TO HUMANS?

Since blood pressure is partially dependent on height and weight, as well as genes, the answer is most definitely yes. Despite recommended levels, even different humans have a range of what is typical. A minimum blood pressure is needed to keep large vessels from collapsing, so the larger the animal – and thus the blood vessels – the higher the blood pressure

needs to be. While dogs and cats have similar ranges to humans, elephants have a much higher average blood pressure to keep their much larger vessels open. While a 'normal' value in human beings might be considered to be 120mmHg (millimetres of mercury), in an elephant 180mmHg is average. To counter this, elephants have much lower resting heart rates.



Where does light end up when it enters a black hole?

Many have grappled with this question since the 1930s, when it became widely accepted that black holes might exist. Einstein's theory of general relativity tells us that all mass deforms space and time, causing paths taken by particles to bend towards the mass. At the event horizon of a black hole – the boundary in space-time through which matter and light cannot escape once crossed – the deformation of space and time is so strong, there are simply no paths that lead away from the black hole. Once matter or light has crossed the event horizon, it becomes impossible to determine what happens to it afterwards, since information from that event can never reach an outside observer.

IF YOU JUMP UP ON A MOVING PLANE, WHY DON'T YOU LAND FARTHER UP THE AISLE THAN WHERE YOU LEAPT FROM?

If you jump straight up on a moving plane, you will land on the same spot you initially jumped from because the air – and indeed everything else inside the craft – is moving at the same speed as the plane. If it were possible for a stationary observer outside to see you jump, they would witness you moving forward through

the air at the same speed as the aeroplane during your leap. Of course, this assumes the plane is moving at a constant speed. If you were to attempt a jump while the aircraft was speeding up or slowing down – though we're certainly not recommending you do – you wouldn't land in the same spot.



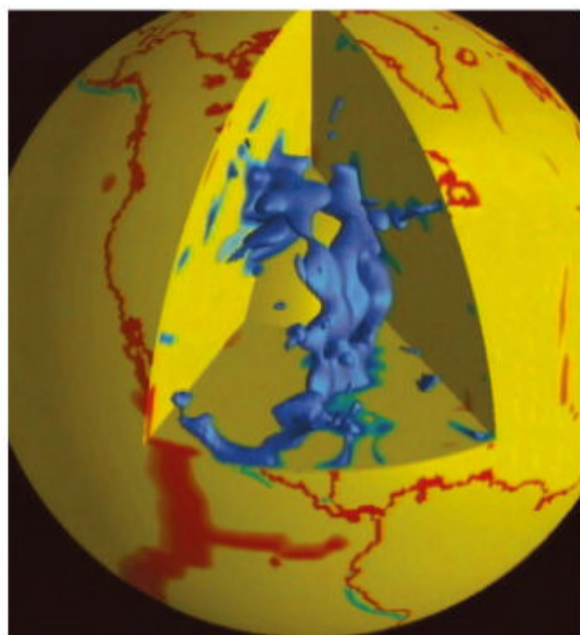
IF THE COSMOS IS ALWAYS EXPANDING, WHAT'S IT EXPANDING INTO?

We've known since 1922 that the universe has been changing since it came into being, but we're still not sure about all the details. A better word might be stretching, rather than expanding. If the cosmos is infinite, then it's always been infinite and it will stretch forever; it's not expanding into anything. If it's finite, it may be stretching out something else, but we can only postulate. Currently, astronomers believe the universe is either infinite or somehow folds back on itself.



WHY DOES COFFEE GIVE SOME PEOPLE HEADACHES?

Caffeine is a common stimulant that acts on the central nervous system. Most people know that caffeine comes in tea, coffee, some fizzy drinks and chocolate, but it's in many medicines too. It's also sold in stimulant tablets that some people take to stay awake. Caffeine can both cause and relieve headaches. When in medications, it acts to improve absorption of the other substances in the product while also causing blood vessels in the brain to constrict slightly, which can relieve headaches caused by dilated veins, such as migraines. However, caffeine can also cause headaches; in fact, it's the caffeine withdrawal that causes the pain. Since caffeine normally induces vasoconstriction of the blood vessels in the brain, a sudden lack of it leads to vasodilation, where the blood vessels swell. This can cause a 'pounding' headache that is relieved as soon as you have some caffeine. It's not just the heavy coffee drinkers who get this; some people can become 'addicted' to very small amounts of daily caffeine.

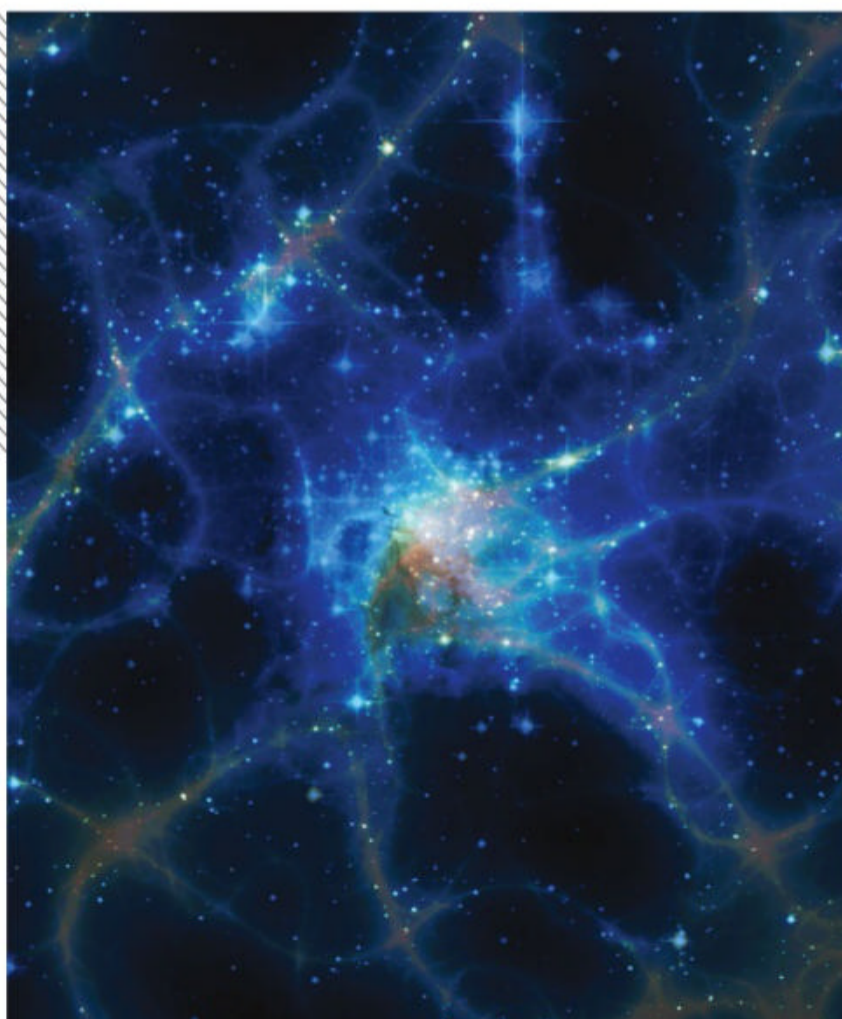


WHAT IS THE FARALLON PLATE?

During the Permian period, about 300 million years ago, all of Earth's landmass was joined together into a single continent called Pangaea. What would eventually become the Americas was on the west coast of Pangaea and the tectonic plate that comprised the seabed that lay to the west of that is known as the Farallon Plate by geologists. When Pangaea began to break up about 200 million years ago, the Farallon Plate slid under North America and into Earth's mantle. This caused the land above it to buckle upwards to form the Rocky Mountains. The Farallon Islands, which lie 27 miles west of San Francisco, are all that is left of the Farallon Plate, which will slide completely beneath America in another 5 million or so years.

What lies between galaxies?

Intergalactic space is what lies between galaxies, and many experts believe it to be filled with some kind of super-thin gas. Then again, there is also the theorised dark matter, the mysterious substance that emits neither light nor radiation and is estimated to account for around 85 per cent of the matter in most galaxies. Recent breakthroughs at the Large Hadron Collider could one day throw much more light on this and other questions about the formation and structure of the universe – but until someone accurately measures either dark matter or intergalactic space itself, it's all just theory.



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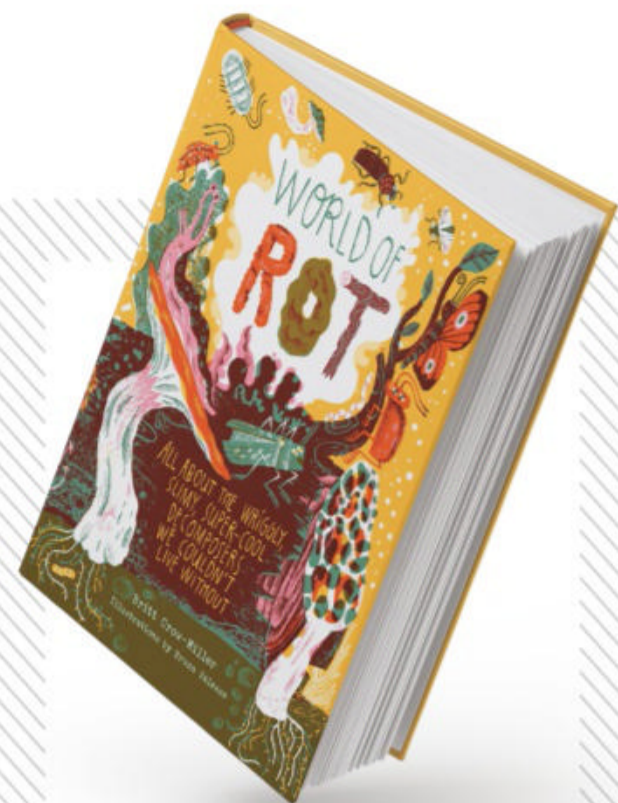
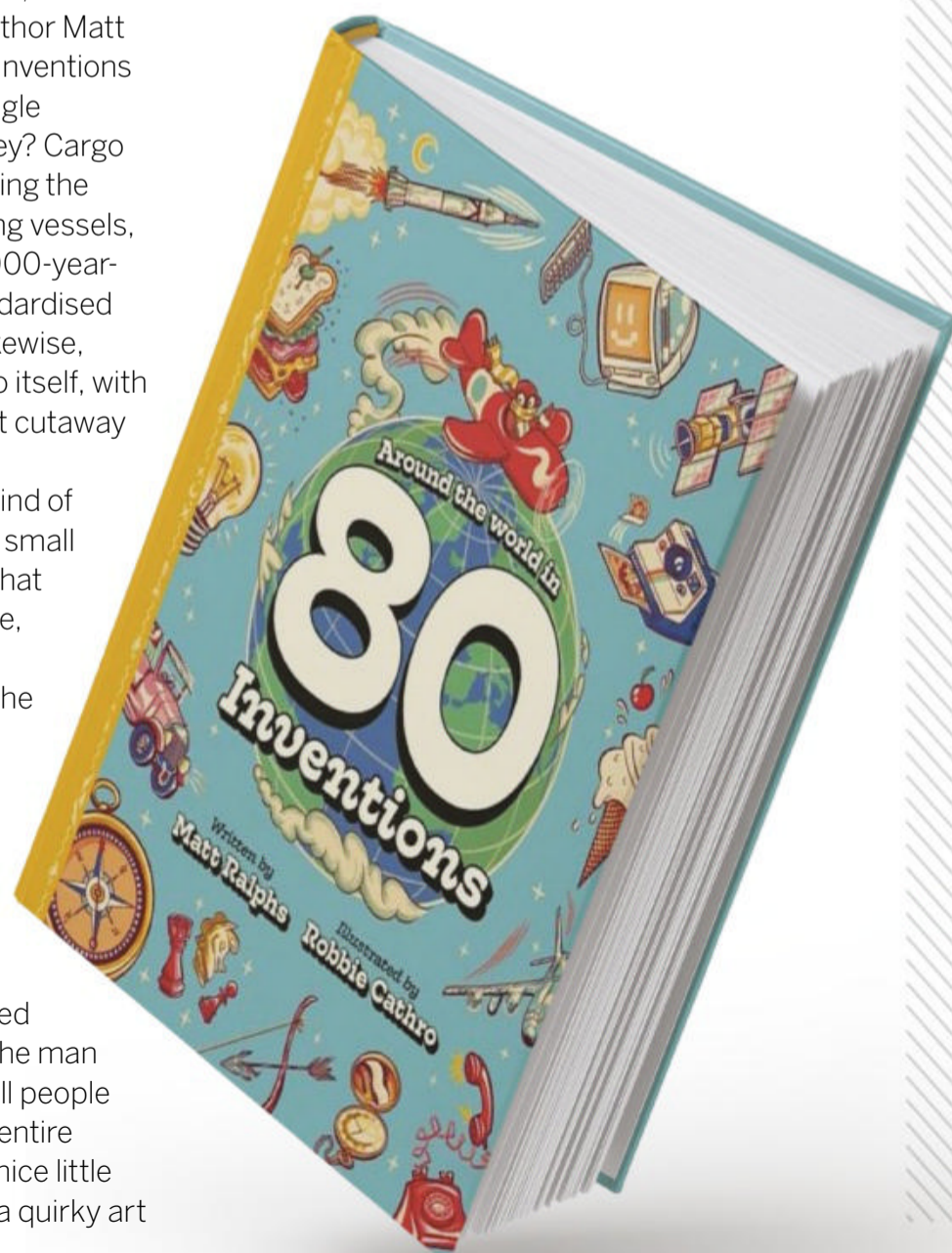
RELEASE OUT NOW

What do we mean by a bit extra? This is another title in the popular series that follows *Around the World in 80 Instruments* and *Around the World in 80 Trees* – both of which we've already reviewed in previous issues of **How It Works**. So if you've read either of those, you'll understand the premise of *Around the World in 80 Inventions*, which is the science, tech and history behind 80 inventions from around the world – nominally, at least. Among the half and single-page entries such as the internal combustion engine, chocolate and kevlar body armour, author Matt Ralphs has grouped entire families of inventions onto double-page spreads under a single number. How's that for value for money? Cargo ships get this special treatment, charting the major developments in these sea-going vessels, with individual inventions from the 5,000-year-old Phoenician sailing ship to the standardised container ships of the modern era. Likewise, nuclear power gets an entire spread to itself, with a fantastic annotated 1930s comic-art cutaway illustration of a nuclear power station.

Even the smaller entries get some kind of extra treatment, often in the form of a small box with a cool nugget of extra detail that adds value. Like dynamite, for example, which was invented by chemist Alfred Nobel: the same inventor who set up the prestigious Nobel Prize, which recognises people who have made great achievements in different fields. He was prompted to do this by a French newspaper, which published an article titled 'The Merchant of Death is Dead' eight years before Nobel's actual death. He was so worried that people would remember him as the man who invented something that would kill people quicker than, when he died, he left his entire fortune to fund the awards. It's these nice little surprises, the fun facts, coupled with a quirky art

style, that brings a smile to your face and really raises the game for *Around the World in 80 Inventions*. Absolutely one for history buffs and trivia fans of all ages, we can imagine this would make a great pub quiz companion, as well as looking quite at home on a school bookshelf.

“Even the smaller entries get some kind of extra treatment”



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PRICE £14.99 / \$18.99

RELEASE 26 SEPTEMBER

Who would have thought that reading about rot would be so fascinating? From the bacteria in your waste bin to the deep-sea creatures that decompose ocean giants, readers can delve into the world of decay and discover the amazing science behind its environmental importance. It's safe to say that the wonderfully disgusting theme isn't a typical one for a children's book, but it's so fun and engaging that children will soon be looking for detritivores in the garden.

The theme of decomposition is carried through the book's brilliantly creative illustrations, bringing to life the termites and slime moulds dedicated to decay. To close out this surprisingly engrossing book, there are heaps of simple experiments and projects to enjoy.

EXTREME WEATHER FOR KIDS

LESSONS AND ACTIVITIES ABOUT HURRICANES, TORNADOES, BLIZZARDS AND MORE

AUTHOR MATTHEW CAPPUCCI
ILLUSTRATOR STEPHANIE HATHAWAY
PUBLISHER QUARTO PUBLISHING
PRICE £14.99 / \$19.99
RELEASE 28 MARCH

This children's book is a great reference guide to the basics of weather and how it can be pushed to the extreme. From the physics of thunder to the science of solar storms, this hearty guide is packed with snippets of knowledge and informative illustrations about the mechanics of weather and how it interacts with the

environment worldwide. There's also an important final section of the book that tackles climate change and how it impacts weather. In a time when younger generations are concerned about global warming, this book provides simple explanations of what's going on in the environment. Aimed at a slightly older preteen audience, *Extreme Weather for Kids* provides an insight into complex concepts without overcomplicating the science. The experiments throughout the book, such as making a pinhole projector and a rainbow in a glass, also put their newfound knowledge to the test.



THE INCREDIBLE OCTOPUS

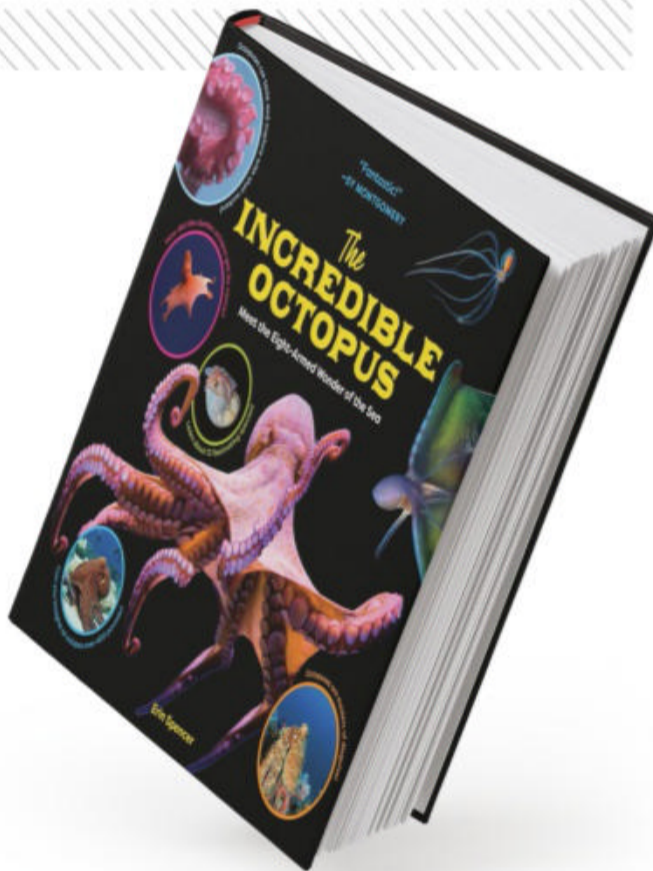
MEET THE EIGHT-ARMED WONDER OF THE SEA

AUTHOR ERIN SPENCER
PUBLISHER WORKMAN PUBLISHING
PRICE £16.99 / \$19.99
RELEASE 2 MAY

Did you know that octopuses have blue blood, three hearts and some of the smartest brains in the animal kingdom? These facts are just the beginning of your oceanic exploration, launching the reader into the fascinating world of the octopus. Aimed at enlightening the minds of children aged seven and older, *The Incredible Octopus* lets the reader examine an octopus up close and get to know features they could never see, even during a rare encounter in the wild. This includes the microscopic details of an octopus' suckers and the complex anatomy inside their heads.

After discovering the biology common to all of their kind, this book highlights some of the most mesmerising octopuses. The bewildering quirks of each shape-shifting species make them a skilful and diverse group. Readers will meet the

Antarctic octopuses that have mastered survival in freezing waters, and the mimic octopus that can disguise itself as a range of toxic animals to deter predators. Some octopuses are so large that people once mistook them as monsters, but they also come in tiny packages too. When you read about the smallest octopus, the star-sucking pygmy, be sure to appreciate the 'actual size' diagram printed on the page. As you flip through *The Incredible Octopus*, each species may seem like something out of a fantasy, but these impressive, vibrant and ingenious octopuses all dance across the sea – with many more fascinating species where they came from.

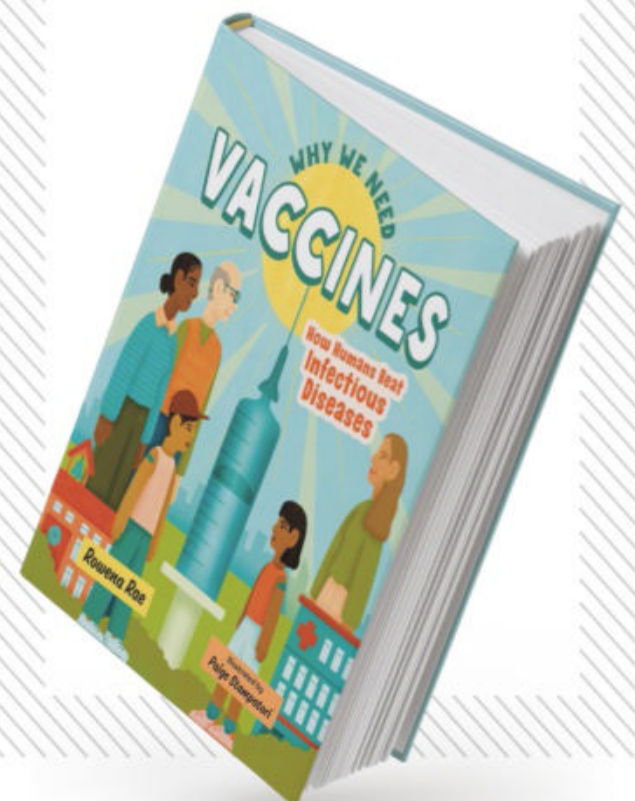


WHY WE NEED VACCINES

HOW HUMANS BEAT INFECTIOUS DISEASES

AUTHOR ROWENA RAE
ILLUSTRATOR PAIGE STAMPATORI
PUBLISHER ORCA BOOK PUBLISHERS
PRICE £23.63 / \$29.95
RELEASE 16 APRIL

Many children fear vaccines. The idea of a sharp needle puncturing your skin is enough to make even an adult wary. But understanding why vaccines are important is essential to braving a vaccination and viewing them as something to be celebrated. *Why We Need Vaccines* expertly communicates a serious topic in a way that children can easily understand. Each section begins with the fundamental science of infectious diseases, explaining what pathogens are and how these can spread between people, impacting our health. *Why We Need Vaccines* takes readers on a journey through the history of human health, the discoveries and inventions that led to today's vaccinations. As you compare ancient medical practices to modern-day vaccinations, you will see how vital this medical technology has proven to be.



BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

			6	1			8	4
1	9		7			5		
	8	4	9	5		3		7
5	1	2	4		9	7		8
	3	9						
4		7			5	1		
7		1			4	6		3
	5				1			
	4	6	5	2	7			9

MEDIUM

	6	8					4	1
2		9			8			
	1						2	8
9	5			8				7
	7	4		5	1	3		
							8	9
4				3		6		
5	3			7	6	9		1
		6						5

HARD

				8	2	4		
	4							9
					6			3
6		5			1			
				9	6			7
		2						8
		4	8		9			6
7	3	6	5					
		1			7	2		

Word search

Find the following words

TIME
MAP
OUTBACK
TONSILS

PLANKTON
SOLAR
GARDENING
BOWLING

FUSION
PLANET
NATIVE
CAR

C	T	I	M	E	Y	L	P	B	O	W	L	G	N	I
W	O	L	B	I	P	L	A	N	E	T	Z	E	A	U
A	G	R	D	E	N	I	N	G	F	D	N	A	T	E
O	N	U	B	A	C	K	J	E	R	X	O	L	I	P
A	I	E	R	A	L	O	S	R	K	C	U	A	V	R
M	N	A	P	L	A	N	A	K	O	N	T	V	E	J
T	E	O	N	S	I	C	L	S	G	A	B	R	C	Y
S	D	L	F	A	R	P	G	L	A	N	A	T	O	N
F	R	I	U	E	M	A	P	N	I	R	C	E	G	O
B	A	C	S	K	U	V	A	E	I	P	K	O	R	T
E	G	O	I	N	Z	E	N	C	A	L	R	P	A	K
W	P	L	O	G	A	R	B	E	M	I	W	N	G	N
Y	O	W	J	L	P	L	A	N	K	T	N	O	U	A
T	O	N	S	I	L	S	Q	A	M	B	T	Y	B	L
K	G	Y	F	U	S	I	O	L	A	R	T	F	J	P

What is it?

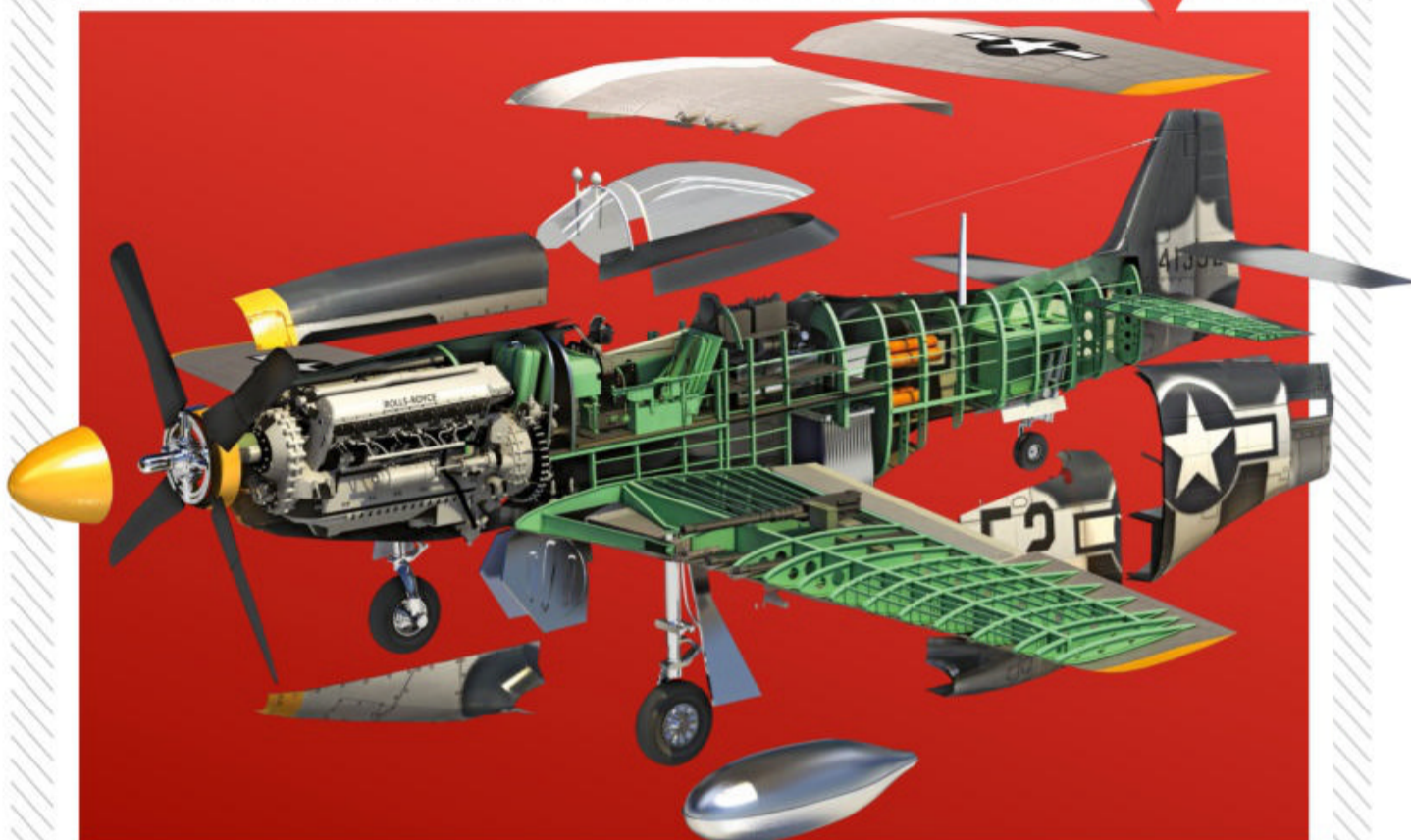
Hint:
Ship-sinking
salad item

A



Spot the difference

See if you can find all six changes between the images below



Answers

Find the solutions to last issue's puzzle pages

- Q1** ELECTRICITY
- Q2** 50
- Q3** 21 METRES PER SECOND
- Q4** VIRUSES
- Q5** 120 DEGREES CELSIUS
- Q6** EYES



What is it?
A FLEA

Spot the difference



QUICKFIRE QUESTIONS

Q1 Which isn't a state of matter?

- Solid
- Gas
- Plasma
- Mass

Q2 Which element makes up most of the human body?

- Oxygen
- Carbon
- Plutonium
- Hydrogen

Q3 What fossil was recently excavated from the cliffs of the Jurassic Coast?

- Plesiosaur
- Pliosaur
- Megalodon
- Ichthyosaur

Q4 What makes up around 70 per cent of the universe?

- Dark matter
- Dark energy
- Atomic matter
- Stars

Q5 What did the Romans use as mouthwash?

- Seawater
- Urine
- Blood
- Wine

Q6 Approximately how many cars are in use worldwide?

- 1 million
- 1 billion
- 7 billion
- 17 billion

KIT LIST

50 centimetres of knitting yarn

A cereal bowl

A sandwich bag

A clothes peg

A small rock

A lipped baking tray

Water

DON'T DO IT ALONE!

If you're under 16, make sure you have an adult with you



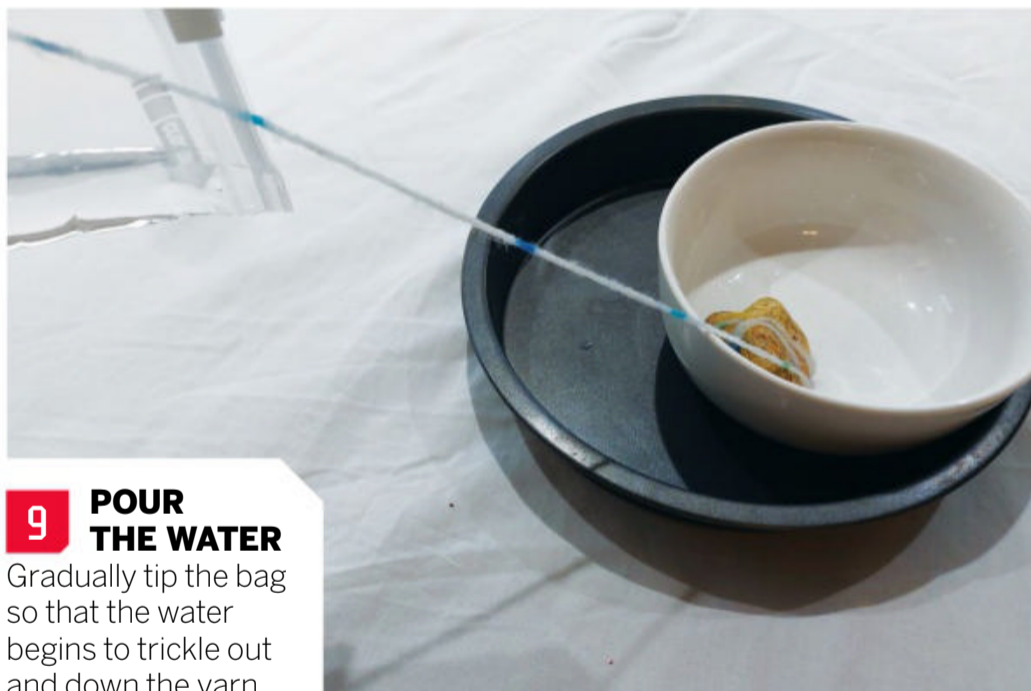
7 CREATE THE BRIDGE

Carefully take the bag over to the baking tray and place the rock into the container.



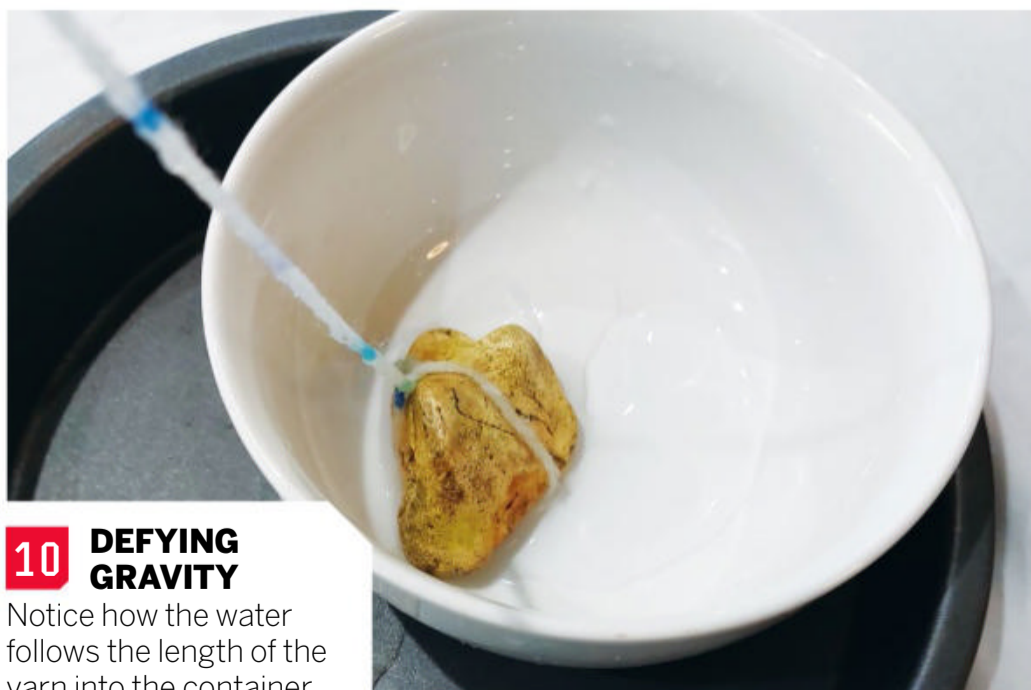
8 TAKE THE SLACK OUT

Holding the bag so that the water doesn't pour out, move the bag away from the container until the string is taut.



9 POUR THE WATER

Gradually tip the bag so that the water begins to trickle out and down the yarn.



10 DEFYING GRAVITY

Notice how the water follows the length of the yarn into the container.

SUMMARY

There are three main physical forces at work here: gravity, adhesion and cohesion. Cohesion allows water molecules to stick to each other. Water will also stick to different surfaces under adhesive forces, and gravity will compel the water to move downwards. These three forces conspire to draw the water out of the bag, over the space between the container and the bag and down the yarn. As long as you hold the bag high and you're not over-enthusiastic about pouring, there shouldn't be too many drips. Yarn is particularly good at soaking up water, so the water that pours from the bag has plenty to cling to as it makes its journey downwards. This experiment will not work as well with less absorbent material such as thin yarn, string or ribbon. You could experiment with different stringy materials to see which are more or less effective at delivering water across the bridge.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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INBOX

Speak your mind

SEND YOUR QUESTIONS OR COMMENTS TO: f HOW IT WORKS MAGAZINE @HOWITWORKSMAG @HOWITWORKSMAG @HOWITWORKS@FUTURENET.COM @HOWITWORKSMAG

GLUTEN AND THE GUT

Dear HIW,
My friend can't eat gluten and I'd like to understand it better. What's the difference between gluten intolerance and coeliac disease?

Magda Baran

They share some symptoms, but differ in severity. Coeliac is an autoimmune disorder, which means the cells in the body's immune system attack healthy tissue. Gluten intolerance is a sensitivity to gluten in the gut, but doesn't impact a person's overall health as significantly. Usually, those with a gluten intolerance just need to limit their gluten intake, while coeliac disease sufferers have to avoid it for life, as each exposure to gluten can have a more severe impact on their health. A gluten reaction may affect someone with coeliac disease for weeks at a time.

Bread, pasta, cereals, cakes and pasta are examples of foods that typically contain gluten



An electric guitar's string vibration frequencies make its notes

SOUND WAVE SCIENCE

Dear HIW,

How do electric guitars work? I started playing with my son. I've tried explaining how music is turned into sound waves, but I wonder if you can explain it better?

Christopher Wright

When playing any instrument, you're manipulating materials to produce sound waves, and each instrument produces these in a unique way. In the case of an electric guitar, sound is produced by plucking metal strings. This makes the string vibrate, which alone is enough to produce sound waves in the air, as the surrounding air molecules are disturbed and vibrate at the same frequency of the string. The frequency is the pitch, or number of vibrations per second.



Acoustic guitars amplify these sound waves through a hole in the instrument, while in electric guitars the sound waves are amplified electrically. Devices called magnetic pickups, which are located underneath the strings, convert the strings' vibrations into electrical signals.

These pickups are magnets with coils of wire wrapped around them, which create a magnetic field around the guitar strings. When you pluck a guitar string, it vibrates and interferes with the magnetic field, causing an electric current in the coils. Although the vibrations have been converted into electricity, they retain their unique pattern based on the note played. The electrical signals are carried from the coils, through the wires of the guitar and to the amplifier, which increases volume.

WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

AROUND THE WORLD IN 80 INVENTIONS

80 incredible world-changing inventions: from the wheel to the rocket and the bow and arrow to the atom bomb



POINTY SHOES

Dear HIW,

Why are shoes so pointy? Can this impact a person's feet?

Zarah Rickard

As shoes have evolved over the centuries, they have been influenced largely by fashion, sometimes more so than comfort. In medieval Europe, for example, a shoe style called the poulaine became popular around the 12th century. This was a pointed shoe that soon became a symbol of the

wearer's wealth. Many sports shoes, which are meant to support the foot during exercise and keep performance high, are also fairly narrow. Shoes can be constricting, and indeed impact your feet. If you want to keep your feet functioning as they should, you should buy shoes that are more foot-shaped and have a wide toe box. Those that get narrower at the top instead of widening can push your big toe inwards and are a leading cause of bunions – boney bumps on your feet.

Narrow toe boxes on footwear can squish your toes together





A young snow monkey enjoying a swim in some hot springs

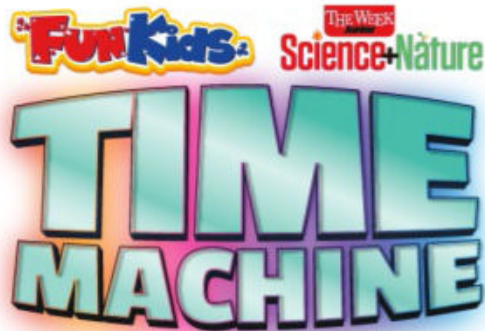
SWIMMING MONKEYS

Dear HIW,

Is it true that monkeys and apes can't swim?

Den Charles

While it is true that many monkeys such as orangutans, chimpanzees, bonobos and gorillas don't swim instinctively and aren't attracted to water, there are many monkey species that swim well in water. Proboscis monkeys, native to Borneo, are very strong swimmers. They have streamlined bodies and webbed fingers and toes, allowing them to swim efficiently while hunting for food. Macaque monkeys swim and dive for food such as crabs, while squirrel monkeys use their aquatic skills to cross rivers in their Amazon habitat. Just as humans enjoy water for leisure, Japanese snow monkeys use the water of hot springs to bathe and relax during harsh winters.



SEND A MESSAGE TO THE FUTURE

To celebrate Leap Day, **The Week Junior Science+Nature** is joining forces with children's radio station Fun Kids for a very special project: Time Machine. This is your chance to send a message to the future.

What do you want the children of tomorrow to know about life today? And what do you hope the world will look like in the future? Record an audio clip or send in a drawing and they'll be placed in a time capsule to go on display at We The Curious museum in Bristol. To record an audio clip visit funkidslive.com/timemachine or post a drawing to **The Week Junior Science+Nature**, 121-141 Westbourne Terrace, London, W2 6JR. If you enter online, you can vote for how long you want the capsule to remain locked for, with a maximum limit of 150 years. The deadline for entries is 29 February.



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WE ASKED YOU

This month on social media, we asked you:

What is the best survival tip you know that could help you in the wilderness?

@DEFINITELY.NOTMAX

PURIFY WATER AND CREATE A SHELTER

NIKO

MOSS GROWS THICKER ON THE NORTH SIDE OF TREES IN THE NORTHERN HEMISPHERE

@SCIMAXFACTS

FIND SERVICE ON YOUR PHONE

@AESTHETICALLY_AJ

MELT SNOW BEFORE INGESTING AS YOU WILL USE MORE CALORIES

@????FATEMEH????

NAVIGATION WITHOUT A COMPASS

JACOB F

ALWAYS CARRY A HEAD TORCH TO FIND YOUR WAY BACK AFTER DARK OR MAKE SOS SIGNALS

NEXT ISSUE

ISSUE 188 ON SALE 14 MAR 2024

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FAST FACTS

Amazing trivia that will blow your mind



80%

Four out of every five animals on Earth are nematode worms

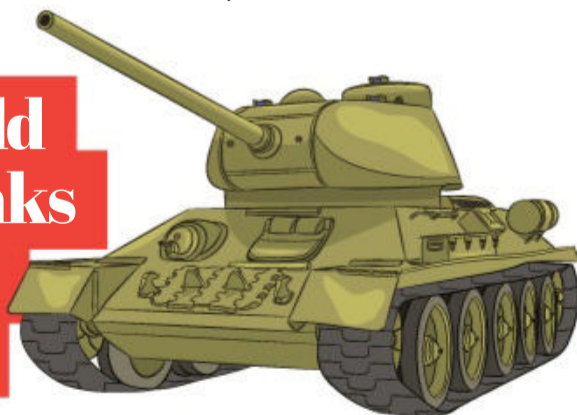
2.6 MILLION LIGHT YEARS

The Andromeda Galaxy is 14.7 quintillion miles away, but is still visible to the naked eye

4.77 METRES

The combined height of the world's tallest couple is about the same as an average giraffe

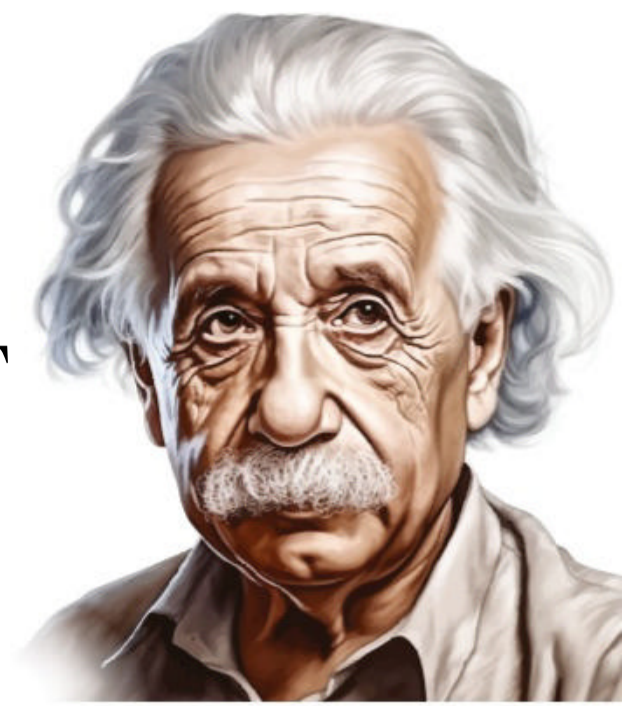
Since the end of World War II, all British tanks have been fitted with tea-making facilities



4.89 BILLION

The equivalent of over half the world's population used social media in 2023

WHEN ISRAEL WAS FORMED IN 1948, ALBERT EINSTEIN WAS OFFERED THE PRESIDENCY, BUT DECLINED



4

In 2023, a small number of boats were sunk by orcas in the Strait of Gibraltar

0

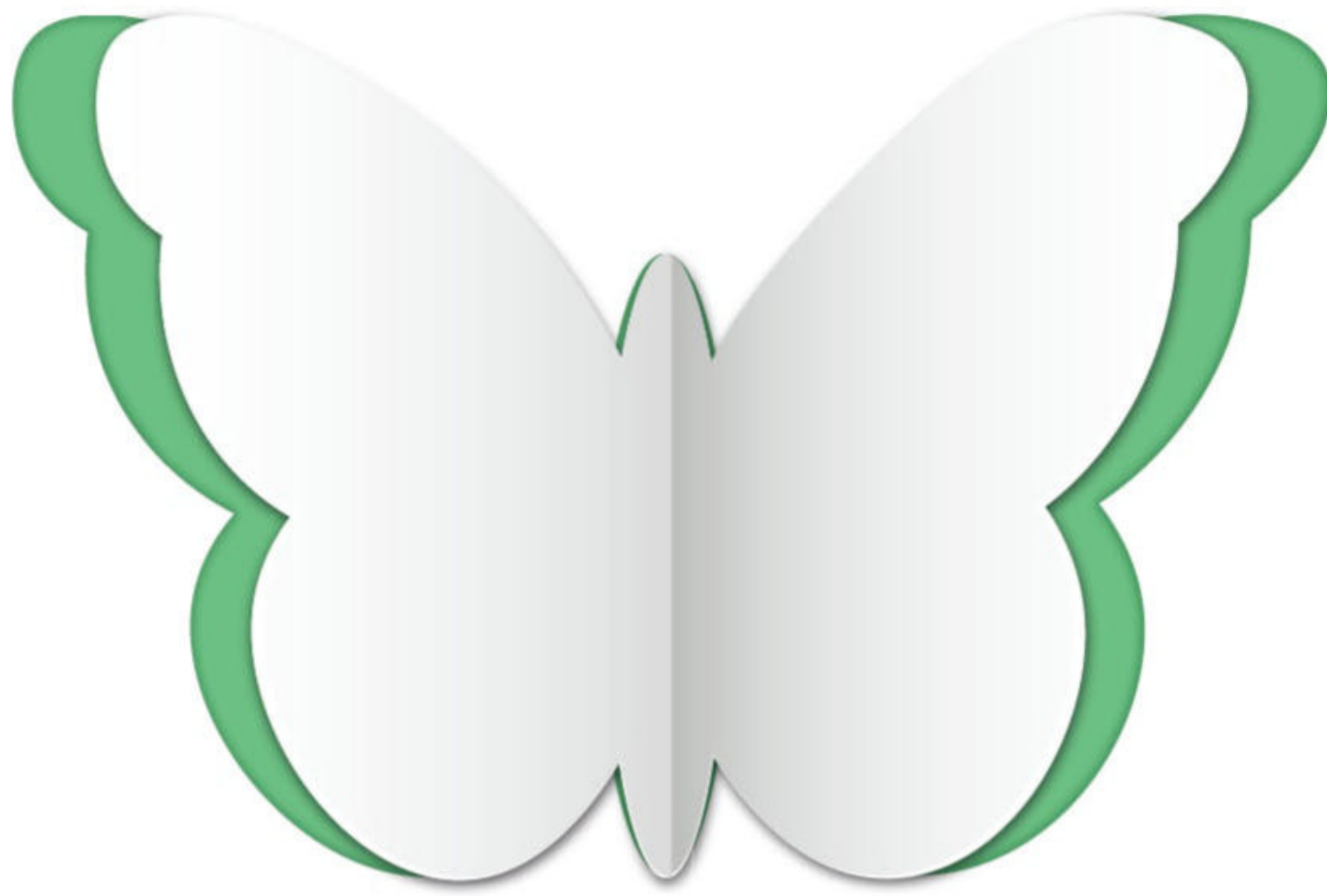
Fusion reactors produce no carbon dioxide or harmful atmospheric emissions

25,008 MILES PER HOUR

Spacecraft need to travel at around Mach 33 to escape Earth's gravity

THE BRAINS OF PROFESSIONAL GOALKEEPERS PROCESS SENSORY DATA FASTER THAN MOST PEOPLE





PAPER & BIODIVERSITY

Forests cover 31% of the world's total land area and contain most of the world's earthly biodiversity. To ensure the long-term health of forests, the European paper industry counts on sustainable forest management as a source for its main raw material.

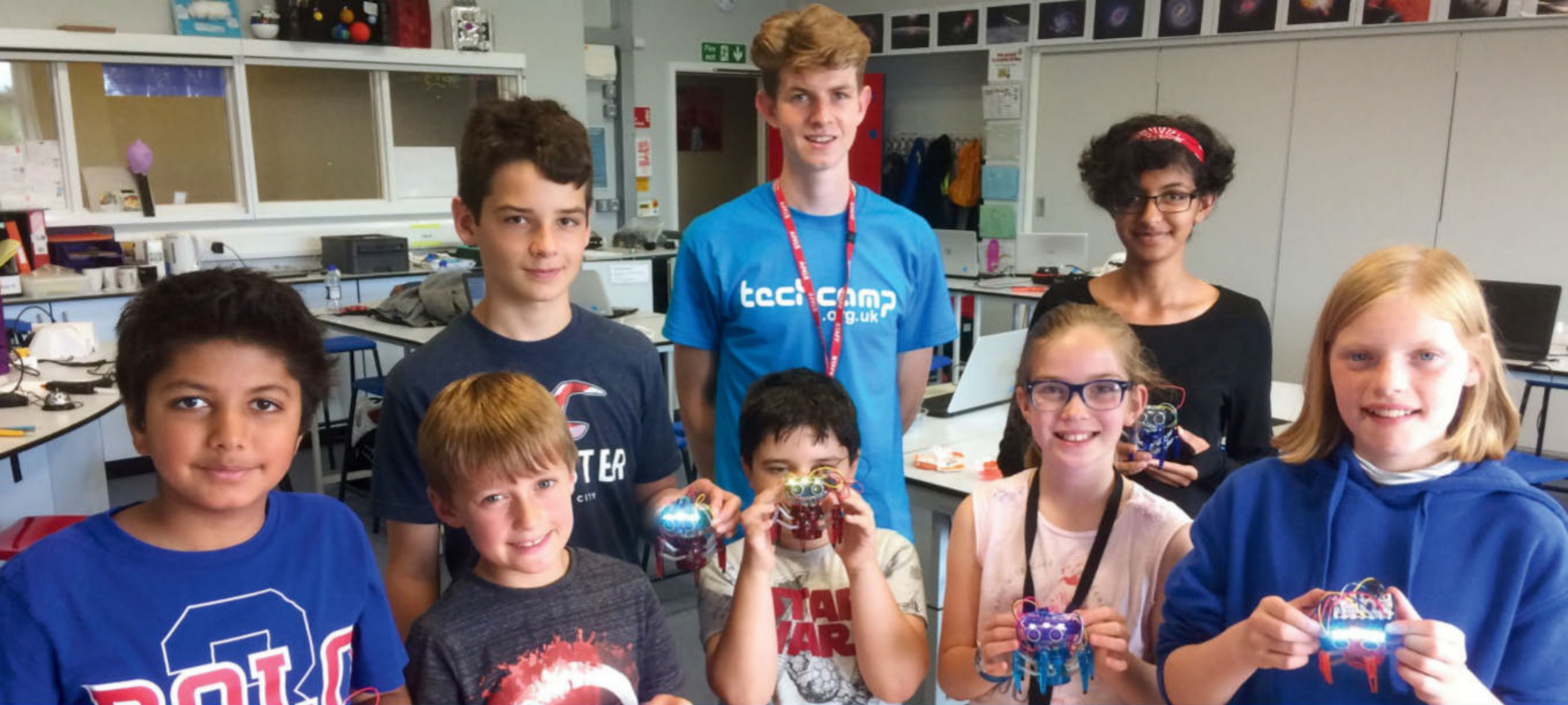
Source: FAO and UNEP, The State of World's Forests, 2020



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