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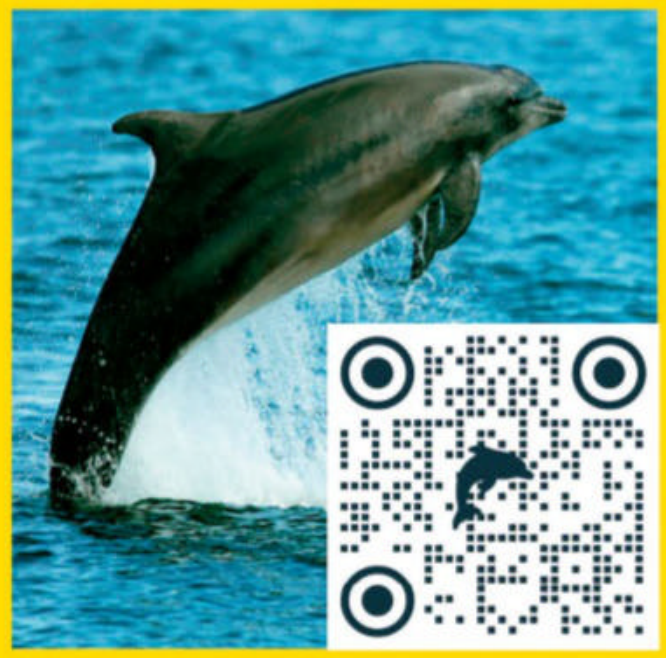

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Issue 183

> "The absence of evidence can't be classed as evidence of absence"

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Does Bigfoot really exist? PAGE 26

The plaster casts in the image above are of alleged Bigfoot tracks – the giant, human-like primate creature that's said to roam the Rocky Mountains in the US and Canada. Like many other monster stories around the world, no one has ever been able to prove the existence of Bigfoot, and it's highly likely that it's just a tall tale. But other monsters have turned out to be real. On page 26, you can explore the evidence behind many monster myths from around the world – the photos, eyewitness accounts and more – to discover which legendary monsters are probably just a figment of someone's overactive imagination, the origin stories of these creatures and which ones turned out to be real after all. Enjoy the issue!

Ben Biggs
EDITOR

HIGHLIGHTS

WHAT WE'RE ANTICIPATING


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Issue 183

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ENVIRONMENT

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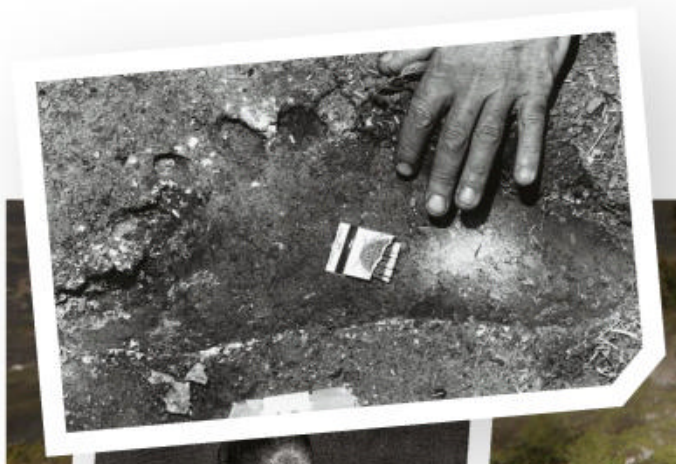
REGULARS



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Win!

ONE OF TWO CODING ROBOTS WORTH £120

Page 82

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Unusual arachnid

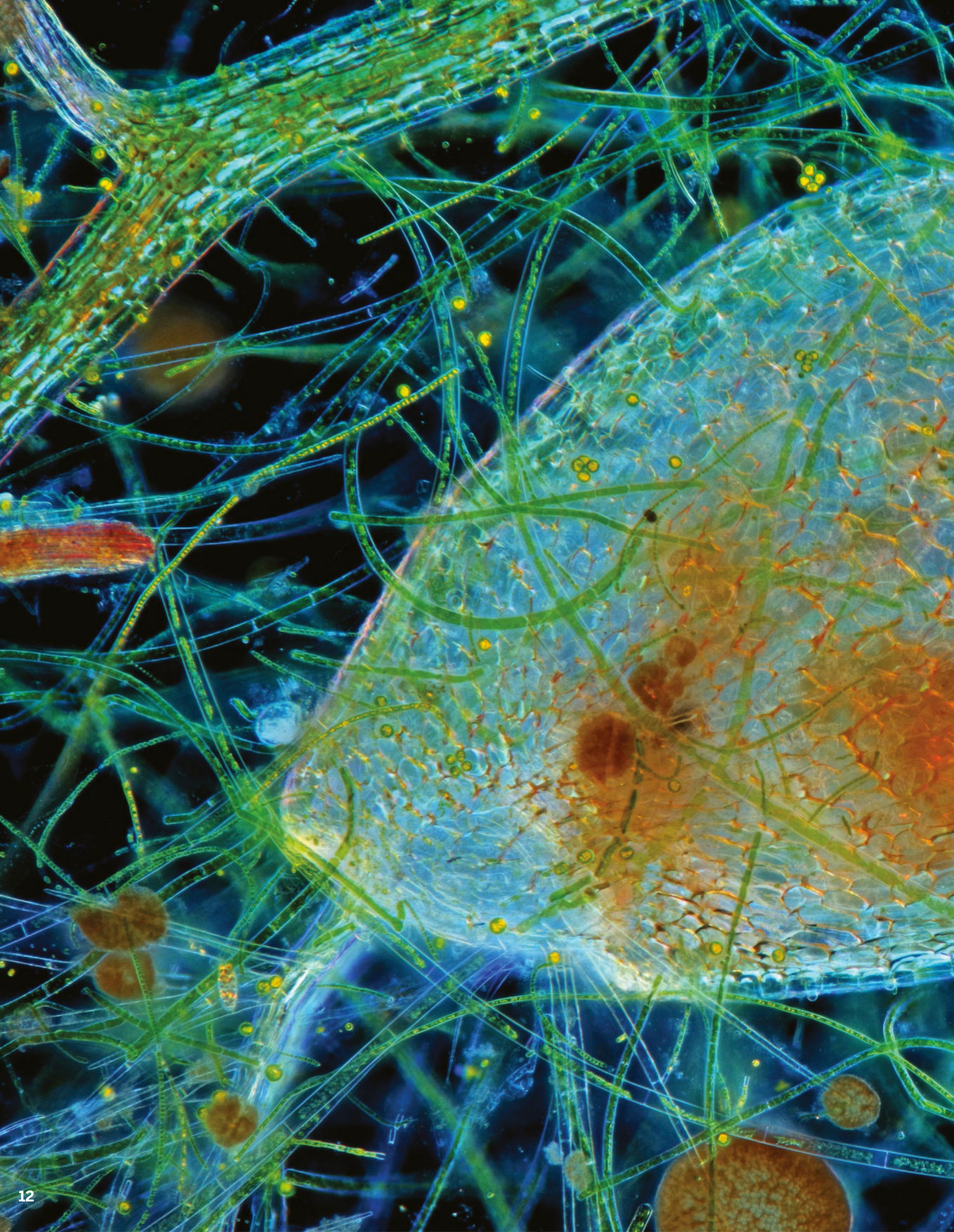
This is a whip spider, also known as a tailless whip scorpion, a nocturnal arachnid that belongs to the order Amblypygi, which means ‘blunt rump’, referring to its lack of a tail and stinger. Unlike typical spiders, these eight-legged freaks can’t spin silk to catch prey, instead using their long, praying mantis-like arms to quickly snatch passing creatures.

Cackling in the cosmos

There's a witch in space about 900 light years away. Plucked straight from a storybook, the Witch Head Nebula, also known as IC 2118, bears a striking resemblance to a hook-nosed sorceress. Its eerie, blue hue is the result of the neighbouring blue supergiant star, Rigel, and cosmic dust and gas reflecting blue wavelengths of light much more efficiently than other wavelengths.

Chinese ghost town

Situated in the suburbs of Shenyang, 400 miles from Beijing, are rows of homes left vacant. In 2010, ground broke on the site and construction began. However, within two years the project was abandoned, leaving rows of unfinished mansions and concrete shells behind. Instead of human residents, local farmers have brought cattle to the site to wander around the unoccupied estates.



Belly of a bladderwort

Unlike earth-rooted plants, bladderwort gets its nutrients from tiny marine creatures that it sucks up into underwater traps. Insects, larvae, water fleas and even tadpoles are among the critters that find themselves falling into this plant's trap. Once prey triggers one of the hair-like structures in the mouth, the mouth of the bladderwort opens and quickly closes, sucking the prey inside.

GLOBAL EYE

Showcasing the incredible world we live in

Stonehenge's Altar Stone probably wasn't sourced from the same region as the bluestones

HISTORY

We might have Stonehenge's Altar Stone origins all wrong

WORDS SASCHA PARE

The largest stone in Stonehenge's inner circle, known as the Altar Stone, may have come from farther afield than its neighbouring monoliths, possibly even from northern England or Scotland, according to a new study that questions a 100-year-old idea about the stone's origins. A century has passed since British geologist Herbert Henry Thomas published his seminal 1923 study on Stonehenge, in which he traced the origin of the 'bluestones' that make up the monument's inner circle to the Preseli Hills in western Wales.

Among these bluestones, so called because they acquire a bluish tinge when wet or freshly broken and to distinguish them from the 'sarsen' stones that make up the outer circle, Thomas included a 4.9 metres flat-lying, grey-green slab of stone known as the Altar Stone. "It seems as though he wanted all the non-sarsen stones to come from a limited geographic area and this basic assertion has not been challenged for 100 years," said Richard Bevins, an honorary professor of geology and Earth sciences at Aberystwyth University, Wales. It now appears that Thomas' assessment was flawed, Bevins and his colleagues have found. While Thomas quite rightly pinpointed the source of some stones to outcrops in western Wales, the Altar Stone likely came from a different location, possibly an unknown quarry in northern Britain, Bevins said.

Stonehenge was erected during Britain's Late Neolithic period, roughly 4,000 to 5,000 years ago, on Salisbury Plain in Wiltshire, in southern England. The monument was built, rebuilt and added to over thousands of years, with the bluestones brought to the site during an early construction phase. Early excavators of Stonehenge called the bluestones 'foreign stones' because they are exotic to Wiltshire. Their long-haul transport over 140 miles from western Wales to Stonehenge is one of the farthest known distances from a source to a prehistoric monument construction site anywhere in the world.

The Altar Stone has always stood out from the other bluestones because it's much larger and made of a different type of rock. There is also "no archaeological evidence as to when the Altar Stone arrived at Stonehenge," Bevins said, raising the possibility that it could have been brought to the site during a later construction phase. To shed light on the stone's origin, the researchers compared its geochemistry and mineralogy with 58 sandstone outcrops stretching from southern Wales to western England. But the search "failed to make a match," Bevins said, and the researchers concluded that they might be looking in the wrong place.

The Altar Stone displays an unusually high amount of the chemical element barium, which has helped the researchers narrow down further potential sources. "Initially, we feel it appropriate to investigate areas where there are known ancient monuments of Neolithic ages," Bevins said. These areas stretch across northern England and Scotland, broadening the horizons of a search and allowing for "creative thinking about the source of the Altar Stone," he said. The characterisation of the Altar Stone as a bluestone is now up for debate, Bevins added, rewriting its archaeological significance in the history of Stonehenge.

The leather shoe had a piece of flax or linen that hinted at how the shoe had been tied

HISTORY

2,200-YEAR-OLD CHILD'S SHOE DISCOVERED IN AUSTRIAN MINE

WORDS **LAURA GEGGEL**

Deep underground in a rock-salt mine in Austria, archaeologists have made an outstanding discovery: the 2,200-year-old shoe of a child. The mine's rock salt, which people have been mining since the Iron Age in the village of Dürrnberg near present-day Salzburg, preserved the well-crafted shoe. The lone footwear is about a UK children's size 11.5. "The condition of the shoe found is outstanding," said Thomas Stöllner, the research department head at German Mining Museum (DBM) in Bochum. "Organic materials generally decompose over time. Finds like this child's shoe... offer an extremely rare insight into the life of Iron Age miners."

Archaeologists noticed that the leather shoe has a preserved remnant of lacing made from flax or linen, which hints at how the shoe was laced. The shoe's design indicates that the footgear was crafted in the second century BCE. While only one shoe was found, its discovery suggests that children were underground in the mines more than two millennia ago. The museum has been carrying out archaeological work in the mine since 2001. Near the shoe, archaeologists found the fragment of a wooden shovel and the remnants of a fur with lacing, which may have belonged to a fur hood.

PLANET EARTH

Dinosaur-killing asteroid allowed flowers to thrive

WORDS **PATRICK PESTER**

The giant asteroid that snuffed out the dinosaurs at the end of the Cretaceous period left flowers relatively unharmed – and the blooms thrived in the aftermath. Earth lost three-quarters of its species, including all non-avian dinosaurs, when an asteroid struck Mexico's Yucatán Peninsula 66 million years ago. Scientists call this cataclysmic period the Cretaceous-Paleogene (K-Pg) mass extinction event. New modelling reveals that, despite widespread devastation, the major families of flowering plants, called angiosperms, were adaptable enough to survive the deadly event and reap the rewards. "After most of Earth's species became extinct at K-Pg, angiosperms took the advantage, similar to the way in which mammals took over after the dinosaurs, and now pretty much all life on Earth depends on flowering plants ecologically," said Jamie Thompson, a postdoctoral evolutionary biologist at the University of Bath, England.

Researchers have a hard time identifying flowering plants in the fossil record; most of the record is made up of isolated leaves that aren't attached to other plant organs. There's evidence for flowering-plant extinctions following the asteroid strike, but not for widespread decline as in other types of organisms. To learn more about how flowering plants responded to the K-Pg extinction event, the authors of the new study looked at major flowering-plant lineages previously mapped from DNA mutations of thousands of species. They used mathematical models to estimate that flowering plants experienced a relatively stable extinction rate over time, with no evidence of a mass extinction. That means that while individual species were lost during the event, the larger family groups survived.

Did you know?

The asteroid that killed the dinosaurs was six to nine miles wide

Most of the flowering-plant families we see today emerged before the K-Pg event, with the ancestors of modern orchids, magnolias and mint living alongside the dinosaurs. Following the K-Pg extinction, the surviving flowering plants spread and diversified. "Flowering plants have a remarkable ability to adapt: they use a variety of seed-dispersal and pollination mechanisms, some have duplicated their entire genomes and others have evolved new ways to photosynthesise," said Santiago Ramírez-Barahona, a researcher at the National Autonomous University of Mexico. "This 'flower power' is what makes them nature's true survivors."

While the dinosaur-killing asteroid wiped out many species of flowering plants, the angiosperms survived the mass extinction

GLOBAL EYE

A new mosaic of Shackleton crater as seen by NASA's Lunar Reconnaissance Orbiter Camera and ShadowCam

SPACE

Haunting images reveal an enormous crater near the lunar south pole

WORDS **JEFF SPRY**

The lunar south pole looks haunting in a new mosaic image that uses photography from two different NASA cameras in orbit around the Moon. National Geographic, in coordination with NASA, shared a never-before-seen, high-resolution composite image of the lunar south pole with a detailed companion map of Artemis III candidate landing sites. This striking image of the Moon's south pole region was composed from a series of photos taken by the Lunar Reconnaissance Orbiter Camera (LROC), a network of cameras mounted on NASA's Lunar Reconnaissance Orbiter which has been circling the Moon since June 2009, and ShadowCam, a NASA-funded instrument on the Korea Aerospace Research Institute's Korea Pathfinder Lunar Orbiter (KPLO). ShadowCam is 200 times more sensitive to light than previously deployed NASA lunar cameras.

Shackleton crater spans roughly 12.4 miles wide and 2.6 miles deep, making it deeper than the Grand Canyon. Along with the mosaic image of Shackleton Crater, National Geographic released a topographical map of the lunar south pole showing potential Artemis III landing sites in the region. On 23 August 2023, India became the first country to land a spacecraft near the Moon's south pole on a mission that allowed its space program to become only the fourth in history to accomplish a soft lunar landing, after the United States, the former Soviet Union and China. Following a two-week mission exploring the vicinity and conducting experiments, the Vikram lander and Pragyan rover went into sleep mode as the Sun set, and remain powered down.

Did you know?

The Moon is the fifth-largest natural satellite in the Solar System

Russia's most recent attempt at reaching the Moon's south pole, meanwhile, the Luna-25 mission, ended in failure when its lander crashed into the lunar surface. Both China and the United States want to send human crews to the Moon's south pole. China has a mission planned for no earlier than 2030, while NASA plans to land a crew of astronauts near the lunar south pole no earlier than 2025 in what is planned to be the first human mission on the Moon in over 50 years.

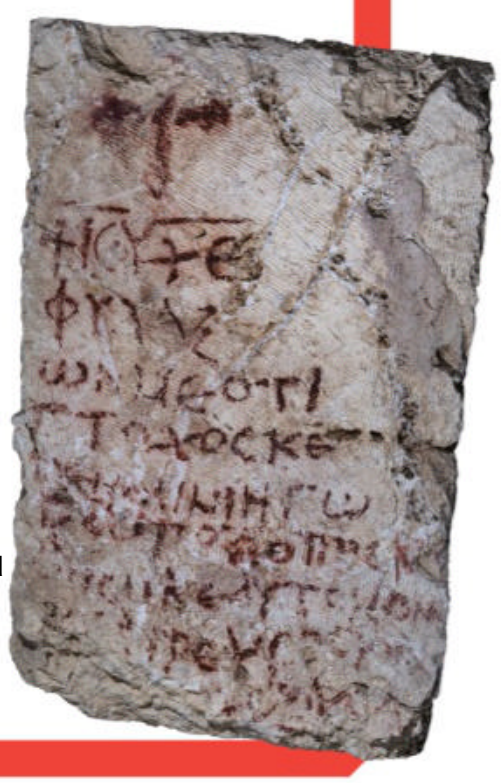
HISTORY

ANCIENT, INCORRECT VERSION OF THE 'PRAYER OF DAVID' DISCOVERED

WORDS **OWEN JARUS**

A 1,500-year-old text recording a section of Psalm 86, also known as 'a prayer of David', has been discovered in what was a monastery 11 miles southeast of Jerusalem in the West Bank. The text is written in Koine Greek, a language often used in early copies of the New Testament. It was inscribed on a building block located on the floor of the monastery and has a cross drawn on it. The text reads: "Jesus Christ, guard me, for I am poor and needy," which is incorrect. However, the original lines of the psalm read: "Hear me, Lord, and answer me, for I am poor and needy. Guard my life, for I am faithful to you."

While the writer wrote in Greek, his text contained grammatical errors, suggesting that the writer's native tongue was a Semitic language. The ancient monastery is located at the site of Hyrcania and was built on the remains of a 2,100-year-old fortress constructed by the Hasmoneans, a dynasty of Jewish rulers that controlled the region at the time. The monastery was built in 492 CE. At that time, the area was part of the Byzantine Empire, which controlled lands stretching from the Balkans to Egypt. In 635 CE, the Rashidun Caliphate, which was Islamic, conquered the region but the monastery kept operating.



This inscription of part of a psalm was found on a stone on the floor of the monastery

A Tasmanian tiger, or thylacine (*Thylacinus cynocephalus*) in captivity, circa 1930

ANIMALS

Genes have been extracted from an extinct Tasmanian tiger

WORDS **STEPHANIE PAPPAS**

Scientists have extracted RNA from a Tasmanian tiger, marking the first time this molecule has ever been sequenced in an extinct animal. Like DNA, RNA (ribonucleic acid) carries genetic information. But instead of having a double strand of nucleotides as DNA does, RNA is made of a single strand. That makes it more likely to degrade over time and harder to extract from long-dead tissue. But understanding RNA is necessary for learning about the biology of an animal. RNA is the intermediary that translates DNA blueprints into the proteins that build cells; it also regulates cellular metabolism.

RNA "gives you a glimpse of the real biology, of how the cell was metabolically working when it was alive, right before the cell died," said Emilio Mármol Sánchez, a postdoctoral researcher at the University of Stockholm. This is particularly interesting for Tasmanian tigers, or thylacines (*Thylacinus cynocephalus*), carnivorous marsupials that lived in Australia until about 3,000 years ago, when the mainland population died out and the only survivors were left on the island of Tasmania. These survivors were driven to extinction by human hunting and trapping; the last known individual died in a zoo in Hobart, Australia, in 1936. Despite being marsupials, thylacines were dog-like; this represents a case of convergent evolution, in which two distinct lineages yield an animal with a lot of similarities, likely because it fills an ecological niche.

Mármol Sánchez and his colleagues extracted RNA from a desiccated Tasmanian tiger that died about 130 years ago, and analysed both muscle and skin tissue. The first hurdle was to show that they could extract RNA from the actual animal, not just DNA or RNA from environmental contamination, like humans handling the hide. By comparing the sequences they uncovered, they differentiated between contamination and actual thylacine RNA.

Using the RNA sequences, the team filled in several gaps in the Tasmanian tiger DNA. Because RNA is transcribed from DNA, it's possible to extrapolate DNA sequences from RNA. In one exciting finding, the researchers identified a never-before-described sequence of microRNA, which plays a regulatory role in which genes are expressed in a cell, apparently present only in Tasmanian tigers. The researchers also found another microRNA sequence that had not been previously described but that turned out to be common across multiple marsupial species.

In total, the researchers raised the number of known microRNAs in Tasmanian tigers from 62 to 325. They also discerned differences between skin and muscle tissue based only on the RNA in those tissue types. Unsurprisingly, the skin samples had high levels of RNA associated with keratin, the protein in skin, hair and nails, while the muscle samples had high levels of RNA associated with muscle fibre proteins such as actin and myosin. These results can now be used to compare across species and across evolutionary time. Moving forward, the researchers plan to sequence more RNA from other Tasmanian tiger tissue, including preserved organs.

PLANET EARTH

SCIENTISTS FIND A NEW VIRUS IN A DEEP PART OF THE PACIFIC

WORDS **BEN TURNER**

A new virus found inside the Mariana Trench is believed to be the deepest ever discovered. The virus, called vB_HmeY_H4907, was found at a depth of 8,839 metres inside the Mariana Trench, which drops to about 11,000 metres at its lowest point on the floor of the Pacific Ocean. "To our knowledge, this is the deepest known isolated phage in the global ocean," said Min Wang, a marine virologist at the Ocean University of China.

The newly discovered virus infects bacteria in the phylum Halomonas and does so lysogenically, which means that it inserts its genetic material into the bacterial genome and replicates without killing the bacteria. This could be due to the harsh environments in which both the virus and bacteria evolved, meaning it cannot afford to kill its host. Halomonas can be found throughout the oceans, including on the Antarctic seafloor and in sediments surrounding deep-sea hydrothermal vents. By conducting a genetic analysis on vB_HmeY_H4907, the researchers discovered that its range is likely just as wide as that of the bacteria it infects.

Little is known about the viruses that populate the deepest regions of the ocean, and the newfound virus is only the third known to infect the Halomonas bacteria that live there.

The new virus has been identified as a bacteriophage

SPACE

James Webb Space Telescope finds a potential signature of life

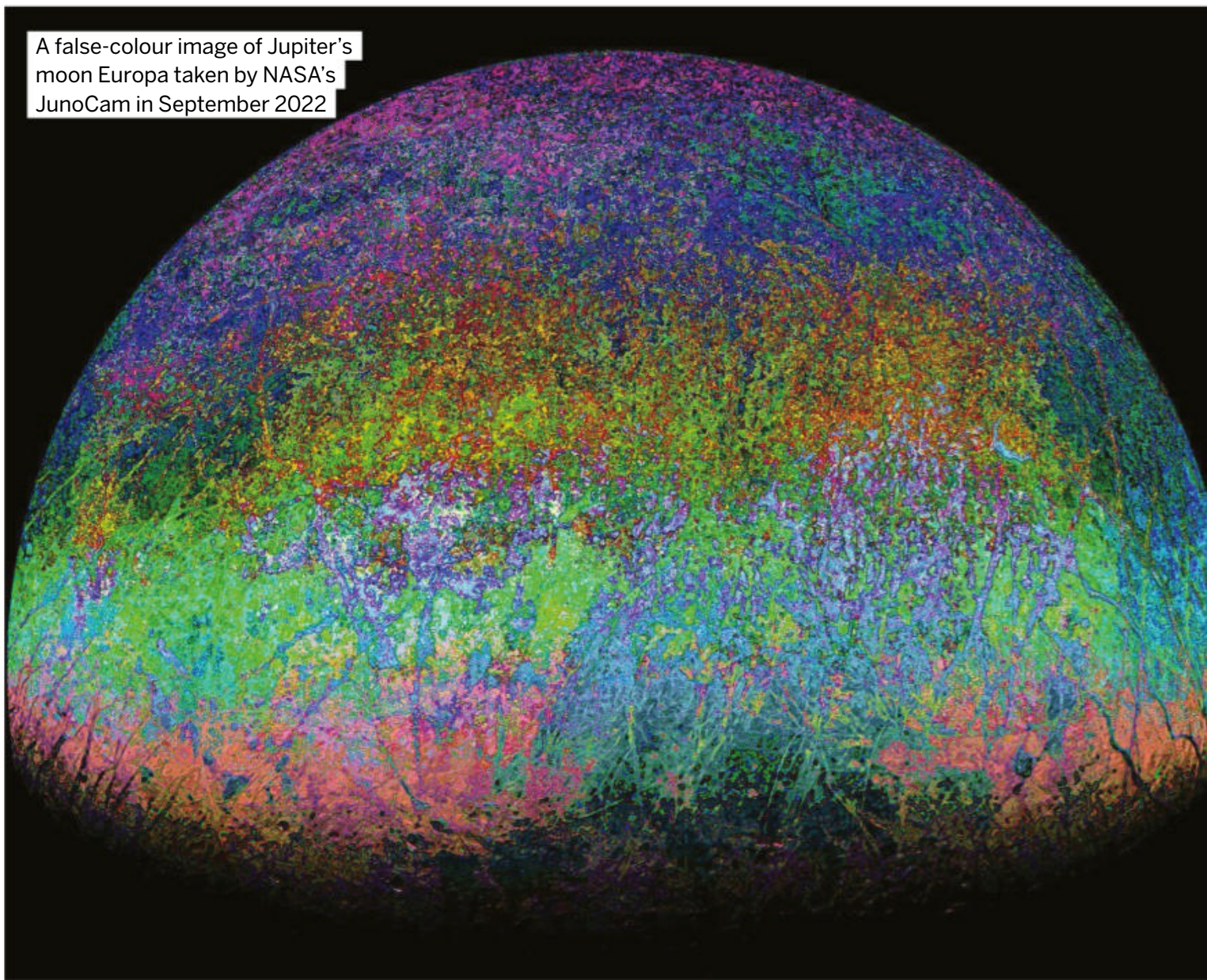
WORDS **STEPHANIE PAPPAS**

NASA's James Webb Space Telescope has revealed homemade carbon dioxide on Jupiter's icy moon Europa, raising the possibility that the frigid water world could host life. Europa, which is a little bit smaller than Earth's moon, is covered with a crust of water ice enveloping a saltwater ocean. The presence of liquid water makes Europa an intriguing object of exploration for scientists interested in extraterrestrial life. But until now, no one had shown that the ocean contained the proper molecules, particularly carbon, which is a fundamental building block of life on Earth.

The new detection by Webb is intriguing because the carbon dioxide does not seem to have been carried by a meteorite or asteroid, and it appears in a geologically young region of the moon called Tara Regio, suggesting the gas may have formed within the moon itself. "Previous observations from the Hubble Space Telescope show evidence for ocean-derived salt in Tara Regio," said Cornell University planetary scientist Samantha Trumbo. "Now we're seeing that carbon dioxide is heavily concentrated there as well. We think this implies that the carbon probably has its ultimate origin in the internal ocean."

The researchers found signs of both crystalline and amorphous carbon dioxide on Europa. 'Amorphous' refers to a disorganised molecular form, as compared with the rigid patterns of crystals. They saw high concentrations in what astronomers call 'chaos regions', where the surface crust has been disrupted and there is likely movement of materials between the crust and interior ocean. Because carbon dioxide doesn't stay stable for long on Europa's surface, the researchers believe that the carbon came up from the ocean relatively recently. Europa's surface is, on average, around 60 million years old, as estimated by the few craters pockmarking the ice. The chaos terrain is generally younger than average.

Scientists are planning two missions to Europa in the upcoming years: NASA's Clipper mission, expected to launch in 2024, will provide observations of the moon from orbit, with a focus on searching for molecules and conditions conducive to life. Meanwhile, the European Space Agency launched the Jupiter Icy Moons Explorer (JUICE) spacecraft in April, which will arrive at the gas giant in 2031. That craft will conduct 35 flybys of the three moons Europa, Ganymede, and Callisto.



A false-colour image of Jupiter's moon Europa taken by NASA's JunoCam in September 2022

Female *Anopheles* mosquitoes carry malaria disease

HEALTH

New malaria vaccine is vital for millions

WORDS NICOLETTA LANESE

The World Health Organization (WHO) has just recommended a second vaccine to prevent malaria in children, almost exactly two years after it recommended the world's first. When given seasonally, the vaccine, called R21/Matrix-M or just Matrix-M, is as effective as the previously recommended vaccine, known as RTS,S or Mosquirix. In trials conducted in regions where malaria spread seasonally, three doses of Matrix-M cut the rate of symptomatic malaria in the following year by about 75 per cent. An additional, fourth dose of vaccine given a year after the third dose carries that protection into the next malaria season.

"As a malaria researcher, I used to dream of the day when we would have a safe and effective vaccine against malaria. Now, we have two," said Tedros Adhanom Ghebreyesus, the current director-general of the WHO. "Demand for the RTS,S vaccine far exceeds supply, so the R21 vaccine is a vital additional tool to protect more children faster, and to bring us closer to our vision of a malaria-free world."

GSK, the maker of the first malaria vaccine, can make 15 million doses a year. That vaccine, called Mosquirix, is given in four doses. This newly-approved second vaccine, developed by Oxford University, is manufactured by The Serum Institute in India, which has said it can manufacture up to 200 million doses of the three-dose vaccine a year. According to Tedros, Matrix-M will cost between £1.70 and £3.30 ($2 and $4) a dose. WHO will now have to give the vaccine a stamp of approval, called prequalification, that will allow partners like UNICEF and the global vaccine alliance Gavi to buy the vaccines to distribute. "The RTS,S vaccine will be rolled out in some African countries early next year, and the R21 vaccine is expected to become available to countries by the middle of next year," Tedros said.

Malaria is caused by a mosquito-spread parasite, and the Matrix-M vaccine works by triggering an immune response against one stage of that parasite's life cycle. It's at this stage, called the 'sporozoite' stage, that the parasite exits a mosquito and enters the human body. Matrix-M contains part of a protein secreted by the sporozoites; part of a hepatitis B virus, which revs up the immune system; and an additional ingredient called an 'adjuvant' that boosts the response even further. Together with Mosquirix, Matrix-M is expected to reduce the rate of severe disease and death caused by malaria. But because these vaccines don't stop the transmission of malaria, they must still be paired with additional safeguards, like bed nets and insecticides. The vaccine alone cannot snuff out the disease.

Did you know?

Mosquitos kill more people than any other animal

PLANET EARTH

Mysterious bamboo regeneration baffles scientists

WORDS JACKLIN KWAN

An unusual species of bamboo is about to flower for the first time in over 100 years, which could enable researchers to find out more about its mysterious regeneration process. Phyllostachys nigra var. henonis, or henon bamboo, flowers only once every 120 years before perishing. The current generation of this species is expected to flower in 2028. However, researchers from Hiroshima University in Japan noticed that a few local specimens had begun to flower early. In a recent study, the researchers found that many of the flowering specimens did not contain any seeds. The team also observed a lack of new culms growing from the root systems of those that had flowered, also showing limited asexual reproduction. This could mean that many dense fields of bamboo may be hard to regenerate, and may disappear and be replaced by meadows.

Henon bamboo was introduced to Japan from China in the ninth century, but scientific recordings of its regeneration process are sparse. Its 120-year flowering intervals were based on ninth-century archival documents, and previous colonies died out right after flowering in 1908, before re-establishing themselves throughout Japan.

The researchers studied a colony of early flowering specimens they found in Hiroshima in 2020 with 334 'culms', the woody, jointed stem in bamboo. They found 80 per cent of the culms that had bloomed over the course of three years produced no seeds. By the end of 2022, no bamboo culms had survived. "The question still remains about how the dead culms were replaced by a new generation," said Toshihiro Yamada, a conservation biologist and forest ecologist at Hiroshima University, "Apparently, sexual regeneration does not work, since this species failed to make seeds."

Yamada said it is possible that the bamboo regenerates underground, eventually sprouting into new individual culms. After these culms are established, the bamboo would then populate vigorously to compensate for its inefficient reproduction. However, this regeneration process may take many years. The scientists say that this would not only mean economic losses to local industries that rely on bamboo as a material, but it may also lead to environmental problems, because bamboo can prevent soil erosion and landslides.

A shoot of henon bamboo (*Phyllostachys nigra var. henonis*) before flowering

Did you know?

The Milky Way contains between 100 and 400 billion stars

An invisible halo of dark matter could explain why the Milky Way isn't flat

SPACE

A gigantic blob of dark matter may be warping our galaxy

WORDS **BEN TURNER**

A gigantic blob of invisible dark matter has bent our galaxy out of shape. Scientists initially believed that the Milky Way was a flat disc dominated by two spiral arms trailing stars from a central bar, but measurements taken since the mid-20th century reveal that it's bent inexplicably out of shape. The warping occurs mostly at our galaxy's borders, where some regions bend downward while others flare upward, giving it the look of a crushed sombrero. Now, computer simulations may have revealed the cause: a mysterious event that knocked our galaxy's invisible halo of dark matter out of alignment. "These results, in combination with data in the stellar halo, provide compelling evidence that our galaxy is embedded in a tilted dark matter halo," the researchers wrote.

Dark matter is a mysterious and somewhat contradictory type of matter. It makes up as much as 85 per cent of the universe's matter; but because it doesn't directly interact with light, it is completely invisible. However, scientists can observe its gravitational effects on its surroundings. Dark matter makes its presence known by accelerating stars to otherwise inexplicable speeds as they orbit galactic centres; warping distant starlight; and by giving shape to the Milky Way's galactic halo.

The galactic halo, a vast sphere of stars floating like leaves on a dark matter pond, rests just beyond the spiral arms of the Milky Way. In a 2022 study, astronomers investigated this region using the European Space Agency's Gaia spacecraft, which maps the positions and movements of the Milky Way's roughly 2 billion stars. By poring through Gaia's data, they discovered that the stars suspended in the galactic halo were strangely off-kilter.

To see what an unbalanced stellar halo might mean for the dark matter halo it is suspended in, the researchers used a computer model to recreate a young Milky Way-like galaxy with a dark matter halo tilted 25 degrees with respect to its disc. After simulating the galaxy over 5 billion years, the researchers found that they had created a similar galaxy to ours. "Here we show that a dark halo tilted in the same direction as the stellar halo can induce a warp and flare in the Galactic disc at the same amplitude and orientation as the data," they wrote.

What caused the dark matter around our galaxy to fall out of tilt isn't clear, but the researchers' simulations suggest it is likely to have been a gigantic collision, likely from another galaxy flying into our own. This collision could have caused the dark matter halo to tilt up by as much as 50 degrees before slowly swinging down to its current 20-degree angle elevation.

SPACE

FIRST-EVER SPACE LITTERING FINE ISSUED

WORDS **BRETT TINGLEY**

The United States government has handed out its first-ever fine to a private company that left space debris in orbit. The US Federal Communications Commission (FCC) issued a $150,000 fine (around £124,000) to satellite TV provider DISH for not safely deorbiting its EchoStar-7 satellite. The satellite was launched in 2002, and DISH originally intended to deorbit the spacecraft in May 2022. The satellite ran out of fuel, however, leaving the company no choice but to leave the satellite 100 miles short of its designated disposal region high above geostationary orbit. In this region, satellites can remain over one fixed spot on Earth. The failure to dispose of the satellite at the end of its operational life violated the FCC's Communications Act.

The FCC issued the fine as part of its efforts to crackdown on irresponsible activity in Earth's orbit. "As satellite operations become more prevalent and the space economy accelerates, we must be certain that operators comply with their commitments," said FCC Enforcement Bureau Chief Loyaan A Egal. "This is a breakthrough settlement, making very clear the FCC has strong enforcement authority and capability to enforce its vitally important space debris rules."

An illustration of a satellite in geosynchronous orbit

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WWW.UNICYCLE.CO.UK

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£59 / $69.99

WWW.GEOSPACEPLAY.COM

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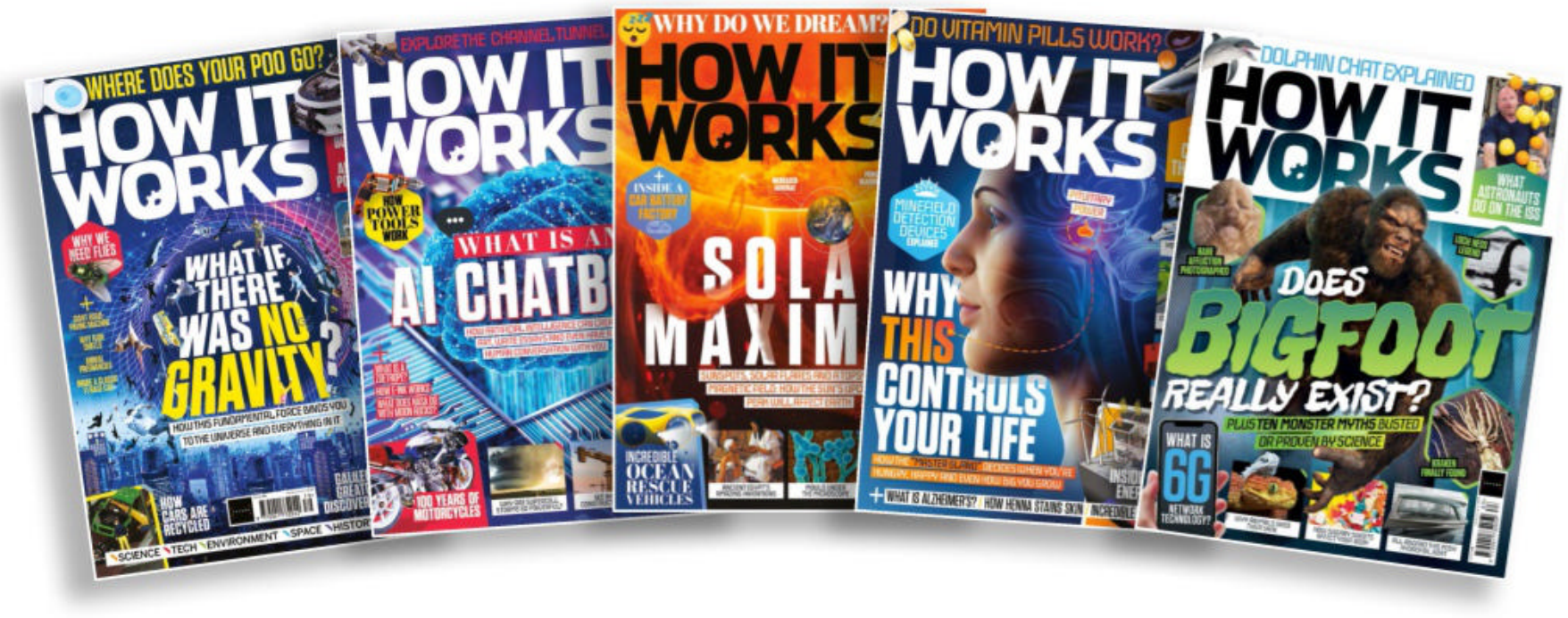

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MONSTER MYTHS

BUSTED

DID YOU KNOW? The oldest known monster myth is that of the Great Sphinx from around 2500 BCE

Folklore tells us that terrifying creatures such as Bigfoot and the Loch Ness Monster lurk on the outskirts of civilisation. But can science explain the harrowing historic encounters humans have had with them?

WORDS AILSA HARVEY

The human brain is hard-wired to make sense of the world around it. When events occur that we can't explain with logic, fear often takes over and our imaginations run riot. In ancient times, ships that became lost at sea must have been attacked by sea monsters, fossilised bones were thought to have belonged to ferocious mystical beasts and natural disasters were the acts of evil spirits.

Over the last thousand years or so of recorded history worldwide, people have conjured up their own explanations for frightful sightings with little or no scientific process. This information was spread through stories, and over time, through their telling and retelling down generations, the more fantastic details became exaggerated. Before long, large communities shared a common fear of the colossal creatures that hid beneath their local lakes or the bloodthirsty beasts that only revealed themselves at night. But even some relatively new myths of younger civilisations still have traction.

How can science start to debunk monster myths that have endured millennia to separate a genuine sighting from a misconception or hoax? Much of the long-standing belief in mythical monsters is justified in the minds of the believers by the fact that there are no photographs for proof, or the photos cannot be explained. When powerful and misunderstood forces are at play, monster believers state that the absence of evidence can't be classed as evidence of absence.

Only recently have video cameras, radar and infrared imaging and deep-sea exploration been able to provide answers to the world's most famous monster mysteries. The study of animals that may or may not exist is called cryptozoology: those who specialise in this may hold the best chance of discovering evidence of new species or debunking long-held myths.

Did you know?

An animal whose existence is disputed is called a cryptid

Barbara van Beck was unusually hairy due to a genetic condition

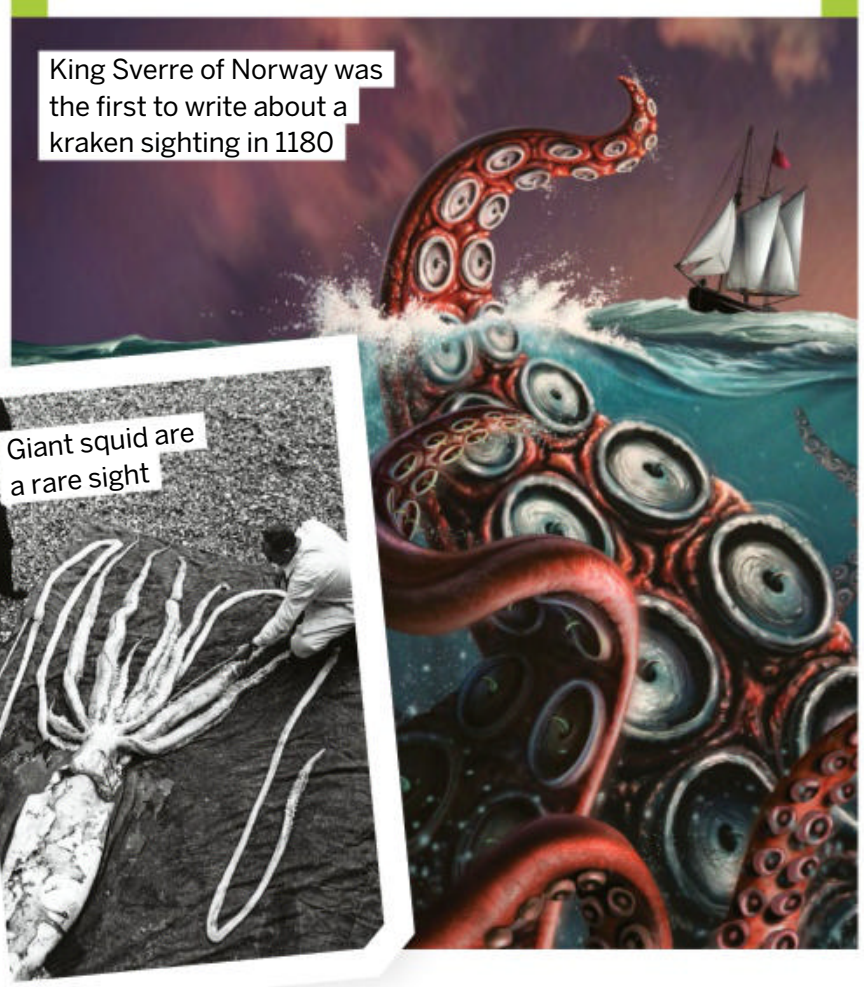
© Alamy / Getty / Shutterstock

ATTACK OF THE KRAKEN

Some tales of this Nordic sea monster describe it the size of an island. With giant, tentacle-like extensions, the kraken appears under ships, making the water appear shallow and brown, and is capable of attacking any large vessel that may cross its path. Since the 1100s, many sailors have told stories of their encounters with a kraken in the seas of Iceland, Greenland and Norway. It became known as a beast that could swallow any ship in the giant whirlpool it whipped the sea surrounding it into. The earliest references to the kraken date back to 1180, and it has since been considered the largest monster ever imagined by humankind. But was it really imagined?

EXPLANATION

The creature that sailors called a kraken was likely to have evolved from real sightings of a real animal that can grow up to 13 metres in length and weigh one tonne. It has eight arms for manipulating objects in the sea and two even longer tentacles with hooks to keep hold of its prey. However, this is no monster: the marine creature described in folklore is likely to have been an imaginative recollection of a giant squid sighting. Giant squid spend most of their time deep in the ocean, so a sighting is rare. But when ancient seafarers set their eyes on one of these beasts, they would return to shore with dynamic tales of the danger they assumed they were in. With each exaggerated retelling, every giant squid that came to the surface for a peek was restyled as an ocean brute.



King Sverre of Norway was the first to write about a kraken sighting in 1180

Giant squid are a rare sight

Ogopogo was originally called N'ha-a-itk and was the protector of the valley

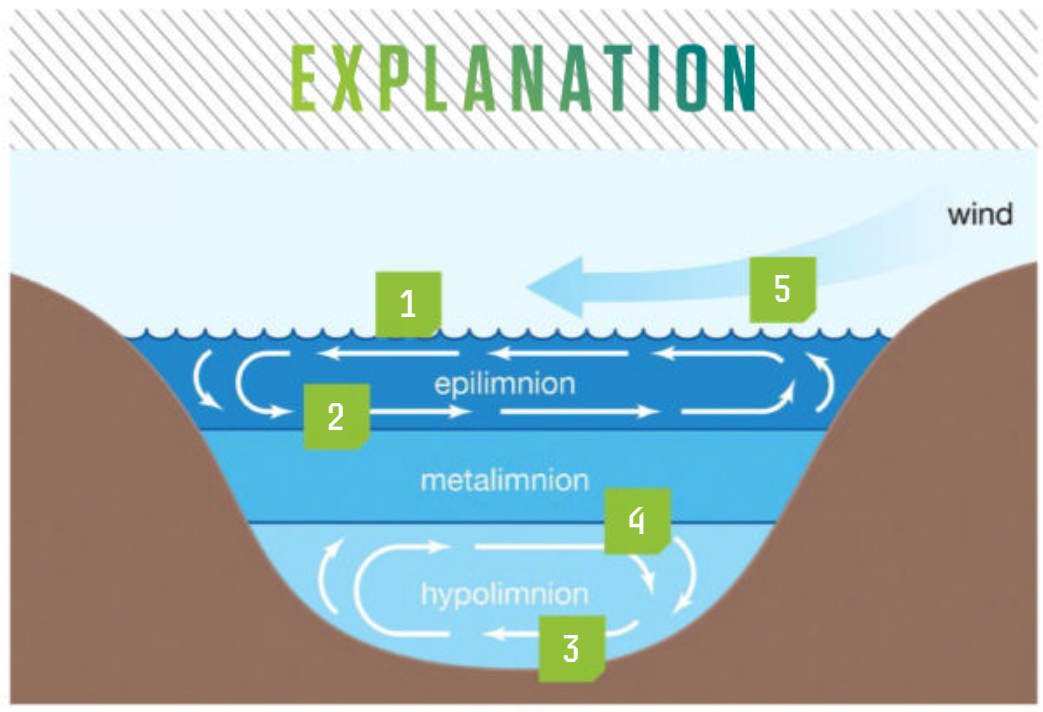
THE ILLUSIVE OGOPOGO

Fringed by sandy beaches, Okanagan Lake in Canada doesn't appear to be a setting for monstrous activity. But 16 per cent of British Columbians believe there's a cunning creature lurking below the lake's rippling surface. This creature is Ogopogo, and before it became a mythical beast, the creature was a sacred spirit. The Indigenous community of Okanagan Lake believed Ogopogo was a spirit that took the form of an aquatic serpent. The Okanagan people told the story of the lake monster for thousands of years. When Europeans settled the area in the 1800s, they became aware of the story of Ogopogo and the sightings and stories began to increase. Photographic evidence of Ogopogo has so far consisted of dark, suspicious-looking shapes near the surface of the water.

Did you know?

There was a $1 million reward for Ogopogo proof in the 1980s

EXPLANATION



A WAVE FROM THE DEEP

A phenomenon called thermal stratification could be to blame

1 SURFACE HEATING
As the Sun shines on Okanagan Lake during summer, the surface layer is heated up.

2 EPILIMNION
When the upper layer of water is heated, it becomes less dense than the cold water below. This prevents it from sinking to the bottom of the lake.

3 HYPOLIMNION
The bottom layer of the lake doesn't get access to sunlight and keeps getting colder, increasing its density and layer separation throughout summer.

4 HOLDING SEPARATION
The water in each layer circulates in confinement until autumn arrives, when the upper layer cools to make the density differences weaker.

5 A MONSTER WAVE
When the layers are returned to similar temperatures, water at the bottom can rise to the top in what is called a lake turnover. Unusually large waves form at the surface as dark, serpent-like shapes.

DID YOU KNOW? Dolphins were imported from America to Scotland so they could be trained to find the Loch Ness monster

THE LOCH NESS MONSTER

For over 1,500 years, there have been claims of a large aquatic creature with a long, rippling body living in Scotland's Loch Ness. It's known as the Loch Ness Monster, or by its nickname, Nessie. The loch is 22 miles long, almost 1.8 miles wide and has a volume of 1.7 cubic miles, making it the largest volume of fresh water in Britain. It can be found in the Scottish highlands near the city of Inverness. Despite there being over 1,100 reported sightings of Nessie, searching the loch's waters for this peculiar specimen is made a difficult task due to the water being made murky by peat being washed into Loch Ness from the surrounding hills.

Saint Columba made the earliest known reference to the monster in 565 CE. In the missionary's account, the Loch Ness Monster was attacking people in the lake. Instead of fleeing the scene, Saint Columba is said to have saved the locals by commanding the monster to "go back with all speed". Later sightings of Nessie in the 1900s were much more tame and usually involved a glimpse of a dark or scaly curved back. The monster is now famous worldwide and attracts half a million tourists to the loch annually. The world remains divided on the existence of Nessie, with great speculation around what the sightings could be and rewards offered to anyone who can prove its existence.

The Loch Ness Monster is described as having a long neck and at least one hump along its back

EXPLANATION

NESSIE SIGHTINGS

Much of the 'evidence' of this aquatic monster has been debunked

1 565 CE
The River Ness was the site of Saint Columba's sighting. Historians suspect the story was made up or exaggerated.

2 1933
The first photo of Nessie was taken by Hugh Gray. This is thought to be a rolling otter.

3 1934
The 'surgeon's photograph', printed in the *Daily Mail* newspaper, was a hoax. A toy submarine and piece of wood were manipulated to look like Nessie.

4 1954
Fishing boat Rival III followed a large object that kept pace with it for 800 metres. This sonar reading was linked to an algal bloom.

5 1962
The Loch Ness Investigation (LNI) group was founded to examine the loch and analyse sightings.

6 1972
The LNI captured a flipper. One LNI member has since confirmed that photos of the loch were enhanced to produce these shapes.

7 1984
Steven Whittle tried to catch the monster in an 18-metre-long cage. The trap remained in the loch for a month but caught nothing.

8 2003
The BBC sponsored a large-scale search of the loch with 600 sonar beams and satellite technology.

9 2019
Eel DNA was detected in the loch by scientists, who theorised that sightings were of giant eels.

10 2023
The biggest search since the 1970s took place in August, involving volunteers from all around the world. No evidence was found.

MEDICAL MISINTERPRETATIONS

Stephan Bibrowski was a Polish performer born in 1890 with hypertrichosis

WHERE WEREWOLVES CAME FROM

Perhaps the most unnerving aspect of werewolf folklore is that the 'monster' could be anyone around you. Perfectly disguised as a regular human during the daylight hours, these beasts transform at night – both physically and mentally – into vicious, body-devouring wolfmen. Curated by alterations through the telling of word-of-mouth stories in European folklore, a werewolf will feast on any animal, human or dead body, and just one bite from this creature is enough to turn another person into a werewolf.

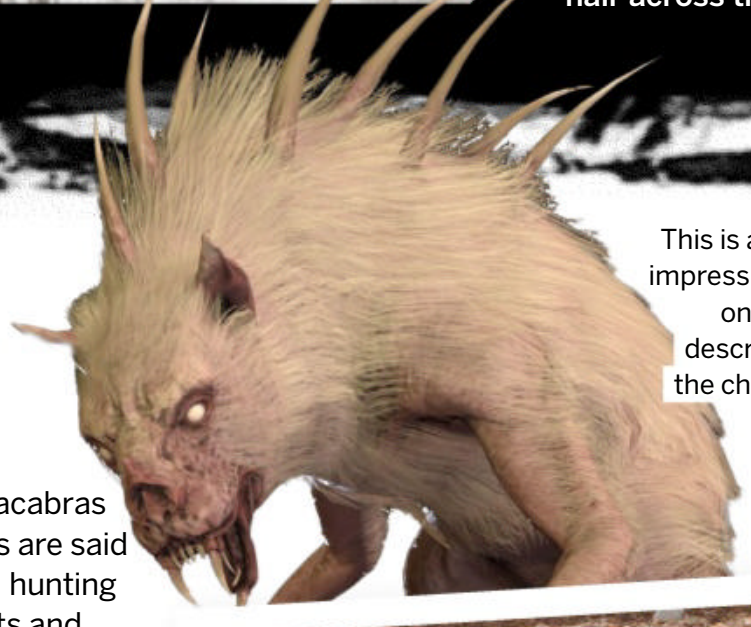
EXPLANATION

Most ancient tales are formed from true encounters, and some elements of the werewolf myth are derived from misinterpreted medical conditions. One that may have shaped werewolf myths and imagery is hypertrichosis. Since the Middle Ages there have only been around 50 people in the world confirmed to have this condition, caused by a mutation in chromosome 17. People with hypertrichosis produce excessive hair across their entire body.

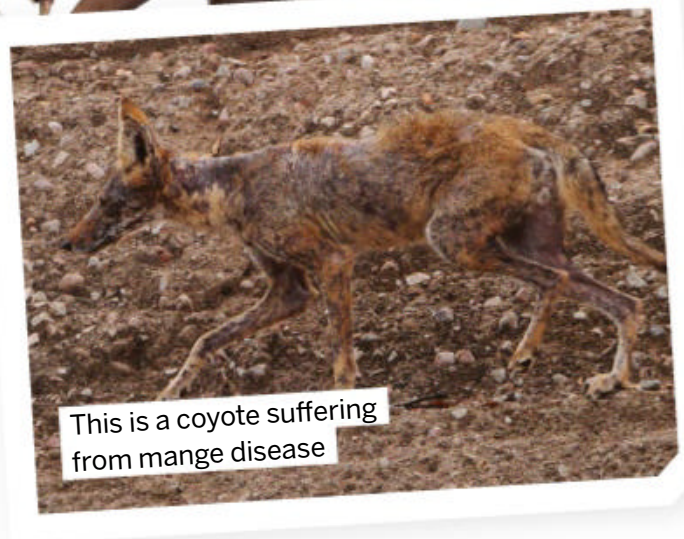
Before medical science made sense of it, people with the condition were treated like they weren't human. People spread stories based on their limited understanding. Werewolf folklore was also likely inspired by rabies, a disease contracted from the bite of an infected animal. Untreated rabies makes dogs and humans hallucinate and act aggressively. This could have made its way into the myths of werewolves.

GOAT-SUCKER CHUPACABRA

In 1995 in Puerto Rico, the first chupacabras were reported. These ghastly animals are said to roam the countryside on four legs, hunting for vulnerable livestock – sheep, goats and similar domestic animals. But when farmers discovered the carnage the next morning, they saw that the flesh of their livestock was left uneaten; instead this monster feasted on their blood. This is where their Spanish name comes from: 'chupar' means 'to suck' in Spanish, while 'cabra' translates to 'goat'. They are described as being hairless, canine-like creatures with crazy red eyes.



This is an artist's impression based on common descriptions of the chupacabra



This is a coyote suffering from mange disease

EXPLANATION

As the livestock massacres continued and the chupacabra became well known, owners of animals stayed alert. Around the beginning of 2010, supposed chupacabra specimens were handed into the authorities. Upon inspection, biologists found that almost all of these predators were coyotes. What gave them their monster-like appearance and habits was a skin disease called mange. This is caused by a mite that burrows into the skin, causing infection, discomfort and hair loss. They lose the energy to hunt and are forced to prey on easier targets, like domestic livestock. Although the wild canines' pained movements make them easily mistaken for monsters, it's the work of miniscule parasites that really makes the skin crawl.

DID YOU KNOW? People were accused of being beasts in the werewolf trials of the late Middle Ages

Vampires were incorporated into popular culture

VAMPIRIC ORIGINS

Biting their victims with a sharp set of fangs, vampires are only after one thing: human blood. They are typically portrayed with pale skin. These undead villains are said to search for their next blood meal at night, while the living sleep in their beds. Vampires avoid sunlight and garlic, which is a powerful antibiotic. Many Eastern Europeans who believed in these creatures thought the origin of the vampire was a disease in the blood, so coming into contact with garlic could harm or kill a vampire. Modern movies still incorporate garlic as a deterrent for the helpless targets of vampire attacks. Many traits of vampires, which were conjured up in medieval Eastern European tales, have been traced back to a disease called porphyria.

EXPLANATION

PORPHYRIA HYSTERIA

The symptoms of this disease have inspired ancient myths and pop culture crazes

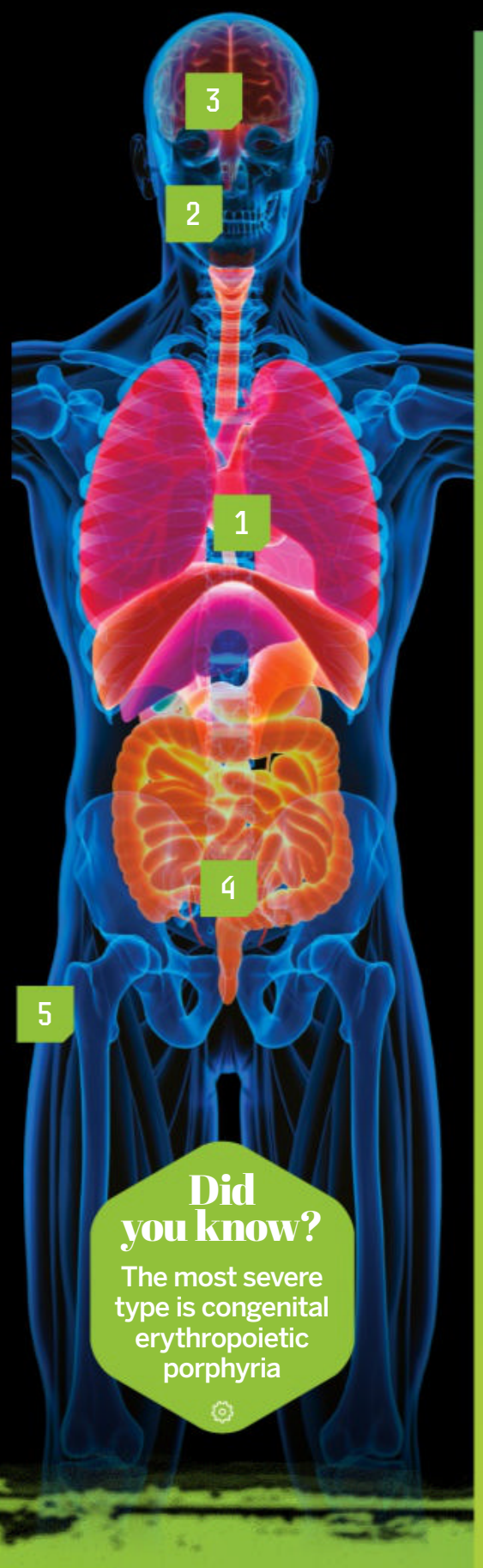
1 PALE-FACED
People with porphyria have less of the protein heme in the blood. This results in fewer red blood cells, reducing the colour in a person's skin.

2 INNOCENT FANGS
Patients' gums begin to recede to expose their teeth. This makes the teeth appear longer, which could be mistaken for fangs.

3 GARLIC REPULSION
Sulphur can bring on intense pain in porphyria sufferers. As garlic is high in sulphur, people with the disease usually avoid it.

4 BLOOD-RED URINE
The pigment that would usually be used to make red blood cells is passed out of the body, giving urine a dark-reddish colouring. In the 17th and 18th centuries, people thought porphyria patients had been drinking blood.

5 SUN SENSITIVITY
As people with the disease can't convert the required organic compounds into haemoglobin, it builds up in the body. A buildup of porphyrin causes light sensitivity.



Did you know?
The most severe type is congenital erythropoietic porphyria

THE UNDEAD AMONG US

Studies show that around half of the population have a fear of death. Going from life to death symbolises the end of everything we're familiar with. Zombies take the phobia of death to the next level by taking on the form of 'living' corpses. They become animated and move as if they're still alive. These monsters have a craving for human flesh, which may already be rotting in their own bodies. What makes zombie folklore even more terrifying is the difficulty of destroying a creature that's already dead. They can't be killed using conventional methods. Instead their heads need to be completely removed to prevent any connection between body and brain.

EXPLANATION

Different cultures around the world initiated the idea of people returning to life. Although zombie myths vary across the globe, there's a common theme of partial resurrection that historians think was imagined to confront the fear of what happens at the end of life. These monsters portray the worst outcome for many people – that is, to not have rest in the afterlife. Those who first believed in the existence of zombies may have observed the release of gases from a body shortly after death. As bacteria feed on the dead tissue, methane and ammonia are released into the body, causing bloating. This natural biological process makes the body's skin move in a way that could be interpreted as it coming back to life. Others who claimed to have seen people return from the dead may have seen a premature burial. Before the 20th century, doctors would often test to confirm death merely by prodding and poking. This led to many incidents where people would be banging on the inside of their coffins in a panic at their own funeral.

Zombies are sometimes described as moving in a slow and clumsy fashion

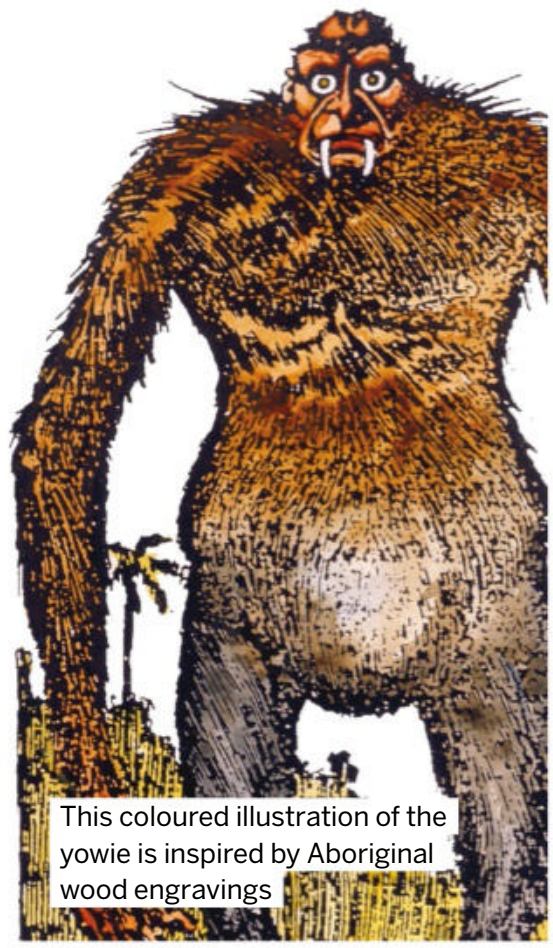
HUGE, HAIRY HUMANOIDS

AUSTRALIA'S BUSH MONSTER

The yowie can be thought of as the abominable snowman's long-lost cousin, though living in a completely contrasting environment to the yeti: in Aboriginal folklore the yowie bush monster is an inhabitant of the Australian outback. The shaggy ape-like creature is around twice as tall as an average human adult, with much larger feet, bat-like ears, a huge toothy mouth and a flat nose. Some say the yowie is an aggressive monster, while others say it's a friendly giant.

EXPLANATION

The Kuku Yalanji tribe of Far North Queensland were first to claim the existence of the yowie. This species lived alongside them, according to legend, and there were two types of yowie. One grew up to three metres tall and the other about half this size. Ancient cave art supports this, but evolutionary biologists think that it was an early hominid species that's now extinct. Yowie may also have come from 'yuwi', the dream spirit in the Yuwaalaraay language of northern New South Wales, or 'yahoo', the name of an evil spirit. Spirits are a core part of Aboriginal beliefs and can appear in a variety of forms.



This coloured illustration of the yowie is inspired by Aboriginal wood engravings

5 FACTS MYTHICAL CREATURES PROVEN REAL

1 GIANT SQUID
Reports of giant squid were made for over 2,000 years before scientists could verify their existence.

2 OARFISH
These fish can be up to 17 metres long. No live oarfish had been filmed until 2001. Before this, sightings were mistaken for sea serpents.

3 KOMODO DRAGON
Komodo dragons were confirmed to be real in 1910. Before this, large lizards were believed to be long extinct.

4 GORILLA
Until 1847, gorillas were classified as 'monster-like humans' who would ransack villages. Gorillas were officially classed as a species in 1902.

5 PLATYPUS
With an otter's feet, a beaver's tail and a duck's bill, scientists first thought the animal was pieced together using other animal parts.

This is how the abominable snowman's appearance is described in stories

THE ABOMINABLE SNOWMAN

In 1921, when English journalist Henry Newman first heard of a 'wild man of the snows' that inhabited the mountains of the Himalayas, he described his learnings in his next article. In his writing he called the creature 'the Abominable Snowman', and these words played a crucial role in the interpretation of huge footprints found on Mount Everest.

EXPLANATION

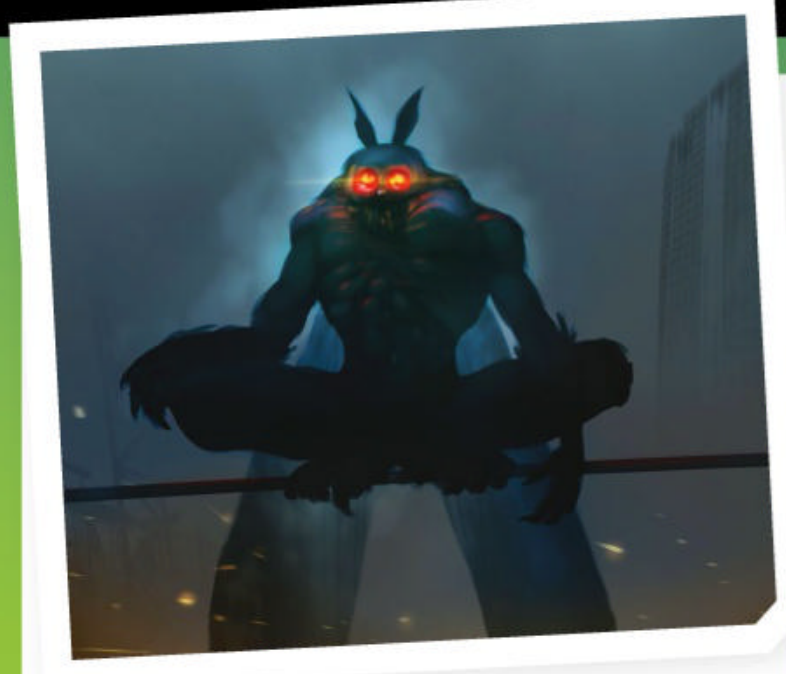
No yeti has ever been captured as concrete evidence, but what was believed to be yeti remains – such as hair, bones and teeth – was held in Nepalese monasteries. In 2017, DNA from nine of these samples was analysed by scientists at the State University of New York. Eight of the nine DNA samples proved to be from bear species – Asian black, Himalayan brown and Tibetan brown bears – and one was from a dog.

Members of Hiroshima University, Japan, found these footprints in 1974, which they claimed belonged to the Abominable Snowman

Did you know?

Alexander the Great saw the Abominable Snowman in 326 BCE

DID YOU KNOW? The largest Bigfoot footprints found were 60 centimetres long



HALF MAN, HALF MOTH

So far we've met the monsters of the land and sea, but beings that haunt the minds of humans can be found as far as people can see... or imagine. The Mothman is a monster of the skies, with its body the size of a fully grown person, its wings measuring around three metres in length and possessing menacing luminous red eyes. The Mothman was first witnessed in the winter of 1966 at a graveyard in West Virginia.

EXPLANATION

There have been multiple sightings of Mothman since 1966, all with matching descriptions of size, shape and unnaturally red eyes. The more the Mothman was deliberated and described, the creepier its appearance became. However, almost all of the early descriptions of Mothman sightings include the phrase 'bird-like'. Wildlife experts estimate that this monster wasn't just bird-like, but a bird. The sandhill crane is the main suspect – a bird that stands at the same height as a human and has vibrant red feathers around its eyes.

The sandhill crane's red eyes and outline could be misinterpreted as Mothman

Bigfoot hunters search for unusually large footprints like this one, discovered in 1980

THE LEGEND OF BIGFOOT

Bigfoot is a famous creature that resides in North America, named by some loggers in California who stumbled across its gigantic footprint in 1958. Since this first discovery, many sightings and tracks have been reported. Among the clearest evidence are pictures of hairy, yeti-sized beings trudging through the wilderness. Some people became obsessed with these photographs, while others were convinced they were pranksters playing dress-up.

EXPLANATION

In 2002, after the death of Ray Wallace – one of the Californian loggers who found early Bigfoot evidence – it was confirmed that the footprints had been deliberately planted. Four decades after starting the monster craze, Wallace's family admitted that he had used large wooden foot templates to create yeti-like foot impressions in the mud. The footprints were initially placed around construction equipment to scare away vandals when it was left overnight. However, after gaining public interest, the Bigfoot story became a fun prank that snowballed into monster hysteria.

WHY ANIMALS SHED

What prompts some creatures to regularly lose their old outer layers and replace them with fresh new skin?

WORDS SCOTT DUTFIELD

Many creatures throughout the animal kingdom undergo a process of physical transformation called moulting. Whether they create ghostly serpent sleeves as a result or just ditch clumps of old skin and fur, shedding is an important stage in an animal's growth and survival. The terms moulting and shedding are often used interchangeably, but there's a slight difference between each process. Moulting is the removal of an animal's entire skin, feathers, shell or exoskeleton as it grows, which often occurs on a seasonal basis. For example, elephant seals (*Mirounga leonina*) undergo what is known as a 'catastrophic moult' during late summer. As dramatic as it sounds, the 'catastrophic' nature of these moults merely relates to the large patches of skin that shed at one time.

DID YOU KNOW? Large reticulated pythons can shed a skin around 6.25 metres long

After around 30 days, king penguin (*Aptenodytes patagonicus*) chicks moult their juvenile feathers

Did you know?

Canadian geese have around 25,000 feathers on their body

A HUMAN'S BEST HYPOALLERGENIC FRIEND

Along with a heap of excess fur to clean up, being around a dog that likes to shed its fur can trigger human allergies. Siberian Huskies, for example, are some of the heaviest shredders in the canine world. This is mainly due to their role as sled dogs in cold climates, as shedding helps maintain their thick, healthy coats. But what's good for plummeting temperatures can wreak havoc on their owner's nose. When dogs shed, they also shed skin cells. These can find their way into the nostrils and mouth of the owner, triggering the body's immune system and causing allergic relations. However, many dog breeds, such as the Afghan Hound and Giant Schnauzer, have been deemed hypoallergenic. This means that while no dog is completely free from shedding, some shed at such a low level that allergic reactions can be avoided.

The coats of Giant Schnauzers don't often shed, making them hypoallergenic

During this time, blood flow within the seals is redirected towards their skin to produce a new outermost skin layer, known as the epidermis. This puts their vital organs at risk in the freezing oceans they inhabit, so moulting has to be carried out on land.

Shedding hair and skin, on the other hand, can occur more regularly and be the result of dryness or a temperature change. Snakes generally moult three to six times a year, whereas many dog breeds shed their fur all year round. Even humans unknowingly spend their time shedding old skin and hair – around 500 million skin cells and around 100 hairs each day.

Snakes are some of nature's best moulters. In the same way that humans outgrow clothes through their early years of life, snakes periodically peel a surface layer of scales to prepare for their bodies to expand and grow. Between 4 and 12 times a year, a snake will undergo a full-body moult, known as ecdysis. The outer layers of skin cells are detached in a continuous sheet from the newly grown dermis below. A protective scale covering the snake's eye, called the spectacle, also sheds during this process. While all snakes and reptiles shed, not all of them create fully formed scale replicas of themselves. Tortoises, turtles and some lizards shed their skin gradually, often in dry patches that flake away.

Like snakes, there's a whole host of animals that undergo complete ecdysis when it's time to grow up, including eight-legged arachnids, crustaceans and all manner of insects. Unlike the cocoon-spinning abilities of many metamorphic insects, such as moths and butterflies, others make their winged transformations beneath their protective exoskeletons. As larvae, dragonflies live beneath the water, often found in ponds and lakes.

Reptiles like chameleons shed their skin in patches

Did you know?

Some bears exfoliate with rocks during moulting

These wingless juveniles skip the pupal stage of metamorphosis and head straight to moulting. After several days of internal metamorphosis underwater, the larva climbs out of the depths to a nearby leaf, and within a few hours the newly winged dragonfly breaks through the beak of the previous exoskeleton, called an exuvia. But what happens to the leftover exoskeleton?

Some insects, like dragonflies and cicadas, don't do anything with their exuviae. However, many insects, such as pill bugs (*Armadillidium vulgare*) and American cockroaches (*Periplaneta americana*), waste no time in munching down on their previous bodies to reabsorb valuable proteins and chitin within the exuviae. Leaving behind a hollow replica of your body can also act as a beacon to predators, signalling that there's prey around that may be without its protective

"A snake will undergo a full-body moult, known as ecdysis"

At the start of their moult, snakes shed a scaly cap from their eyes

EATING YOUR OWN SKIN

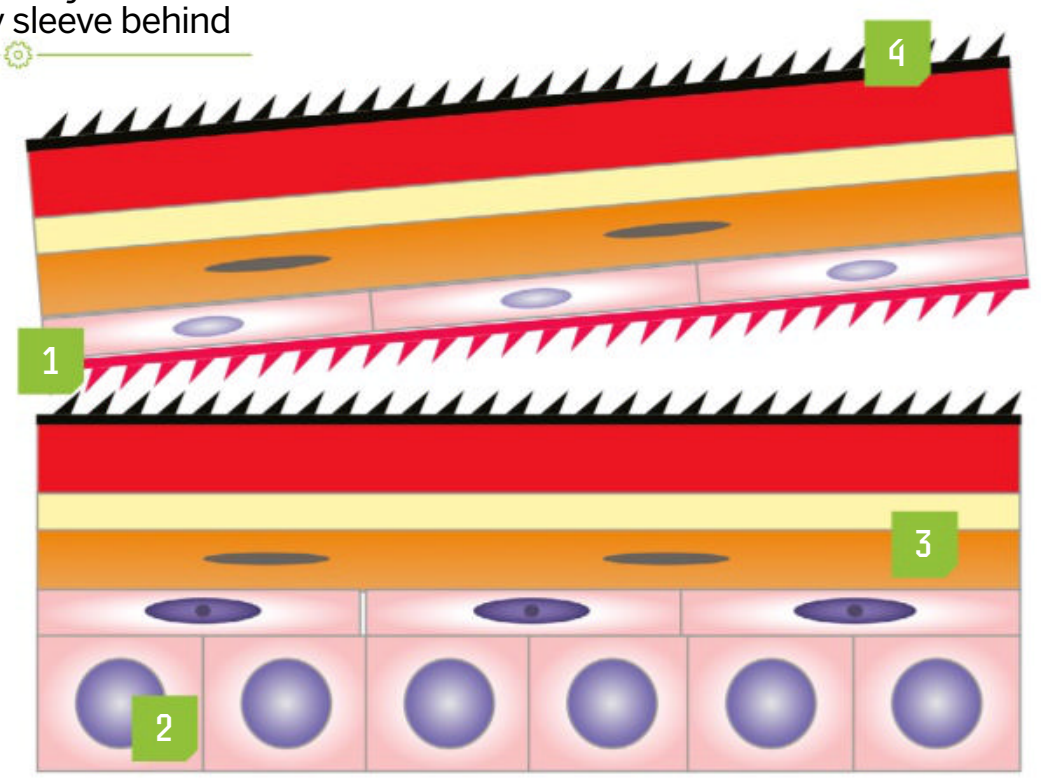
For amphibians, skin is much more than a protective barrier – it's also how they breathe. Frogs and toads have both evolved moist skin that allows gases such as oxygen to pass through the surface and into their bloodstream. As amphibians grow, their skin sheds, but not as a whole piece like their reptilian cousins. Instead, patches flake away from the body regularly, with some species shedding their entire skin daily and others taking a weeks to completely shed. Once the old skin layer has separated, amphibians ferry the flake along the body towards the mouth and eat it. Known as dermatophagy, the process of regularly eating their skin not only lets the amphibian recuperate some of its nutritional losses but also prevents it from drying out. Ensuring that their skin is soft and permeable enough to exchange atmospheric gases is vital to their survival.

A green tree frog (*Hyla cinerea*) feeding on its own moulted skin

DID YOU KNOW? A male reindeer's antlers can grow to around 1.3 metres long

SCALE SEPARATION

How snakes peel away their skin and leave a scaly sleeve behind



1 HORMONES

Days before shedding begins, hormones are released throughout the snake's body that trigger ecdysis.

2 CELL PROLIFERATION

During moulting, all the cells in the snake's outermost layer, called the epidermis, rapidly increase in numbers.

4 TERMINAL DIFFERENTIATION

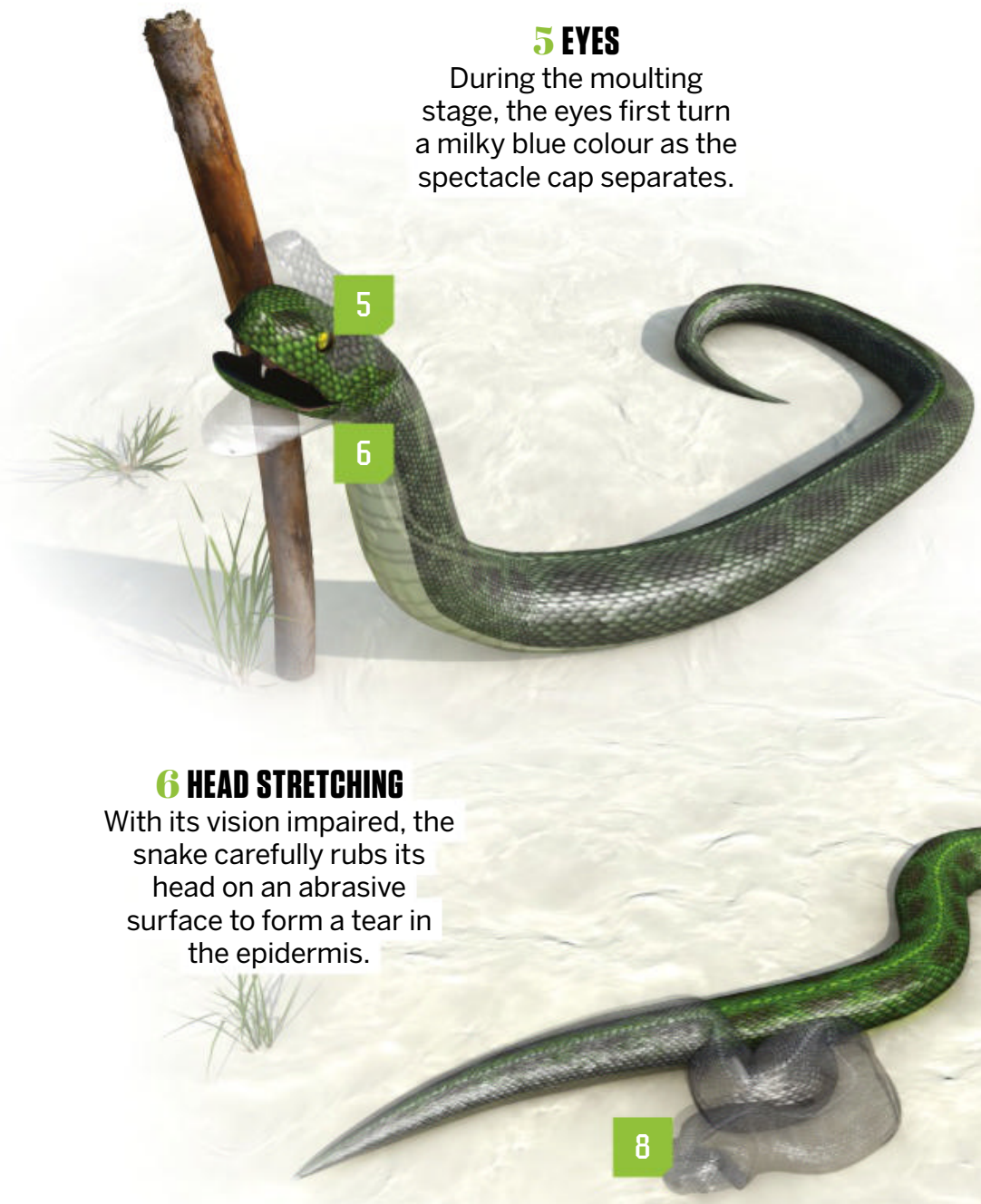
The old epidermis breaks away from the hardest surface layer of the snake's skin, called the oberhautchen.

3 DIFFERENTIATION

Cells called keratinocytes change to form new layers that make up the snake's epidermis.

5 EYES

During the moulting stage, the eyes first turn a milky blue colour as the spectacle cap separates.



6 HEAD STRETCHING

With its vision impaired, the snake carefully rubs its head on an abrasive surface to form a tear in the epidermis.

7 SNAKE SKIN UNDRESS

Crawling through tight spaces and weaving through rocks and plants causes the epidermis to peel away from the body along the tear.

8 OLD SKIN

Once the snake has wriggled its way out of its old skin, what remains is an inside-out serpent sleeve made from both robust keratin scales and stretchy epidermis cells.

Like many animals, birch trees shed their bark to remove parasitic pests

exoskeleton. Eating their old body reduces the risk of being discovered.

Instead of shedding an entire body's worth of skin and exoskeleton, some animals, such as reindeer and moose, undergo a partial moulting process to reveal a new set of antlers. Unlike the horns on the heads of buffalo or gazelle, reindeer have similar structures called antlers. Antlers are bony appendages that grow out of the skull, as opposed to horns, which are not attached to the skull and are predominantly made of the same material as human hair and nails, called keratin. As antlers grow, they emerge from the head covered in skin and soft hair, commonly called velvet. As the animal grows, the bone within develops and compacts to form rigid antler bone. When the antlers are fully developed, the velvet dries out and begins to feel itchy. This causes the antler owner to scratch them against hard surfaces such as trees and rocks to tear away the skin and velvet, leaving only the bone behind. This stage of a reindeer's development might look like a scene from a gory movie, but blood supply is reduced during shedding, and it's believed that this prevents the animals from feeling any pain. The process is swift – it takes around 24 hours to remove the velvet.

It's not just scales and fur that need to be shed during the changing seasons. Before the chill of winter descends, many bird species begin maintenance work on their bodies,

The exuvia of a cicada is a perfect copy of its former body

STEPPING OUT OF YOUR SHELL

The stages of separating the crustacean from its crust

1 RUPTURE
Ecdysis begins when a membrane connecting the crab's thorax and abdomen ruptures.

2 HEAD SEPARATES
The head of the crab divides from the thorax and the abdomen, revealing the start of a new head.

3 ABDOMEN SPLITS
The abdomen underneath the crab breaks away from the new body, creating enough space for the crab to escape the old shell.

4 SLIPPING OUT OF THE LEGS
The legs of the crab, called the pereiopods, are pulled free from the old shell.

5 FINAL PUSH
In the last phase of ecdysis, the abdomen is fully withdrawn.

6 FREE AT LAST
Once the claws, also known as the chela, are free from the shell, ecdysis is complete.

DID YOU KNOW? The land-dwelling coconut crab (*Birgus latro*) digs a burrow to moult in for up to 16 weeks

HERMIT HOUSE-SWAPPING

There are more than 800 different species of hermit crabs throughout the world's oceans. Like other crustaceans, hermit crabs undergo ecdysis and moult their bodily shells. Hermit crabs also need to replace the gastropod shells that they call home when they've outgrown them. Once a larger, unoccupied shell has been spotted, the small crustacean releases its old shell and backs into the new one. Hermit crabs use the tip of their adapted abdomen to clasp onto a pillar-like structure found within many shells, called the columella, to secure themselves in place. Although crabs often make the switch when they encounter a rogue shell, crabs such as long-wristed hermit crabs (*Pagurus longicarpus*) exchange houses in a chain with other crabs. When these exchanges aren't amicable, crabs will attack each other by striking each other's shells in the hope of securing a shell eviction.

If a hermit crab can't find a shell that fits, they'll reduce their size between moults

particularly their feathers. Throughout the year, some feathers may have suffered wear and tear, and so the birds embark on patterns of shedding, though this can come at a cost to their ability to fly. During moulting, some birds, such as swans and geese, lose all of their flight feathers at the same time, completely grounding them for around six weeks before they can grow new ones.

Other than outgrowing their own body, there's one other reason an animal might want to step outside of their old skin... parasites. The natural world is full of fungal, bacterial and animal parasites whose main goal is to find a way to extract sustenance from their host. The ocean is littered with parasitic organisms that are just waiting to find their way into the cracks of a crustacean's shell. Parasites such as isopods and barnacles try to burrow their way past the protection of crab and lobster shells to syphon off nutrients and find a source of food. To prevent parasites from taking hold, crustaceans undergo ecdysis to grow a new body within their existing shell and then step out of their old one, hopefully leaving the parasites behind.

Creating a new shell or exoskeleton comes at a cost to the creature. Once a giant mud crab (*Scylla serrata*) has completed ecdysis, the body that emerges from the previous shell is completely soft. While the crab is vulnerable to predation without its usually tough exterior, it can find a protected spot and wait for its new shell to harden. Within a matter of days, the new shell hardens and the crab is free to face the world again.

It's not just critters and crabs that shed to strip away parasites, with some plant life doing the same. Throughout late spring and early autumn, the silver birch tree (*Betula pendula*) sheds thin paper-like layers of its bark. This reduces the opportunities for parasites and other invertebrates to burrow into healthy bark and potentially cause an infection. The fallen bark also releases nutrients back into the soil when it decomposes, which can then be reabsorbed through the tree's roots.

Did you know?

Pea crabs have shells just two centimetres long

But moulting isn't for everyone. Some animals have avoided shedding entirely, despite their growth. Fish scales, for example, grow with the fish rather than being shed and replaced. This can be handy for scientists trying to accurately age them; some fish species have scales with concentric ridges – similar to the rings in the trunk of a tree – that are used as an indication of age.

ANATOMY OF A COMPOST HEAP

WORDS AILSA HARVEY

How the natural process of composting converts your leftovers into valuable fertiliser

Leftover food, garden trimmings and other organic waste items don't need to be discarded. Instead they can be recycled in a process called composting. Composting is the breaking down, or decomposition, of organic material into nutrient-rich soil. After decomposition, these materials turn into organic molecules made up of carbon dioxide, water, simple sugars and salts. Compost heaps are places where this process is accelerated from years to months or even just a few weeks.

Composting mostly takes place outdoors, and there are two main types: cold, or passive, and hot, also called active compost. Cold composting is much slower but is easier to manage. All you need to do is add the right materials and allow the natural process to take place. The soil created from this process usually can't be recycled for at least one year, as much of the decomposition takes place slowly without oxygen.

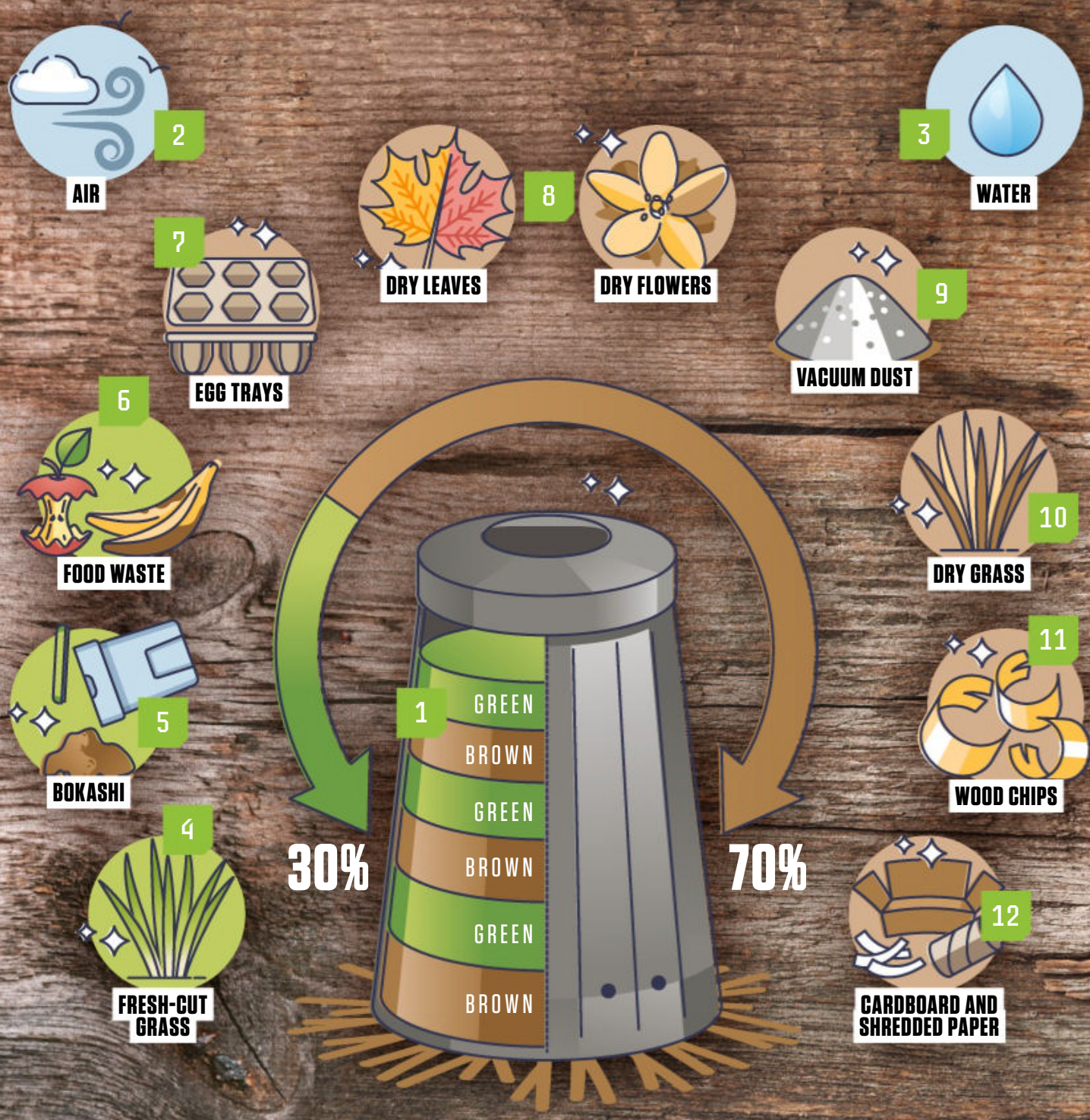
Hot composting is more efficient, but requires you to maintain consistent layers of carbon-rich and nitrogen-rich materials while optimising the water and oxygen levels regularly. The ideal temperature for quick active composting is 55 to 60 degrees Celsius. This temperature is achieved when the heap is well aerated with peak composting conditions. Adding piping into the top of a compost heap is a simple way to ensure air is entering the middle of the soil.

DID YOU KNOW? Australian brushturkeys build compost heaps in the wild to incubate their eggs in

WHAT IS VERMICULTURE?

Another term for vermiculture is worm composting, which involves using worms to break down organic matter into nutrient-rich soil. Just by existing in the soil, worms improve the health of soil and break down garden waste. Additionally, the soil they produce is ideal for growing more plants that can be given back to the worms as food. Vermiculture can break down more waste than traditional composting. This is because worms eat a wide variety of products, such as meat and dairy. In standard compost, these foods take too long to decompose, and infectious bacteria such as *Escherichia coli* and *Salmonella* can accumulate. Worms can demolish these quickly, but adding these foods still isn't recommended as they can create strong and unpleasant smells.

Vermiculture experts recommend adding worms and waste to compost in equal weights for the best results



A RECIPE FOR RICH SOIL

What ingredients work best in a compost heap?

1 ALTERNATING LAYERS
A successful compost heap has alternating layers of dry, carbon-rich 'brown' items and wet, nitrogen-rich 'green' items.

2 AIR
Larger items add air pockets. Air is needed for essential microbes to survive.

3 MOISTURE
Compost should be between 40 and 60 per cent water.

4 FRESH GRASS
Grass clippings are high in nitrogen, which increases reproduction in microorganisms.

5 BOKASHI SOIL
The soil from bokashi – a process that breaks down food waste by fermentation – can be added to compost to increase friendly microbes.

6 FOOD WASTE
Scraps of food can be completely broken down into compost in just a few weeks.

7 EGG TRAYS
The natural materials in egg trays break down quickly to make rich fertiliser.

8 DRY FLOWERS AND LEAVES
Dry plant matter is high in carbon. The best leaves to use are those from ash, maple fruit, poplar and willow trees.

9 VACUUM CONTENTS
The dust from a vacuum cleaner has some fast-composting materials such as human and pet hair and skin flakes.

10 DRY GRASS
Dry grass is a useful brown layer if it hasn't been treated for a couple of weeks.

11 WOOD CHIPS
Pieces of wood are rigid and create air pockets in the compost pile.

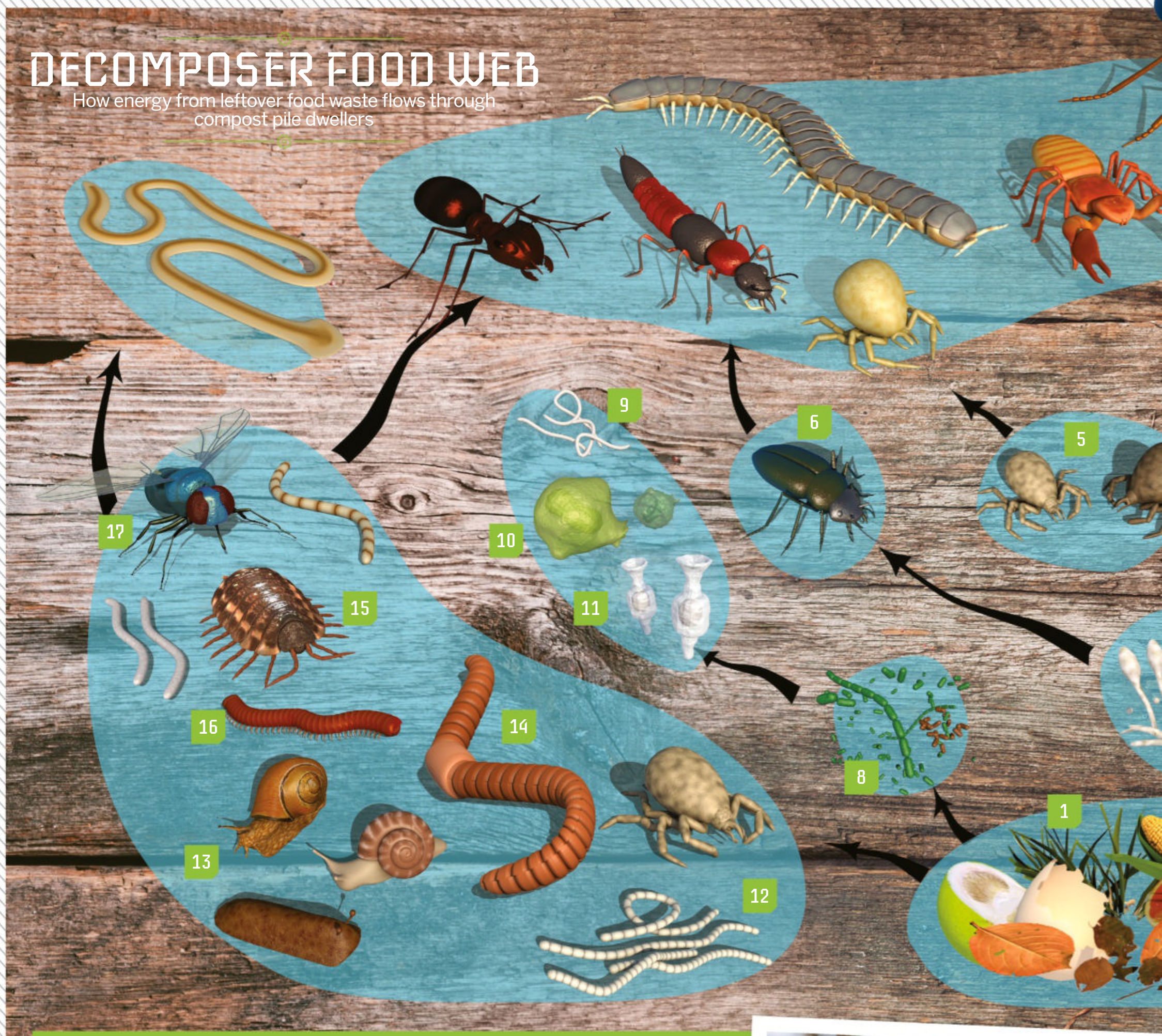
12 CARDBOARD
Cardboard and paper can be soaked and shredded to add moisture to the compost.

Did you know?
Farmers have been composting for 12,000 years

© Getty / Shutterstock

DECOMPOSER FOOD WEB

How energy from leftover food waste flows through compost pile dwellers



ENVIRONMENTAL BENEFITS

Around one-fifth of all household waste is food – the second-largest waste type after paper. Without composting, almost all of this food ends up in landfills. Landfills aren't sustainable; they pollute the natural composition of the ground and release pungent odours and greenhouse gases such as methane. One demonstration of the impact large-scale composting can have on landfills is seen in San Francisco. In 2009, composting became a requirement for everyone in the city. By separating their compostable waste, the city prevented 80 per cent of waste items from going to landfills. Composting also produces much healthier soil, with the organic matter holding soil together better, retaining more water and increasing nutrients naturally so that fertilisers aren't needed. Many plants can thrive in the soil made by composting, and the soil traps more carbon dioxide, which would otherwise accumulate in the atmosphere.

Around 7 million homes in the UK have separate food waste bins

DID YOU KNOW? Compost heaps can reach 23 degrees Celsius in just a few days

1 FOOD WASTE
Compostable leftovers can be shredded and consumed by the compost pile's primary consumers.

2 ACTINOMYCETES
These bacteria thrive in soil with high alkaline pH levels. Actinomycetes break down woody materials, cellulose and proteins.

3 FUNGI
Fungi can break down complex materials so that bacteria can begin the composting process quicker.

4 SPRINGTAILS
These insects are pests to plants in large numbers, but eat the fungi growing within the compost.

5 MOULD AND BEETLE MITES
Transparent mites are attracted to the mould that grows in compost.

6 FEATHER-WINGED BEETLE
Very common in compost heaps, they live off fungal spores and leaf litter.

7 TERTIARY CONSUMERS
At the top of the compost pile food chain are centipedes, ground beetles and ants. These help control pest levels.

8 BACTERIA
Microorganisms break down organic matter. They release heat as they break down material, making a warm habitat for other creatures.

9 ROUNDWORMS
These are the most abundant invertebrates in compost soil. They eat bacteria, fungal spores and each other.

10 PROTOZOA
Protozoa are single-celled animals that live in water droplets. They have a small role in decomposition and consume bacteria and fungi.

11 ROTIFERS
These multicellular microbes break down organic material and eat bacteria.

12 WHITE WORMS
When you notice more white worms in your compost, it's a sign of acidic conditions. These worms aid decomposition by breaking down starchy foods.

13 SNAILS AND SLUGS
These eat leaves and plants in the compost to break them down.

14 EARTHWORMS
Earthworms feed on fresh and decaying matter. Their waste mixes nutrients through the compost and helps to aerate the soil with oxygen.

15 SOWBUGS
These small bugs eat vegetable matter. Decaying produce is their main food source, so they like to live in compost.

16 MILLIPEDES
These critters do much of the shredding work in compost heaps. They consume up to ten per cent of the leaf litter.

17 FLIES
Placing food scraps further towards the bottom of compost heaps can reduce flies. However, they assist in decomposition and their eggs are often consumed by other creatures.

Did you know?
Urine is a good ingredient for compost

HOW TO MAKE COMPOST

1 CHOOSE THE RIGHT PLACE
A dry area away from direct sunlight is an ideal spot. You should consider somewhere far from your home but still near a source of water, like a garden hose.

2 ADD ITEMS
Using items from the recipe on the previous page, start constructing your compost pile in layers. These should each be around ten centimetres deep.

3 MOISTEN THE SOIL
As you build the layers, keep adding water every so often. This will ensure the soil is evenly damp throughout.

4 KEEP THINGS MOVING
Mixing the compost speeds up the decomposition process. Do this at least once every couple of weeks using a garden rake or similar tool.

5 HAVE SOME PATIENCE
Make sure the soil remains damp, but not too wet, like a sponge after being wrung out. It will take around two to four months for matter to decompose when regularly mixed.

HOW DOLPHINS SPEAK

These chatty marine mammals have multiple methods of communication

WORDS SCOTT DUTFIELD

The two main methods dolphins use to communicate are clicking and whistling, with whistles being heard up to 12.4 miles away through the ocean. Whistling noises are made in different patterns and frequencies to speak with other dolphins, while clicking is used for echolocation. Echolocation is the method of releasing sound waves into the surrounding water in order to hunt for food and visualise the objects moving around them. The sound waves bounce off nearby objects and return to the dolphin's head. Their brain then converts the returning sound waves into the shapes and distances of objects in the murky water, including threats, potential food and obstacles.

Scientists are trying to work out more about the meanings behind specific whistle patterns, as this would enable humans to listen to and understand the dolphin world much more intricately. However, it's thought that dolphins communicate in a very different manner to humans, and thus their speech shouldn't be deciphered using typical human language patterns.

Did you know?

Sound travels around five times faster in water than air

Studies have shown that when a dolphin appears to be in distress, it will produce its signature whistle at a loud volume so that those in its group, also called a pod, can assist. When one dolphin whistles, another usually acknowledges what has been communicated by whistling back, or in some cases by swimming over towards the whistling dolphin. It's also quite common for a mother and calf to continuously whistle when they become separated until they're reunited.

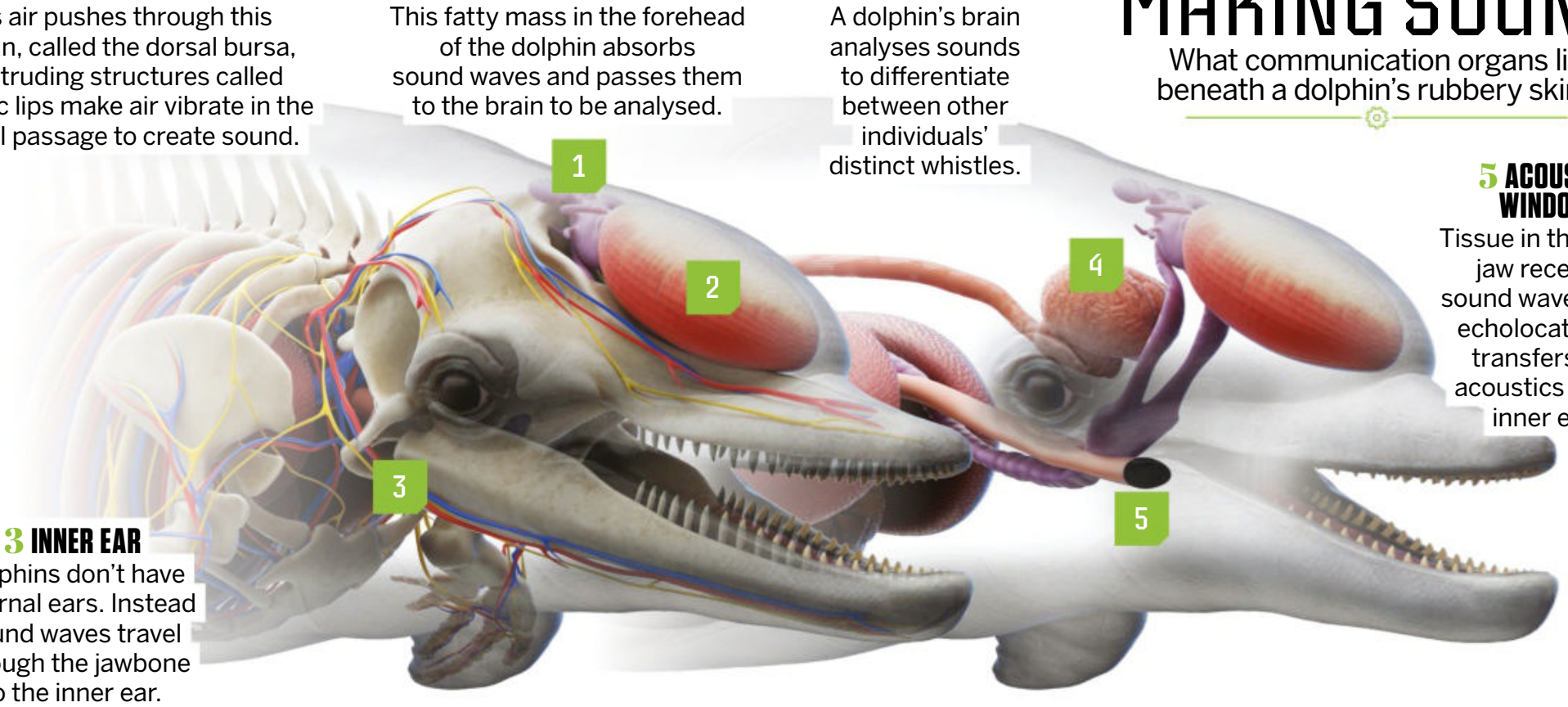
SOCIAL PODS

Dolphins are very sociable animals. In regions with a lot of food, pods can grow to around 1,000 individuals. Much of the communication they display between pod members is physical. For example, a dolphin may rest its fin on another to show close friendship or slap the water's surface to communicate warning or playfulness. The patterns and force of tail and flipper slapping hold different meanings to the rest of the pod. Aside from body language, a dolphin pod can be fairly noisy. Each dolphin has a unique whistle pitch, which they use to identify each other. These whistles are part of one of the most complex animal speech methods ever studied. So far, due to dolphins spending so much time underwater, researchers are unable to decipher dolphin conversation in detail.

Dolphins sometimes imitate other pod members' whistles to get attention

MAKING SOUND

What communication organs lie beneath a dolphin's rubbery skin?



1 PHONIC LIPS
As air pushes through this organ, called the dorsal bursa, protruding structures called phonic lips make air vibrate in the nasal passage to create sound.

2 MELON
This fatty mass in the forehead of the dolphin absorbs sound waves and passes them to the brain to be analysed.

3 INNER EAR
Dolphins don't have external ears. Instead sound waves travel through the jawbone to the inner ear.

4 BRAIN
A dolphin's brain analyses sounds to differentiate between other individuals' distinct whistles.

5 ACOUSTIC WINDOW
Tissue in the lower jaw receives sound waves from echolocation. It transfers the acoustics to the inner ear.

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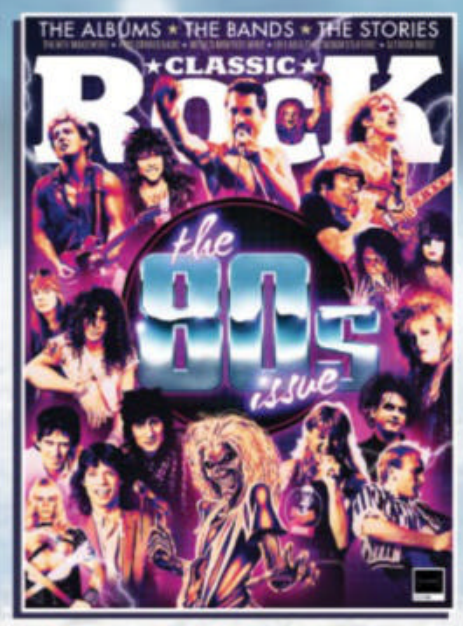

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SWEETIE SCIENCE

Find out why you have a sweet tooth, how different candies are perfected and how sugar affects your body

WORDS **AILSA HARVEY**

Sugar is found all over in nature, from the apples growing on trees to grains in the ground and dairy products, so why is it that sweets are classed as unhealthy and you're told not to eat too many of them? The major difference is in the processing of sugar in sweets and the types of sugars that make up the main ingredients of a product. Sucrose is the favoured type of sugar used to make confectionery. This comes from a plant called sugar cane, but by the time it enters your favourite sweet treat, it's usually had all its natural fibre and antioxidants removed.

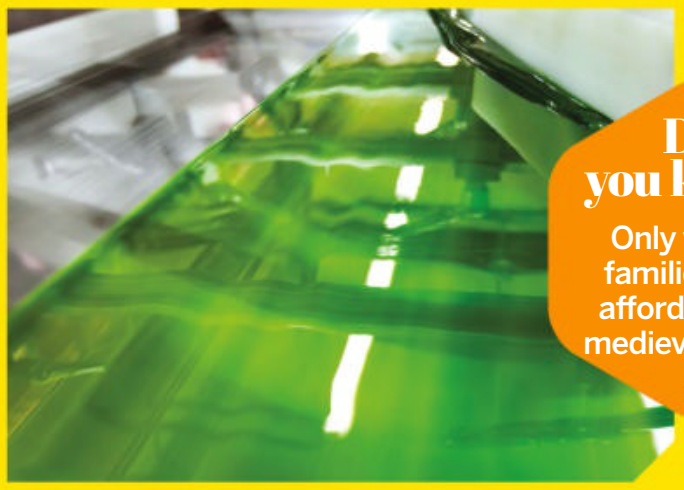
Health experts advise that less than ten per cent of your daily calorie intake should come from sugary sweets and 90 per cent of your energy should be derived from more nutritional sources. But if sweets aren't the best choice for our health, why do some people crave them? Many of your taste preferences are written into your genetics. Your unique DNA determines what your taste buds will sense, and some people have a stronger reaction to sweets than others. Children are usually bigger fans of sugary snacks because their bodies are growing and crave high-sugar items for the easy energy hit.

DID YOU KNOW? Sugar doesn't stretch, so you need to chew out all the sugar in bubble gum to blow a large bubble

MAKING A BOILED SWEET

1 BOILING AND MIXING
Firstly, sugar and water are boiled over a stove to create a candy syrup.

2 POURING
When the mixture has cooled enough that it can be pulled apart in thick strings that don't break, it's ready to be poured onto a flat surface.



Did you know?
Only wealthy families could afford sugar in medieval Europe

3 ADDING ACID
Citric acid is added into the mixture so that the sucrose breaks up and doesn't crystallise.

4 CUTTING
The syrup is similar to soft glass in consistency. Now it can be cut into smaller pieces ready to be accurately portioned.

5 ROLLING
The syrup is fed through two printed rollers to mould the hardening mixture into the boiled sweet's shape.

6 COOLING AND SEPARATING
The sweets continue to dry on the conveyor belt until they are solid. They're then dropped vertically onto a hard surface to make sure the individual sweets are separated for packaging.

CRYSTALLISATION CHEMISTRY

Sweets such as fudge and rock require the process of sugar crystallisation to create their distinctive textures. Sugar takes on a crystal structure when the liquid mixture cools down and starts to harden, forming a particular repeating pattern. However, the sugar will only crystallise if it's in a supersaturated solution – this means that there's more sugar in the boiling water than can be fully dissolved. The way that you cool sugar for crystallisation determines what kind of texture is produced. Hard rock candy is left to cool over a few days to form large solid crystals. Meanwhile, fudge is formed of sugar microcrystals that have a smoother texture.

As the temperature lowers, more molecules are added to the sugar crystals to form this shape

"Many of your taste preferences are written into your genetics"

CREATING CONSISTENCIES

GELATINE GUMMIES

A large majority of modern candy-makers strive for a sticky or gummy consistency in their sweets. While some manufacturers opt for ingredients from plants, such as vegetable starch, to get this texture, most gummy sweets will list gelatine as an ingredient. This is a clear, odourless protein called collagen, extracted from the bones of animals like pigs and cows. Gelatine melts when placed in the mouth, but dissolves slowly so the sweets can last longer. The protein is hard when dry and squishy when wet, making it a widespread ingredient across sweet brands.

MALLOW AERATION

A marshmallow is a spongy, pillow-like sweet made using corn syrup, sugar, egg whites and gelatine. More corn syrup is added than sugar, as it dissolves more easily and prevents crystallisation, which would reduce the softness of the sweet. The ingredients are mixed and boiled, but as it's cooling, the mallow mix is strained before being whipped into a foam. This step increases the sweet's volume. Finally, the mixture is pushed through a mould into long lines of marshmallow, ready to be cut into the preferred size and shape. They are cut and left to cool.

ESSENTIAL EMULSIFIER

When making chocolate, it's important to include an emulsifier. This stops many of the ingredients in chocolate separating. Emulsifiers such as lecithin, which is extracted from soybeans, sunflowers or eggs, helps the cocoa butter, milk solids and sugar stick together. This keeps the chocolate smooth and extends its shelf life so you can enjoy it for longer.

Did you know?

Candy floss is almost pure sugar that's been melted and spun

PREHISTORIC TREATS

Today sweets come in unlimited colours, flavour combinations, textures and special effects – like popping candy's miniature explosions when they hit your tongue. But sweets were originally much simpler. The earliest known sweets were made of honeycomb that was cut and shaped by cavemen. The ancient Egyptians began experimenting with sweet honey by combining it with figs and nuts, while the ancient Greeks coated fruits and flowers with sugar. You're likely to have been told that sweets are bad for you at some point, but before the Industrial Revolution in the 1700s you may have been given a bag of sweets as a form of medicine. They would be made from sugar and a carefully selected combination of spices that were said to aid digestion or soothe a bad throat.

Before sugar was widespread, honey was used to make sweets

DID YOU KNOW? Marshmallows were first made from the root sap of a plant called marsh mallow

SUGAR HIGHS AND LOWS

How do sugary sweets impact your body's health and energy levels?

1 SWEET TOOTH

Bacteria in the mouth break down the sugar in sweets. This produces acid that can dissolve the minerals in your teeth, leading to tooth decay.

2 FAT-FORMING

Refined sugar is often referred to as 'empty calories', as it has very little nutritional value but gives your body a rush of readily available energy. If too much is eaten, it's converted into extra body fat instead.

3 SUGAR HIT

Humans particularly enjoy sweet foods as these high-energy fuels would have sustained us in the wild. Our brains' reward system still releases the feel-good hormone dopamine when we eat them.

4 HEART STRAIN

Too much sugar intake can cause inflammation, high blood pressure and high cholesterol.

5 FAST FUEL

Sweets are mostly made of sugar and are low in fibre. They release energy quickly after they're eaten, but it's followed by a crash in energy levels.

6 CELL ENERGY

Sugar competes with vitamin C in the body and takes up some of the space that vitamin C would usually claim in white blood cells. Vitamin C strengthens the immune system, while glucose in white blood cells makes them less reactive to harmful cells.

HOW FIREWORKS WORK

Discover the science behind the glitter and sparkle of these pyrotechnics

WORDS SCOTT DUTFIELD

Whether it's the Fourth of July, Guy Fawkes Night or New Year's Eve, you're sure to see the sparking light of nearby fireworks, followed quickly by their boisterous booms. But igniting colourful chemicals and shooting them into the sky isn't a new tradition by any means. The first fireworks were hurtling into the sky in around 600 BCE in ancient China. Ancient alchemists discovered that mixing potassium nitrate, sulphur and charcoal produced a black powder that's now referred to as the 'first gunpowder'. When this powder was stuffed into a bamboo stick and ignited, it created the first firework propulsion system. Early fireworks were used to celebrate weddings, births and even to ward off evil spirits.

Modern fireworks still use black powder, but now incorporate small pellets of packed minerals, called stars, to produce colourful explosions. When the chemicals in the stars are heated, the electrons making up their atomic structures are excited and release energy in the form of different wavelengths of light. For example, when a copper-filled star ignites it burns a brilliant blue colour. Stars are held within a shell, often concealed within a rocket, and are placed in a launching tube called a mortar. A pile of black powder beneath the shell is ignited, and its combustion generates enough force to send the shell flying into the sky before another charge inside the shell combusts, igniting the shells, and the stars within them. If the stars inside are arranged in a particular orientation or design, the erupting fireworks will also resemble that design. If the stars are arranged to look like a heart in the shell, the resulting firework will also resemble a heart.

Did you know?

Each year, around 16,000 Fourth of July firework displays occur

Shells come in different shapes and sizes. In the US shells are typically spherical, whereas in Europe shells are more cylindrical and stack layers of different stars on top of each other, separated by a portion of black powder, to ignite them in stages. Of course, the fireworks aren't purely visual – there's also a range of hissing, crackling and booming sounds that come with a good firework display. These auditory elements of a firework aren't necessarily natural byproducts of a firework explosion... some are purposefully put into the firework shell. Minerals such as bismuth create crackling sounds, while potassium salts make fireworks whistle as they travel.

AI-DESIGNED DISPLAYS

Like in many other industries, artificial intelligence (AI) has found its way into the toolset of firework display designers. Along with being able to simulate a digital display, AI is being used to gather data from displays around the world to choreograph new and unique experiences. AI is capable of precisely calculating the optimal timing, position and safety of fireworks to produce a display that's not only visually exciting, but one that is perfectly synchronised with any accompanying music. It can even be used to respond to changes in the weather in real time, such as adjusting the position of a launching mortar to account for changing wind speed.

AI is often used to calculate the perfect combinations of fireworks for ideal displays

CREATING COLOURS

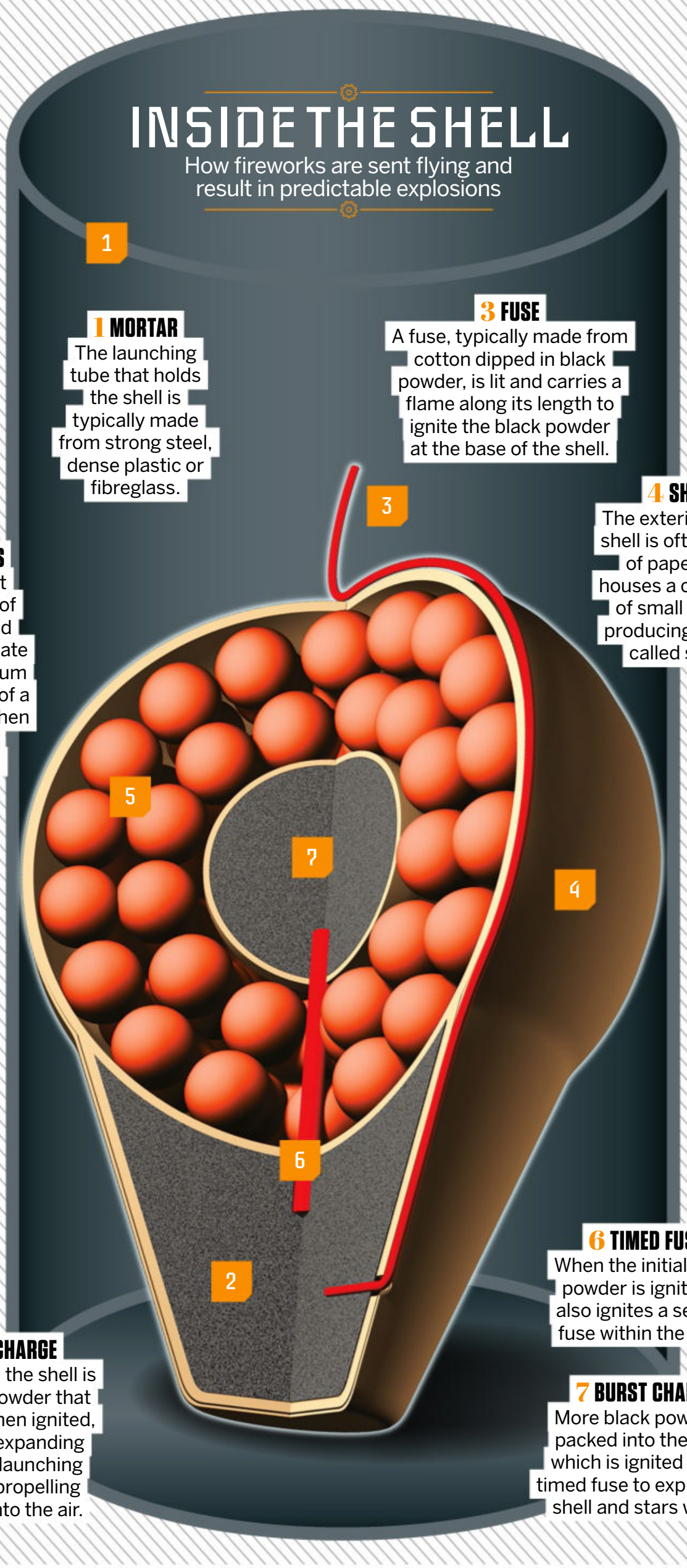
The elements that give fireworks their colours

DID YOU KNOW? The world's largest firework shell measured 1.44 metres in diameter


A firework mortar with fuses, ready to be filled with black powder and shells

INSIDE THE SHELL

How fireworks are sent flying and result in predictable explosions



1 MORTAR
The launching tube that holds the shell is typically made from strong steel, dense plastic or fibreglass.

3 FUSE
A fuse, typically made from cotton dipped in black powder, is lit and carries a flame along its length to ignite the black powder at the base of the shell.

4 SHELL
The exterior of the shell is often made of paper that houses a collection of small colour-producing pellets, called stars.

5 STARS
Different varieties of powdered metals create the spectrum of colours of a firework when they're ignited.

6 TIMED FUSE
When the initial black powder is ignited, it also ignites a second fuse within the shell.

2 LIFT CHARGE
Underneath the shell is black gunpowder that explodes when ignited, forcefully expanding out of the launching tube and propelling the shell into the air.

7 BURST CHARGE
More black powder is packed into the shell, which is ignited by the timed fuse to explode the shell and stars within.

5 FUN FIREWORK PATTERNS

1 WILLOW
As well as coloured salt, a large amount of charcoal is put into the stars of a willow firework. When the stars explode, the charcoal burns in trails as it falls.

2 PALM
When larger grains of minerals are used within the shell's stars, it takes longer for them to combust, creating a palm tree-like effect.

3 STROBE
The composition of the compounds used in these fireworks produces a strobing effect; chemical byproducts of the combustion re-ignite following the initial explosion.

4 COMET
A large amount of charcoal, along with titanium or aluminium, is used to produce long gold and silver tails radiating from a comet firework.

5 CROSSETTE
Unlike a typical firework star, the stars of a crossette firework have a four-sided cavity filled with a burst charge and capped at one end. When the firework explodes, the star separates in four different directions.

A DAY IN THE LIFE OF AN ASTRONAUT

Here's a typical 24 hours on the International Space Station

WORDS ANDREW MAY

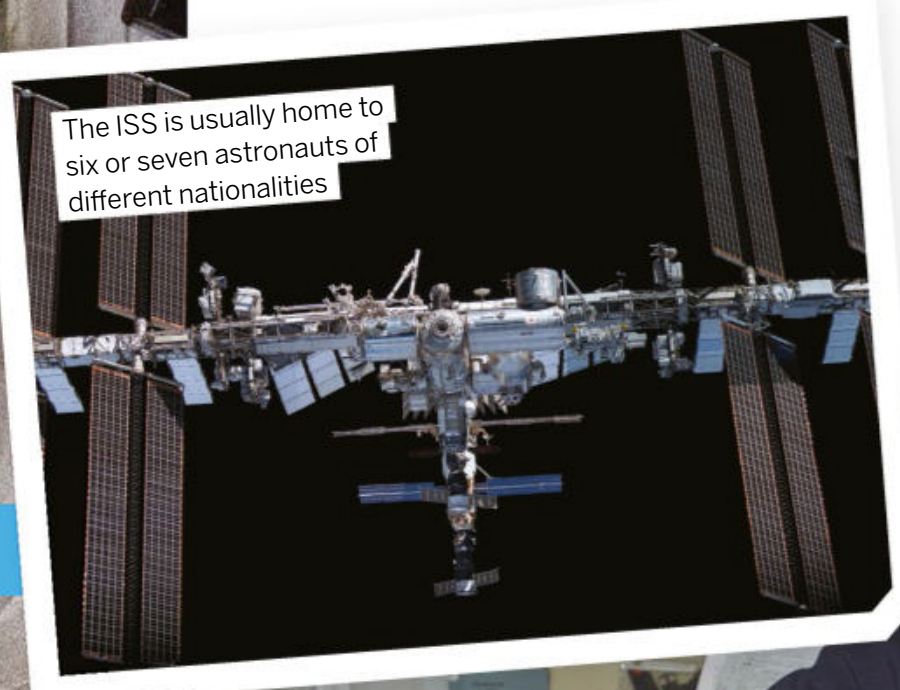
DID YOU KNOW? The first person to spend a full 24 hours in space was Russian cosmonaut Gherman Titov in August 1961

...OUT

Being an astronaut is one of the most prestigious and sought-after careers in the world, with thousands of applicants for each vacancy. But what does the job actually entail? Here we take a look at the daily routine of the crew on board the International Space Station (ISS). No two days are quite the same on the ISS, and even on a particular day different crew members will have different tasks to perform. But a typical working day will be focused around two shifts – one in the morning and one in the afternoon – with an hour's break for lunch between them. The main work activity involves a range of scientific research, although there are also routine maintenance chores to be done as well.

Did you know?
The ISS has two bathrooms on board

Occasionally there's work that has to be carried out on the exterior of the station, and this means donning a spacesuit and going outside for a spacewalk. Spacewalks inevitably make more eye-catching headlines than work inside the station, so people may get the impression they happen more often than they do. In reality, however, spacewalks are expensive, time-consuming and potentially dangerous affairs, so they're only embarked on when they're absolutely necessary – the polar opposite to the kind of 'everyday' life in space that we're focusing on here. Let's put spacewalks to one side and take a look at an astronaut's more typical daily routine – from brushing their teeth in the morning to tucking into bed at night.


The ISS is usually home to six or seven astronauts of different nationalities

USING THE BATHROOM

Some of the most basic everyday tasks are much trickier in space due to the lack of gravity. In an ordinary toilet, for example, it's the pull of gravity that ensures the waste goes where it's meant to, instead of floating all over the place. Space toilets have to use suction, rather like a vacuum cleaner, to achieve the same effect. Showers also rely on gravity, both to get water onto you in the first place and then off you and down into the drain. NASA once experimented with a high-tech 'space shower', but it took over two hours to use. Today, astronauts just rub liquid soap onto their skin, and use rinseless shampoo on their hair, before drying themselves with a towel.


NASA astronaut Cady Coleman washing her hair on board the ISS


NASA astronaut Peggy Whitson visited the Russian segment of the ISS for a haircut

Astronauts demonstrating the lack of 'up' and 'down' on the ISS

SLEEPING IN SPACE

Each crew member on the ISS has their own small cabin with a firmly anchored sleeping bag that allows them to sleep comfortably without floating around in microgravity. Even so, there are a couple of hazards associated with sleeping in space that don't affect us down here on Earth. One is a kind of personal 'firework show': sudden, bright flashes of light, seen even with the eyes closed, which are caused by cosmic rays and can be an annoying source of sleep disturbance. A second hazard arises in microgravity because exhaled carbon dioxide can remain close to an astronaut's face if they fall asleep in an area with poor air circulation, resulting in a bad headache.

ESA astronaut Samantha Cristoforetti in her personal crew quarters on the ISS

Did you know?

Alcohol is prohibited on board the ISS

LIVING IN MICROGRAVITY

Some features of everyday life on the ISS are unusual, but not unique. The isolation of the crew and the need for a long-term, self-contained supply of air, water and food, are shared with life on board a submarine. But the one thing that's truly unique about life in space is the almost complete lack of any perceptible force of gravity – a condition that NASA refers to as microgravity. This phenomenon isn't due to the absence of gravity. If you could build a tower 250 miles high, then the top would be at roughly the same altitude as the ISS. The strength of gravity you'd feel would be about 90 per cent of its value at ground level, and if you stepped off, you'd fall back to Earth. The ISS is constantly falling under gravity, but it's also moving horizontally at very high speed. This balances the falling effect enough to keep it in a circular orbit. Because the station and everything inside it share the same motion, they appear to be 'weightless' with respect to each other.

The presence of a microgravity environment on the ISS is one of the primary reasons for its existence. In essence, it's a scientific laboratory where the effects of microgravity – on everything from human health to manufacturing processes – can be studied in detail. In terms of the crew members' daily lives, however, microgravity can make basic things like eating, sleeping and going to the toilet far more complicated than on Earth. It can also be very disorientating because there is no longer such thing as 'up' or 'down'. That's not the case in the training simulators on Earth, so despite knowing the latter like the backs of their hands, newcomers often get lost because they fail to recognise a room they've only ever seen the other way up. Another consequence of microgravity is that objects don't fall to the ground when you let go of them – they remain floating in mid-air. After spending six months on the station, astronauts sometimes forget this doesn't happen down here on Earth and end up dropping things as a consequence.

SPACE FOOD REQUIREMENTS

The space environment puts a number of constraints on what astronauts can eat

1 STRONG TASTE

Fluid shifts in microgravity desensitise an astronaut's taste buds, rather like having a cold, so they prefer very spicy food.

2 NUTRITIOUS

A healthy diet is important for everyone, and astronauts are no exception.

3 COMPACT

The space inside the ISS is limited and already packed with equipment and living quarters, so compact food is essential.

4 LIGHTWEIGHT

Space food should be as light as possible to reduce the rocket fuel needed to launch it into orbit.

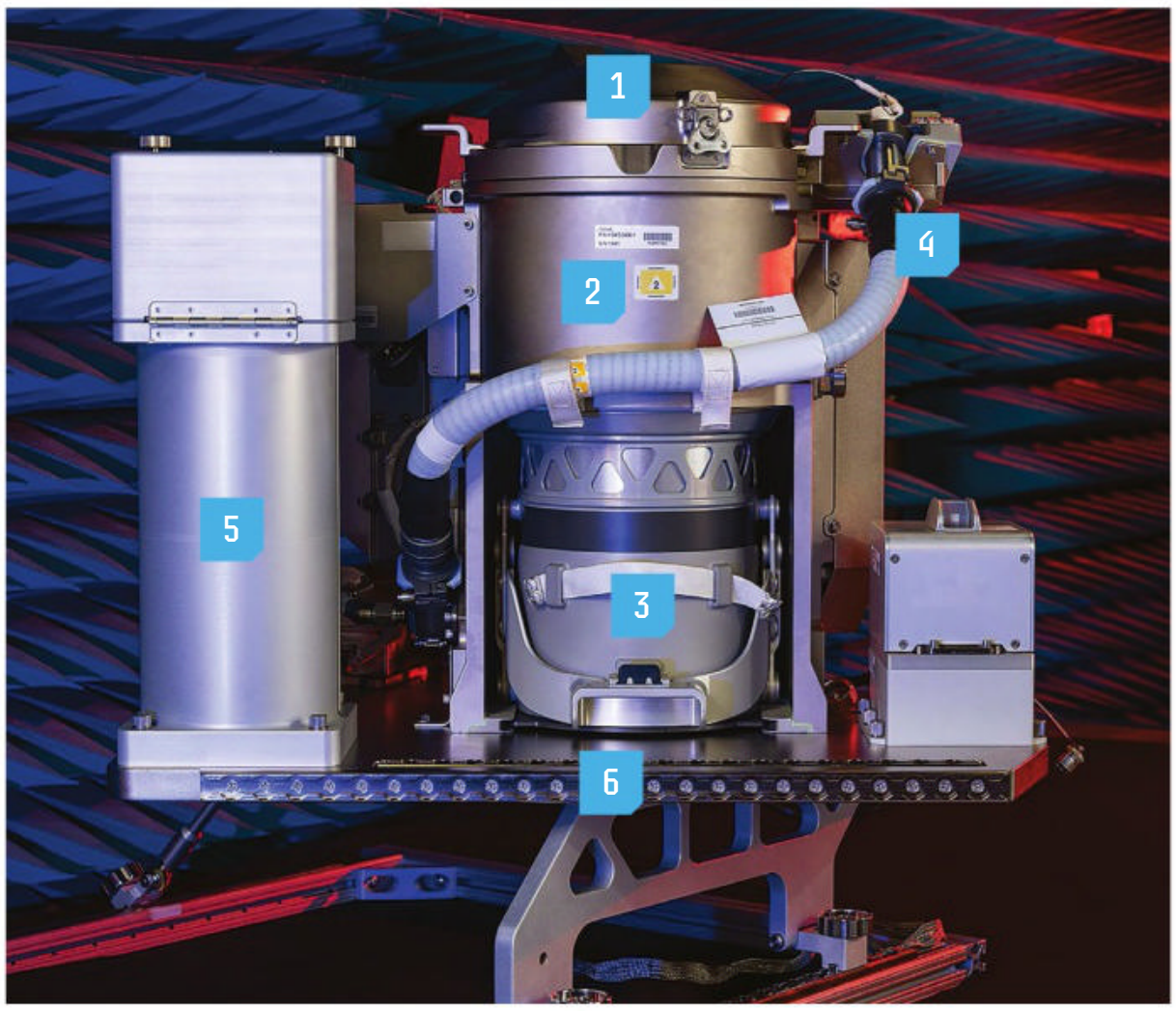
5 NOT CRUMBLY

Crumbs float everywhere in microgravity, so food that is moist and sticky is preferable to dry and crumbly.

6 LONG SHELF LIFE

It can often be two months or more between resupply missions, so food on the ISS has to last.

DID YOU KNOW? The perils of space crumbs were discovered by the Gemini 3 crew, who smuggled a sandwich on board in 1965



NASA'S UNIVERSAL WASTE MANAGEMENT SYSTEM

A look at the latest generation of space toilet, installed on the ISS in 2020

1 SEAT
A big improvement on previous designs, this is specially contoured to be comfortable for both female and male astronauts.

2 FILTER
To prevent the container from getting too smelly as it fills up, this filter is designed to kill odour-producing bacteria.

3 WASTE CONTAINER
Solid waste goes into this bin, which fills up after about 30 uses and is then ejected into space.

4 SUCTION HOSE
This is used to collect urine, and the funnel on the end is designed for use by any gender.

5 URINE STORAGE
The water in urine is much too valuable to throw away, so it's stored and purified before being reused.

6 TOE RESTRAINTS
Astronauts put their feet here to make sure they don't float away while they're using the toilet.

Pizza is the ideal space food, as these astronauts demonstrate

ASTRONAUT ANECDOTES

Five astronauts talk about dealing with microgravity on the ISS

1 US ASTRONAUT VICTOR GLOVER
"Floating for an extended period is truly amazing. My brain is constantly trying to figure out which way is up. It's an interesting challenge, one I find slightly amusing."

2 US ASTRONAUT SUNITA WILLIAMS
"It's like being a fish since you can catch food in your mouth easily because it's suspended in the air, just like when you put fish food in a tank."

3 CANADIAN ASTRONAUT CHRIS HADFIELD
"The cool thing about space is when you put your pants on here, you can put them on two legs at a time."

4 US ASTRONAUT ANNE MCCLAIN
"You kind of just float inside your sleeping bag... our arms kind of float up, so we look a little bit like zombies."

5 BRITISH ASTRONAUT TIM PEAKE
"Gravity is horrible when you come back to Earth, except in a few cases. When it comes to using the loo, gravity is your friend."

AN AVERAGE DAY IN SPACE

What a typical day on the ISS looks like

07:00

BREAKFAST

Astronauts have several breakfast menus to choose from, much like a hotel buffet breakfast. If they want cereal, they have to add dried milk and water rather than fresh milk.

BREAKFAST MENU

- French toast
- Canadian bacon
- Orange juice
- Coffee

08:00

MORNING WORK SHIFT

The primary purpose of the ISS is to carry out scientific research in space, and this is what the crew spends most of their time doing. This research ranges from studying the effects of microgravity on physical systems and living things to remotely observing Earth from their vantage point in orbit. To provide a safe environment for the study of liquids and hazardous materials in space, the astronauts have a special 'microgravity glovebox' they can use. They also carry out medical research using themselves as guinea pigs and grow their own food using the Vegetable Production System, affectionately known as 'Veggie'.

06:00 02:00 08:00 09:00 10:00 11:00 12:00 13:00

06:00

WAKE-UP CALL

As the ISS completes a full orbit of Earth in just 90 minutes, it never spends very long in a particular time zone. By convention, astronauts use what we call Greenwich Mean Time, also referred to as Coordinated Universal Time (UTC). The astronauts are woken at 06:00 UTC with a call from Mission Control, and then spend an hour or so on their morning routine: brushing their teeth, shaving, using the toilet and generally freshening up. Some of these tasks, such as using a toothbrush, are just as easy as they are on Earth, while others, such as going to the toilet, can be a little more complicated.

13:00

LUNCH

As befits hard-working astronauts, lunch is often a multi-course meal, with a variety of starters and desserts to choose from as well as a substantial main course.

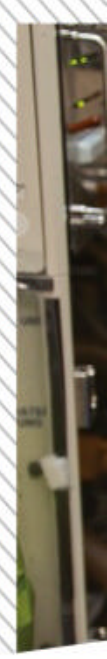
LUNCH MENU

- Oven-fried chicken
- Macaroni cheese
- Peaches
- Tropical fruit juice

14:00

AFTERNOON WORK SHIFT

Although research activities form the bulk of an astronaut's work, during both the morning and afternoon shifts they also have other more mundane tasks to perform. These include routine housework, such as vacuuming and disinfecting the living quarters, and the kind of maintenance chores that all homeowners have to do. One picture here shows Canadian astronaut David Saint-Jacques repairing one of the ISS' toilets. Sometimes new equipment needs to be calibrated and installed to keep the station up to date, and that's what Tim Peake is doing in the other picture here. But maintenance work on the ISS isn't always as humdrum as it is on Earth, with astronauts occasionally having to venture outside on a spacewalk to make repairs or install vital new components.



DID YOU KNOW? The rationing of water on the ISS means astronauts can't wash clothes


Italian astronaut Umberto Guidoni using one of the exercise machines on the ISS

17:00
EXERCISE

If you were confined 24 hours a day in a live-in laboratory down here on Earth – in Antarctica, for example – you would need to spend an hour or so of that time doing gym-style exercises. But there's another reason why exercise is even more important for the crew of the ISS, and that's because living in microgravity causes the body to lose the muscle and bone that we normally need just to stand up. Regular sessions on gym equipment, such as a treadmill or exercise bike – suitably modified so that astronauts can use them without floating away – are essential to counteract potentially dangerous tissue loss.

18:00
DINNER

In the evening the astronauts eat another full three-course meal, with a similar range of options to lunch. As a bonus, they sometimes add fresh lettuce that they've grown themselves.

DINNER MENU

Sliced turkey with potatoes and asparagus

Cornbread

Pumpkin pie

Cherry drink


ISS crew members are seen playing chess in this photo from April 2023

20:30
FREE TIME

This schedule is for a typical work day on the ISS. Astronauts usually get Saturdays and Sundays free to relax. Even on working days they get an hour of leisure time in the evening. This is for whatever they enjoy doing, whether it's reading a book, playing a game, watching a movie or using social media. However, there's another popular activity that's unique to life in orbit, and that's gazing out of the window. There's always something new to see as Earth spins beneath them, with never more than 45 minutes to wait until the next sunrise or sunset.

14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00

Did you know?

In 24 hours, the ISS orbits Earth 16 times

21:30
BEDTIME

We've already looked at some of the more exotic quirks of sleeping in space, such as the flash of cosmic rays and the lack of perceptible gravity, but there's another more mundane problem too. That's the constant sound of machinery, which forces most crew members to sleep with earplugs in. Even so, many of them have difficulty sleeping for more than about six hours, despite having 8.5 hours of scheduled sleep time. Fortunately, all the sleeping compartments have laptop computers to keep insomniac astronauts entertained.


ESA astronaut Wubbo Ockels gets into a customised sleeping bag he designed himself

SPACE JUNK UNCOVERED

Over 60 years of spaceflight has cluttered Earth's orbit with debris. How do we track this material, and can we bring it safely back down?

WORDS **ALEX DALE**

On 4 October 1957, the Soviet Union launched Sputnik 1, the first artificial satellite to orbit Earth. But that historic day also saw another first – the rocket that propelled Sputnik into space detached and became the first piece of space junk. Space junk, or orbital debris, is the common term for any human-made object in orbit which no longer serves a purpose. It ranges from bus-sized items, such as non-functional spacecraft, to nuts and bolts and dust from motors. Since 1957, the amount of space junk surrounding our planet has steadily grown, to the point where the US Space Surveillance Network is tracking the movement of more than 34,600 objects five centimetres wide or larger.

While the risk to life on Earth is low, space junk poses a significant problem for craft in orbit. It can travel at up to 17,500 miles per hour, and at that velocity, even a collision with a piece of debris a couple of centimetres wide could be terminal to a spacecraft. To prevent its satellites and spacecraft being damaged, in 2007 NASA entered into an agreement with the United States Strategic Command, which tracks the flight paths of thousands of pieces of debris daily via ground-based radar, as well as lidar that measures distance by illuminating a target with a laser and analyses the reflected light. If the likelihood of a collision is one in 10,000 or higher, NASA is informed and can steer the craft out of the way. The International Space Station has had to make dozens of these evasive manoeuvres since its construction was completed in 2011.

Even if we never launch another item into space, it's possible that the amount of orbital debris will remain stable until around 2055, and may then increase. This is a scenario proposed by NASA scientist Donald Kessler in 1978, called Kessler syndrome, in which the increased amount of debris heightens the chance of collisions, creating more debris and causing a domino effect. "We have already reached the tipping point," Kessler says. "We must remove some of the objects to make Earth orbit sustainable." If we don't act, space exploration could become unfeasible. "Collisions between large objects will generate small fragments at an increasing rate," says Kessler. "This will require more shielding on spacecraft, until the use of space becomes too expensive."

While there are proposals to remove debris, they are in their early stages. Until we can develop cheaper techniques, international guidelines have been drawn up to prevent further launches exacerbating the problem, including ensuring that objects are removed within 25 years of them becoming obsolete.

2 EXTERNAL FUEL TANKS
Discarded fuel tanks are some of the most dangerous items currently in orbit due to their combustible nature. Under current international guidelines, fuel tanks discarded by rockets need to be emptied of fuel after the mission is complete so they do not explode at a later date, causing yet more debris.

3 FLECKS OF PAINT
Even tiny paint chips can cause massive damage if they collide with a spacecraft due to the remarkable speeds at which they orbit our planet. In 1983, a fleck of paint 0.2 millimetres in size hit Space Shuttle Challenger's front window, leaving a crack.

DID YOU KNOW? In 1997, part of a Delta II rocket struck a woman in Oklahoma

COMMON FORMS OF ORBITING DEBRIS

NASA estimates there are over 500,000 pieces of space junk the size of a marble or larger in orbit, and millions more too small to be tracked

1 ROCKET BOOSTERS

Boosters are rockets that give spacecraft enough thrust to escape Earth's gravity and are then discarded. Lower stage boosters, such as the Space Shuttle's iconic solid rocket boosters, separate during the first few minutes, and so do not enter orbit, crashing harmlessly into the ocean. But later stage boosters are deployed and released in orbit. These can break up or explode, and are a leading cause of space debris.

7 COLLISION DEBRIS

Collisions between artificial satellites – such as the 2009 incident that destroyed the US' Iridium 33 communication satellite and the deactivated Russian Kosmos 2251, generate large amounts of debris due to the speed of impact. This has been calculated to be around 26,170 miles per hour by space debris expert Dr Hugh Lewis of the University of Southampton.

4 DROPPED EQUIPMENT

Some space junk is down to human error on spacewalks. In 2008, astronaut Heidemarie Stefanyshyn-Piper dropped a toolbox containing grease guns and a putty knife. American spacewalker Ed White lost a glove in 1965, and it stayed in orbit for a month. Piers Sellers dropped a spatula during a test of heat-shield repair materials in 2006.

5 MICROMETEOROIDS

Some types of space debris are naturally occurring and date back to the birth of the Solar System. Micrometeoroids are tiny rock particles that typically weigh less than a gram, and can often survive entry into Earth's atmosphere. These razor-sharp rocks are common and pose a threat to spacewalkers, damaging handrails and tearing spacesuit gloves.

6 OBSOLETE SATELLITES

In 2022, there were 3,409 inactive satellites orbiting our planet. As some orbit at high altitude, it could take centuries for many to re-enter Earth's atmosphere. Vanguard 1 holds the record for the oldest satellite currently in orbit. Launched in 1958, it ceased to function in 1964 and is expected to remain in orbit for 200 more years.

SPACE JUNK BY NUMBERS

1 in 1 trillion

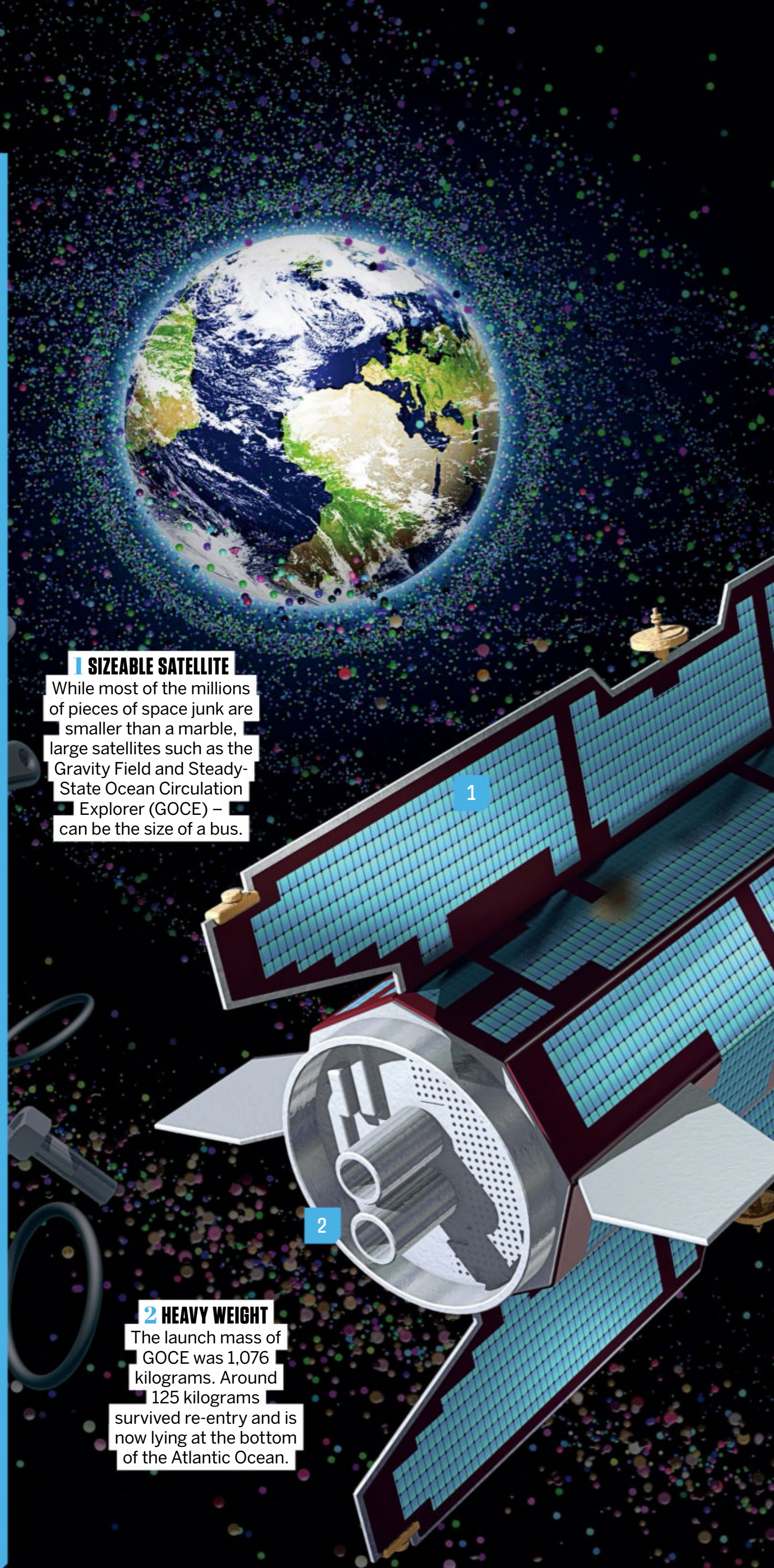
The tiny chance you'll be hit by a piece of space junk

3,000

Thousands of trackable pieces of debris were created when China destroyed a weather satellite in an anti-satellite test in 2007

22,369 MILES PER HOUR

The average speed of space junk on impact with another object



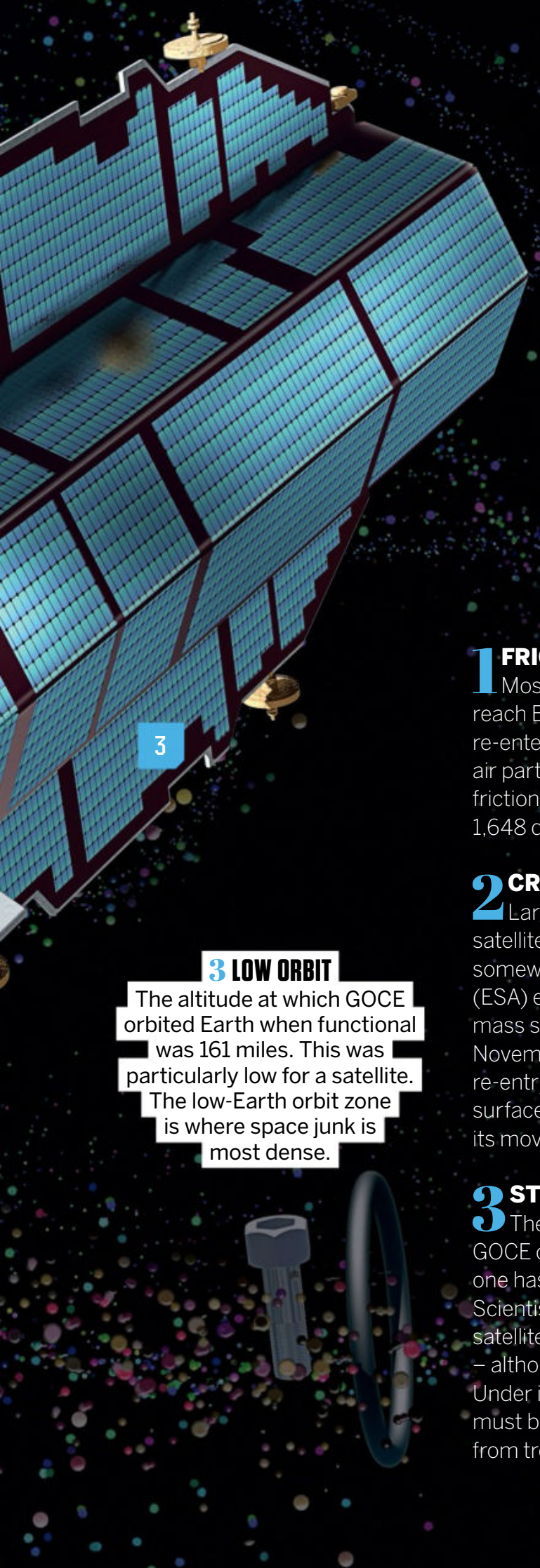
1 SIZEABLE SATELLITE
While most of the millions of pieces of space junk are smaller than a marble, large satellites such as the Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) – can be the size of a bus.

2 HEAVY WEIGHT
The launch mass of GOCE was 1,076 kilograms. Around 125 kilograms survived re-entry and is now lying at the bottom of the Atlantic Ocean.

DID YOU KNOW? Earth-based lasers could be used to rob large pieces of junk of their momentum, hastening their fall to Earth

THE FATE OF SPACE JUNK AS IT RE-ENTERS EARTH'S ATMOSPHERE

Human-made debris of all shapes and sizes is continually falling towards Earth as it leaves orbit, so why is the risk to human life so low?



3 LOW ORBIT
The altitude at which GOCE orbited Earth when functional was 161 miles. This was particularly low for a satellite. The low-Earth orbit zone is where space junk is most dense.

Did you know?
There is frozen astronaut urine floating in space

1 FRICTION BURNS
Most space junk burns up long before it can reach Earth's surface. This is because when it re-enters our atmosphere at great speed, it hits air particles, which rub against it and cause friction. This subjects junk to heat of around 1,648 degrees Celsius.

2 CRASHING TO EARTH
Larger space junk, such as the GOCE satellite, is capable of surviving re-entry somewhat intact. The European Space Agency (ESA) estimates as much as 25 per cent of its mass survived, splashing into the Atlantic in November 2013. This was an uncontrolled re-entry. However, since 70 per cent of Earth's surface is water, the risk to life was minimal and its movements were tracked by radar.

3 STEERING MECHANISM
The ESA estimates a re-entry the size of GOCE occurs around once a week, but so far no one has been seriously hurt by space debris. Scientists can minimise risks by steering falling satellites so that they land in unpopulated areas – although falling debris can cover a vast area. Under international guidelines, all new satellites must be designed so they can be directed away from trouble when they re-enter.

Number of objects tracked by the US Space Surveillance network:

1966	2,000
1976	2,000
1988	8,000
2000	10,000
2010	15,000
2013	21,000
2021	27,000
2023	34,600

135 tonnes

The space station Mir was the largest piece of junk to re-enter our atmosphere

15,880

The number of satellites placed in Earth orbit between October 1957 and September 2023

How long will space junk typically stay in orbit?

Orbiting at an altitude of 372 miles or below: several years

372 to 620 miles : several decades

Above 620 miles: a century or more

INSIDE MEDIEVAL HOMES

Step inside the grand designs of the Middle Ages and discover what life was like

WORDS SCOTT DUTFIELD

Following the fall of the Roman Empire, Europe was propelled into a new era commonly known as the medieval period, or the Middle Ages, which lasted until around 1500. Without emperors to dictate society, new feudal systems slowly emerged throughout the continent, where kings would bestow land and residences on nobles and lords, and ultimately the creation of the early class system was born. With that came a new way of life for different people.

At the bottom of the social ladder were peasants, also known as serfs, who lived in the most desolate of conditions. During the early medieval period, peasants' homes were made of sticks and earth. Heat and a means of cooking food were provided by a fire, the smoke from which would billow through the thatched roof. These often single-room occupancies were sparsely furnished, with straw beds usually shared with livestock. Life as a serf during the Middle Ages was profoundly impacted by the movement of the Sun. Those who lived in basic homes were not able to live by expensive candlelight, instead resorting to the fleeting illumination of a rushlight. To make a rushlight, a long stick from a rush plant was dipped in spare animal fat, called tallow, and lit so that it burned horizontally. Unlike the hours of light a wax candle can provide, these homemade lights would burn for less than an hour.

Did you know?

Prague Castle covers around 70,000 square metres

On the next rung of the ladder were the middle classes, such as doctors and merchants, who were often found in townhouses enjoying some luxuries, such as fireplaces and canopied beds, which emerged during the 13th and 14th centuries. Wood remained the prominent building material, with timber frames forming the bones of many townhouses, farmhouses and

DID YOU KNOW? Livestock were tried in court for killing people during medieval times

guildhalls. Walls were formed using a combination of wattle and daub – rows of short timber or stacks, known as wattles, were woven together and packed with a malleable clay-and-mud plaster called daub. Once dried, the wattle-and-daub walls hardened, creating a waterproof barrier from the outside world. Many homes were built as large open spaces, where families gathered within the main living space, called the hall. There were few internal walls, meaning privacy was a novel concept until the use of hallways and separated rooms became popular during the 1200s. Within two-storey homes, a separate private room called the solar was constructed above the hall and included bed chambers.

The upper echelon of society – nobility and the royal head of the feudal pyramid – occupied Europe's many manors and the first stone castles from the 11th century. Seen as an unyielding and permanent building material, the use of stone was reserved for castle-making. Some of the first stone castles in Europe, such as Colchester Castle in England, were even built on top of the foundations of Roman temples. Manors and castles boasted separate bedrooms throughout connected wings, often placing the king's room at the highest point in the castle for protection. Unlike the public bathhouses used by the lower classes, the nobility enjoyed private bathrooms to wash themselves. Similarly, while peasants did their business in the woods and the middle classes used outhouses or public latrines, the nobility used constructed castle 'garderobes' or 'privy chambers' to release their waste into the encompassing moat.

Did you know?

The world's first mechanical clock was invented in the 13th century

To fill the long dining tables of the great hall, food was plentiful in medieval kitchens and pantries. Throughout the thousand years of medieval history, people invented new and innovative ways to store food, both in the royal kitchens and humble pantries. Pickling, salting and smoking were some of the many ways people kept food safe. Some purpose-built 'still houses' were constructed to dry out fruits and herbs in places where domestic homes didn't receive enough sunlight to dry them out.

Before the stove was invented during the 18th century, medieval cooking was carried out directly over a fire. Among the poorer members of society, community kitchens were built to provide public sustenance, whereas wealthy homes were kitted out with pots and pans for private meals. To redirect the smoke produced from cooking on an open fire, outdoor chimneys were invented in Western Europe during the 12th century.

BEHIND MEDIEVAL DOORS

Discover some of the facilities wealthy people enjoyed during the 13th century

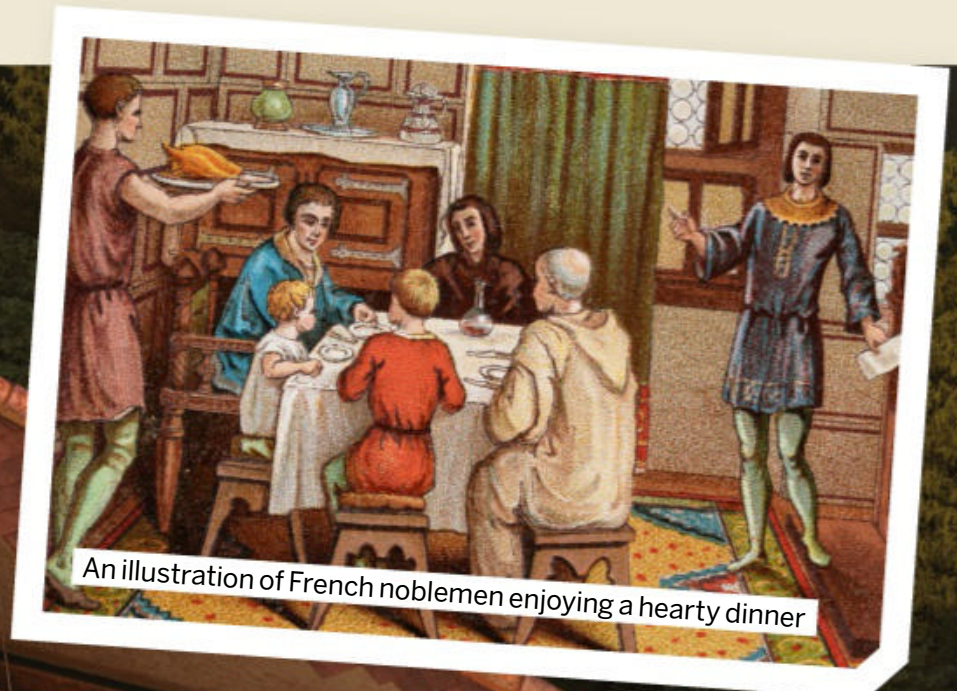
DID YOU KNOW? Between 1000 and 1347 CE, the population of Europe grew from 35 to 80 million people

9 ROOF

A variety of materials were used to build the roofs of European medieval homes, inducing clay and slate. Water reeds were commonly used on farmhouses to create thatched roofs.

5 BED

The construction of beds differed across the classes in the Middle Ages. Peasants stuffed mattresses with straw and wool, whereas the wealthy lay on mattresses made from feathers.



An illustration of French noblemen enjoying a hearty dinner

9

5

6

10

4

6 WINDOWS

Despite the Romans' use of glass windows, many homes in medieval Europe weren't privy to the methods of glass-making until later in the era, so they resorted to using wooden shutters and even linen soaked in tallow for transparency.

10 FURNITURE

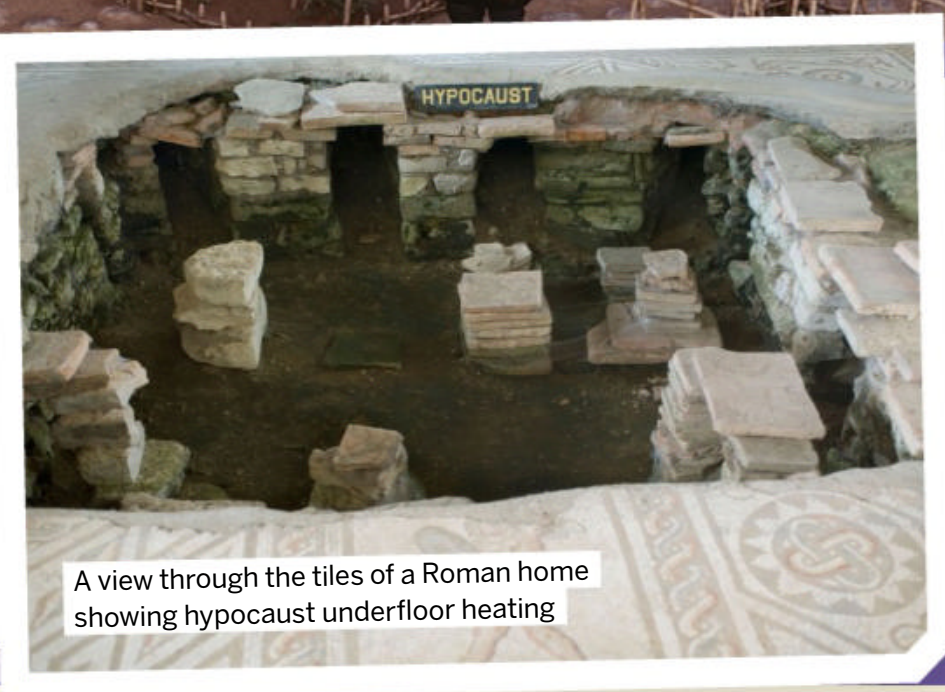
Home decor consisted of basic wooden tables, chairs and trunks until a flurry of new furniture, such as cupboards and four-poster beds, emerged during the 14th and 15th centuries.

4 HALL

Homes during this time were built as open spaces that generally included some sort of hall in which the residents gathered to eat and sit aside a roaring hearth.

LOST HEATING SYSTEM

During the reign of the Romans, countless quality-of-life inventions were made, including an underfloor heating system known as a hypocaust. Hypocausts lay beneath the floors of Roman homes, which were raised by pillars called pilae, which themselves were placed on a tiled floor. The hot air produced by adjoining fires circulated through the hypocaust and heated the floors of the home. However, during the Middle Ages, this technology was lost in many countries throughout Europe, including Britain. Unaware of the heating abilities of the Roman hypocaust, the Saxons that came to Britain's shores destroyed or ignored the systems, resorting to the less efficient method of smoke-billowing open fires for heat.



A view through the tiles of a Roman home showing hypocaust underfloor heating

An example of a peasant's home during the Middle Ages

HOMES AROUND THE WORLD

Delve into the many different dwellings of the Middle Ages

Privy chambers were used for the quick removal of human waste from castles into the moat

"During the early medieval period, peasants' homes were made of sticks and earth"

3 RUSSIA

Traditional peasant homes called izba were found across the rural landscapes of Russia during the Middle Ages. Until the 10th century, simple homes were made from stacking logs of wood, with no windows or doors – just a small entrance hole. With a stone hearth, smoke was vented through the only opening. As time progressed, the izba developed to include wooden windows and doors, as well as a brick Russian stove for heating and cooking.

Did you know?

Peasants made up 90 per cent of the English medieval population

DID YOU KNOW? The average life expectancy during the Middle Ages was 33 years old

2 MONGOLIA

During the 13th century, when the empire of Genghis Khan controlled Mongolia, many nomadic families resided in a circular tent-like structure called a ger, also known as a yurt. Their ingenious design allowed people to erect their wooden skeletons quickly while on the move. Layers of sheep wool felt were then draped over the wooden frame and secured using animal hair rope.

5 KOREA

A traditional private Korean home during the Middle Ages was known as a hanok. Timber formed the interior of the supporting structure of the hanok, while its walls were made of brick and stone. Clay tiles coated the roofs and windows were made from interlocking pieces of wood. Interior rooms were divided by sliding paper doors called changhoji and heated with a similar underfloor heating system to the hypocaust, called the ondol system.

1 JAPAN

Between 1185 and 1606 CE, many who lived outside of the lavish castles and villas of Japan's most wealthy resided in traditional homes known as minka. Minka came in a variety of categories, such as farmhouses called nōka, mountain houses called sanka and urban homes called machiya. Each type was different in its construction, but usually featured a hardened earth floor, called a doma, for the purpose of cooking and a raised wooden platform for sleeping.

4 CHINA

Siheyuan, which translates to 'quadrangle', were common homes in China during the Middle Ages. Built around a central courtyard, a siheyuan is typically made up of four one-storey buildings connected in a rectangle, with one front gate. These buildings were traditionally constructed from simple materials such as wood and tile.

HOW BIG BEN WAS BUILT

It's one of the most famous sights in London's skyline, but how and when was this clock constructed?

WORDS AILSA HARVEY

Big Ben is actually the bell of London's iconic clock tower, rather than the tower itself, perched high on the banks of the River Thames at the Palace of Westminster, otherwise known as the Houses of Parliament. The tower, which was given the name Elizabeth Tower in 2012, was built shortly after the fire that ravaged the Palace of Westminster in 1834. The design of the replacement building was commissioned to architects Charles Barry and Augustus Pugin, who designed the clock tower as part of the palace in the fashionable neo-Gothic style of the time. It wasn't until September 1843 that construction work on Big Ben began, the challenge being to produce the world's biggest and most powerful chiming clock.

The most difficult feat of engineering to achieve, however, was its exceptional time-telling accuracy. Big Ben has such a large clock that the minute hands are four metres long. Due to it being exposed to the elements, clock-makers worried that the mechanics commissioned for the tower would be greatly manipulated by strong winds. Unlike most clock towers of the time, Big Ben was built with heavy weights that pull the hands around the clock at a consistent pace. This pace is controlled by two swinging arms as they move a pendulum backwards and forwards. As the pendulum moves, it turns a mechanical wheel one position every second. This ingenious design was the brainchild of Edmund Beckett Denison and George Biddell Airy and ensures that London continues to run on time nearly two centuries later.

WHY THE TOWER WAS RENOVATED

If you visited Big Ben between 2017 and 2022, you likely would have noticed that much of the tower was hidden away beneath scaffolding and tarpaulin. During this time, Big Ben was undergoing renovations to stop leakage and erosion, as well as returning the clock's dials to their original blue colour. This project cost around £80 million ($98 million). In the original design, the clock face was lit up using gas power. Since the renovation, more environmentally friendly and energy efficient LED lights have been installed. A large portion of the original materials have now been replaced so that cracks in the tower don't become hazardous in the future. The work included around 700 pieces of original stone that were newly carved at the building site. Among the main challenges of the renovation were the dismantling, repair and repainting of all the components of the Big Ben bell, followed by its reconstruction.

Around 500 people worked on Big Ben's renovation

CREATING THE WESTMINSTER CHIMES

Big Ben's famous tune needed to be composed before the bells could be manufactured. The large, central bell rings in the note E natural, and the four smaller bells in G sharp, F sharp, E and B. Dr Joseph Jowett was tasked with writing the short tune in 1793. Big Ben chimes on every quarter of the hour, with the full version being played on the hour. Casting of the original bell began on 6 August 1856 in a large mould. Inside two specially made furnaces, 18 tonnes of melted metal was produced. After cooling and being stood upright, the bell measured two metres tall with a diameter of nearly three metres. The first bell casting failed to chime at the right pitch, so it was remelted. Luckily the second casting was approved and could be transferred to the tower. The chunky bell required 16 horses and pre-planned road closures to haul it safely to Westminster.

Londoners lined the streets to watch the horses pull the new bell towards the clock tower in 1858

INSIDE THE TOWER

Discover Big Ben's intricate construction

1 ROOF TILES
3,433 cast-iron roof tiles make up the spire. These were removed for waterproofing to be added during the renovation work.

2 HAMMERS
Hammers built on the exterior of the bells move to strike them from the outside.

3 CLOCK FACE
There are 324 opal glass pieces making up each dial of the clock.

4 CLOCK MECHANISM
Someone needs to wind up the clock three times a week. This process takes an hour and keeps the pendulum ticking accurately within two seconds per week.

5 PENDULUM
The pendulum is 4.4 metres long and weighs 310 kilograms.

6 LOCKED UP
Prison rooms were built into the lower levels of the tower. These were originally for members of parliament who didn't follow the rules in the House of Commons.

7 SOFT LANDING
Sand bags were placed at the bottom of Big Ben to prevent damage if any components fell.

8 TOWER LIFT
The tower has a 334-step staircase. Alternatively, its central lift can be used to climb it.

9 PENDULUM WEIGHTS
Big Ben made no sound for nine months in 1976 when this 203-kilogram weight broke and needed repairing.

10 BELFRY
A cast-iron frame was built to encase the bells. During renovations these rusted parts were replaced.

11 GREAT BELL
The central 13.7-tonne bell is called Big Ben, which is surrounded by four smaller bells.

Did you know?
Big Ben was originally called St Stephen's Tower

DID YOU KNOW?
Snowfall in 1962 caused Big Ben to ring in the New Year ten minutes late

INSIDE A LUXURY HYDROFOIL YACHT

Discover how this all-electric watercraft sails above the surface

WORDS **SCOTT DUTFIELD**

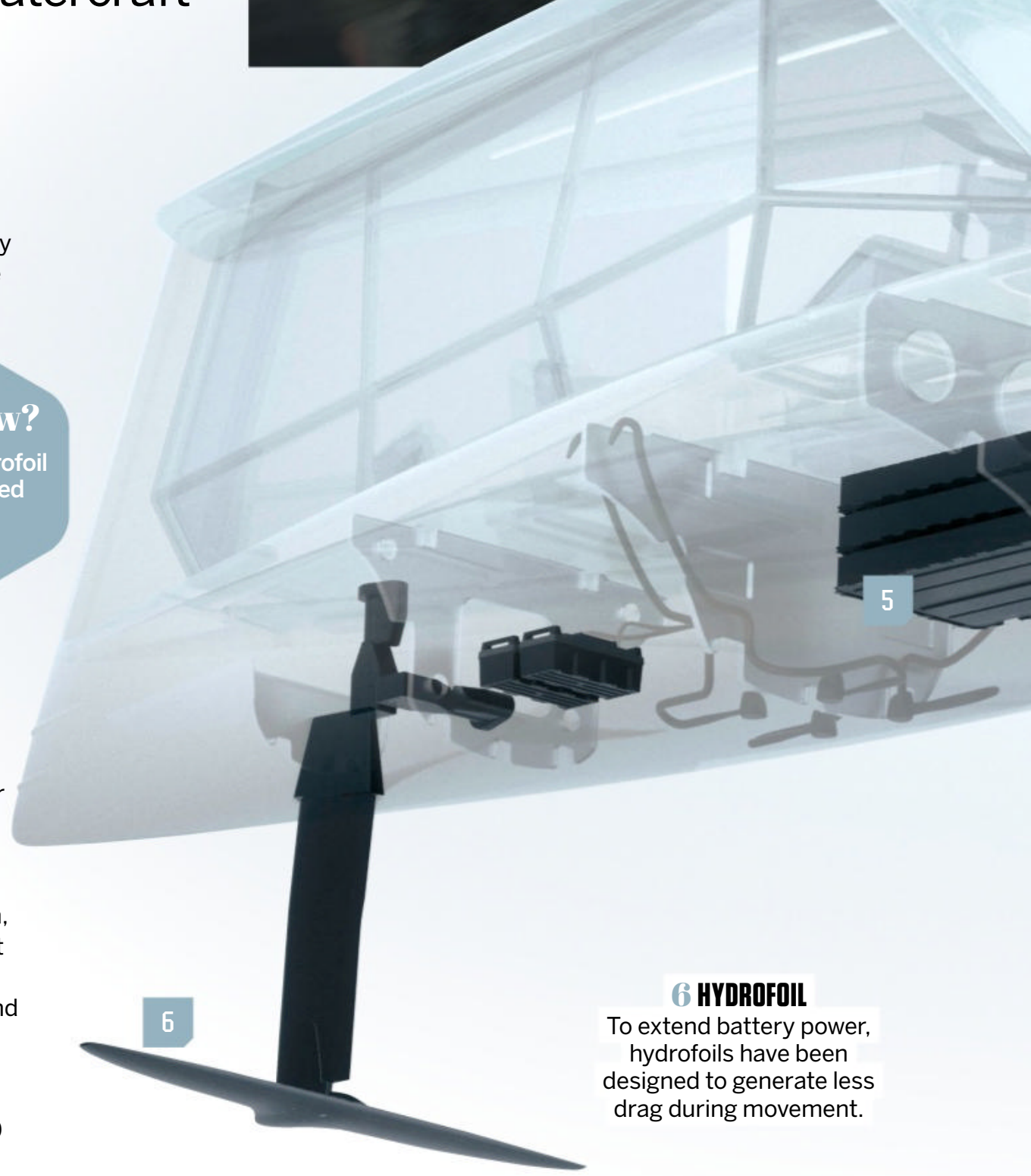
A 3D render of the Icon racing through the water

In May 2023, car manufacturer BMW unveiled its new, all-electric foiling watercraft called the Icon, a 13.5-metre-long vessel that relies entirely on battery power. Like other hydrofoil vessels in the ocean, the Icon uses a set of hydrofoil wings and propellers for motion. However, instead of fossil-fuelled motors, propellers are spun by two 100-kilowatt electric motors that are supplied by six batteries beneath the watercraft. Much like the wings of an aircraft, hydrofoils such as the Icon use underwater wings that reduce the amount of drag a vessel experiences, increasing speed and fuel efficiency. They achieve this by utilising Newton's third law of motion, which states that when one object exerts a force on another object, the second object exerts an equal and opposite force on the first. For hydrofoils, this equates to the force pushed down on the water and the water's equal returning force, which keeps it stable while it sails.

Did you know?

The first hydrofoil was patented in 1869

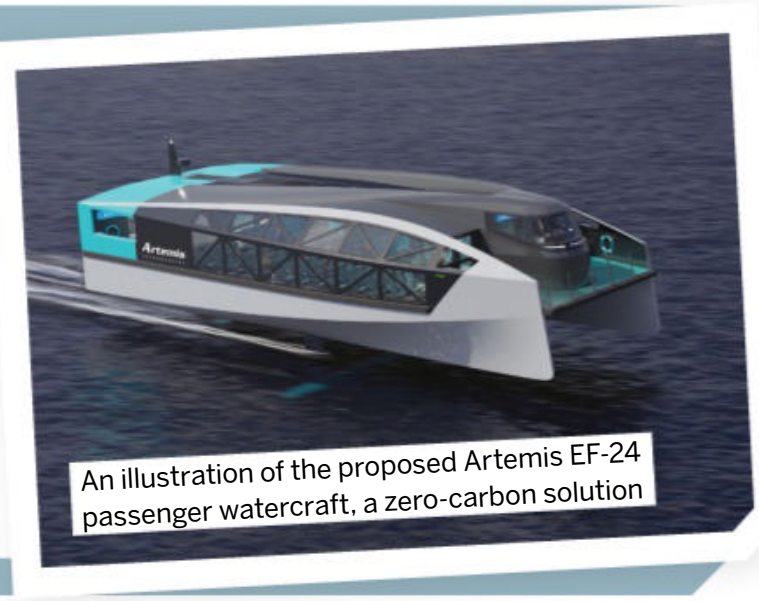
The curved shape of a hydrofoil wing is what gives it its hydrodynamic abilities. While moving, water has to travel faster over the longer top side of a hydrofoil wing than the water moving beneath it. As water rapidly passes over the top of the wing, its pressure decreases – a phenomenon known as Bernoulli's principle. The pressure below the wing remains high, which causes the wing to lift upwards. When the force of the lift is greater than the weight of the vessel and the force it applies on the water, the hull of the vessel will rise above the surface and appear to fly above the waves. Thanks to the Icon's hydrofoil wing and hull design, BMW and partner TYDE claim that the energy requirement is reduced by up to 80 per cent compared to other hydrofoil designs. This gives it a range of more than 50 nautical miles, which is around 58 miles.



6 HYDROFOIL
To extend battery power, hydrofoils have been designed to generate less drag during movement.

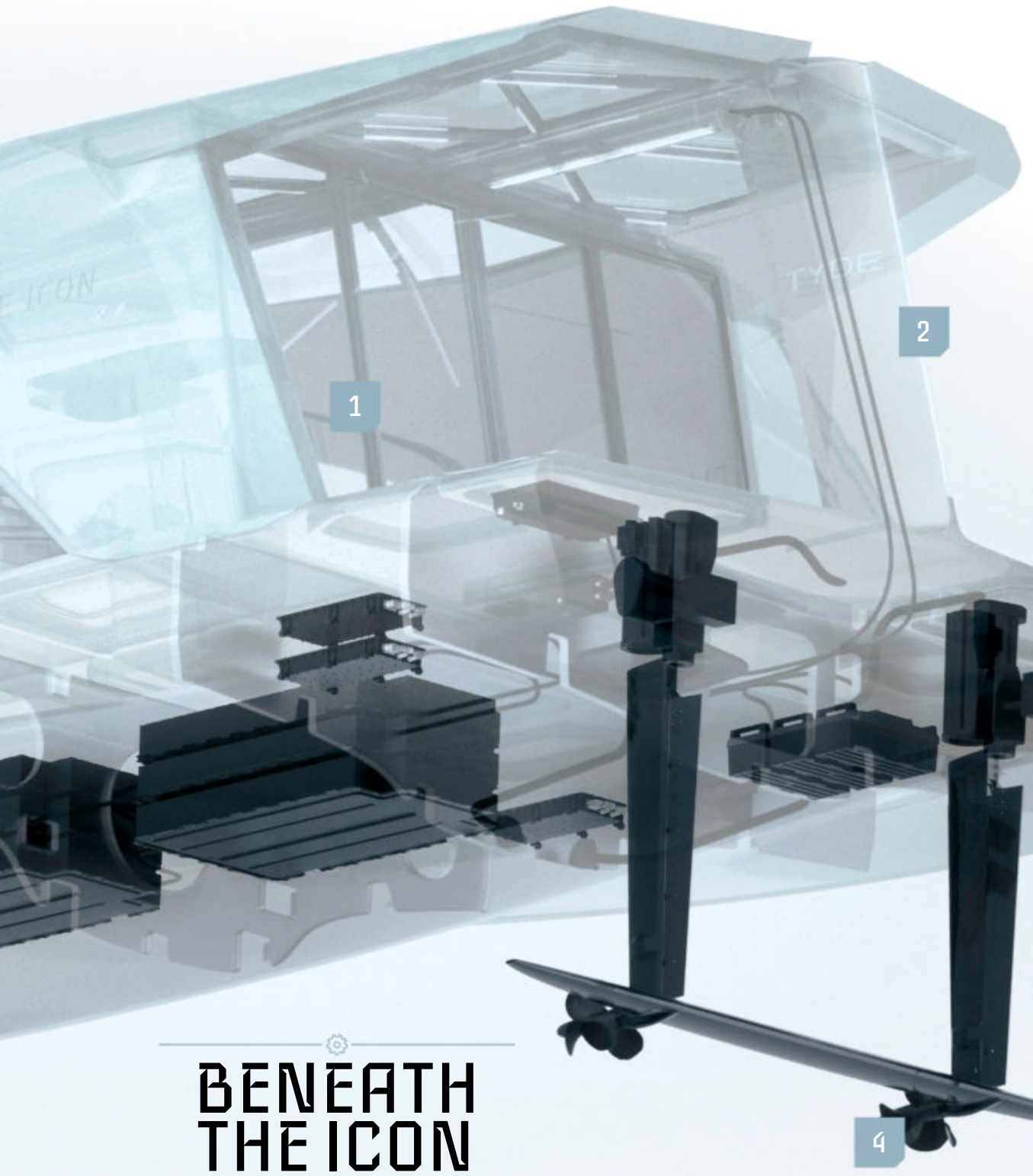
FUTURE FERRIES

Private yachts and surfboards are where you'll often find hydrofoil technology. However, there's a growing interest in their use for public transport. As an all-electric alternative to the diesel-guzzling engines of commercial ferries, hydrofoils might become the zero-carbon norm. Hydrofoil ferries aren't a new concept, having been used since the mid-1900s. Several companies around the world are developing all-electric watercraft as a sustainable solution. For example, Artemis Technologies, a Northern Ireland-based manufacturer, is developing several different hydrofoils for public transport, such as the EF-24 passenger craft. Countries around the world are also beginning to turn to future all-electric hydrofoils, including two new hydrofoil Artemis ferries that are set to start a trial service around the Orkney Islands in Scotland in 2025.



An illustration of the proposed Artemis EF-24 passenger watercraft, a zero-carbon solution

DID YOU KNOW? The largest passenger hydrofoil in the world weighs 165 tonnes and can carry 250 passengers



BENEATH THE ICON

How this all-electric watercraft stays afloat

1 DIGITAL HELM
From navigation charts to AI-based collision avoidance, all aspects of the vehicle can be accessed through a touchscreen display with voice activation.

2 RECHARGING CABLES
At a standard marina charging station, the Icon's battery system can charge to 50 per cent in just two hours.

3 CONTROL SYSTEM
Computerised rudders autonomously stabilise the Icon through the vessel's flight-control system.

4 PROPULSION
Two foil propellers provide a maximum speed of 30 nautical knots, or around 35 miles per hour.

5 BATTERIES
High-voltage BMW i3 batteries hold 240 kilowatt hours of power.

ARTIFICIAL INTELLIGENCE SAILING

The gap between the hull and hydrofoil wings can create instability while a hydrofoil is travelling above the surface of the water. To combat this, Swedish manufacturer Candela has created the C-8 series of hydrofoil watercraft, which use artificial intelligence to correct hydrofoil wing positions in real time. Using an array of sensors around the hull of the C-8, the distance between the vessel and the surface of the water can be continuously monitored. As the distance changes, either as a result of the wind or waves, the AI program informs actuators on the wings, which automatically change their position under the water to keep the vessel as stable as possible.

The Candela C-8 out on the water

Inside the Icon are 360-degree rotating chairs and a 32-inch touchscreen control panel

The Icon watercraft at a TYDE charging port

SELF-POWERED PAVEMENTS

With the implementation of piezoelectric systems, the movement of traffic and pedestrians could light the way

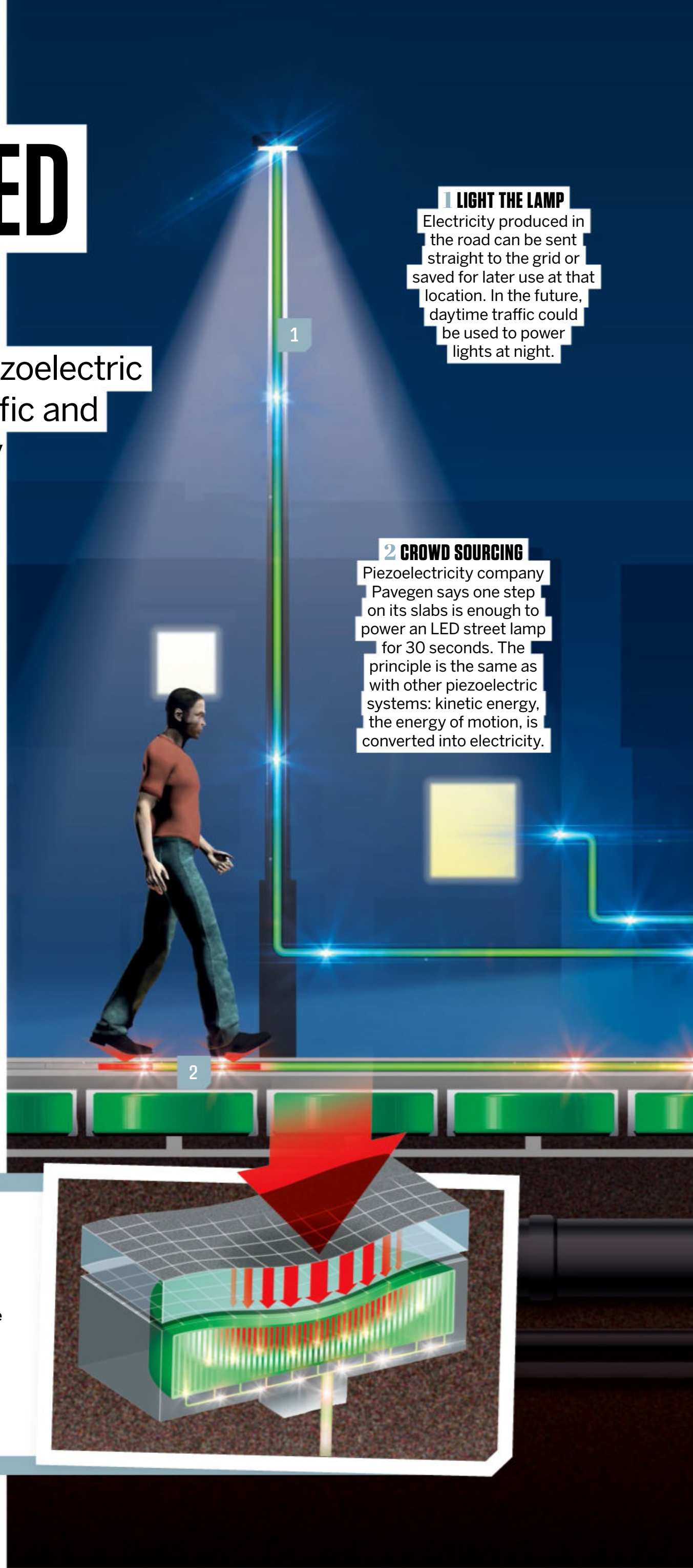
WORDS **MAGGIE PHILBIN**

Something for nothing always appeals. Why pay a fortune to power a motorway when it could just as easily power itself? If our roads were paved with the right stuff, we could store the electrical charges that accumulate under the ground and use that to illuminate our roads.

Piezoelectricity is electricity that's generated from pressure, and it's used in a wide range of applications today, from cigarette lighters to inkjet printers. The only question is, can it scale? It's one thing to generate low-level lighting by dancing on a disco floor – as seen in 'eco-discos' in London and Rotterdam – but could piezoelectric pads set under tarmac power the lights and signage along our major roads?

Piezoelectricity is a rapidly expanding industry, and London-based Pavegen Systems is one of the companies spearheading its development. Launched by industrial designer Laurence Kemball-Cook, it designs 'smart' pavement tiles that act as an off-grid power source. They were trialled at West Ham station during the London 2012 Olympics, lined the approach to the finishing line of the 2013 Paris Marathon and floor the corridors of schools in Kent and Gloucester. More recently, in 2017, California's Energy Commission awarded grants to two organisations to demonstate the technology in San Jose.

"The biggest challenge is to change attitudes and perceptions," says Kemball-Cook. "Many people simply don't believe it works." His vision includes tiling large public spaces and football stadiums, where excited capacity crowds could power the local community while supporting their favourite teams.



HOW PIEZOELECTRICS TURN MOVEMENT INTO ENERGY

Piezoelectricity is generated in certain materials, such as ceramic and crystal, most commonly quartz, when they are put under pressure, for example by a passing car. In these materials, an electrical charge builds up on their surface as ions are displaced. Piezoelectric crystals produce high voltage with low currents; this makes them ideal for small applications, such as the ignition on a gas oven. Whether it can be efficient on a larger scale remains to be seen.

DID YOU KNOW? Viruses can produce power. California researchers created a current from the M13 bacteriophage

STEPPING UP

Further advances in storage are needed if piezoelectricity is going to power traffic lights and street lamps by itself

3 SMART ROADS

Piezoelectric roads can collect data on traffic conditions, meaning one day they could be used to monitor and advise traffic management systems.

4 ENERGY HARVESTING

The harvesting module collects and stores the energy generated by the piezoelectric pads, which would otherwise be wasted as heat.

5 CONGESTION CHARGE

Pads of metallic crystals are encased in a thin box underneath a layer of asphalt. When a car drives over the road it compresses the crystals, generating electricity. The electricity then flows towards the harvesting module.

Did you know?

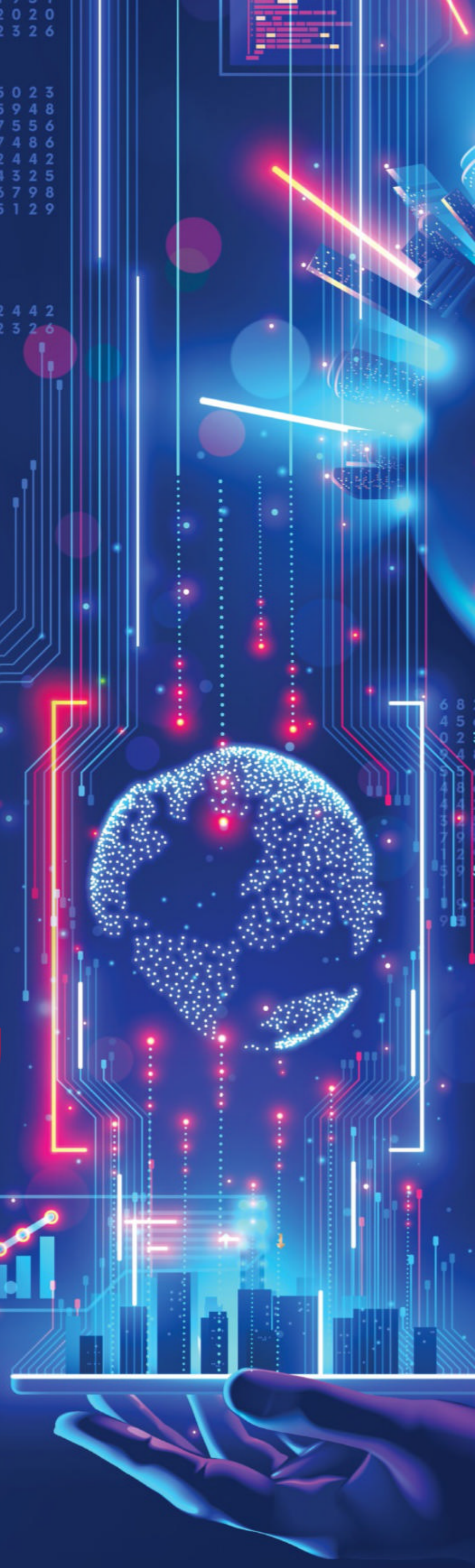
Pierre and Jacques Curie discovered piezoelectricity in 1880

"The biggest challenge is to change perceptions. Many people simply don't believe it works"

6G FASTER, SMARTER, BETTER

WORDS MARK SMITH

Experts are already laying the groundwork for 6G, but what is this new type of network?



DID YOU KNOW? While smartphones will remain a key device, new human-machine interfaces will make them more convenient to use

Picture a world where you control machines with your mind, where driverless cars move through rush-hour traffic with no chance of being in a crash or where the internet is a thousand times faster than it is today. This is the promise of 6G. We've all heard of 5G, and most of us have probably already used this wireless technology to watch movies and play games, search online and do any number of other things at speeds that simply wouldn't have been possible even a few years ago. But progress never stops, and now we're entering a new era: 6G. But beneath its rather predictable name lies a technology that could change the world. So what is 6G?

The world around us is filled with an invisible web in which data from our smartphones, televisions, sensors, doorbells and pretty much every other type of smart technology communicates. The problem is that previous iterations of this invisible web – wireless networks like 4G – didn't have the bandwidth to send complex data like you'd have in, say, industrial devices. But that's changing. The 6G generation will use technology that enables it to send data at ultra-high frequencies.

Did you know?

Terahertz signals can pass through ceramics, plastic and paper

While 5G can support frequencies up to 100 gigahertz (GHz), for 6G the aim is to transfer data across waves in the hundreds of gigahertz, or terahertz (THz), ranges using technology such as edge computing, artificial intelligence and terahertz waves.

One of the goals of 6G is to support something called 'one microsecond latency'. Latency is the delay in information getting from one place to another – think of the annoying buffering when you're watching a movie on a tablet. 6G would work at one microsecond latency, which equates to one-millionth of a

Mobile World Congress visitors experiencing the Human Augmentation Platform, which allows people to communicate haptic sensations by being connected to a 6G network

© Getty

A 6G smart city model at the Ericsson stand at the Mobile World Congress

second – virtually instant. The ability to send and receive data in such volume opens up a whole new era of possibilities. There have been major advances in recent years in things like artificial intelligence, smart sensors and virtual reality, but they all still largely exist in isolation from one another. The end goal is to plug them all together virtually, and that's what 6G could do. It would have the bandwidth and low latency to form a new invisible network. But instead of just games and televisions, it would be robots, cars and even chips that might one day be plugged directly into our brains to enable us to interact with devices.

Another relatively new technology that 6G will help underpin is edge. Up until now, most smart technology has been connected to a central processor operating in the virtual cloud. Sensors on roads, for example, would have to send their traffic or weather data wirelessly to the cloud for a system to crunch the numbers. But edge means those sensors can be genuinely 'smart', with all the brains they need to decipher the data at the source rather than send it wirelessly to a central cloud network. This makes things faster and reduces the possibility of signals being interrupted, vital for something like controlling a driverless car in traffic. The use of 6G could also underpin a true virtual world for the very first time, where your physical self can operate virtually – perhaps working in a virtual office with virtual representations of your real-world colleagues or studying at a distant college or school. 6G would enable you to interact virtually with objects because it could transmit the vast quantities of data needed to represent things like touch and sensation in a minuscule amount of time. Mobile giant Ericsson is one of the companies working on this, and has called it the 'cyber-physical continuum'.

The same company also wants to create something called the 'internet of sensors', where things like physical touch or truly immersive experiences through next-generation augmented-reality glasses can be brought to life in vivid detail. Digital twin models will also be enabled by 6G. They allow experts to analyse what's happening in the physical world and simulate possible outcomes, anticipate needs and then take action back into the real world.

This all sounds really exciting, but we're not quite there with the technology yet. There are still few details on what 6G could actually look like in practice. The International Telecommunication Union (ITU) standardises wireless generations every decade, and it still remains to be seen how 6G will function. Most experts are predicting a launch date of around 2030 and for 6G to become fully commercially deployed by 2032, with companies like Huawei and Ericsson already laying the groundwork.

Did you know?

6G peak data rates could be up to 50 times faster than 5G

THE RACE TO 6G

With the future of communication within arms reach, companies and nation states alike are vying to be the first to make 6G a reality. The key players include the main network and wireless device providers such as Huawei, Samsung, Ericsson, Intel and Qualcomm. The Chinese and South Korean governments are also invested in taking the technology to the next level. Samsung is currently looking into the use of terahertz frequencies in order to build a network with an ultra-fast data transfer rate. Nokia and Ericsson are also developing networks which can operate in the 100 to 300 GHz frequency range.

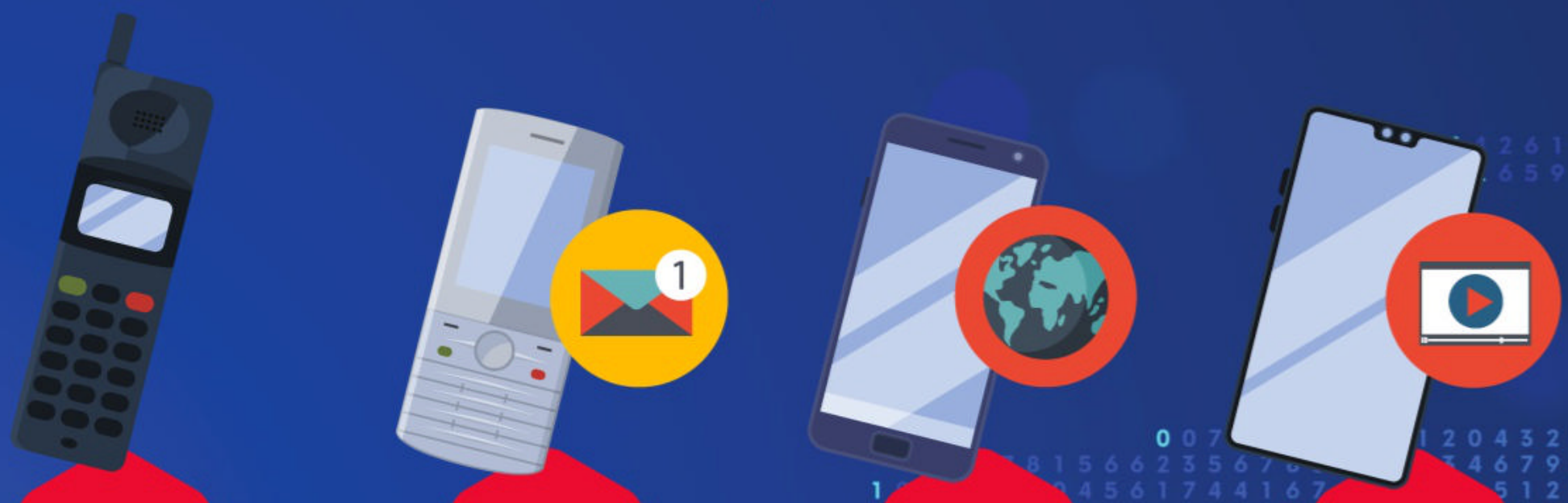
China is currently making big strides in 6G technology research

Smart cities of the future will be connected by an invisible network of 6G signals

DID YOU KNOW? Touchscreen typing will gradually get replaced by gesture and voice control

EVOLUTION OF NETWORKS

The 6G network is just the latest in a series of networking advances



1G

This had very basic voice call capabilities, was launched by Nippon Telegraph and Telephone in 1979 and was at first only available in Tokyo.

2G

In 1991 the Global System for Mobile Communication launched in Finland, and a year later in the US. It featured encryption and a download speed of 0.2 megabytes per second.

3G

Launched in Japan in 2001, it had data speeds of two megabytes per second, enabling things like video chat and faster web browsing.

4G

Brought in at the end of 2009, this was a big improvement on 3G, with a download speed of 12.5 megabytes per second. But it required a new generation of mobile phones to make it work.

5G

The version most of us are familiar with today, South Korea introduced it in 2019 and it can be between 20 and 200 times faster than 4G. It opened up a new era of machine connectivity, which is still being fully explored.

6G

The latest technology could underpin things like remote surgery, immersive reality and real-time communication between machines and the human brain.

CHALLENGES AHEAD

As with any other great advance in technology, not everything is going to be straightforward, and there remains much uncertainty around the timescale for 6G, with some potential roadblocks to be cleared first. One issue is the lack of available spectrum. Spectrum essentially means the range of radio frequencies allocated to the mobile industry and other sectors for communication over the airwaves. The problem is that there's only so much of it to go around before it all becomes one big untidy mess where nothing makes sense, and 6G needs a lot more of this spectrum than 5G. Another issue is the sheer expense of creating 6G networks. They'll have to be designed and built from the ground up, covering land, air and space. Companies are still weighing up whether they'll be able to monetise 6G enough to recoup their costs and make a decent profit.

A 6G low-latency operated robot that mimics the movements of sensors

5G towers are now a common sight, but 6G will require its own infrastructure

HOW 6G WILL WORK

The new network will feature a range of technology working in concert

Did you know?

China launched the world's first experimental 6G satellite in 2020

SPACE NETWORK

22,236 MILES

SMALLSAT CONSTELLATION

1,242 MILES

186 MILES

100 MILES

31 MILES

AIRSHIP FORMATION

AIRBORNE NETWORK

6.2 MILES

DRONE FORMATION

CONTROL LINK

FEEDER LINK

USER LINK

100 METRES

TERRESTRIAL NETWORK

3 MOBILE EDGE

Mobile edge technology will allow 6G signals to be processed faster at the source.

TELEMETRY, TRACKING AND CONTROL STATIONS

GATEWAY

DID YOU KNOW? Another benefit of terahertz-frequency signals is related to security and imaging

HIGH-EARTH ORBIT

LARGE SATELLITES

1 EYES IN THE SKY
Satellites in different orbits will provide connections in hard-to-reach areas of the globe.

ONBOARD PROCESSING

CUBESATS

LOW-EARTH ORBIT

2 INTEGRATED FLIGHT
The needs of 6G will require craft at various heights, including drones and airships to relay signals.

HIGH ALTITUDE

LOW ALTITUDE

4 GROUND NETWORK
A network of 6G towers or other technology will be constructed on the ground.

5 SMART TECHNOLOGY
Things like driverless vehicles will be able to send and receive signals to the network via the 6G infrastructure.

TERRESTRIAL HETNET

MOBILE EDGE COMPUTING

8G CORE

6 DATA CRUNCHING
Sophisticated data centres will be able to perform complex calculations and send them over the network almost instantly.

BUILDING A QUAKE-PROOF BRIDGE

Constructing a bridge that can withstand an earthquake is as simple as building a seesaw and swing over a playground puddle

WORDS **BRENDAN WALKER**

How do you build an earthquake-proof bridge when the geological conditions are too wobbly for conventional supports, and the locals are demanding an architectural wonder to rival the Golden Gate Bridge? That was the unique challenge facing California's Department of Transportation when it was tasked with building a new span connecting Oakland with Yerba Buena Island. The San Francisco area takes great pride in its skyline, but it's also notorious for its seismic activity. So this new span had to have brawn as well as beauty. Fortunately, an answer was found, taken straight from the playground.

The simplest way to understand how the San Francisco-Oakland Bay Bridge works is to think of the engineering principles of seesaws and swings. Imagine building a seesaw in a muddy, waterlogged playground. It requires only a small spot of firm ground to build the single central support to carry the weight of the two equal spans. Two children sit at either end of the seesaw, with their feet on the ground. The children can easily keep it balanced by producing relatively small forces with their legs, without having to hold the weight of the seesaw or themselves.

But what if one span is made much longer to avoid a big puddle? The child seated on this long span, now furthest from the pivot point, has to push harder through the mud to keep the seesaw horizontal and balanced. But their slender legs can't cope with the compression forces. To rebalance the system, the feet of the child on the short span are cast in a concrete block and used as an anchor. This poor child's legs are now in a state of permanent tension, and likely to snap. Stress is alleviated by pre-stretching a rubber cord by just the right amount and hitching the concrete block to the short span. The seesaw is now balanced, and the legs of both children can go back to dealing with much smaller forces.

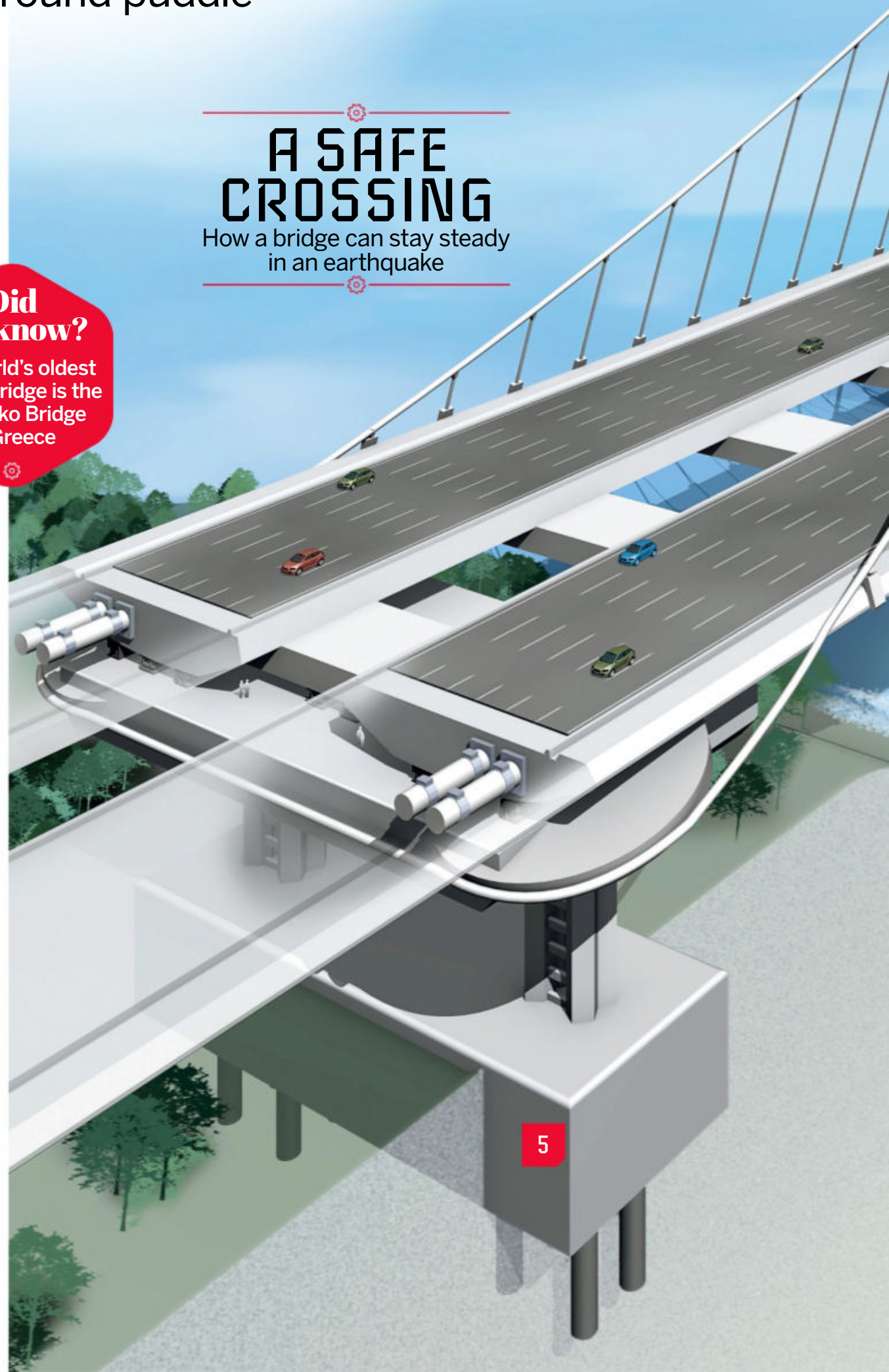
But how about surviving an earthquake, where shaking seismic forces are transmitted from the playground, through the central support, to devastate the attached spans? The central support is made taller, and both spans are attached at multiple points along their length and suspended. Now, like a swing hanging from a tree, the support structure can shake violently while the unequal spans below remain relatively steady.

Did you know?

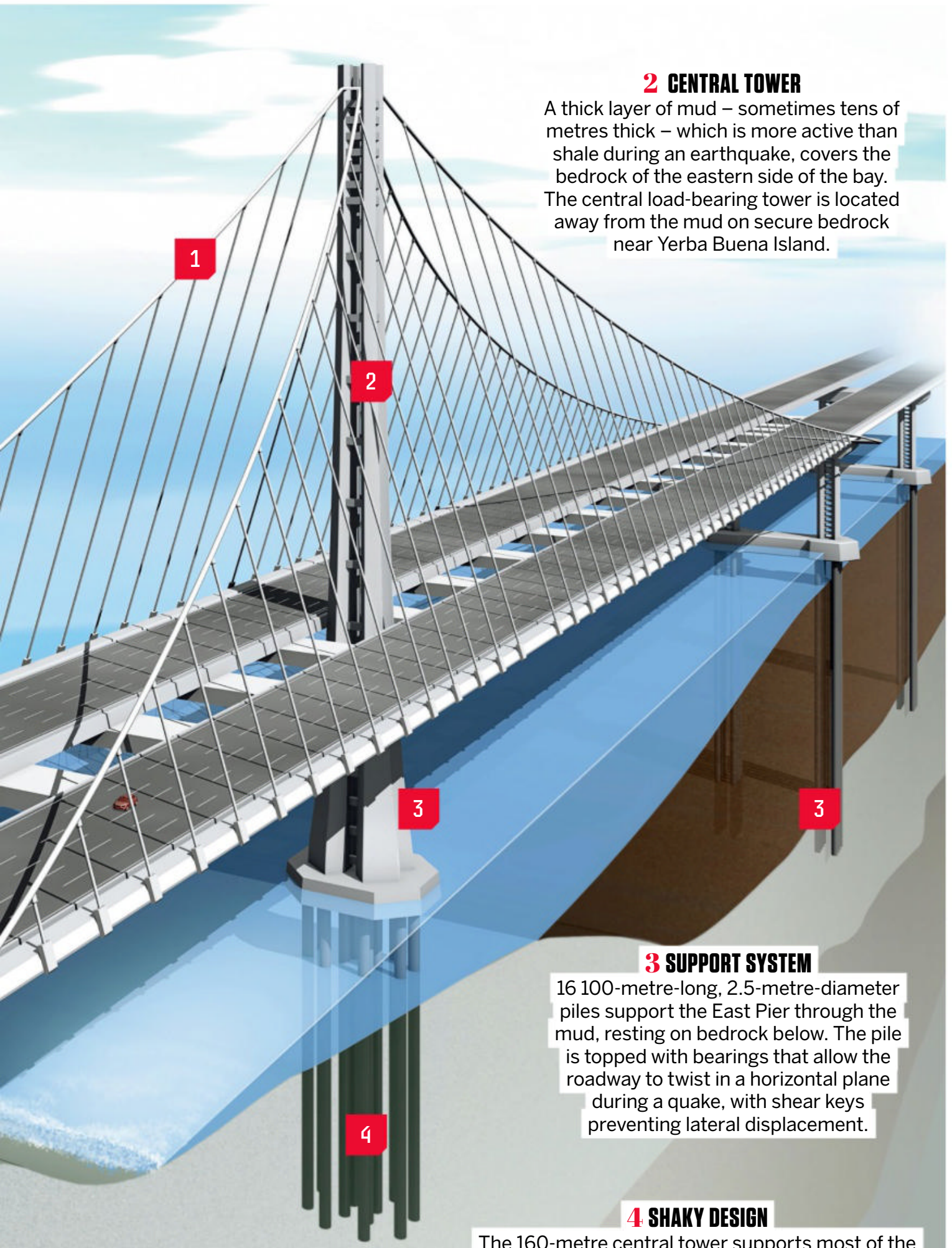
The world's oldest known bridge is the Arkadiko Bridge in Greece

A SAFE CROSSING

How a bridge can stay steady in an earthquake



DID YOU KNOW? The 102-mile-long Danyang–Kunshan Grand Bridge is the world's longest



2 CENTRAL TOWER

A thick layer of mud – sometimes tens of metres thick – which is more active than shale during an earthquake, covers the bedrock of the eastern side of the bay. The central load-bearing tower is located away from the mud on secure bedrock near Yerba Buena Island.

3 SUPPORT SYSTEM

16 100-metre-long, 2.5-metre-diameter piles support the East Pier through the mud, resting on bedrock below. The pile is topped with bearings that allow the roadway to twist in a horizontal plane during a quake, with shear keys preventing lateral displacement.

4 SHAKY DESIGN

The 160-metre central tower supports most of the bridge's dead load, but isn't connected directly to the roadways, which pass suspended either side of the tower. The tower is designed to remain elastic and shake independently of the roadways during an earthquake.

5 SELF-ANCHORING

The bridge's asymmetry subjects the West Pier to a lifting force. This pier is tied down to gravity footings cast into the rock below, further secured by four ten-metre-long piles. Stress created by the uplift is counterbalanced by a pre-stressed concrete cap beam, which means the bridge is balanced without relying on this pier to carry tension.

"The San Francisco area takes pride in its skyline, but is also known for its seismic activity"

THE QUAKE TEST

Could these British bridges survive a magnitude 7.0 earthquake?

TOWER BRIDGE, LONDON (1894)

Most rigid stone bridges would crack, lose structural integrity and collapse. However, this bridge's stone cladding is just cosmetic, and conceals a sturdy steel-framed lattice. This London bridge would be unlikely to tumble, although some repointing may be necessary.

SPAGHETTI JUNCTION, BIRMINGHAM (1972)

With 559 concrete columns carrying 2.5 miles of roadway, this isn't built to withstand the magnitude of lateral movement anticipated by freeways around the San Andreas Fault. The roadway is likely to buckle and twist, with columns failing catastrophically.

FORTH BRIDGE, SCOTLAND (1890)

At over 1.5 miles, this cantilever railway bridge carries the Edinburgh–Aberdeen line across the Firth of Forth. Another truss bridge, Minato Bridge in Japan, is being retrofitted with earthquake-proof features. Without a similar retrofit, the Forth may end up in the Firth.

Win!

ONE OF TWO CODING ROBOTS WORTH £120

This month we're giving you the chance to win one of two Ozobot Bit+ Entry Kits. Through creative coding software, children can learn how to program how and where the Ozobot moves using its optical sensors and colour-coded instructions

For your chance to win, answer the following question:

Which of these describes a fear of spiders?

A: ARACHNOPHOBIA B: COULROPHOBIA C: TRYPOPHOBIA

Enter online at **howitworksdaily.com** and one lucky entrant will win!

Terms and Conditions: Competition closes at 00:00 GMT on 23 November 2023. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: **www.futuretcs.com**. Entries must be received by 00:00 GMT on 23/11/2023. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

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BRAINDUMP

Amazing answers to your curious questions

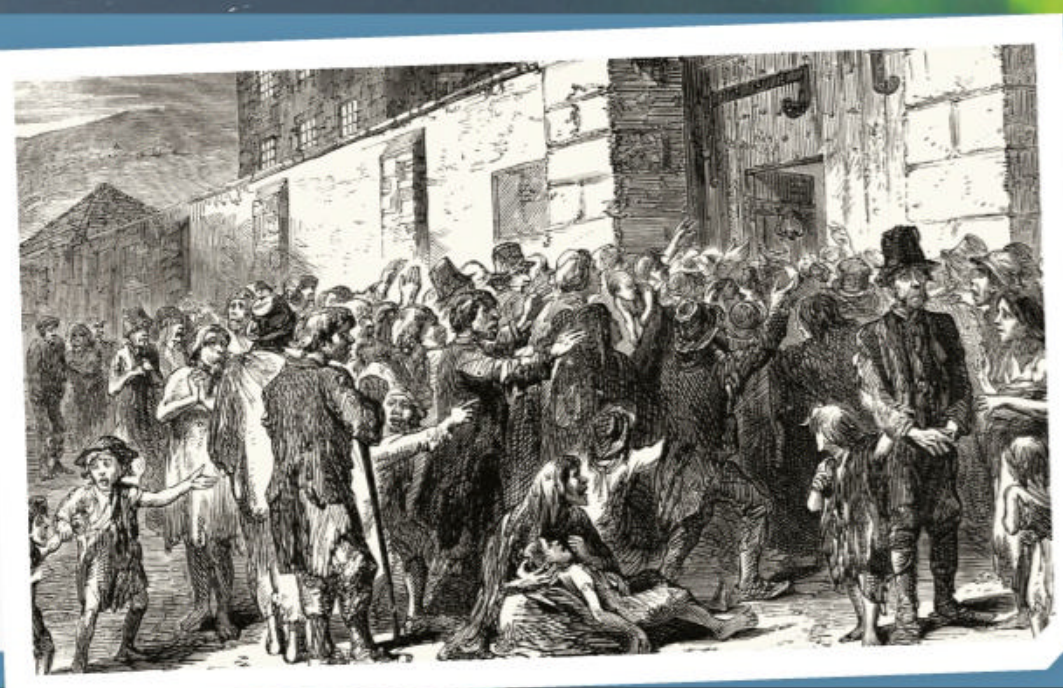
Do photons have mass?

Photons are tiny packets of light and have energy in the form of electromagnetism. They don't have mass, but they do have momentum – a property in physics that's usually attributed to an object's mass. However, the momentum of a photon isn't dependent on mass, but on its frequency. One way of imagining a photon is not to think of it as a particle, but as a little packet of energy made of oscillating electric and magnetic fields. Like any wave, it has a frequency which determines the type of radiation it makes up. If it's a low frequency it might be radio waves, whereas a high frequency could be X-rays.

Another odd effect that makes light 'appear' to have mass is that it interacts with gravity. For instance, light follows curved paths around stars and cannot escape from a black hole, but this is not due to it having mass. Einstein's theory of general relativity explains how stars and black holes have so much gravity that the space and time around them becomes warped. In this scenario, the light is travelling in a straight line, but its path has become curved due to the bending of space-time.

WHAT CAUSED THE IRISH POTATO FAMINE?

The famine was caused by a fungal disease called potato blight, which came to Ireland from Mexico. Blight made the potatoes quickly rot, and since one-third to half of all peasants were dependent on the crop for food, this led to more than 750,000 deaths. But the famine was also the result of the social and political system in the 1840s. As Irish Catholics could not own land or hold a profession, the peasants resorted to growing mostly potatoes – which could be grown in large quantities on plots of rented land – to feed their families.



WHY DON'T MALTESERS HAVE A FLAT BOTTOM?

Mars has never confirmed the manufacturing process that it perfected for Maltesers back in 1937, when they were marketed as 'energy balls'. The centres are made from a sweet, dough-like mixture and probably subjected to low air pressure to make the air bubbles expand and assume a honeycomb texture. However, from here on we have to make some intelligent guesses. The most logical solution would be that the honeycomb spheres are rolled through liquid chocolate and then down an incline – possibly rollers – so a flat surface can never form. However, with the manufacturer still refusing to reveal its secret, we can't be 100 per cent sure.

WHY DO FLAMINGOS STAND ON ONE LEG?

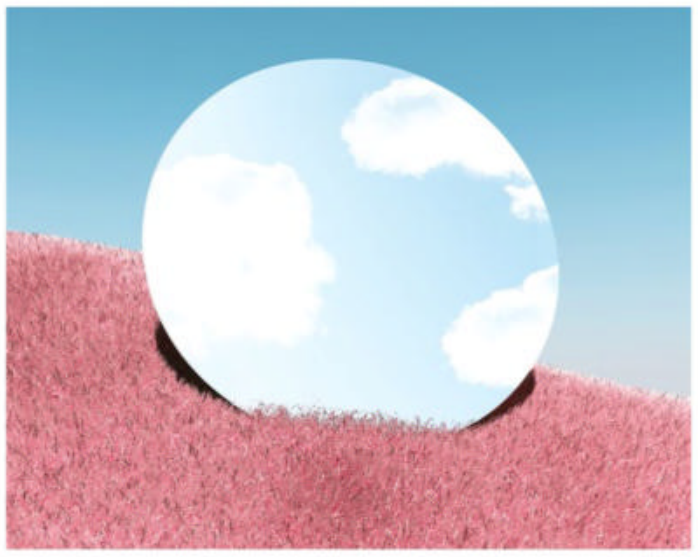
For a long time this was a mystery. In 2009, two American psychologists studied a captive flamingo colony and concluded that it's about conserving heat. Although flamingos are native to tropical climates, they spend most of their time standing in cold water, and their long legs mean lots of exposure to it. Tucking one leg up helps regulate their body temperature. They usually vary which leg is up, and when the weather is warmer they're more likely to stand on two legs.

Did you know?

Flamingoes get their pink colour from their diet

WHAT COLOUR IS A MIRROR?

Mirrors were originally created by placing a transparent, greenish glass over a reflective silver backing, which is still usually visible at the edges. This is why mirrors are often perceived as silver. However, strictly speaking, a mirror has no colour at all. Colours are created by the light that bounces off an object – if it looks red, that's because red is the main colour not being absorbed. A mirror, however, is designed to reflect everything, and with no colours absorbed at all, by definition it has no intrinsic colour of its own.



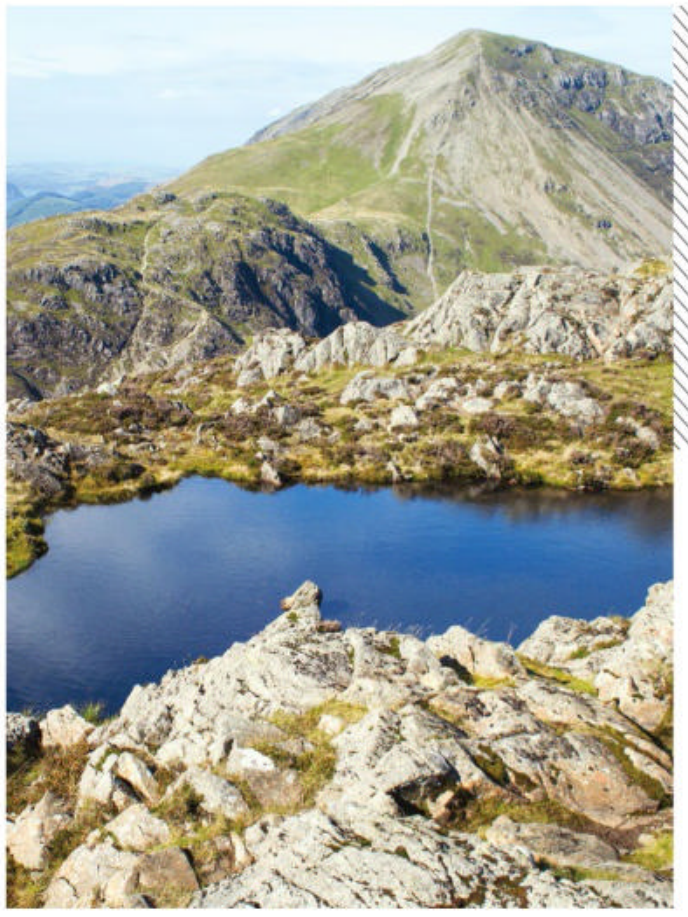
Why is Costa Rica's geography so good for growing coffee?

Coffea arabica produces the finest coffee beans. This shrub flourishes in Costa Rica because of the fertile soil, altitude and climate. Most Costa Rican coffee is grown in the highland valley region, Meseta Central, between 800 and 1,500 metres. Here the soil is acidic and mineral-enriched by lava and ash spewed from volcanoes. There are also two distinct seasons. The rainy season from May to November has cool, wet afternoons that promote coffee growth, and sunny mornings. During the dry harvest season, meanwhile – from around December to March – hot, sunny days aid coffee bean ripening.

BRAINDUMP

IF OUR BODY IS 37 DEGREES CELSIUS, WHY DO WE FEEL HOT WHEN IT'S 30 DEGREES CELSIUS?

The cells in our bodies are always producing heat from the energy stored in the food we eat. This heat is needed to keep our vital organs at 37 degrees Celsius at all times. Depending on the temperature of the environment, your body can regulate the amount of heat that's produced, and to an extent how much it loses. However, if the environment temperature is around 30 degrees Celsius, your body loses this internal heat much slower, as there is less of a temperature difference between your body and its surroundings. Nevertheless, your body still needs to produce heat in order to keep you warm on the inside, so you end up feeling hot, even though the outside temperature is actually cooler.



When does a hill become a mountain?

Unlike with many other landforms, there's no universally accepted definition of a mountain. Many geographers state that a mountain is greater than 300 metres above sea level. Other definitions, such as the one in the Oxford English Dictionary, put the hill limit at twice that, while others make distinctions about the degree of slope. In Scotland, meanwhile, landforms with distinct summits are called 'hills' no matter what their height. However, in America there are several 'mounts' that are less than 300 metres tall. Essentially, a hill becomes a mountain when someone names it as such.

WHERE IS THE BERMUDA TRIANGLE AND WHY ARE PEOPLE SAID TO DISAPPEAR IN IT?

The Bermuda Triangle is an imaginary area in the Atlantic Ocean off the southeast US. The three corners are Bermuda, Miami in Florida and San Juan in Puerto Rico, an area covering about 500,000 square miles. Many theories exist for the disappearance of perhaps 2,000 vessels and 75 aircraft in the region. Among the most far-fetched are alien abductions, sea monsters or energy rays from the lost city of Atlantis. But it's likely that the Bermuda Triangle is a modern myth. Marine insurer Lloyd's of London reports ships are no more likely to disappear in the area than anywhere else, and doesn't charge extra for passing through.

The myth emerged when a flight of five US Navy Avengers vanished without trace in 1945 after the pilot reported bizarre compass readings. A magazine article in 1964 about the doomed flight coined the name 'Bermuda Triangle', and it stuck. Investigators have blamed pilot errors, malfunctioning heaters or compasses, treacherous reefs and bad weather on some high-profile disappearances. Any wreckage or bodies could have sunk without a trace because the triangle contains some of our planet's deepest ocean.

WHY DO WE HAVE EYEBROWS?

Eyebrows keep moisture out of the eyes. This includes rainwater and sweat, which could be irritating in your eyes if you were running away from a predator. Eyebrows have taken on a key meaning for appearance and non-verbal communication. Lifting your eyebrows can express many things depending on the appearance of the rest of your face and body.

WHY DOES PEPPER MAKE YOU SNEEZE?

The nose is designed to repel anything that enters except air. Its three main defences are fine hairs in the nostrils, mucus and sneezes. Any rush of particles may trigger sneezes, but pepper is irritating due to the substance that gives it its flavour. Piperine is an alkaloid that stimulates the nasal nerve endings, causing the brain to trigger muscles in the nose and throat to expel the foreign particles in a sudden burst of air.

Did you know?

Our Solar System is around 4.5 billion years old

How does our Solar System stay suspended in space?

Gravity isn't just for keeping planets in their respective orbits; it's a force that acts on all matter in the universe. That's the basis of Isaac Newton's theory of universal gravitation. The greater the object's mass – and the closer it is – the greater the gravitational force on other objects around it. All of the bodies in our Solar System are affected by the gravitational pull of the Sun. However, the Sun is just one of hundreds of billions of stars in our galaxy, which in turn is one of more than 100 billion galaxies – all of which have gravitational pull. All of these are also moving. For example, the Sun completes one rotation around the centre of the Milky Way every 230 million years or so.

Einstein disagreed with Newton on gravity. His general theory of relativity stated that gravity isn't a force at all, but a curvature in space-time. This means that objects like Earth are actually travelling along a straight path – because objects always seek the shortest distance between two points – but due to a curve in space-time, that straight path is spherical. There are some newer theories about gravity, but the important thing to note is that it's ultimately what holds everything together.

WHY ARE THERE INNIES AND OUTIES?

The umbilicus is the transition point between the blood of the foetus and its mother through the umbilical cord that connects to the placenta. At birth, the umbilical cord is clamped a few inches from the baby, and then severed. This several-centimetre protrusion is left to shrivel and fall off, which takes a couple of weeks.

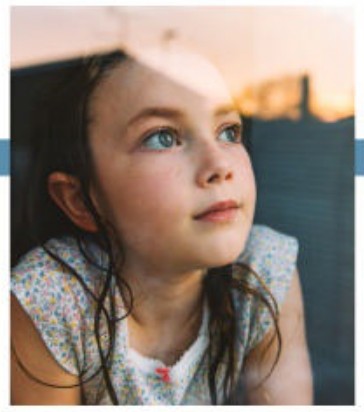
At this stage, most babies are left with an 'innie' belly button, while a minority get an 'outie'. There is no scientific explanation for this – it's probably all luck. This is very different from an umbilical hernia, where a small portion of the abdominal contents protrudes through a defect in the abdominal wall under the umbilicus; this causes a lump that bulges when you cough. In babies, these mostly disappear after a couple of years, but in adults they may need an operation. However, developing one as an adult has nothing to do with the shape of your navel.

How do salt flats form?

Salt flats are dried-up desert lakes. They form in closed hollows where rainfall can't drain away. In a wet climate a lake would form, but in a desert the water is heated and evaporates into vapour faster than it is replenished by rain. The salt and minerals dissolved in the water are left behind as a solid layer. Some salt flats are massive. The Bonneville Salt Flats in Utah were formed by the evaporation of an ancient lake as large as present-day Lake Michigan. They are flat enough to be used as a raceway for setting land-speed records.

WHY DO VEGETABLES HEAT UP QUICKER THAN SOUP WHEN THEY'RE ON THE SAME PLATE IN A MICROWAVE?

Water molecules (H_2O) are polar molecules because the oxygen is slightly negatively charged and the hydrogen is slightly positively charged. Due to this polarity, H_2O molecules are attracted to one another and don't move as freely as those in other materials. For this reason, water has a high specific heat capacity – the amount of heat required to raise the temperature of the material by one degree Celsius. Vegetables contain some water, but soup contains much more. Water's high specific heat capacity means it needs more energy than other materials to raise its temperature, which for microwave cooking means the higher the water content in food, the longer it will take to heat up.



WHY IS GLASS TRANSPARENT IF IT'S A SOLID?

Photons have a specific energy according to the frequency of light they make up. How photons interact with a material is determined by their frequency, along with how electrons in that material are arranged. Electrons can occupy different energy levels, the lowest of which is called the ground state. In opaque materials, photons of visible light are mainly absorbed by electrons. The electrons use the energy to jump to a higher state. In the case of glass, the amount of energy needed to raise an electron to the next level is higher than in most materials. The photons don't have enough energy to bridge this gap, so the photons pass through.

HOW DO OPTICAL ILLUSIONS AFFECT HOW WE PERCEIVE SIZE?

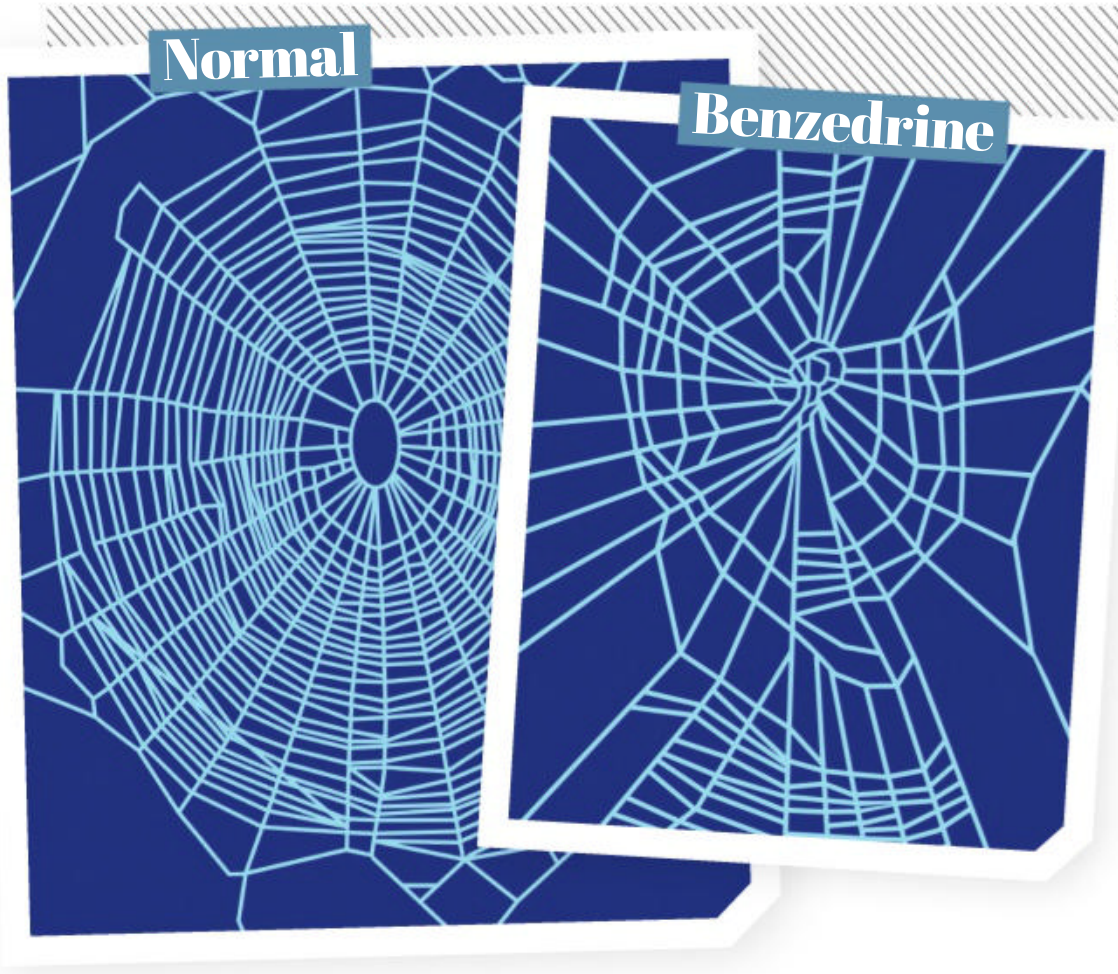
Visual perception of colour and size is a complex and incompletely understood phenomenon. While we understand how colours are formed and how the brain interprets images, there's much more to looking at an object; there is a complex interplay between its own dimensions and its surroundings. This includes the differences in colour between the object and its background, which can make objects appear more striking or distant. Small objects of the same size that are in colour or shape order take on a grouped appearance and patterns that are visually different to the same objects arranged in different orders. Colour and line placement are often used to make a 2D picture seem 3D, such as in a painting, with lighter or darker objects towards the back, depending on lighting. The fashion industry has made use of this theory too; dark colours with vertical stripes are said to make you appear slimmer than bright colours with horizontal stripes.

Did you know?

Illusions are utilised in film production as an alternative to special effects

WHAT ARE INDIA'S DECCAN TRAPS?

The Deccan Traps are a huge stack of volcanic rocks more than 1.2 miles thick that cover nearly 200,000 square miles of India. They were formed by a massive volcanic eruption 60 to 65 million years ago, which spewed out enough lava to cover Earth three metres deep. The gases released may have changed the global climate and contributed to the extinction of the dinosaurs. Scientists blame the supersized eruption on a hotspot, a stationary plume of superhot buoyant rock in Earth's interior that forms a volcano when it reaches the surface. Hotspots create island chains as the rock plates forming Earth's surface move over them. The Deccan Traps hotspot may have led to the formation of the French island Réunion in the Indian Ocean.



How do drugs affect spiderwebs?

Caffeine is a stimulant that most people ingest at some point, in the form of coffee, tea, fizzy drinks or chocolate. To test some of its psychological effects, and also those of other common drugs, scientists administered them to spiders to see how they impacted web construction. The most famous of these experiments was conducted by NASA in the 1990s. While marijuana led to slowly spun, incomplete webs and benzedrine led to fast-spun, poorly organised webs, it was caffeine that had the biggest effect. It almost completely stopped spiders spinning webs at all, except for a few poorly organised strands with no structure. Caffeine is also a natural pesticide, with some plants having developed caffeine within their seedlings to protect against insects. While caffeine kills certain bugs that feed on these plants, others have adapted to it and are unaffected, such as many beetles.

THE LIBRARY

The latest book releases for curious minds

WEIRD AND WONDERFUL NATURE

ALSO FREAKY, HORRIBLE AND DOWNRIGHT DISGUSTING

AUTHOR **BEN HOARE**
ILLUSTRATOR **KALEY MCKEAN**
PUBLISHER **DORLING KINDERSLEY**
PRICE **£20 / $24.99**
RELEASE **OUT NOW**

One way to describe the plants, animals and natural phenomena in this lovely hardback from DK would indeed be weird and wonderful. The Cook's pine trees on the New Caledonian islands in the Pacific Ocean fit the bill: they all tilt towards the equator no matter where they grow, and the farther from the equator they are, the more they lean towards it, which scientists still cannot explain. *Weird and Wonderful Nature* is full of these little mysteries, as well as odd stuff that science can explain like the immortal jellyfish, which we've featured in **How It Works** before – it effectively cheat death by putting its life cycle into reverse and reverting from adult to polyp form, doing so over and over again.

But some behaviours and characteristics are much better described as freaky, gross and even horrific. Case in point, lily beetle larvae, which smear their entire bodies with their own poo to put predators off eating them. Or the horned lizard, which shoots blood from its eyes at any potential threat, and the female Surinam toad, whose eggs are implanted into her back, subsequently swelling up under the mother toad's skin like bubble wrap before they hatch.

That's enough to induce body-horror shudders in anyone – and you don't need to look much further for something really awful: *Weird and Wonderful Nature* opens with a section on fungi and the zombie ant fungus, the spores of which stick to an ant – or other insect – and begin to eat it alive before hijacking the creature's brain and forcing it to climb high up into the treetops, where the ant dies and the fungus can burst through its exoskeleton to spread its spores over a much wider area... truly nightmarish.

There's a big selection of beautiful, cool and creepy things in *Weird and Wonderful Nature*, and even if you want to skip over the parts that might keep you awake at night, you won't have to flick more than a page or two ahead to find a species or phenomenon that's genuinely wonderful. Coupled with some stunning photography and annotated illustrations, it's a fascinating read whatever your age.

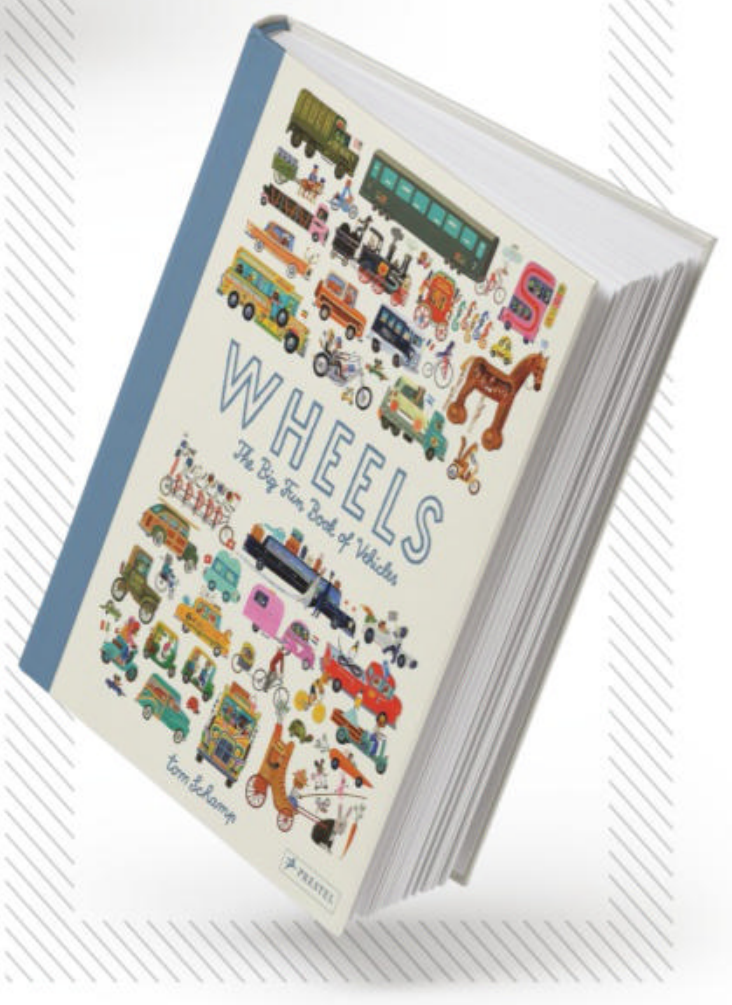
"Full of these little mysteries, as well as odd stuff that science can explain"

WHEELS

THE BIG FUN BOOK OF VEHICLES

AUTHOR **TOM SCHAMP**
PUBLISHER **PRESTEL**
PRICE **£18.99 / $24.99**
RELEASE **OUT NOW**

From rickshaws to race cars, you'll discover the entirety of the world's wheels throughout history in this illustrative children's book. Following its ancient invention, young readers will ride through time and discover not only the evolution of the wheel, but also how people around the world prospered alongside it. What's most striking about this book is the volume of vibrant and imaginative illustrations, of which there are too many to count. Although the facts that accompany the illustrations can feel a little sporadic, they are interesting and amusing. It's safe to say that by the end of this big, fun book of vehicles, you'll think you've seen every possible wheeled vehicle and machine to have ever rolled across the Earth.

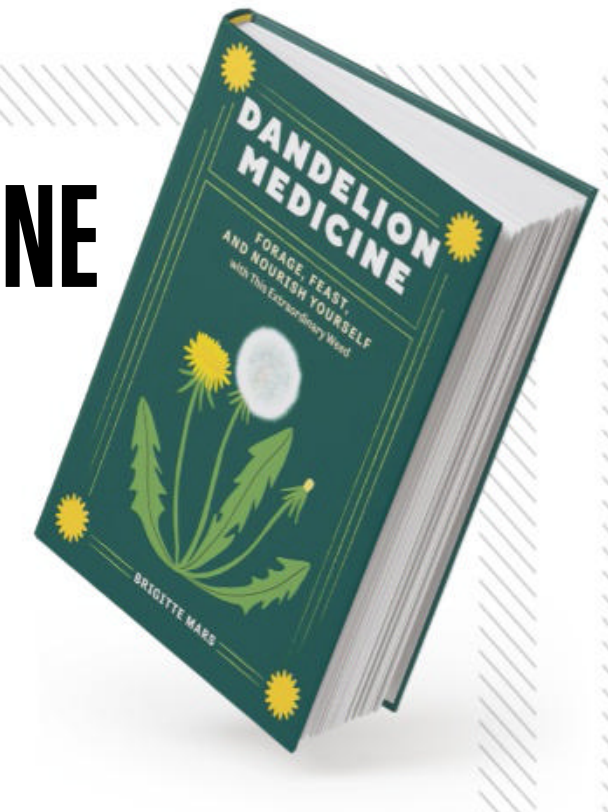


DANDELION MEDICINE

FORAGE, FEAST AND NOURISH YOURSELF WITH THIS COMMON BUT EXTRAORDINARY WEED

AUTHOR **BRIGITTE MARS**
PUBLISHER **WORKMAN PUBLISHING**
PRICE **£13.99 / $16.99**
RELEASE **3 NOVEMBER**

No garden stone is left unturned when it comes to the vast world of dandelions in *Dandelion Medicine*. Much more than a book of herbal remedies to treat common ailments such as inflammation, each chapter reveals the history, mythology and ecology of these surprisingly diverse plants. Within this tome there are several intriguing dandelion-inspired recipes to try, such as dandelion flower waffles, marmalade and even a fascinating twist on traditional sauerkraut.



As well as being deliciously insightful, *Dandelion Medicine* is beautifully designed, with simple yet effective illusions that highlight the anatomy of these fruitful flowers. From herbal baths to flower cookies, you'll be hard-pressed to find a guide to dandelions that's packed with this much information about these often-discarded garden weeds.

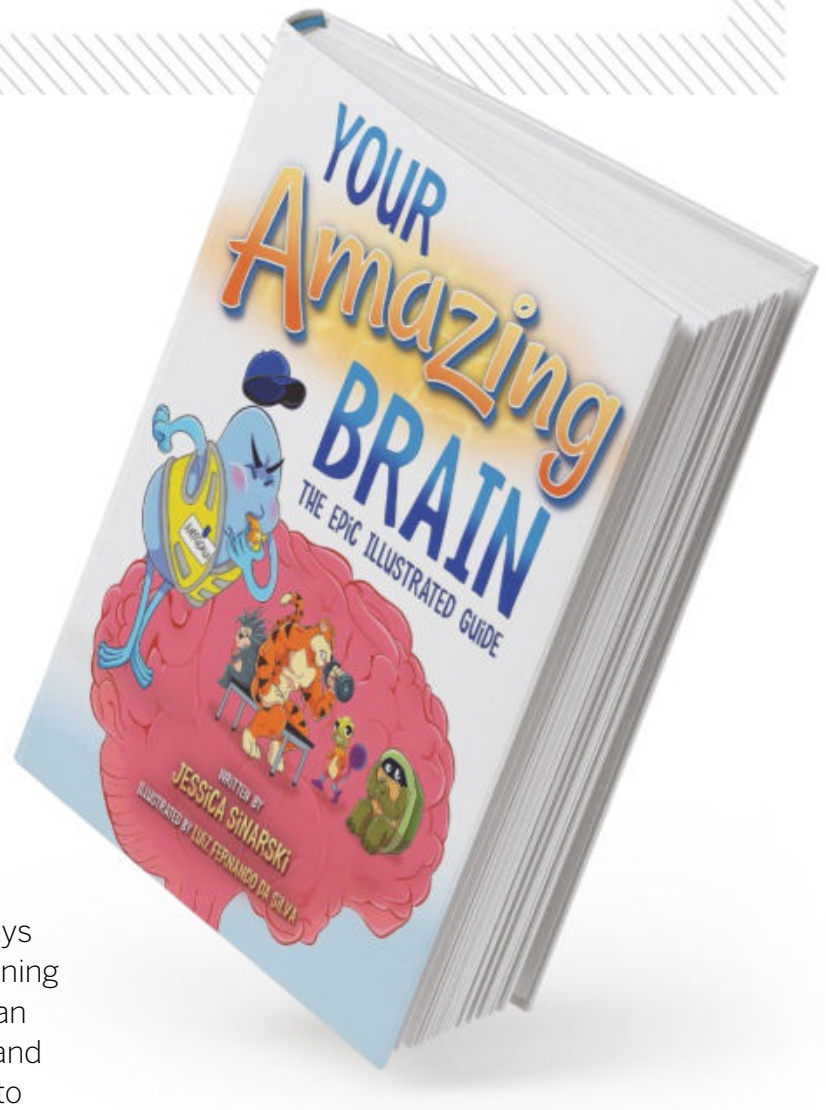
YOUR AMAZING BRAIN

THE EPIC ILLUSTRATED GUIDE TO YOUR BODY'S MOST COMPLEX ORGAN

AUTHOR **JESSICA SINARSKI**
ILLUSTRATOR **LUIZ FERNANDO DA SILVA**
PUBLISHER **NATIONAL CENTER FOR YOUTH ISSUES**
PRICE **£14.69 / $17.95**
RELEASE **OUT NOW**

There's so much to uncover in the world of neuroscience, and this information isn't always accessible to children. However, this entertaining and informative book provides readers with an engaging tour of their brains. The illustrator and author have collaborated perfectly together to deliver clear depictions of the most complex cellular functions within the brain, defining axons, dendrites, soma and the myelin sheath in language children can process.

Different chapters connect the internal workings of the brain to daily activities and how they translate to a person's actions. For example, what's going on in the brain while you play a game of football, experience hunger or feel scared? This book will reveal them all. *Your Amazing Brain* is suitable for 8 to 12 year old children, is designed to teach the neuroscience essentials and holds a lot of information, so it's best read in small chunks to make the most of the content and digest the knowledge at your own pace. At the end of the book there are tips, questions and activities to provide an essential interactive element for learning.

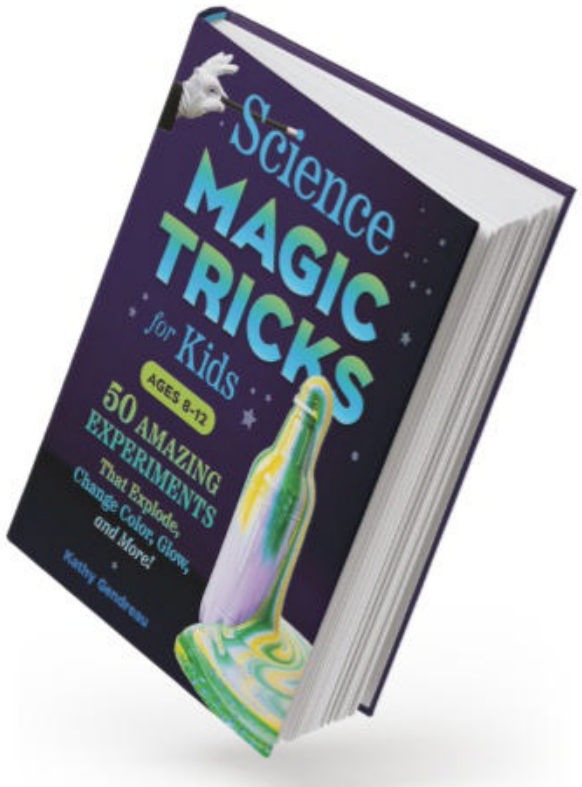


SCIENCE MAGIC TRICKS FOR KIDS

50 AMAZING EXPERIMENTS THAT EXPLODE, CHANGE COLOUR AND GLOW

AUTHOR **KATHY GENDREAU**
PHOTOGRAPHER **NANCY CHO**
PUBLISHER **ZEITGEIST**
PRICE **£15.99 / $16.99**
RELEASE **OUT NOW**

Chemical reactions, smart physics and other science tricks could be perceived as magic, so why not use it to amuse yourself and your friends? If you're a fan of the **How It Works** 'how to' page, optical illusions, magic or carrying out practical science experiments, this book is ideal for you. It contains all the advice, instructions and information needed to pull off an at-home magic show for all your friends and family. Most of the experiments use simple household materials or items that are relatively inexpensive and easy to get hold of. And each experiment has an accompanying photograph so that you know whether you're assembling the items correctly. With each experiment are 'ask the audience' questions that help guide children through their presentation skills as well as mastering the practical side. Some of the tricks you can learn in this exciting book include making vibrant elephant toothpaste, a mesmerising lava lamp, an invisible fire extinguisher and mysterious rising water. Included are safety instructions and equipment, so make sure you read these carefully as you have fun experimenting.



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

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

MEDIUM

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

HARD

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

Word search

Find the following words

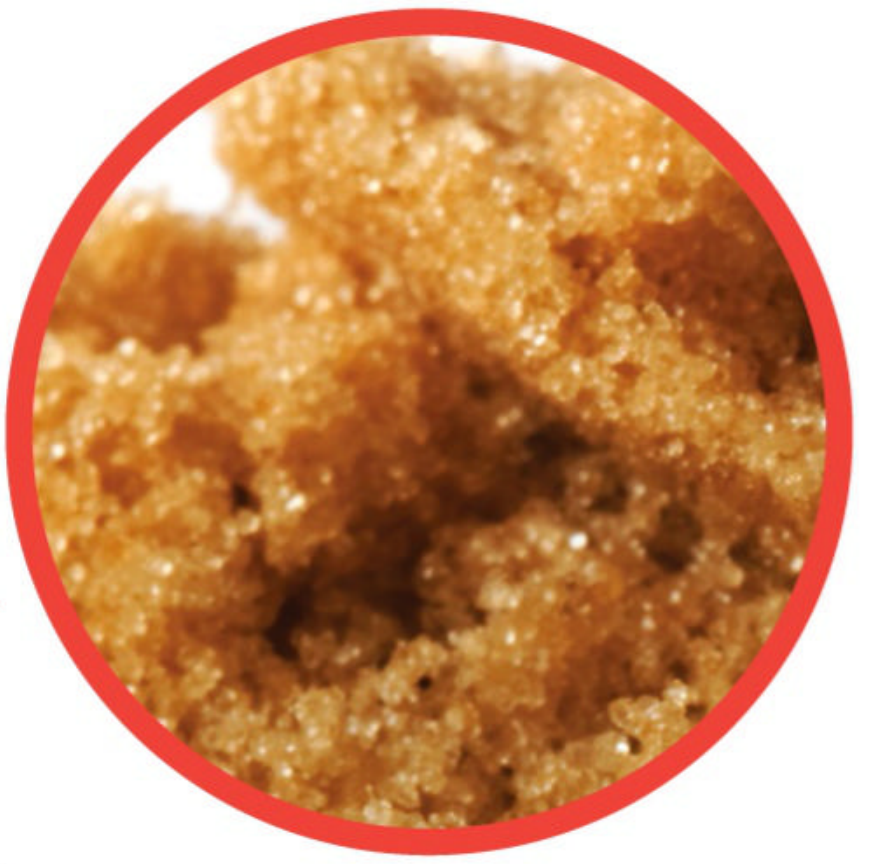
DOLPHIN
COMPOST
CLOCK
BEN
MONSTER
FIREWORKS
SWEETS
SLOUGH
HYDROFOIL
MEDIEVAL
ASTRONAUT
BOAT

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

What is it?

Hint:
Crystallised cane

A



Spot the difference

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

QUICKFIRE QUESTIONS

Q1 What kind of object did OSIRIS-REx return from?

- Planet
- Asteroid
- Moon
- Star

Q2 Which of these animals is the only one with a brain?

- Ant
- Jellyfish
- Sea urchin
- Coral

Q3 Which of these vestigial body parts don't we have?

- Tail
- Second nose
- Second brain
- Third eyelid

Q4 Which of these animals is, or was, the heaviest?

- Woolly mammoth
- Blue whale
- Brontosaurus
- Argentinosaurus

Q5 How many Suns could fit inside the biggest known star, UY Scuti?

- 500
- 5,000
- 5 million
- 5 billion

Q6 Which famous scientist discovered gravity?

- Galileo Galilei
- Isaac Newton
- Marie Curie
- Albert Einstein

Answers

Find the solutions to last issue's puzzle pages

Q1 OXYGEN
Q2 1 QUADRILLION
Q3 17,000 MILES PER HOUR
Q4 OSTRICH
Q5 GREEK
Q6 RADIUM

What is it?

DOG'S TONGUE

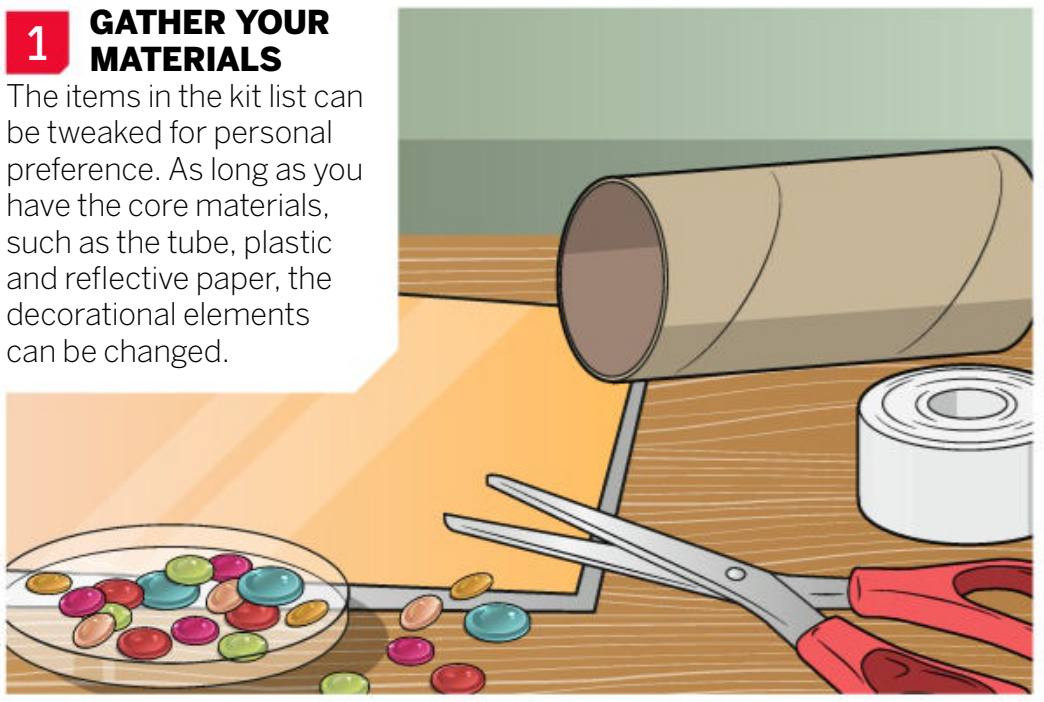
Spot the difference

HOW TO...

Practical projects to try at home

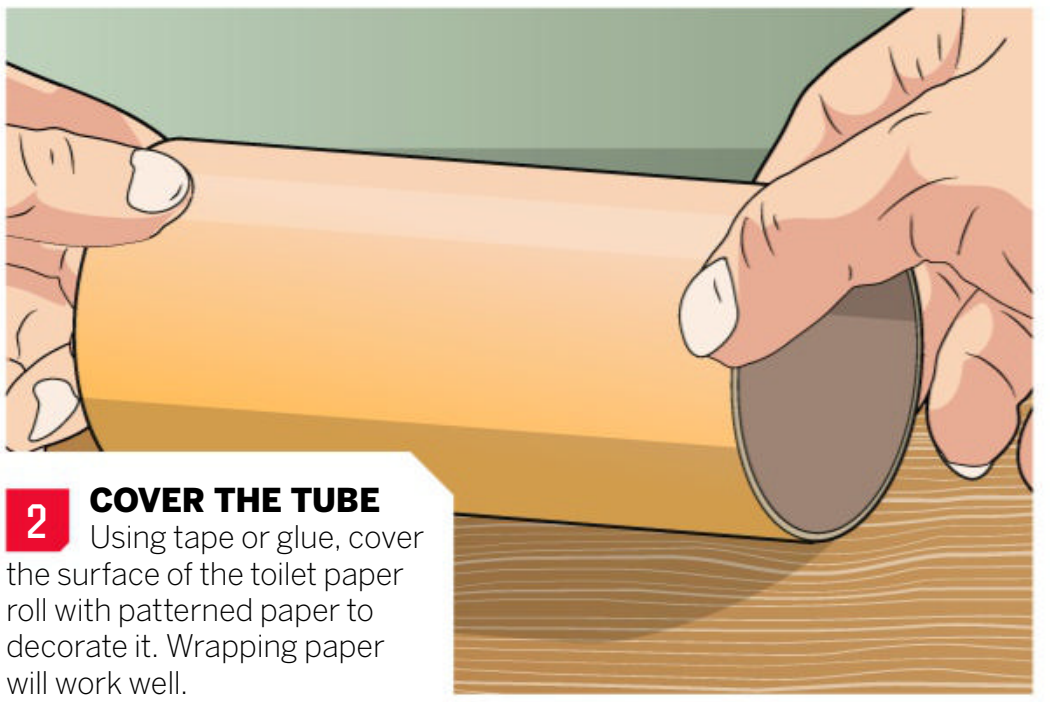
MAKE YOUR OWN KALEIDOSCOPE

With this optical toy, you can produce mesmerising mirrored patterns



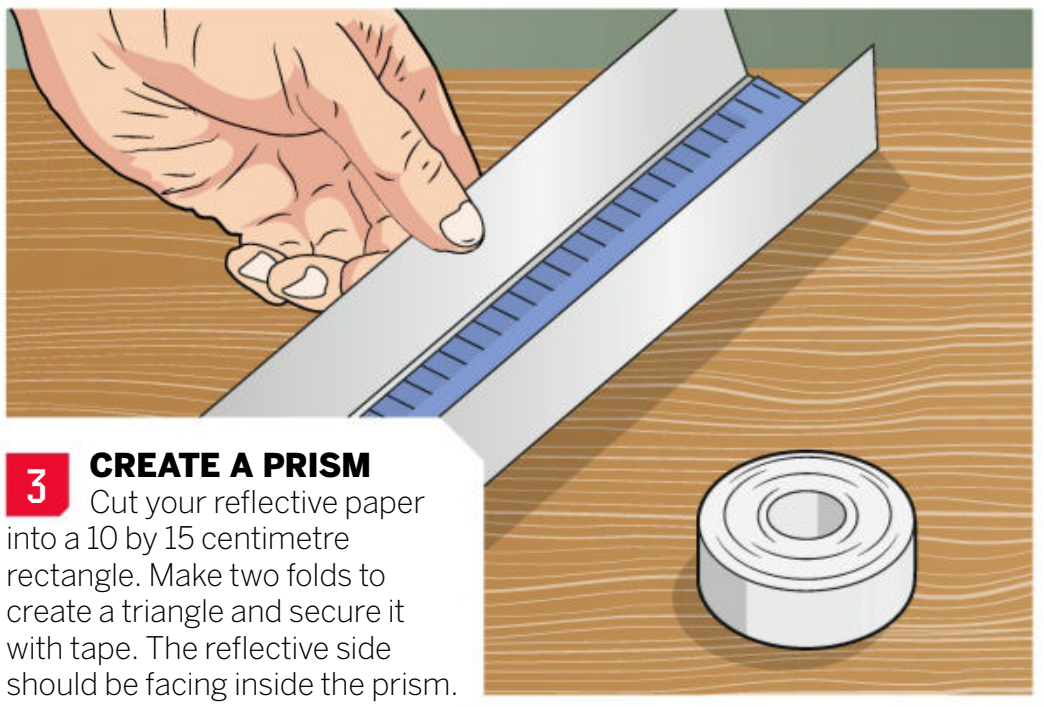
1 GATHER YOUR MATERIALS

The items in the kit list can be tweaked for personal preference. As long as you have the core materials, such as the tube, plastic and reflective paper, the decorational elements can be changed.



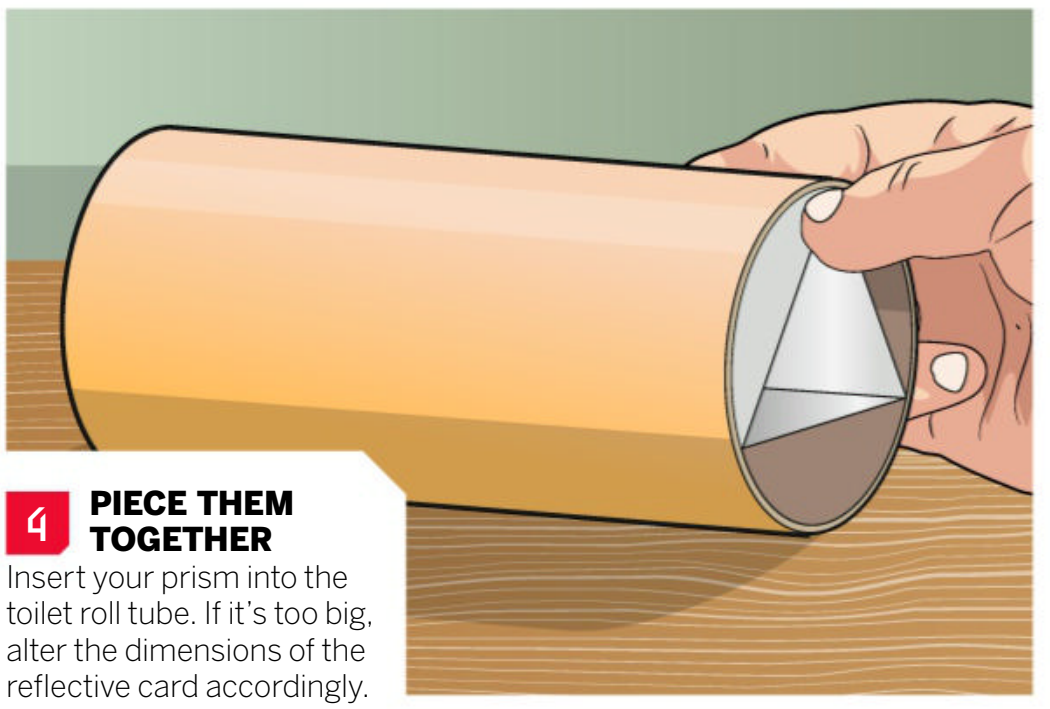
2 COVER THE TUBE

Using tape or glue, cover the surface of the toilet paper roll with patterned paper to decorate it. Wrapping paper will work well.



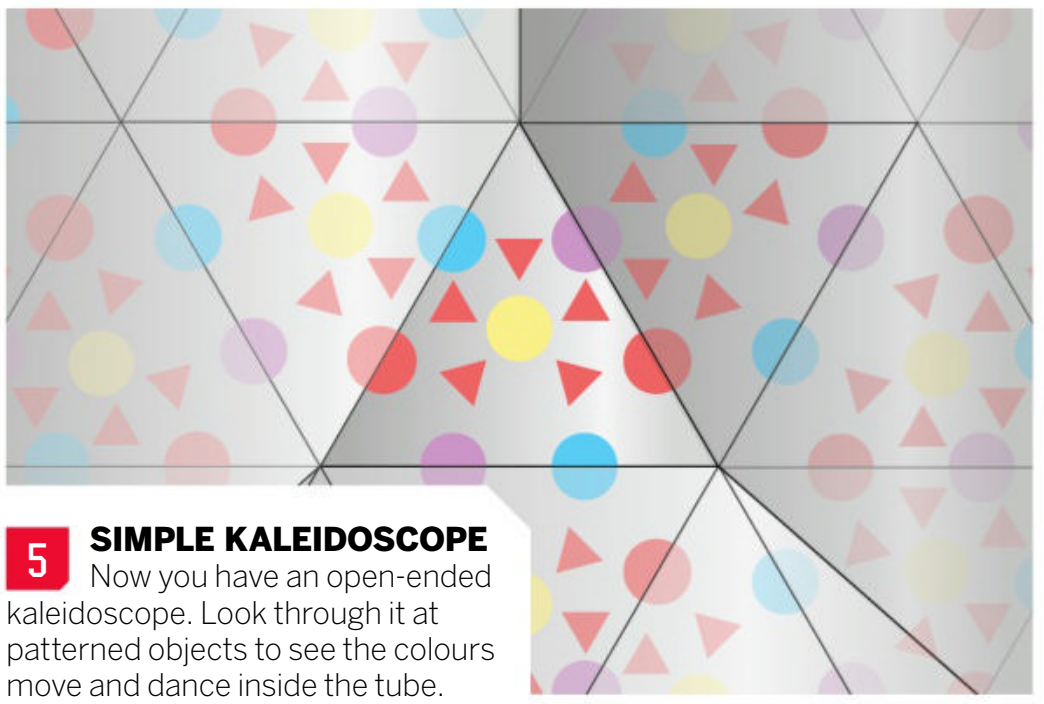
3 CREATE A PRISM

Cut your reflective paper into a 10 by 15 centimetre rectangle. Make two folds to create a triangle and secure it with tape. The reflective side should be facing inside the prism.



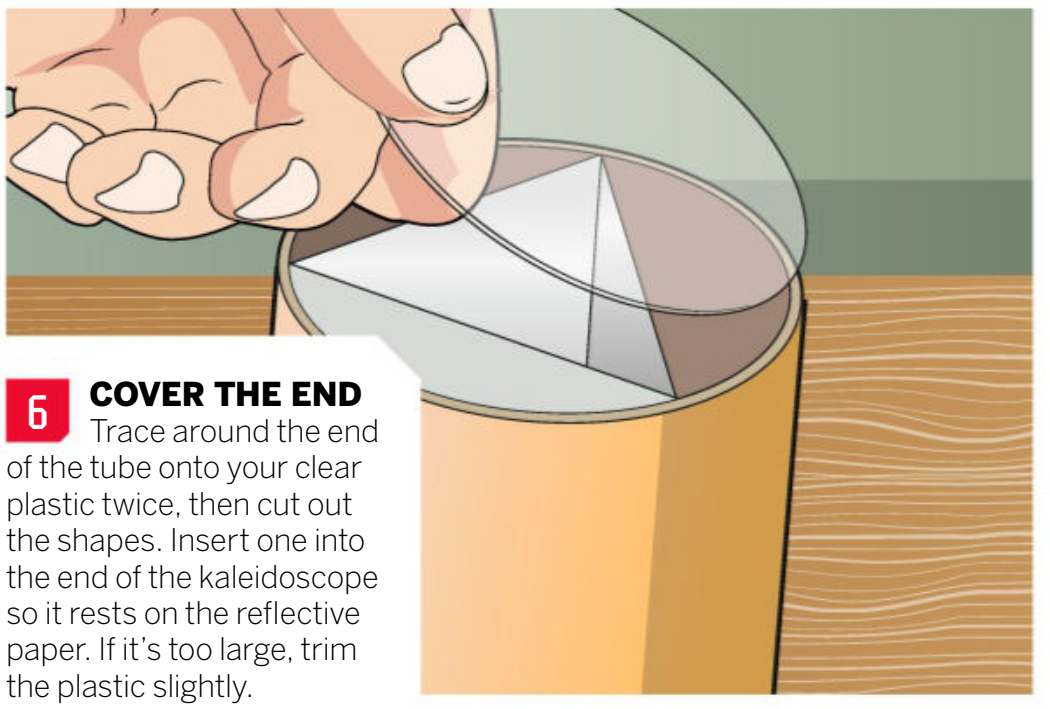
4 PIECE THEM TOGETHER

Insert your prism into the toilet roll tube. If it's too big, alter the dimensions of the reflective card accordingly.



5 SIMPLE KALEIDOSCOPE

Now you have an open-ended kaleidoscope. Look through it at patterned objects to see the colours move and dance inside the tube.



6 COVER THE END

Trace around the end of the tube onto your clear plastic twice, then cut out the shapes. Insert one into the end of the kaleidoscope so it rests on the reflective paper. If it's too large, trim the plastic slightly.

KIT LIST

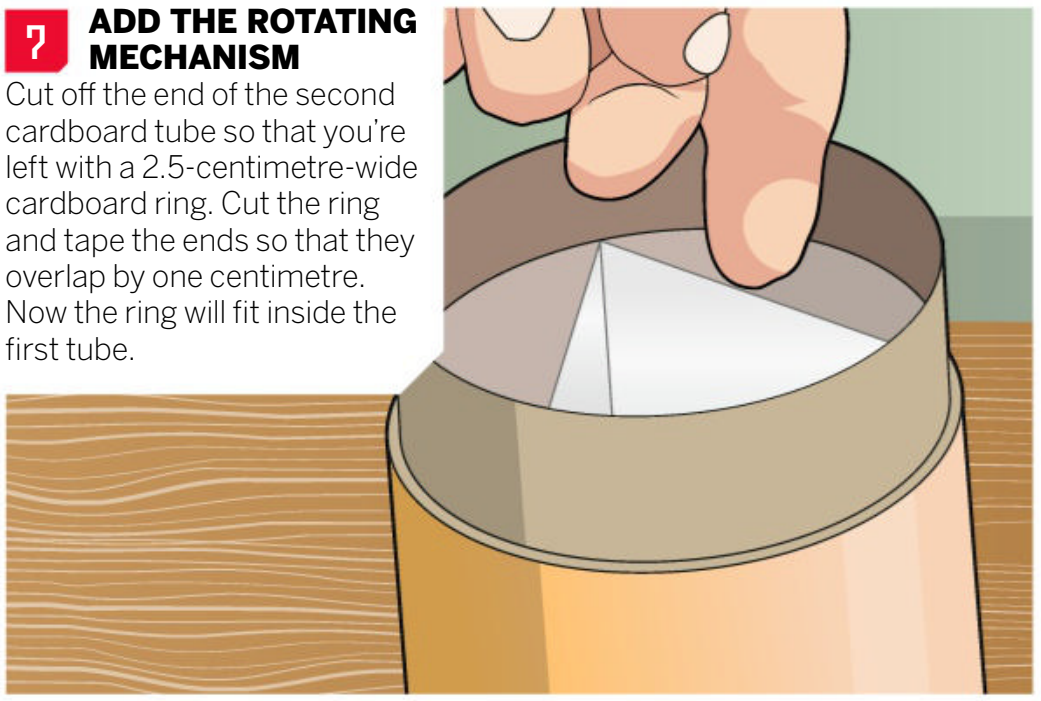
- Two empty toilet paper rolls
- Coloured beads
- Clear plastic
- Tape
- Patterned or glittery paper
- Mylar or reflective paper

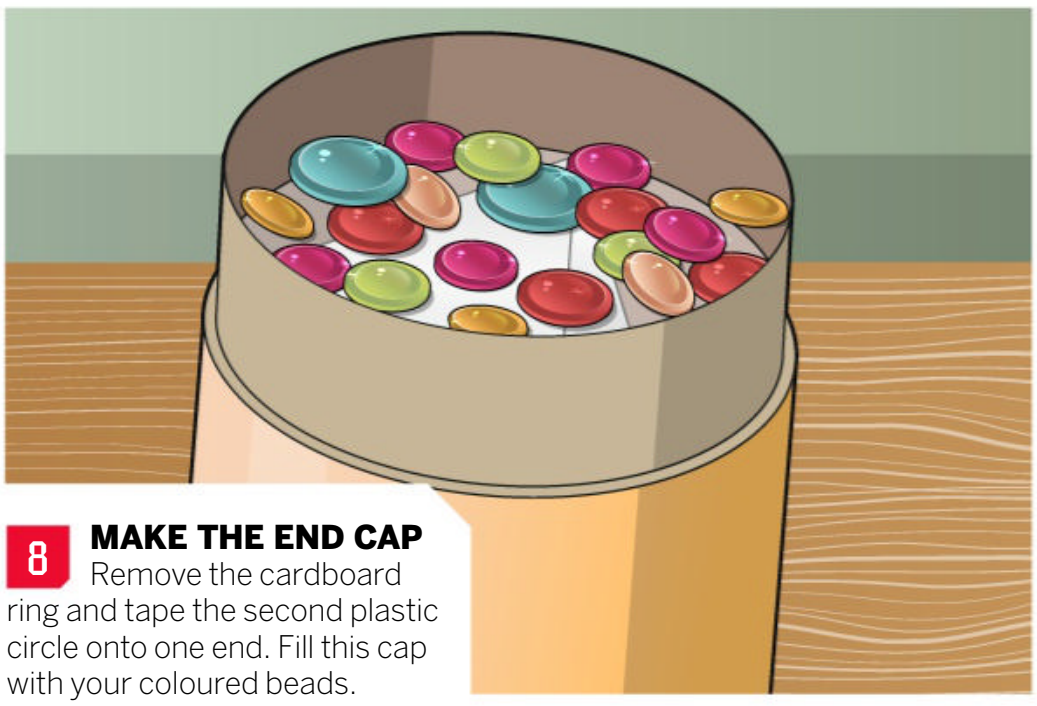
DON'T DO IT ALONE!

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

7 ADD THE ROTATING MECHANISM

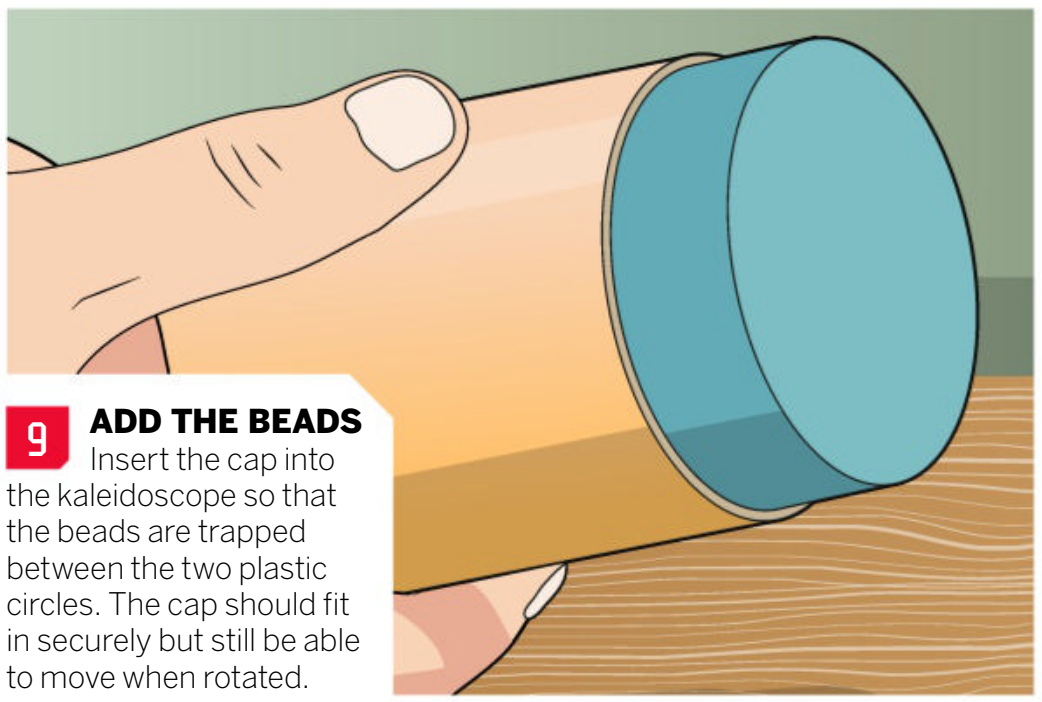
Cut off the end of the second cardboard tube so that you're left with a 2.5-centimetre-wide cardboard ring. Cut the ring and tape the ends so that they overlap by one centimetre. Now the ring will fit inside the first tube.





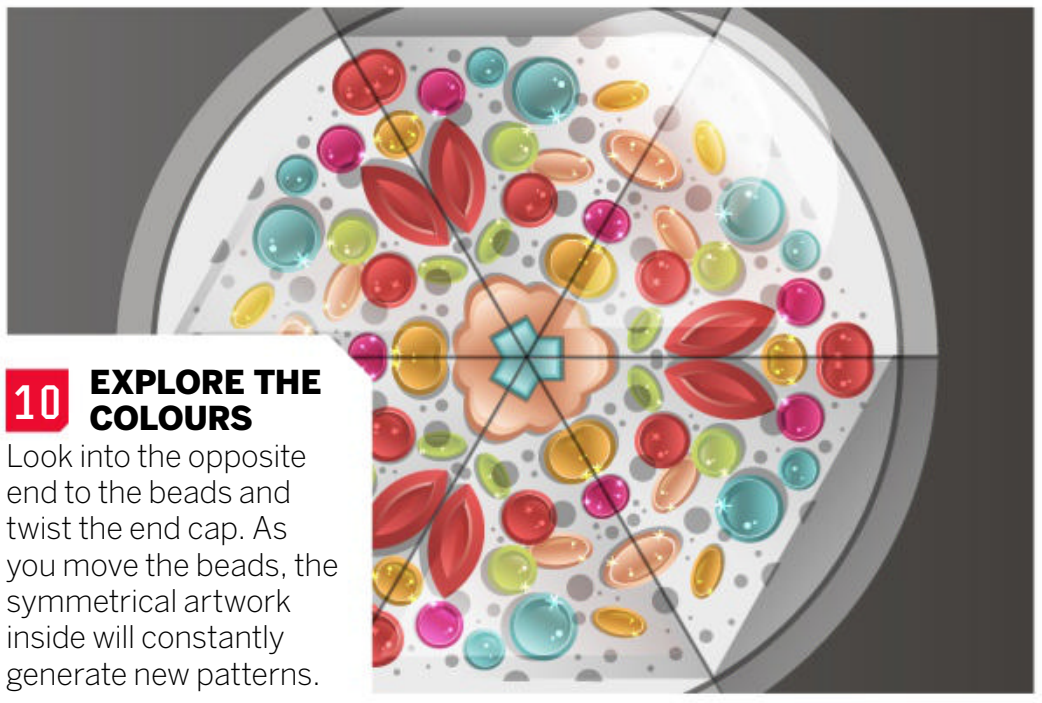
8 MAKE THE END CAP

Remove the cardboard ring and tape the second plastic circle onto one end. Fill this cap with your coloured beads.



9 ADD THE BEADS

Insert the cap into the kaleidoscope so that the beads are trapped between the two plastic circles. The cap should fit in securely but still be able to move when rotated.



10 EXPLORE THE COLOURS

Look into the opposite end to the beads and twist the end cap. As you move the beads, the symmetrical artwork inside will constantly generate new patterns.

SUMMARY

The word kaleidoscope is a translation of the Greek for 'beautiful form to see'. What makes these instruments so mesmerising is that no two people will have the exact same experience when they look through it. The kaleidoscope, which was invented by physicist David Brewster in 1816, requires two or more reflective surfaces, angled to face each other in a V formation. The central triangle and the beads that move around in this space are reflected multiple times in the reflective edges. This gives the illusion that the space you are looking through is much bigger than it really is.

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.

INBOX

Speak your mind

Radioactive waste can be classified as either high-level or low-level waste

RADIOACTIVE OCEAN

Dear **HIW**,
I'm a school student in New Zealand. I've been reading your magazine since the start of this year. I'd like to take this opportunity to thank you and the team for making such an incredible magazine to read. I heard that Japan has been dumping radioactive waste in the sea. Is this true, and how could it affect sea life and humans?
Ella

Towards the end of August 2023, it was announced that Japan will release treated radioactive wastewater into its seas. This wastewater was used to cool down parts of the Fukushima Daiichi Nuclear Power Plant, which was flooded by a tsunami in 2011, causing radiation to leak from the plant. Everyone in the local town of Okuma was evacuated while work to decontaminate the site began. This process involved using water to cool the reactors, mixing the used water with rain and groundwater and storing the contaminated waste in large tanks. Recently, however, Japan stated that there was limited space left to store this, and a new plan was revealed to dilute the water to make it safer, then release it into the ocean from 24 August 2023.

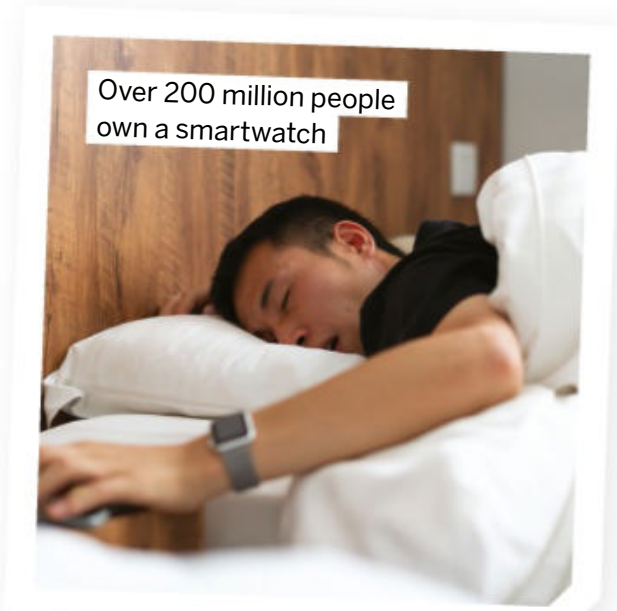
There have been protests about this release around the world and bans on the importation of Japanese seafood in certain countries, but some experts say that the diluted volumes of radioisotopes (unstable atoms) are too low to affect human health. For example, the tritium atoms that will be released from Fukushima are said to have seven times less tritium per litre than is recommended for drinking water by the World Health Organization (WHO). However, some marine biologists are concerned about how these isotopes could impact local marine life by accumulating as they enter the food chain.

LETTER of the MONTH

WATCH READING

Dear **HIW**,
My smartwatch knows when I'm sleeping, but I don't tell it when I go to sleep or wake up. When I remove my watch in the morning a flashing green on the back is briefly seen. How does the watch work out my sleeping pattern from my wrist?
Jeff Jacobs

When you enter the state of sleep, your heart rate lowers noticeably. In each of the different stages of sleep your heart rate will differ, too. This green flash that you mention is what the watch uses to measure the blood flow in your wrist. The green LED is used to illuminate the wrist, as green is absorbed best by the red blood cells. Optical sensors in the watch can then make more accurate measurements of the changes in blood flow and heart rate to estimate which sleep stage your body is in and for how long.



Over 200 million people own a smartwatch

WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

WEIRD AND WONDERFUL NATURE

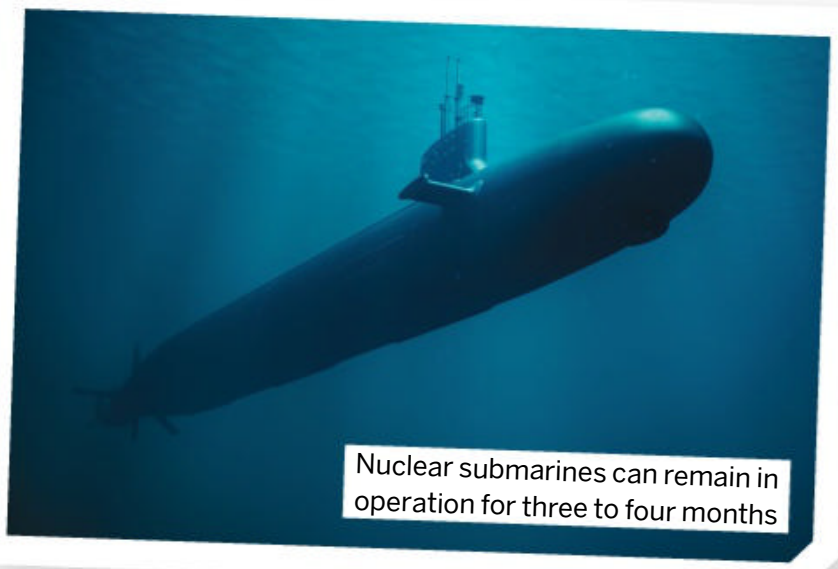
This book is filled with facts about the most surprising and curious plants, animals, rocks and phenomena in nature

VOLCANIC LAKES

Dear **HIW**,
How do lakes on inactive volcanoes form? If there is a vent underneath it, why doesn't the water sink to the bottom of the volcano?
Huanyu Shi

Lakes at the tops of inactive volcanoes can be dramatic sights. They are called crater lakes and are made possible by the collapse of the top section of the volcano. The vents of inactive volcanoes usually give way under the force of volcanic activity, and when the volcano cools, a caldera is formed. A caldera is a kind of crater that's formed when the top of the vent collapses, creating a basin. Rain water and water runoff from the surrounding peaks accumulate in the new crater to form a lake.

This is Tiwu Nuwa Muri Koo Fai, a volcanic lake on the island of Flores, Indonesia



Nuclear submarines can remain in operation for three to four months

UNDERWATER OXYGEN

Dear **HIW**,
How do the crews of nuclear submarines get air for breathing?
Stephen C

Submarines that are built to be submerged for multiple weeks or months at a time can actually produce their own oxygen for crew members to breathe using the surrounding water. Machines on board the submarine use a process called electrolysis, which breaks water into hydrogen and oxygen molecules using electricity.

Neurons synchronise with the beat in music, and this makes you want to dance

MUSICAL BIOLOGY

Dear **HIW**,
What makes humans like music so much? Do other animals?
Alfie Mayer

If you've ever felt happy or like you want to dance after hearing music, this is due to a part of the brain called the limbic system. This controls your emotional and behavioural responses. When your ears detect music, the limbic system is activated. Music can make the brain release a reward chemical called dopamine when you listen to songs. If you become familiar with a particular song, the body can release this earlier. Although many studies show that animals aren't as interested in music as humans, more recent research suggests this is just the case for 'human music'. Other species may have similar responses to music of the same pitches, tones and tempos that their bodies have evolved to detect and they're more familiar with.

WE ASKED YOU

This month on social media, we asked you:

Do you think any monsters could exist?

@FUN.SCIENCE.FACTS

Dragons could be real. There's so many legends all around the world about them

@MERLE.HAHA

Yes, pretty sure Nessie exists because we talk about it so much and no other water has one

GAVIN STEELE

Maybe some sightings are real, but I don't think they're monsters – just misplaced animals

@JEANMCDOUGALL8333

Yes!

@CAROLJSHELDON

Loch Ness Monster, as it's not yet been proven it doesn't

@MAIA_H3

Yes, somewhere in the deep sea, because so much of it is unexplored

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HOW IT WORKS

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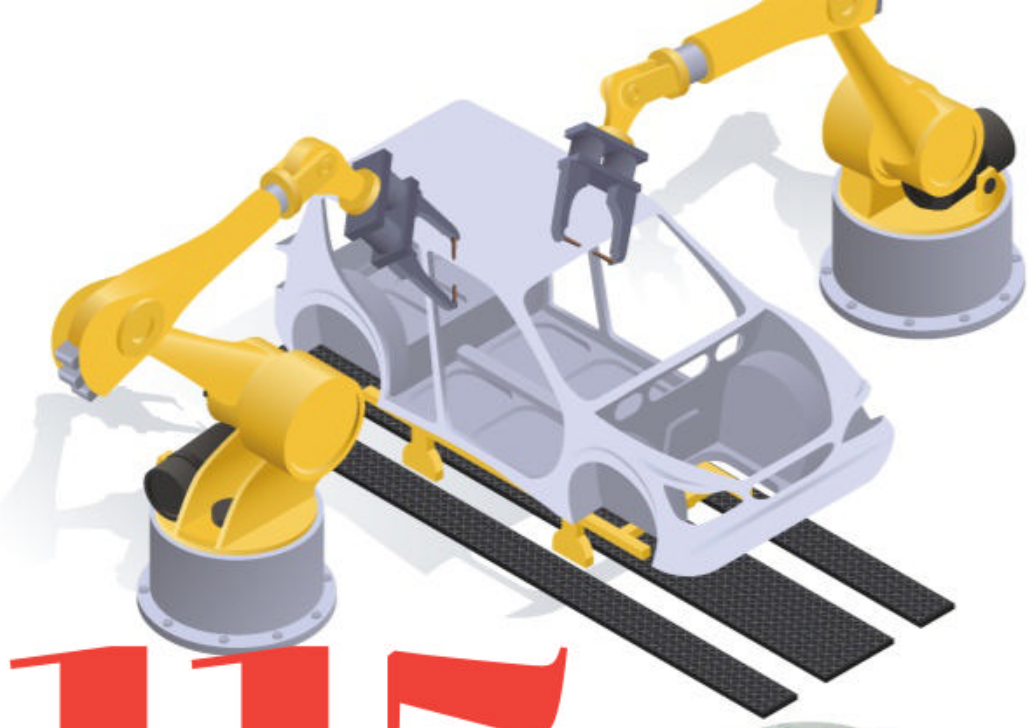
FAST FACTS

Amazing trivia that will blow your mind

WE CAN'T TASTE FOOD WITHOUT SALIVA

ONE MINUTE

It takes around 60 seconds for a blood cell to circulate your body



115

Over 100 cars are made every minute worldwide

Dwarf planet Pluto was named by an 11-year-old girl

TEN CENTIMETRES

Sea levels have risen dramatically in the last 25 years

1983

In this year, Motorola created the first mobile phone, the DynaTAC 8000x

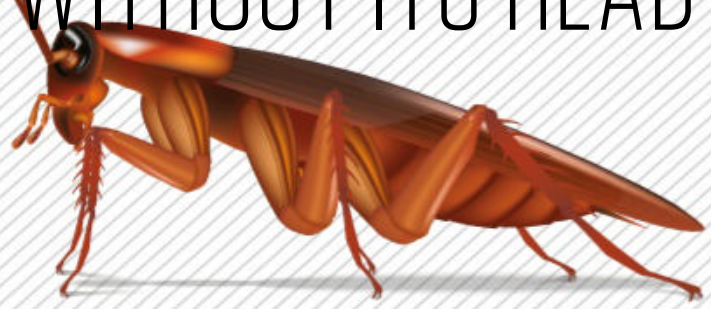
300 WINS

Abraham Lincoln had an impressive wrestling record prior to becoming president

100 METRES PER SECOND

Wind speed on Venus can reach over 220 miles per hour

A COCKROACH CAN LIVE FOR A WEEK WITHOUT ITS HEAD



38 MINUTES

The shortest war in history was between Britain and Zanzibar in 1896

IF I HAD SOMEWHERE TO LIVE...

I COULD GO ANYWHERE IN LIFE

When Abi's mum died, life got tough. She didn't get on with her dad and the arguments became violent. Abi felt her only choice was to leave home. With just the clothes on her back, and no idea where to go, she ended up sleeping on the streets in the freezing cold.

Right now, you could give a homeless young person like Abi somewhere to start their future

Abi's life changed when she was given a room at Centrepoint. A safe place to sleep and recover. A place to develop the skills and confidence she needed to rebuild her life – and leave homelessness behind for good. Now, Abi believes she can go anywhere.

Thousands of homeless young people like Abi are desperately trying to find their place in the world – but first they need a place to start again. **You could help right now by sponsoring a room at Centrepoint for just 40p a day.**

We know this support changes lives. 88% of the young people we help move on positively in life. So please, help someone like Abi today. Thank you.

Text PLACE to 78866 to donate £3
Call free on 0800 472 5798
Visit centrepoint.org.uk/place
Or complete and return the form below

SPONSOR A ROOM. HELP A HOMELESS YOUNG PERSON FIND THEIR PLACE.

YES, I WANT TO SPONSOR A ROOM FOR £12 A MONTH

Please collect my payment on the 1st/15th of every month (please circle preferred date).

Instruction to your Bank or Building Society to pay by Direct Debit

To the Manager:
Name and full address of your Bank or Building Society:

_____

_____ Postcode _____

Name(s) of Account Holder(s) _____

Originators Identification No. 6 5 9 1 0 7

Bank Sort Code: ☐☐-☐☐-☐☐ Account Number: ☐☐☐☐☐☐☐☐

Instructions to your Bank or Building Society: Please pay Centrepoint Direct Debits from the account detailed in this instruction, subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with Centrepoint and, if so, details will be passed electronically to my Bank/Building Society.

Signature(s) _____ Date _____

Banks and Building Societies may not accept Direct Debit Instructions for some types of account.

Increase your donation by 25p for every £1 you donate with Gift Aid giftaid it

☐ By ticking this box I confirm I am a UK taxpayer and want Centrepoint to Gift Aid all donations I've made in the last four years and any donations I make in the future until I notify you otherwise. I understand that if I pay less Income Tax and/or Capital Gains Tax in any tax year than the amount of Gift Aid claimed on all my donations it is my responsibility to pay any difference.

Your name and address are needed to identify you as a current UK taxpayer.

Your donation will go towards funding Centrepoint's vital work with young people all year round providing accommodation and support. We sometimes use models and change the names of the young people we work with to protect their identity; however all stories are true and as told by the young person.

Full Name: _____
Address: _____
_____
Postcode: _____ Telephone: _____
Email: _____

Thank you for donating to Centrepoint today.

We'd love to show the impact of your support and share how young people continue to need your help, through newsletters, fundraising appeals and information about events. Please let us know how best to stay in touch with you by adding your details above, and ticking the relevant boxes:

☐ **Please contact me by email** ☐ **Please contact me by phone**

Last year our supporters helped us change the lives of over 15,000 homeless young people. By letting us know we can count on you, we can continue helping young people with a home and a future.

Your privacy is key.

We promise never to sell or swap your details, and will always keep them secure. You can view our Privacy Notice in full at www.centrepoint.org.uk/privacy. You can opt out of post and change how we communicate with you at any time. Please call 0800 232320 and speak to one of our friendly team or email supportercare@centrepoint.org to do this and ask us any questions.

Please return this form to: Freepost Plus RTXY-LBEA-UTJJ, Angel Fulfilment Services Ltd, Communication Centre, Par Moor Road, Par PL24 2SQ.

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