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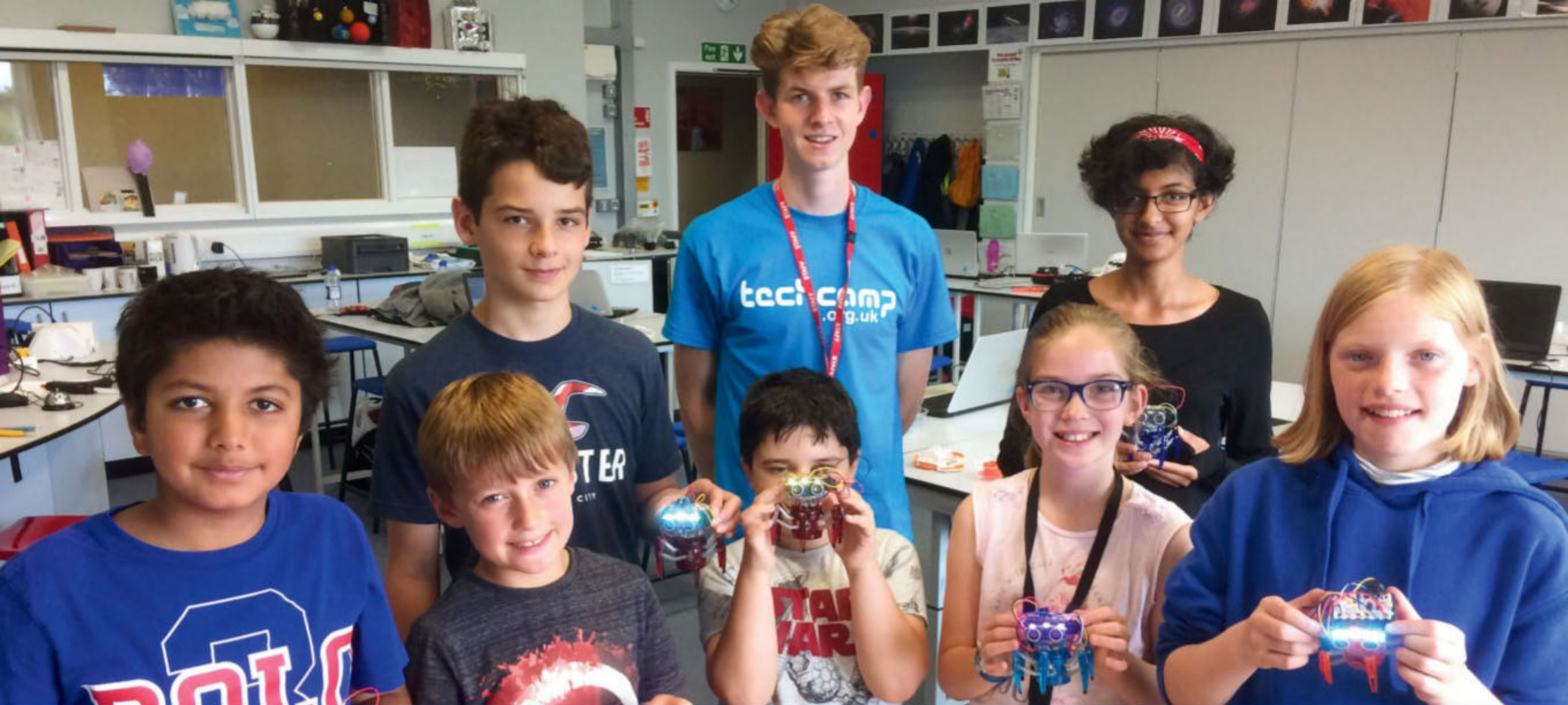


SUPER-QUIET SUPERSONIC X-59 JET



NATURE'S DEADLIEST HUNTERS

FUTURE
ISSUE 188



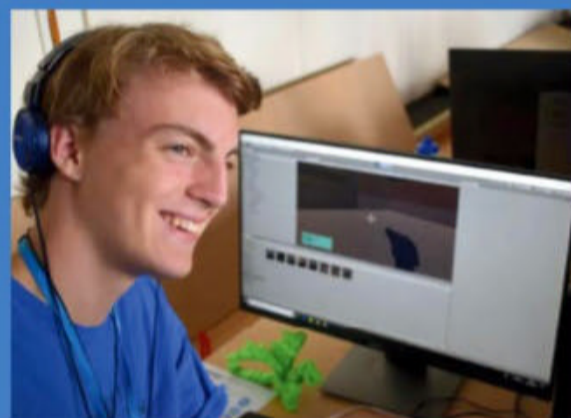
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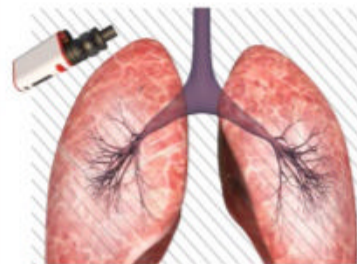
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Total eclipse



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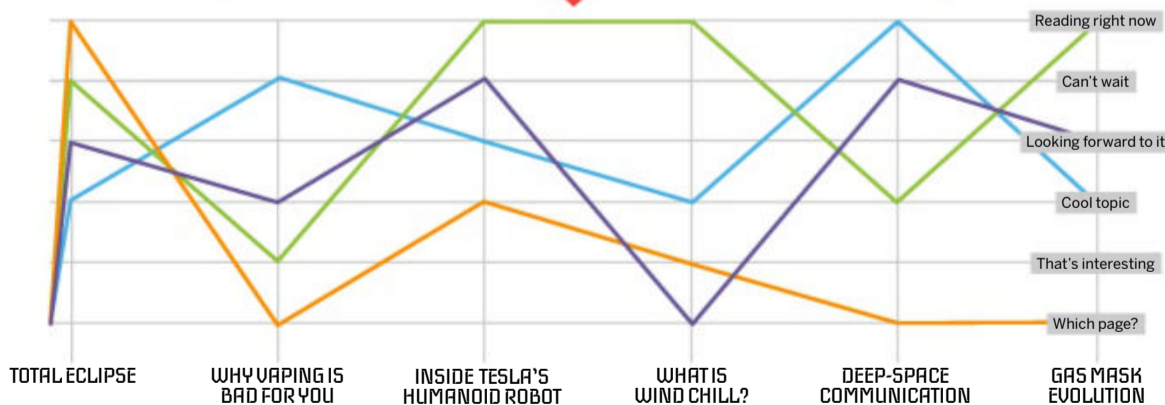
One of the most spectacular astronomical events is occurring at the beginning of April, and some of us will be able to view it in its glorious totality from our own backyard. A total solar eclipse is a rare and fleeting thing indeed, and can occur on Earth because of some very specific conditions that mean we're in a window of time when the Moon can completely cover the Sun in its passage across the sky.

In this issue of **How It Works**, we explain why we get total eclipses, where and when to view them and how other types of eclipses occur, including why lunar eclipses happen so much more frequently. We'll also show you a cool way to safely view the Sun. Enjoy the issue!



Ben Biggs
EDITOR

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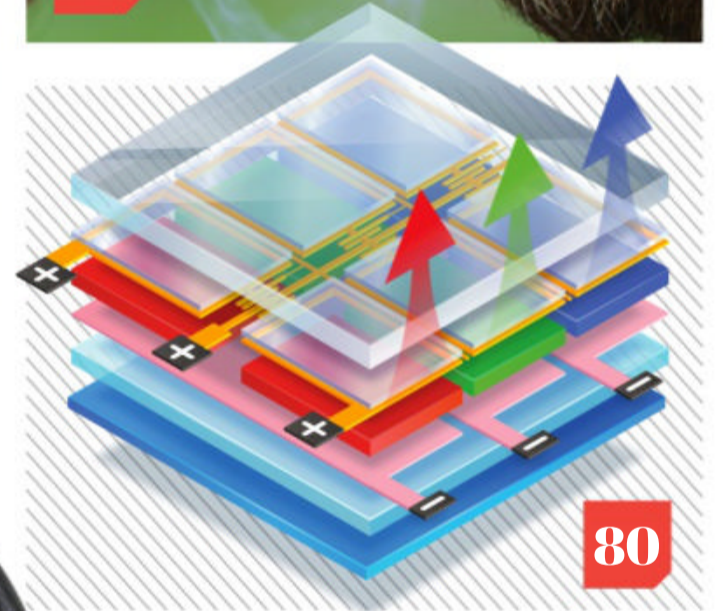
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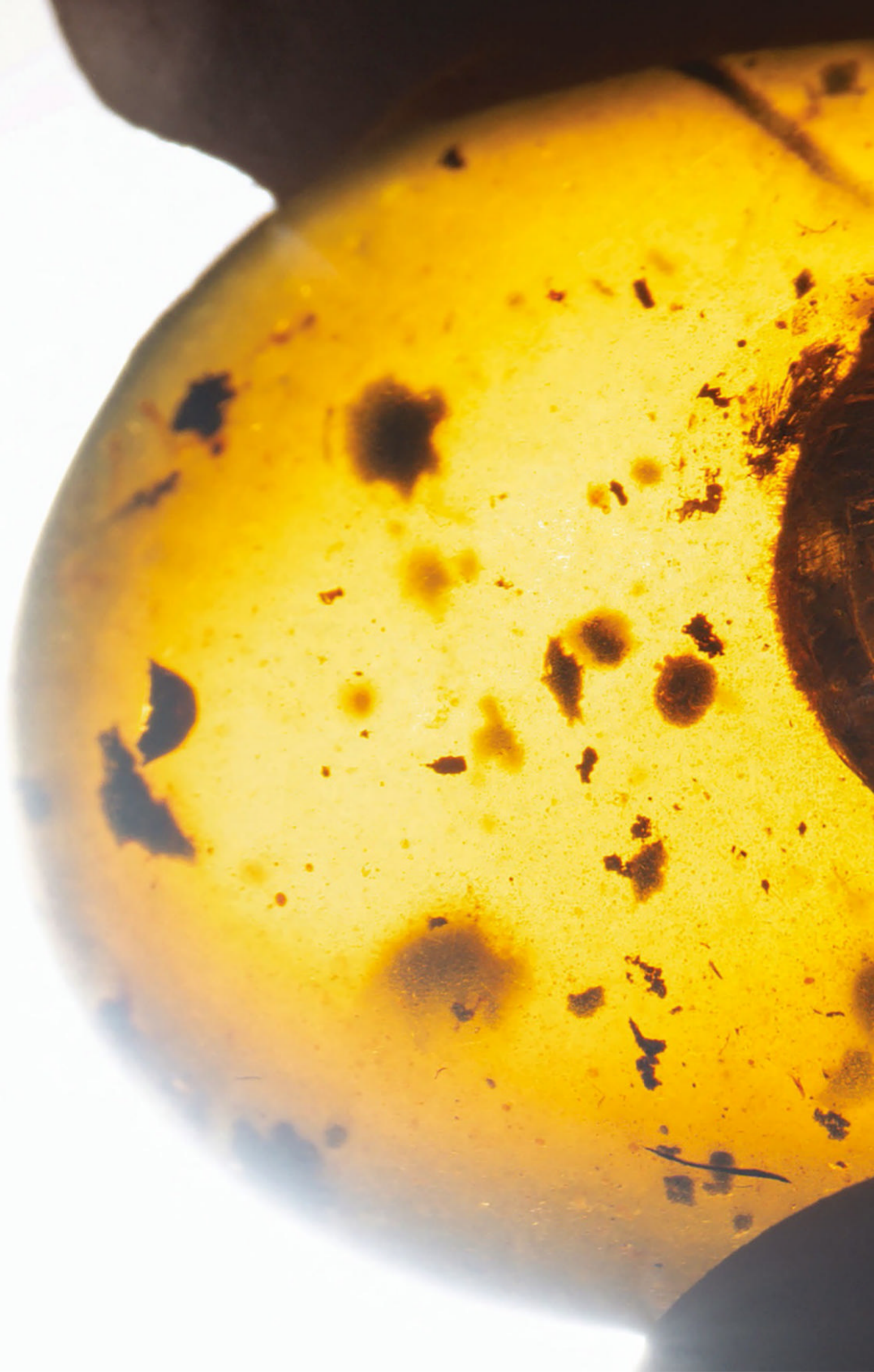
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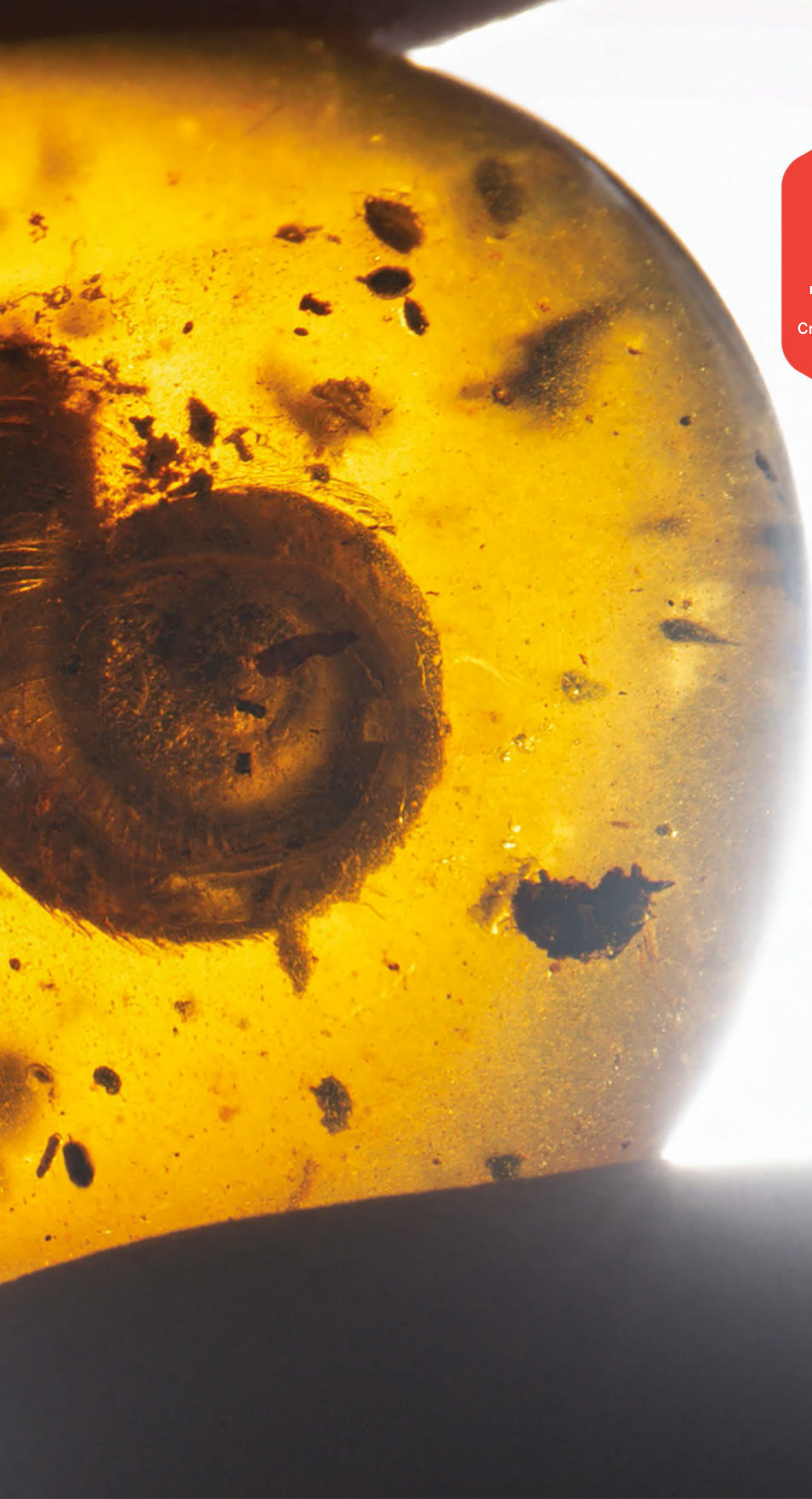


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Trapped in amber

Around 99 million years ago, this tiny, hairy snail, called *Archaeocyclotus brevivillosus*, was trapped in a lump of amber, fossilising it in the process. Researchers uncovered the nine-millimetre-long snail in Hukawng Valley in northern Burma in March 2023. The Cretaceous critter would have been slowly moving through vegetation at the same time the dinosaurs walked the Earth.







Supernova study

Around 11,000 light years from Earth is a supernova remnant called Cassiopeia A. Details of the cosmic explosion, first discovered by astronomers in 1948, have been seen in a new light thanks to a collaboration between NASA's Chandra X-ray Observatory, the James Webb Space Telescope and the Spitzer Space Telescope, which observe in different wavelengths.







Hiding in plain sight

This is the Vietnamese mossy frog, a well-disguised amphibian that has evolved to seamlessly blend in with its leafy surroundings. Along with their cryptic colouring, these ingenious frogs avoid facing off with predators, such as arboreal snakes and mammals, by curling up into a ball and playing dead. Often dwelling in water, these frogs leave their eyes above the surface to scan for predators.







Carving Jefferson's face

In this image from the 1940s, sculptors can be seen lowered from the top of the 152-metre face of Mount Rushmore on 'bosun chairs', to finish the second presidential face of Thomas Jefferson. Originally, Jefferson's stony portrait was intended to sit to the right of George Washington. However, unstable granite meant workers had to move the effigy of Jefferson to Washington's left side.



ANIMALS

A trillion cicadas will descend on the US this spring in a rare event

WORDS SASCHA PARE

More than a trillion cicadas could emerge throughout the Midwest and Southeast of the US this spring, as the schedules of two separate broods align for the first time since 1803. Brood XIII and Brood XIX represent two distinct groups of periodical cicadas that emerge according to 17 and 13-year life cycles respectively. In a rare natural event that occurs once every 221 years, these two broods will both tunnel through the ground to the surface, starting in late April, across 16 states.

The event, known as a dual emergence, could potentially lead the two broods to interbreed. "Under just the right circumstances and with just the right number of individuals cross-breeding, you have the possibility of the creation of a new brood set to a new cycle," said Floyd Shockley, an entomologist and collections manager at the Smithsonian National Museum of Natural History.

Periodical cicadas, which comprise seven species, spend most of their lives underground as nymphs and feed off sap that oozes from tree roots. After 13 or 17 years starved of daylight, depending on the species, the insects burrow to the surface using their

front legs and transform into adults. The males vibrate membranes on the sides of their bodies to produce a song that attracts mates. Once a pair has finished mating, the females cut slits in tree branches to lay their eggs in. Adult periodical cicadas survive for three to four weeks and don't live to see their eggs hatch roughly three weeks later. The newly hatched nymphs then drop to the ground and tunnel down into the soil to repeat the cycle.

Brood XIII, which has a 17-year cycle, and Brood XIX, which has a 13-year cycle, will overlap along a narrow band in northern Illinois and eastern Iowa. Brood XIII, also known as the Northern Illinois Brood, will also emerge in parts of Wisconsin and Indiana, whereas Brood XIX, the Great Southern Brood, will appear throughout the Midwest and Southeast.

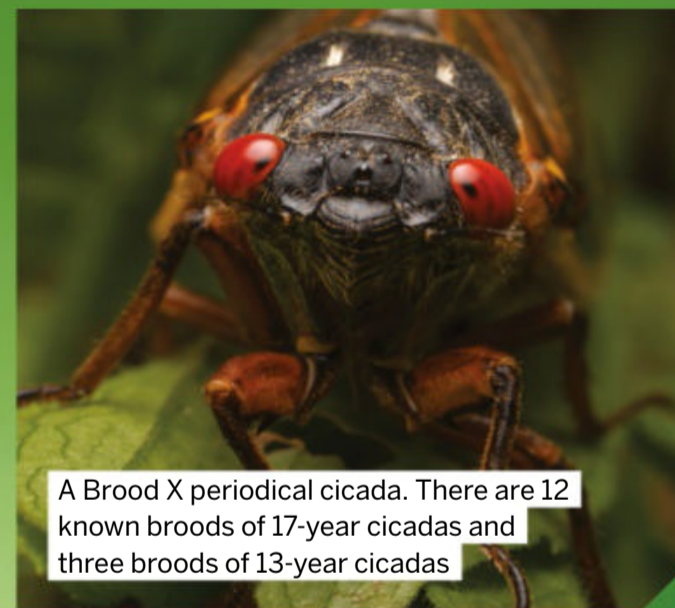
More than 1.5 million cicadas may emerge within an acre of forest, but deforestation has eliminated much of the canopy these insects need to thrive. Cicadas will likely cluster in forested areas and green urban spaces close to where the insects emerge. "In urban areas there will be sufficient numbers to necessitate removal of their bodies," which produce a smell similar to that of rotting nuts

as they decay, Shockley said. The dual emergence will likely end in early July.

Scientists recommend leaving the cicadas alone if possible, as they are beneficial to the ecosystem, don't bite or sting and don't carry diseases. Emerging cicadas aerate the soil when they burrow to the surface, and when the females lay their eggs they perform a natural pruning service that results in more flowers and fruit growing the following year. "Don't be scared of it," Shockley said. "Embrace it for the wondrous event that it is, and embrace the fact that it's very temporary. It will be intense but short-lived."

Did you know?

There are almost 3,400 species of cicada on Earth



A Brood X periodical cicada. There are 12 known broods of 17-year cicadas and three broods of 13-year cicadas





An artist's impression of a bright quasar

SPACE

The brightest black hole ever discovered devours a Sun's worth of matter every day

WORDS BEN TURNER

Scientists have spotted the brightest and fastest-growing quasar ever seen, a monster black hole that's devouring a Sun's worth of material every day. The brightly burning object, named J0529-4351, weighs between 17 and 19 billion solar masses and is located 12 billion light years from Earth, meaning it dates to a time when the universe was only 1.5 billion years old. Black holes are born when giant stars collapse in on themselves, and they grow by devouring all they encounter – be it gas, dust, stars, planets or other black holes. Friction can cause the material spiralling into the maws of these gluttonous space-time ruptures to heat up, which emits light that can be detected by telescopes, turning them into so-called active galactic nuclei (AGN).

The most extreme AGNs are quasars, supermassive black holes that are billions of times heavier than the Sun and shed their gaseous cocoons with light blasts trillions of times more luminous than the brightest stars. The quasar initially showed up in a 2022 survey by the European Space Agency's Gaia spacecraft, which has been mapping the positions and movements of the Milky Way's roughly 2 billion stars. However, as quasars often burn at least as brightly as stars, J0529-4351 was initially misidentified as one.

After searching for potentially misidentified black holes in the survey, a recent study revealed that researchers had found J0529-4351 hiding in plain sight. Further observations by the Very Large Telescope (VLT) in Chile's Atacama Desert confirmed that the bright object is a gigantic quasar, not a star.

By measuring the quasar's perceived brightness and adjusting for its distance from Earth, the researchers estimated that the object was burning with the power of roughly 50 trillion Suns. This intense burn is owed to the fact that J0529-4351 is so big and consuming material so fast that it's very close to the Eddington limit, an upper limit on how bright an object can be given its size.

The researchers hope that by studying the monstrous object they can both learn how quasars grew to such inexplicable sizes, as well as get better at distinguishing the monsters from among the brightest stars. "Although their luminosity implies rapid growth, their existence is hard to explain," the researchers wrote in the new study. "When black holes start from the remnant of a stellar collapse and grow episodically within the Eddington limit, they are not expected to reach the evident masses in the time from the Big Bang to the epoch of their observation, which has triggered a search for alternative scenarios."

PHYSICS

SCIENTISTS ACCIDENTALLY CREATE THE WORLD'S TIGHTEST, SMALLEST KNOT

WORDS KILEY PRICE

Scientists recently tied the smallest, tightest knot ever recorded, with just 54 atoms. The microscopic twist is in the form of a trefoil, the simplest type of nontrivial knot, with three interlaced crossings and no loose ends. The newly formed 'metallaknot' contains gold and even assembles itself. Scientists discovered this unintentionally. The researchers were originally trying to connect carbon structures to gold acetylides, a class of chemical compounds. During this process, one of the reactions yielded a golden chain that tied itself into a tangle resembling a three-leaf clover.

Along with being exceedingly tiny, the knot was also the tightest ever tied. Knot tightness is measured by its backbone-to-crossing ratio (BCR), with the smallest value representing the tightest knot. The previous record holder for tightest knot had a BCR of 24, but this new trefoil just edges it out with a BCR of 23.

Knot structures are crucial for binding together DNA, RNA and proteins that the human body depends on. Unravelling the mysteries of knots could also have real-world applications, from building more effective plastics to creating new types of chemotherapies.

A rendering of a golden trefoil knot



ARCHAEOLOGY

A JADE MASK DEPICTING A MAYA STORM GOD UNEARTHED IN A ROYAL TOMB

WORDS JENNIFER NALEWICKI

A 1,700-year-old royal tomb in Guatemala is overflowing with funeral offerings, including an intricately designed jade mask depicting a Maya deity. The tomb, located at an archaeological site known as Chochkitam near the borders of what are now Mexico and Belize, was the burial site for a previously unknown king. Along with the mask, designed to resemble the Maya storm god, researchers found 16 mollusc shells and hieroglyphs carved into human femurs, including one drawing depicting a man holding a jade mask similar to the artefact tucked inside the tomb. Researchers think the hieroglyphs identify the king's father and grandfather, and serve as a link to the ruler of the Maya states of Tikal and Teotihuacan. "A discovery like this is a bit like winning the lottery in terms of information," said Francisco Estrada-Belli, an archaeologist who discovered the tomb in 2022. "It opens a window into an obscure time we have little texts about." This era, known as the Maya Classic period, stretched from roughly 250 to 900 CE and is considered the height of the Mesoamerican civilisation's rule.

The mask was just one of many items found inside a 1,700-year-old tomb



© Francisco Estrada-Belli/Tulane University

HISTORY

Bedbugs plagued Britain 1,900 years ago

WORDS LAURA GEGGEL

Bedbugs have been plaguing the British for at least 1,900 years. Archaeologists discovered the earliest evidence of the bloodsucking parasites in the UK at Vindolanda, a Roman auxiliary fort just south of Hadrian's Wall in northeast England. Katie Wyse Jackson, a graduate student of archaeology at University College Dublin, made the discovery while investigating ancient insect remains at the fort. She found two thoraxes – the insects' midsections – at the lowest layers of Vindolanda, which was initially built in the late 1st century CE and was remodelled over the years.

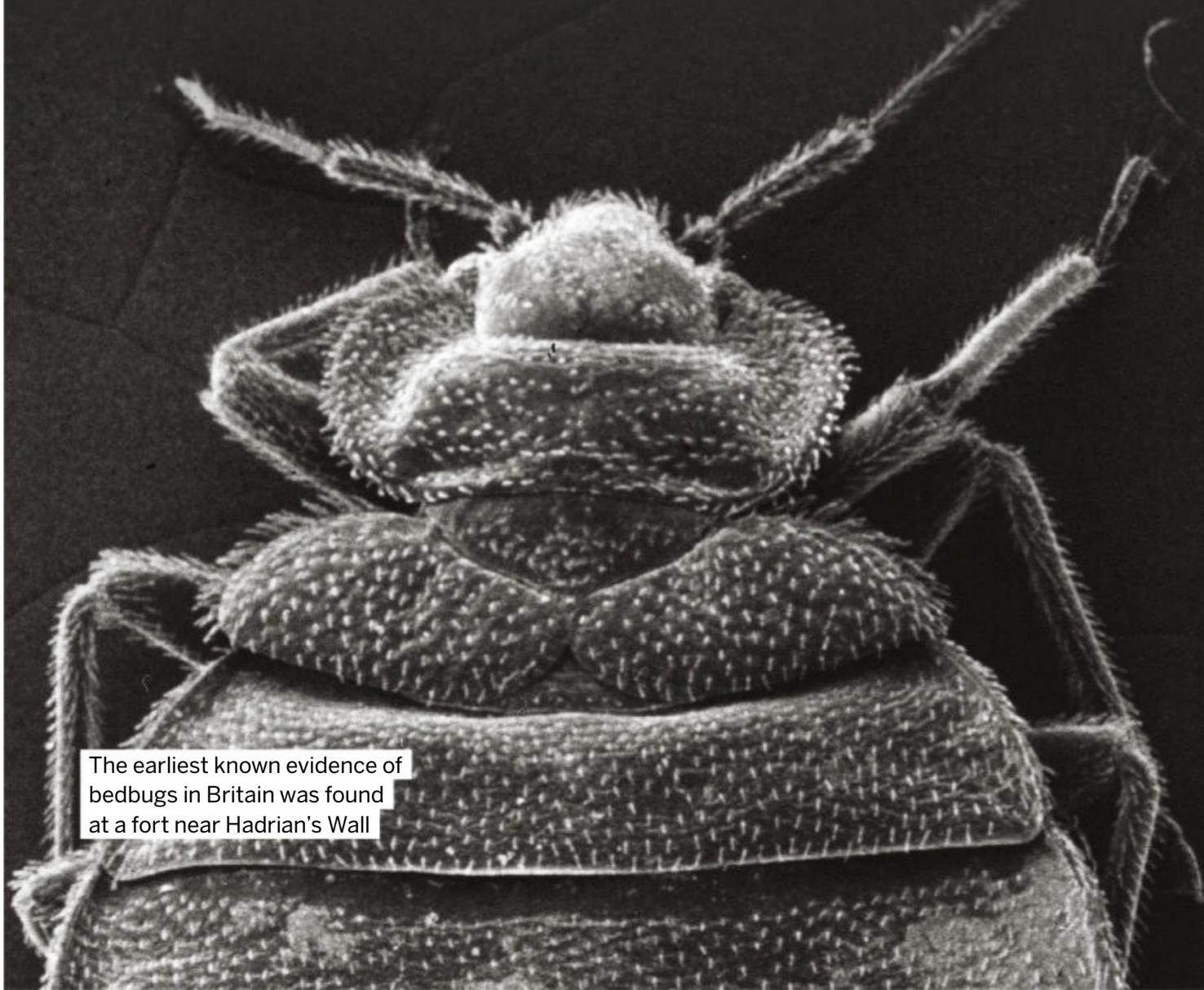
The finding supports the idea that the Romans brought bedbugs to Britain after they invaded the isle in 43 CE. Despite the empire's penchant for frequent bathing, evidence of bedbugs has been found at other sites in England, including a Roman settlement in Warwickshire dating to the middle to late 2nd century, and ancient Roman sites throughout Europe. In fact, a 2016 study found just as many bedbugs at Roman archaeological sites as in Viking and mediaeval ones. Considering the Romans bathed much more frequently,

the finding highlights how hard it was to eliminate these pests. "The Romans do have that reputation as being extremely clean, and so it's interesting to find all of these insects that are contrary to that," Wyse Jackson said.

To look for the insects, Wyse Jackson went to Vindolanda in August 2023 and excavated several soil samples from excavation layers, dating from 100 to 105 CE. "Insects are preserved extremely well in waterlogged material," she said. Wyse Jackson used paraffin wax, which easily sticks to insect remains in dirt, and then added water to the mix. "When the water is added, insects are more likely to float to the surface, allowing for the collection of as many insects as possible," she explained.

It's unknown how bedbugs travelled to Britain with the Romans, but one idea is that the pests hitchhiked over on straw mattresses. "It's very likely they came with whatever the Romans were bringing over," Wyse Jackson said. "The Romans were bringing over clothes, straw and grain in great quantities as they were setting up their camps," providing ample opportunity for bedbugs to join them, Wyse Jackson added.

The earliest known evidence of bedbugs in Britain was found at a fort near Hadrian's Wall



The universe might be merging with other 'baby universes', causing it to expand

WORDS ANDY FELDMAN

A new theoretical study suggests that the universe is expanding due to absorbing a 'baby universe', rather than being driven by dark energy

Our universe is expanding at an ever-accelerating rate, a phenomenon that all theories of cosmology agree upon, but none can fully explain. Now, a new theoretical study offers an intriguing solution: perhaps our universe is expanding because it keeps colliding with and absorbing 'baby' parallel universes. Studies of the cosmic microwave background (CMB) – the afterglow of the Big Bang – have revealed that our universe is experiencing accelerated expansion. For this observation to fit alongside the main theory of cosmic evolution, called the Standard Cosmological Model, physicists assume that the universe is filled with an enigmatic substance, dubbed dark energy, that drives this expansion. But this elusive form of energy does not manifest itself in any other way, leading many astrophysicists to question its existence and explore the possibility of an alternative cause for the universe's expansion.

In the recent study, scientists proposed the idea that the expansion of the universe may instead be driven by constantly merging with other universes. "The main finding of our work is that the accelerated expansion of our universe, caused by the mysterious dark energy, might have a simple intuitive

explanation, the merging with so-called baby universes, and that a model for this might fit the data better than the Standard Cosmological Model," said Jan Ambjørn, a physicist at the University of Copenhagen.

While the idea of multiple universes interacting with ours isn't new, this study develops a mathematical model to explore the hypothetical impact of this on the evolution of our universe. The researchers' calculations showed that merging with other universes should increase the volume of our universe, which could be perceived by our instruments as an expansion of the universe. The scientists also computed the rate of expansion of the universe using their theory, and their calculations more closely fit with observations of the universe than the traditional Standard Cosmological Model.

The authors' theory also addresses the problem of cosmological inflation, the mysterious super-rapid expansion that occurred in the early moments of the universe. Physicists have previously proposed that this expansion was caused by the 'inflaton', a hypothetical field that drove ultra-rapid expansion in the first milliseconds after the Big Bang. But in the new study, the

Did you know?

It's estimated that there are around 2 trillion galaxies in the universe

authors suggest this super-rapid early expansion could have been caused by our young universe being absorbed by a larger universe. "The fact that the

universe has expanded... in a very short time invites the suggestion that this expansion was caused by a collision with a larger universe; it was really our universe which was absorbed in another 'parent' universe," the researchers wrote in their paper. "Since we have presently no detailed description of the absorption process, it is difficult to judge if such a scenario could take place in a way that would actually solve the problems inflation was designed to solve, but one interesting aspect of such a scenario is that there is no need for an inflaton field."

The scientists suggested that after being absorbed, our newly enlarged universe then continued to collide with other 'baby universes' and incorporate them as well. Although the authors' theory enables us to solve some important problems of modern cosmology, only observational data can validate their hypothesis. Many experiments are currently being carried out to study the properties of the CMB, so scientists may be able to answer these fundamental questions in the near future.



Inside the JET tokamak, with a superimposed image of hot plasma

PHYSICS

A nuclear fusion reactor in the UK has set a new world record for energy output

WORDS JOANNA THOMPSON

A nuclear reactor in the UK has just broken a new fusion record. On 8 February 2024, representatives from the Joint European Torus (JET) facility declared that the reactor's final tests yielded 69.26 megajoules of heat from just 0.21 milligrams of fuel, the equivalent of burning two kilograms of coal. This is more total energy – though not more net positive energy – than any other fusion reaction has produced thus far. Tests such as this could help unlock fusion as a viable source of clean near-limitless energy.

JET first fired up in 1983 in Oxfordshire. Its doughnut-like shape, known as a tokamak, allows scientists to whip modified hydrogen atoms into hot plasma by accelerating them to breathtaking speeds using a magnetic field. This creates the necessary conditions for nuclear fusion, the combination of two light atomic nuclei into one heavier one, releasing enormous amounts of energy in the process.

Over the course of its 40 years of operation, JET has produced numerous fusion milestones, including becoming the first reactor to use a 50/50 mixture of deuterium and tritium atoms, now considered a standard fusion fuel. "We can

reliably create fusion plasmas using the same fuel mixture to be used by commercial fusion energy power plants, showcasing the advanced expertise developed over time," said Fernanda Rimini, JET's scientific operations leader.

However, this record will be JET's last. The project was decommissioned in December 2023, shortly after the record-breaking test took place. Researchers have now begun the arduous process of taking the reactor apart, a task that is expected to last until 2040. But over that time they hope to learn even more about what made JET tick, including how renegade plasma blasts affected the tokamak's internal structure. It will also help scientists develop safer strategies to dispose of radioactive waste.

JET's legacy will live on in the International Thermonuclear Experimental Reactor (ITER), a massive tokamak in southern France scheduled to start up in 2025. "JET has been remarkably helpful as a precursor to ITER," said Pietro Barabaschi, ITER's director-general. "The results obtained here will directly and positively impact ITER, validating the way forward and enabling us to progress faster towards our performance goals once operation begins."

PLANET EARTH

LAVA BLEEDS FROM AN ICELANDIC VOLCANO IN AN INCREDIBLE SATELLITE IMAGE

WORDS SASCH PARE

Lava flowed like crimson blood from a massive tear in Earth's surface during the latest volcanic eruption on Iceland's Reykjanes Peninsula. An image taken by the European Union's Sentinel-2 satellite seven hours after the 1.9-mile fissure appeared shows lava flows coursing 2.8 miles west from the eruptive site and a huge eruption plume extending southward from the peninsula into the Atlantic Ocean.

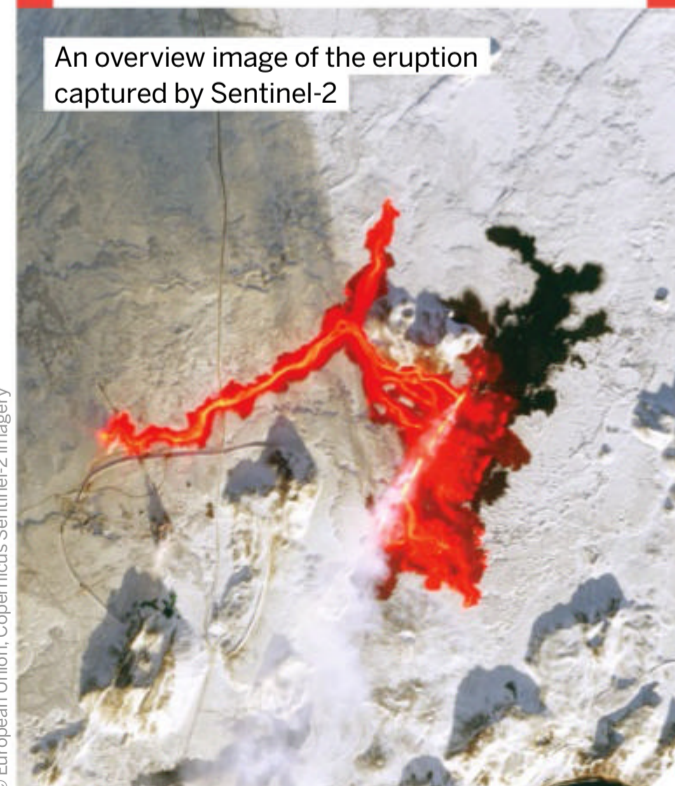
The volcano simmered down after staging its third eruption in three months on 8 February 2024. Unlike the previous eruption on 14 January 2024, which opened fissures along the southern tip of the magma dyke and propelled lava flows into the fishing town of Grindavík, February's eruption occurred in the northern part of the dyke closer to Svartsengi, 2.5 miles north of Grindavík. The latest eruption followed a similar pattern to the two previous eruptions, the first of which occurred on 18 December 2023. All three eruptions lasted around two days, with most of the magma extruded in less than 24 hours.

Did you know?

Lava can reach temperatures of up to 1,200 degrees Celsius



An overview image of the eruption captured by Sentinel-2



© European Union, Copernicus Sentinel-2 imagery

New mRNA ‘cancer vaccine’ trial launches in the UK

WORDS NICOLETTA LANESE

An 81-year-old man from Surrey became the first patient in the UK to receive a new ‘vaccine’ designed to treat solid-tumour cancers, such as the skin cancer melanoma. Therapeutic cancer vaccines act as a kind of immunotherapy, meaning they help train the immune system to fight cancer cells. They’re different from vaccines that prevent cancer, such as the HPV vaccine that’s incredibly effective at preventing cervical cancer. In the US there are a handful of therapeutic cancer vaccines approved for melanoma, prostate cancer and bladder cancer. The new vaccine being tested in the UK and elsewhere around the world is called mRNA-4359. Similar to the Pfizer-BioNTech and Moderna vaccines against COVID-19, the treatment contains a genetic molecule called mRNA. This cousin of DNA can relay instructions to the protein-building factories in cells, prompting them to churn out specific proteins.

In the case of mRNA-4359, the vaccine instructs cells to make proteins commonly found on cancerous solid tumours. These proteins then get presented to the body’s immune system, which builds up an arsenal to go after the cancer cells. mRNA-4359 is considered a ‘ready-made’ cancer vaccine; it’s designed to be used in any patient with

a particular type of cancer, off-the-shelf, because it goes after proteins commonly present on those tumour types. Other mRNA cancer vaccines currently in development are more personalised. For example, there’s a pancreatic cancer vaccine that’s made using genetic information drawn from a patient’s own tumours – thus it’s tailored to target proteins found on that specific patient’s cancer cells.

The mRNA-4359 trial is testing whether the vaccine appears safe and tolerable to human patients. It will both be tested in isolation and as an add-on to an existing immunotherapy called pembrolizumab. As a secondary measure, the trial organisers will also see whether the treatment shrinks the tumours of lung and skin cancer patients. The effectiveness of the vaccine will be probed further in future studies. “This research is still in the early stages and may be a number of years from being available to patients,” said Dr David Pinato, a clinician scientist at Imperial College London’s Department of Surgery and Cancer. “But this trial is laying crucial groundwork that is moving us closer towards new therapies that are potentially less toxic and more precise.”

The first person treated in the UK arm of the trial wishes to remain anonymous, but

said: “I was pleased to be offered a chance to take part in a new trial. Fundamentally, it’s a relief. I knew from my original diagnosis that I had something that was never going to go away, or unlikely to go away.”

The man has a treatment-resistant malignant melanoma, and he’d already received a different immunotherapy and radiotherapy prior to the trial. The trial is sponsored by the pharmaceutical company Moderna, and is set to recruit patients around the world over the next three years. Each patient will be followed up for a period of up to 34 months after treatment.



A new cancer vaccine being tested in trials contains mRNA, like the COVID-19 vaccines made by Pfizer-BioNTech and Moderna

“The trial is testing whether the vaccine appears safe”

Genomes of 51 animal species mapped in record time

WORDS KILEY PRICE

Researchers just mapped and published the genomes of 51 animal species, from fish-eating crocodiles known as gharials to fierce cloud leopards. These genetic blueprints could have broad implications for humans, particularly for understanding our evolutionary history. “In some ways we’re building an evolutionary time machine,” said Michael Schatz, a Bloomberg distinguished professor of computer science and biology at Johns Hopkins University. “Having the genes of our evolutionary cousins mapped out will help us better understand ourselves.”

All mammals share a common ancestor, which many scientists believe to be *Morganucodon*, a tiny, shrew-like creature that lived more than 200 million years ago, though some say otherwise. In any case, this shared ancestor means that a large chunk of our genetic make-up resembles those of other mammals, particularly chimpanzees, which share up to 99 per cent of our DNA. By comparing the DNA of humans and other animals, researchers can learn when and how humans diverged from other species. But a single vertebrate genome can be billions of characters long, and researchers must use different tools to break this genetic material into chunks before piecing it into a full picture. As a result, mapping genomes has historically been a painstaking process. Beginning in 1990, it took researchers 13 years to create the first genetic blueprint for humans.

However, DNA mapping technology for different species has advanced rapidly in the past few decades, and this new project marks another step, cutting the sequencing time from years and months to just days.

To achieve this, the team used research from two projects: the Vertebrate Genomes Project and the European Reference Genome Atlas. From these projects, they developed algorithms and computer software to assemble short genetic segments into a full genetic map, and eventually tested how well their workflow reproduced the complete genome of a zebra finch, which had been previously published.

The team found that their new technology was more effective than existing approaches at reassembling segments of the genome and creating an accurate map. Their software is open-source and available online via Galaxy, a free web-based platform based at Johns Hopkins and Pennsylvania State University. Researchers focused only on vertebrates; other animal, plant or fungal species might have “something distinctive or unique about their genome,” which means “some of the processes that are in this pipeline aren’t going to work as well in that species,” said Elinor Karlsson, director of the Vertebrate Genomics group at the Broad Institute. But this could be fixed “by modifying a few parameters” in their technique, according to the researchers. The goal is to sequence the genomes of at least one species across all 275 vertebrate orders.



Using a new technique, scientists created genetic blueprints for kangaroos, penguins, sharks and more



A newly discovered underwater canyon was carved out of the seabed by extremely salty currents

PLANET EARTH

Colossal underwater canyon discovered in the Mediterranean Sea

WORDS SACHA PARE

Scientists have discovered a giant underwater canyon in the eastern Mediterranean Sea that likely formed just before the sea transformed into a mile-high salt field. The canyon formed around 6 million years ago at the onset of the Messinian salinity crisis (MSC), when the Gibraltar gateway between the Atlantic Ocean and Mediterranean Sea narrowed and eventually pinched shut due to shifts in tectonic plates. The Mediterranean Sea became isolated from the world's oceans and dried up for roughly 700,000 years, leaving behind a vast expanse of salt up to two miles thick in some places.

As sea levels dropped, increasingly salty currents eroded the seabed and incised gullies several hundred metres deep along the steepest edges of the Mediterranean Sea. In a new study, researchers describe a giant U-shaped canyon located 75 miles south of Cyprus, in the depths of the Mediterranean's Levant Basin. The 500-metre-deep and 6.2-mile-wide canyon, which the researchers named after the nearby Eratosthenes seamount, likely formed underwater shortly before salt piled onto the seabed. Unlike the more coastal gullies, the canyon had no older 'pre-salt' roots. "To explain the submarine formation of the Eratosthenes Canyon, we suggest incision by dense gravity currents scratching and carving the deep-water seafloor," the researchers wrote in the study.

Weighed down with salt and sediment, these currents rushed along faster than the surrounding water and gradually scooped out enough of the seabed to form the colossal canyon. Precisely when this occurred remains unclear, but it likely coincided with the beginning of the MSC, between 5.6 million and 6 million years ago. The incision process may have lasted anywhere from tens of thousands to half a million years. The discovery sheds light on a decades-long debate over whether Messinian gullies and canyons that now lie underwater formed above or below the sea surface. "This new evidence strengthens the arguments that at least part of the erosion across continental margins occurred [below water]," the researchers wrote.

"The canyon formed around 6 million years ago"

The newly discovered canyon sits within a wider network of canyons and channels in an area known as the Levant Basin, which extends from the coast of Syria in the north to Gaza in the south, and northwest towards Cyprus. To the northwest of the canyon, beyond the Eratosthenes Seamount, sits the much deeper and older Herodotus Basin, which receives currents loaded with sediment from the southeast. These currents may have crossed the area that now boasts the Eratosthenes Canyon long before it was incised. "The absence of older roots under the Eratosthenes Canyon does not rule out the possibility that a shallow pre-MSC channel system predated the Eratosthenes Canyon," the researchers wrote.

SPACE

A TINY ASTEROID JUST SNUCK BETWEEN EARTH AND THE MOON

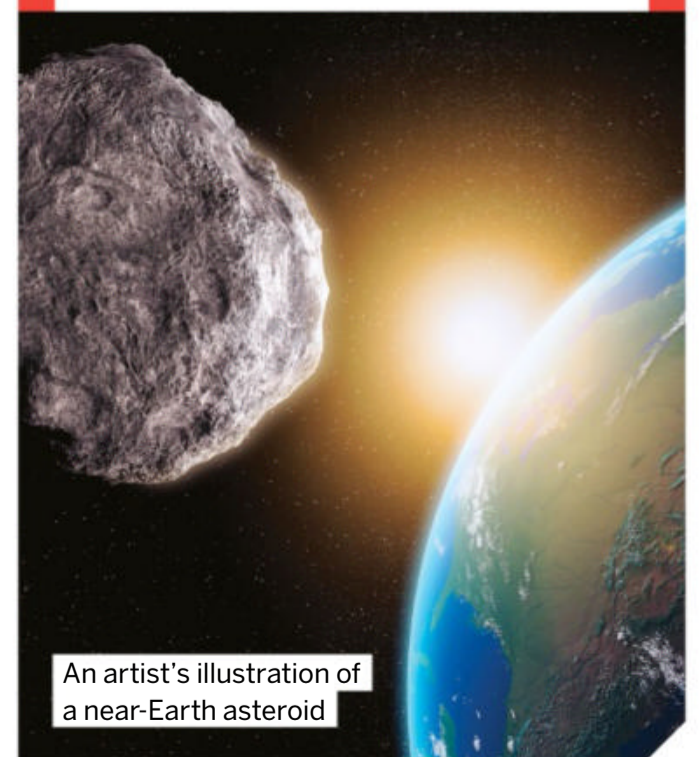
WORDS SAMANTHA MATHEWSON

On 12 February, an asteroid named 2024 CY1 travelled within 75,278 miles of Earth, which is about 31 per cent of the average distance to the Moon. 2024 CY1 was discovered on 9 February, only three days before its close approach. Astronomers spotted the asteroid using the Pan-STARRS 2 telescope located near the summit of Haleakala on Maui, Hawaii. Pan-STARRS 2, which stands for Panoramic Survey

Did you know?
Vesta, the largest asteroid, is 329 miles wide

Telescope and Rapid Response System, is designed to hunt for near-Earth objects, such as asteroids and comets, that may pose a risk for potential Earth impact. Most near-Earth objects are asteroids that range in size from about 3.0 metres to nearly 25 miles across. Measuring between 3.8 and 8.4 metres in diameter, 2024 CY1 is a relatively small asteroid, posing no risk to Earth.

2024 CY1 belongs to the Apollo group of near-Earth asteroids, which includes asteroids that cross Earth's orbit. Using instruments like Pan-STARRS 2, astronomers are able to calculate an object's orbit and determine if – and when – it could come close to Earth.



An artist's illustration of a near-Earth asteroid

WISH LIST

The latest **WEARABLE GADGETS**

QUIETON 3.1 SLEEP EARBUDS

£249 (APPROX. \$316) QUIETON.COM

If standard foam earplugs don't block out the world and allow you to have a good night's sleep, the QuietOn 3.1 sleep buds might be your solution to snoozing. The technology inside these compact earbuds uses active noise cancellation that automatically generates opposing sound waves as it detects ambient sound. The two sound waves collide, nullifying their vibrations and cancelling each other out, leaving you oblivious to any surrounding noise. The QuietOn 3.1 triggers its active noise cancellation gradually over 20 seconds to ease you into silent sleep. A pair of these earbuds can last for up to 28 hours on a single charge, and they come in a range of sizes to fit many different ear shapes.



TAPXR

\$299 (APPROX. £236) TAPWITHUS.COM

Combining motion and optical sensors, the TapXR gives its wearer the ability to communicate with your smart devices in a whole new way. Through hand-tracking technology, the TapXR translates tapping into a command that it passes onto a Bluetooth-paired device to carry out a function. Practically any surface can be used to carry out preassigned tap gestures, at a rate of ten gestures per second. From typing out messages to creating shortcuts on your device, there are 150 unique tap commands and actions this wrist-worn device can carry out. As well as smartphones and computers, the TapXR can be paired with VR headsets as a controller to navigate the virtual world.

NOWATCH FROM €450 (APPROX. £385 / \$488) NOWATCH.COM

The NOWATCH is a smartwatch that focuses largely on monitoring your body's stress levels through several metrics, including skin conductance, heart rate and breathing rate. Within the companion app, these metrics are collected into a graphic that summarises your physiology so that you can restore balance to your body. Along with tracking your sleep cycle, the NOWATCH works with your smartphone's alarm settings to gently wake you up during a preset time frame when your body has entered a period of light sleep. Unlike other smartwatches, the NOWATCH

doesn't come with a digital display to showcase the data it's collected. Instead, all that data is transmitted and stored in the NOWATCH app. Instead of the traditional smartwatch display, this smart accessory can be purchased with an array of modular faces, including an analogue clock, a metal disc or an array of stone discs.



OWO ORIGINAL EDITION KIT

€499 (APPROX. £427 / \$541) OWOGAME.COM

Bringing your gaming world into reality, the OWO haptic skin shirt uses an array of sensory pads to deliver more than 30 different sensations during gameplay. From the force of blowing wind to the impact of a gunshot, the skin's built-in sensors are placed across the chest, arms and abdomen for a full upper-body experience. The sensitivity of each of the microsensors can be adjusted using the skin's companion app, as well as collating all the different sensations you wish to feel during play to customise your gaming adventure. The OWO skin is compatible with a range of different games, including *Assassin's Creed Mirage*, *Halo Infinite* and *Fortnite*.



RINGPAY 2

FROM £99.99 (APPROX. \$127) MCLLEAR.COM

Making countless payments at the till might not get much easier than using the RingPay 2. Simply hover the sleek smart ring over the reader, like any contactless credit card, and the transaction is complete. One of the many benefits of the RingPay 2 is that it doesn't need charging. Unlike a smartphone or smartwatch, which can find itself without charge, leaving you without

a way to pay, the RingPay 2 doesn't need to be recharged. The accompanying app also lets you manage your money and how much you spend by creating a money pot which you can top up at any time. The app also lets you pause the ring's ability to make payments if it's misplaced. The RingPay 2 is made out of zirconia ceramic, which is both hypoallergenic and waterproof.



GOOGLE PIXEL WATCH 2

£349 / \$349

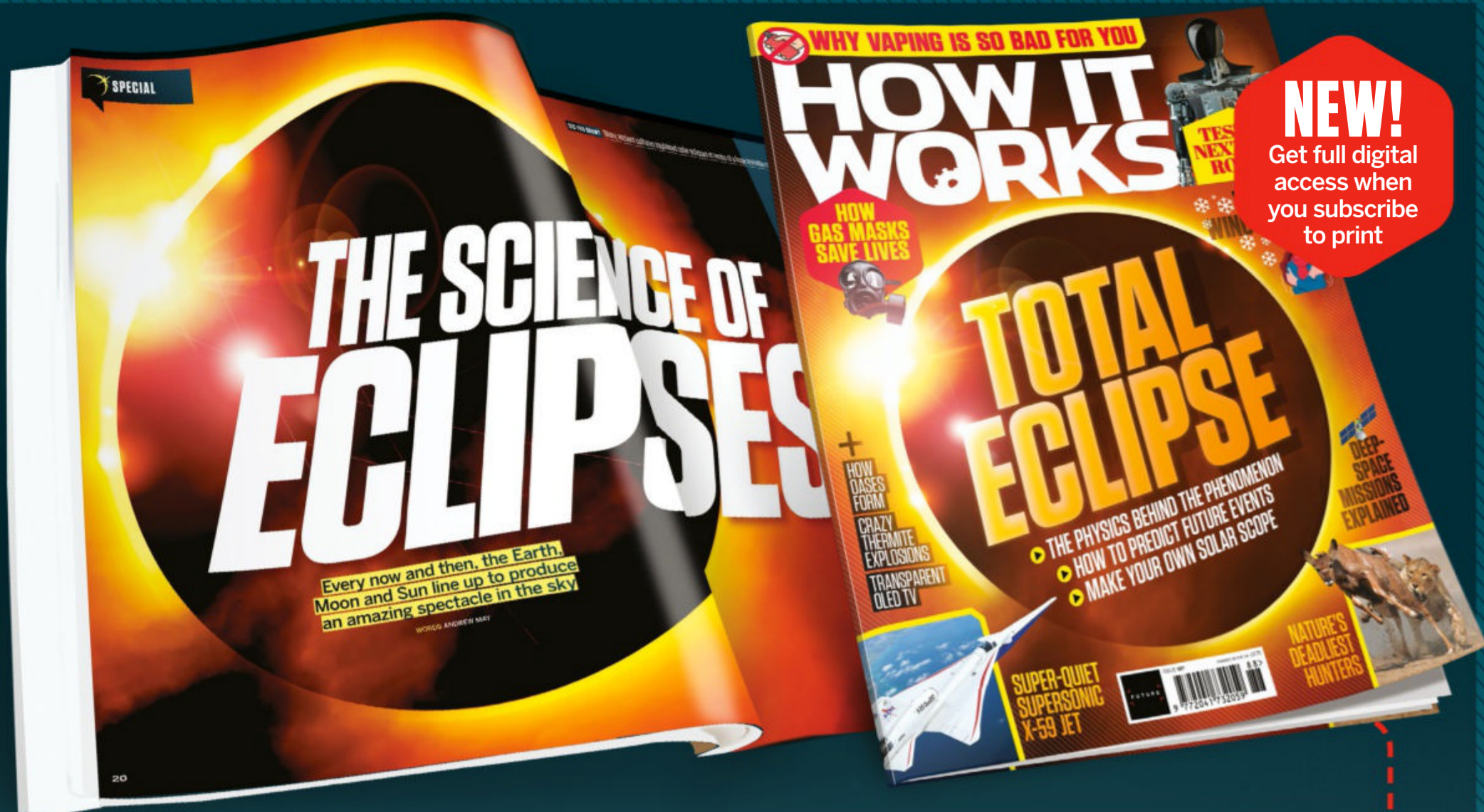
STORE.GOOGLE.COM

Packed with all the statistical bells and whistles a smartwatch can offer, the Google Pixel Watch 2 can help you keep tabs on your body's health and fitness, along with keeping you connected through your smartphone. Along with the typical heart rate and step monitor, this intuitive device monitors your skin temperature, blood oxygen level and sleep habits to supply a detailed analysis of your health. It also includes a continuous electrodermal activity sensor that monitors stress in your body and how it might affect your mood. The Pixel Watch 2 also comes with a handy safety feature that will share information such as your location and battery life with a chosen contact after a certain amount of time.

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THE SCIENCE *ECLIPSE*

Every now and then, the Earth,
Moon and Sun line up to produce
an amazing spectacle in the sky

WORDS ANDREW MAY

WITNESS OF ECLIPSES

Solar eclipses, particularly of the total or near-total kind, are among the most dramatic and memorable of all astronomical events. But what causes these striking phenomena in the first place, and why do they occur at certain times and not others?

Eclipses occur due to the alignment of three different celestial bodies: the Earth, Moon and Sun. Without going into too much astronomical detail, you can picture the Moon as revolving around the Earth in a roughly circular orbit, while both bodies are illuminated by the much more distant Sun. The Moon takes about a month to complete a single orbit, during which time there are two occasions when the Sun, Moon and Earth lie along an approximately straight line. When it happens in that order, and the Moon looks very close to the Sun in Earth's sky, we call it a 'new Moon'; when it's in the order Sun-Earth-Moon, we call it a 'full Moon', because the Moon's disc is fully illuminated by sunlight when viewed from Earth.

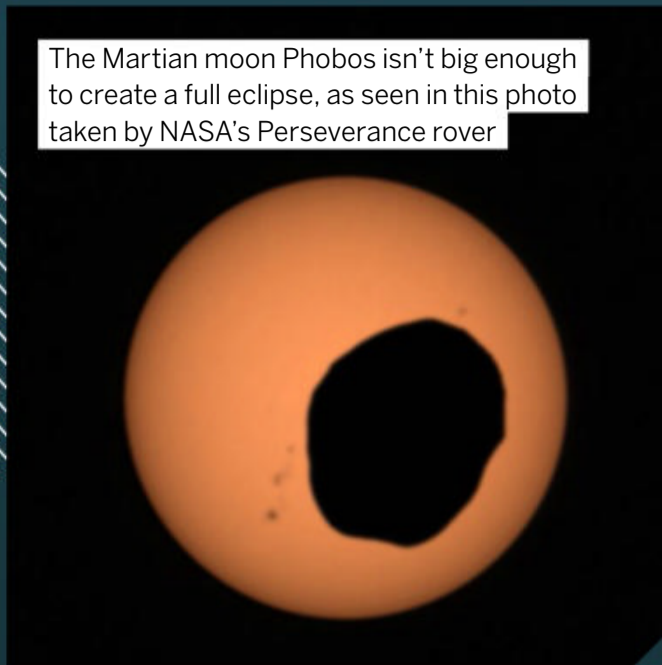
Most months, this alignment isn't perfect because the Moon orbits Earth in a slightly different plane from the orbit of the Earth-Moon system around the Sun. For example, a new Moon usually appears slightly offset from the Sun in the sky, rather than bang on top of it. But occasionally, the three bodies really do lie in a perfectly straight line, and that's when we get an eclipse. The eclipse that occurs at new Moon is called a 'solar eclipse', and it results in all or part of the Sun's light being blocked out by the Moon.

There's an odd coincidence that makes solar eclipses even more striking on Earth than they would be on other planets. That's



Most locations see a 'blood Moon', or total lunar eclipse, every two or three years

The Martian moon Phobos isn't big enough to create a full eclipse, as seen in this photo taken by NASA's Perseverance rover



because even though the Sun is around 400 times larger than the Moon, it's also 400 times further away, so the two objects look almost exactly the same size in the sky as seen from Earth. This creates the possibility of a 'total solar eclipse', in which the Moon fits neatly over the Sun, just leaving its outer atmosphere, or corona, visible.

There's another type of eclipse – called a 'lunar eclipse' – that happens when a similar alignment occurs at full Moon. In this case, it's Earth that's blocking the Sun's light from reaching the Moon, so you might expect the Moon to disappear completely. This never actually happens, though, because some of the sunlight passing through Earth's atmosphere still manages to reach the Moon. This gives it a strikingly red appearance, often referred to as a 'blood Moon'. A blood Moon can be a very dramatic, even ominous, sight, especially for someone who isn't expecting it. For example, it's said that in 1453, when the city of Constantinople (now Istanbul) was under siege, a blood Moon caused such a slump in morale that the defenders caved in shortly afterwards.

As striking as a lunar eclipse is, however, its impact still can't compare with a total solar eclipse. As well as the sky suddenly becoming dark during daytime, it can cause temperatures to plunge, wind direction to change and wildlife to get thoroughly confused. For astronomers and the majority of the public, however, eclipses are a great chance to observe things they might otherwise never see – such as stars during daytime or the Sun's corona. It's therefore very fortunate that we always know well in advance when an eclipse is coming up.

That's not so surprising today, when we have a good understanding of orbital motions in the Solar System and powerful computers to do the calculations, but to some extent it's been true for millennia. In many ancient cultures, from Greece to Mexico, there were some people – skilled astronomers, if not the general populace – who kept careful track of the motions of the Sun and Moon, and were often able to make a pretty good guess of when the next eclipse might be coming up.

In fact, eclipses may be a more frequent occurrence than many people realise. Including both solar and lunar types, there are at least four eclipses each year, and

occasionally as many as seven. These numbers are more or less equally divided between solar and lunar – a fact that may come as a surprise. You've probably seen, or at least read about, far more lunar eclipses than solar eclipses. The reason is that whenever a lunar eclipse occurs, it's visible from the whole of the night side of Earth – meaning to roughly 50 per cent of the world's population. On the other hand, solar eclipses are only visible in a narrow band where the Moon's shadow passes over Earth – and even then, they may only be partial rather than total.

Any particular spot on Earth has to wait an average of 375 years from one total solar eclipse to the next – making them rare events indeed. In recent times, however, North America has had something of a lucky streak, beating the odds with two total solar eclipses in the space of just seven years. One crossed the United States on 21 August 2017, and it will be followed by another one – also passing over some parts of Canada and Mexico – on 8 April 2024.

Did you know?

When we see a new Moon, the Moon sees a full Earth

HOW A SOLAR ECLIPSE WORKS

An eclipse occurs when the Sun, Moon and Earth line up almost exactly



TOTAL



ANNULAR



PARTIAL

TYPES OF SOLAR ECLIPSE

Solar eclipses come in several types, depending on the exact circumstances. The best-known and most exciting of all is a total solar eclipse, in which the Moon completely blots out the face of the Sun, leaving just the corona visible. If the alignment isn't perfect, however, we get a partial eclipse, where only part of the

Sun is obscured by the Moon. A third possibility, called an annular eclipse, has the same basic geometry as a total eclipse, but occurs when the Moon is at the far point of its orbit around Earth, so it isn't quite big enough to cover the whole Sun. This leaves a ring of sunlight visible around the lunar disc.

1 THE SUN

In reality, the Sun is much bigger and much further away than it appears in this diagram, which isn't to scale.

2 MOON'S ORBIT

The Moon orbits Earth once a month, appearing as a 'new Moon' when it roughly lines up with the Sun.

3 MOON

If everything lines up perfectly at new Moon, we get a solar eclipse.

4 UMBRA

Inside this area, the Sun's light is completely blotted out by the Moon.

5 PENUMBRA

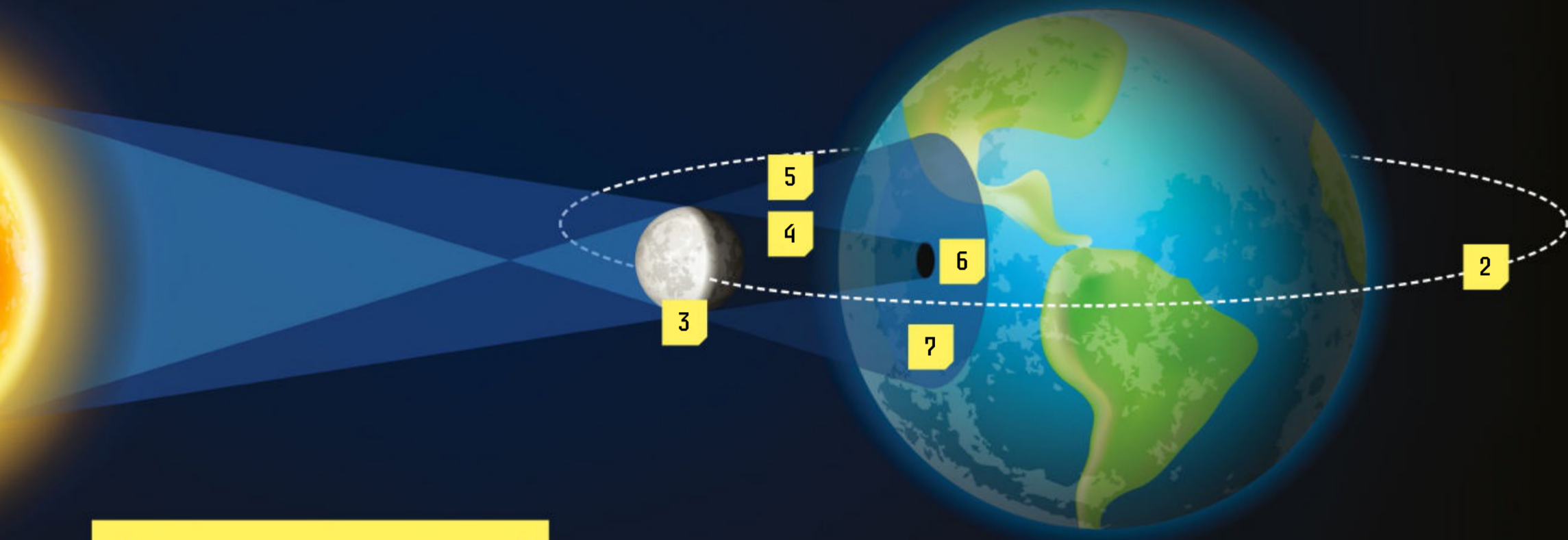
Inside this larger region, the Sun's light is partially blocked by the Moon.

6 TOTAL ECLIPSE

Where the umbra intersects the Earth's surface, observers will see a total eclipse.

7 PARTIAL ECLIPSE

At the intersection of the penumbra with Earth's surface, a partial eclipse will be visible.



LUNAR ECLIPSES

The best way to picture what happens during a lunar eclipse is to imagine yourself on the surface of the Moon. Once a month, Earth passes very close to the Sun in the sky, and occasionally it blots out the Sun entirely. This lasts longer than our own eclipses, because Earth seen from the Moon is much bigger than the Moon seen from Earth. As dramatic as this would be for a Moon-based observer, it's more subtle for us, because sunlight seeps through Earth's atmosphere and still illuminates the Moon a little bit. Even so, lunar eclipses have an advantage over the solar kind in that they usually last for many hours.

The Moon within Earth's shadow



“Solar eclipses are only visible in a band where the Moon's shadow passes over Earth”



Even a partial solar eclipse can be very dramatic if seen at sunrise

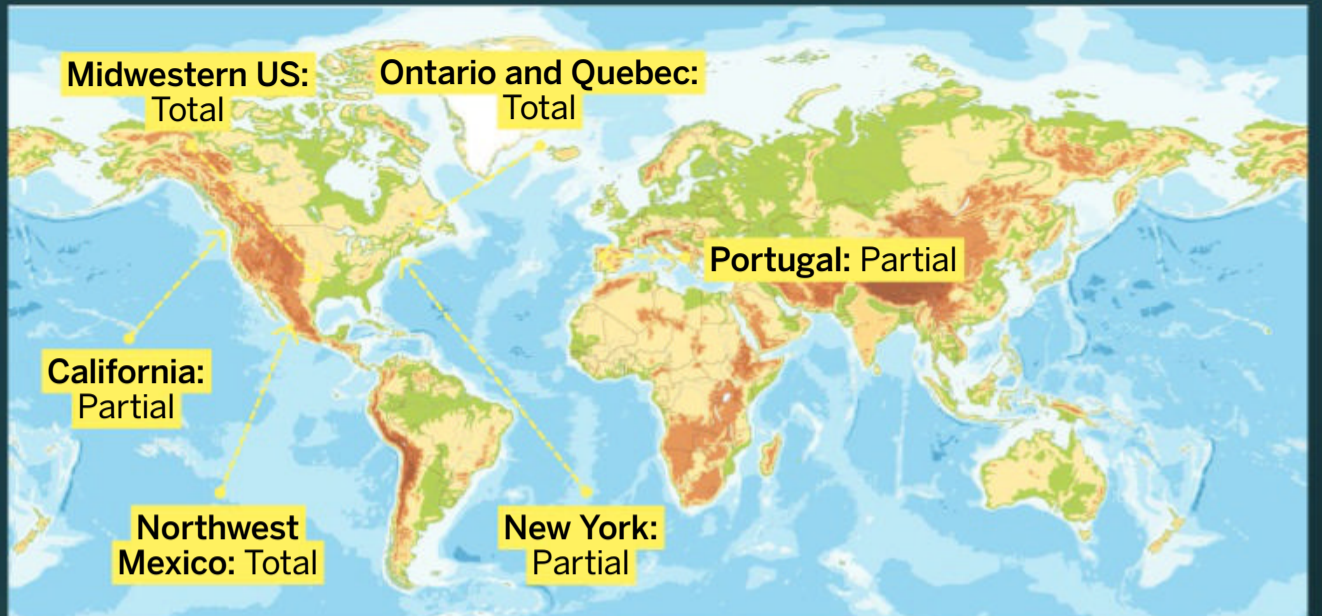
AMERICA'S 2024 ECLIPSE

The most important solar eclipse of the year will take place on Monday 8 April 2024. There will be a relatively narrow swathe, known as the 'path of totality', from which a total eclipse will be visible, with a wider band on either side of this witnessing a partial eclipse. The path of totality will start in the Pacific Ocean before passing over the western coast of Mexico, then northeastward over the United States to the eastern coast of Canada.

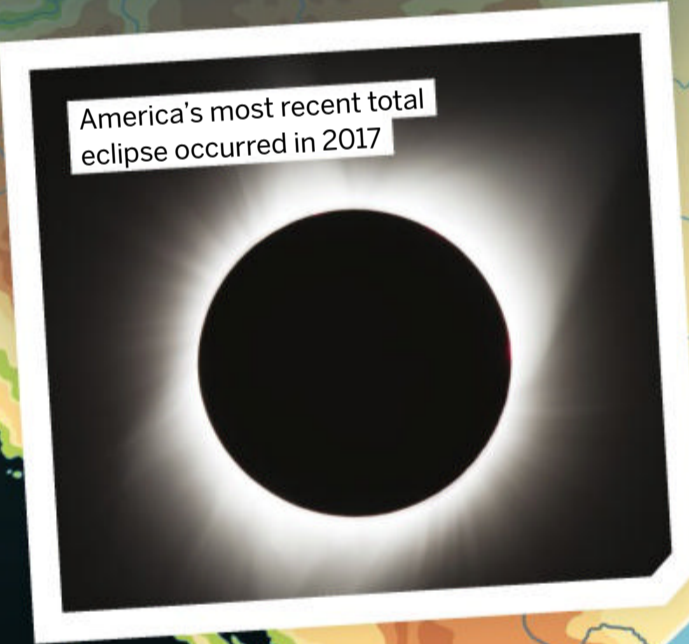
The area experiencing totality at any moment during the progress of the eclipse will be roughly circular. In effect, this is the shadow cast by the Moon on Earth's surface. When the eclipse first reaches Mexico, this shadow will be about 120 miles across, and totality will last around 4 minutes and 18 seconds, with these figures getting slightly smaller as the eclipse progresses.

Regarding the partial eclipse visible on either side of totality, this will be viewable across the whole of the continental United States. But the eastern side of the Atlantic will be much less fortunate, with only observers in Portugal having any real chance of seeing a partial eclipse, just before sunset.

MAPPING THE 2024 ECLIPSE



Did you know?
America's next total solar eclipse will be in 2044



PATH OF TOTALITY

1 MAZATLÁN, MEXICO
This will be the first place on the North American continent to see a total eclipse, at 11:07 local time.

2 TEXAS
Several cities in Texas will be in the path of totality, including San Antonio at 13:34 and Dallas at 13:42.

3 INDIANAPOLIS
As the eclipse passes through America's Midwest, this will be the largest city to see totality, at 15:06 local time.

4 MONTRÉAL
Finally, the path of totality will pass this large Canadian city at 15:27 local time.

THE PATH OF TOTALITY

A look at some of the places likely to get a good view of the eclipse





A solar filter can be fitted to a telescope to view the Sun safely



Even without an eclipse, observing the Sun can be fun – for example, counting sunspots

ECLIPSE SAFETY

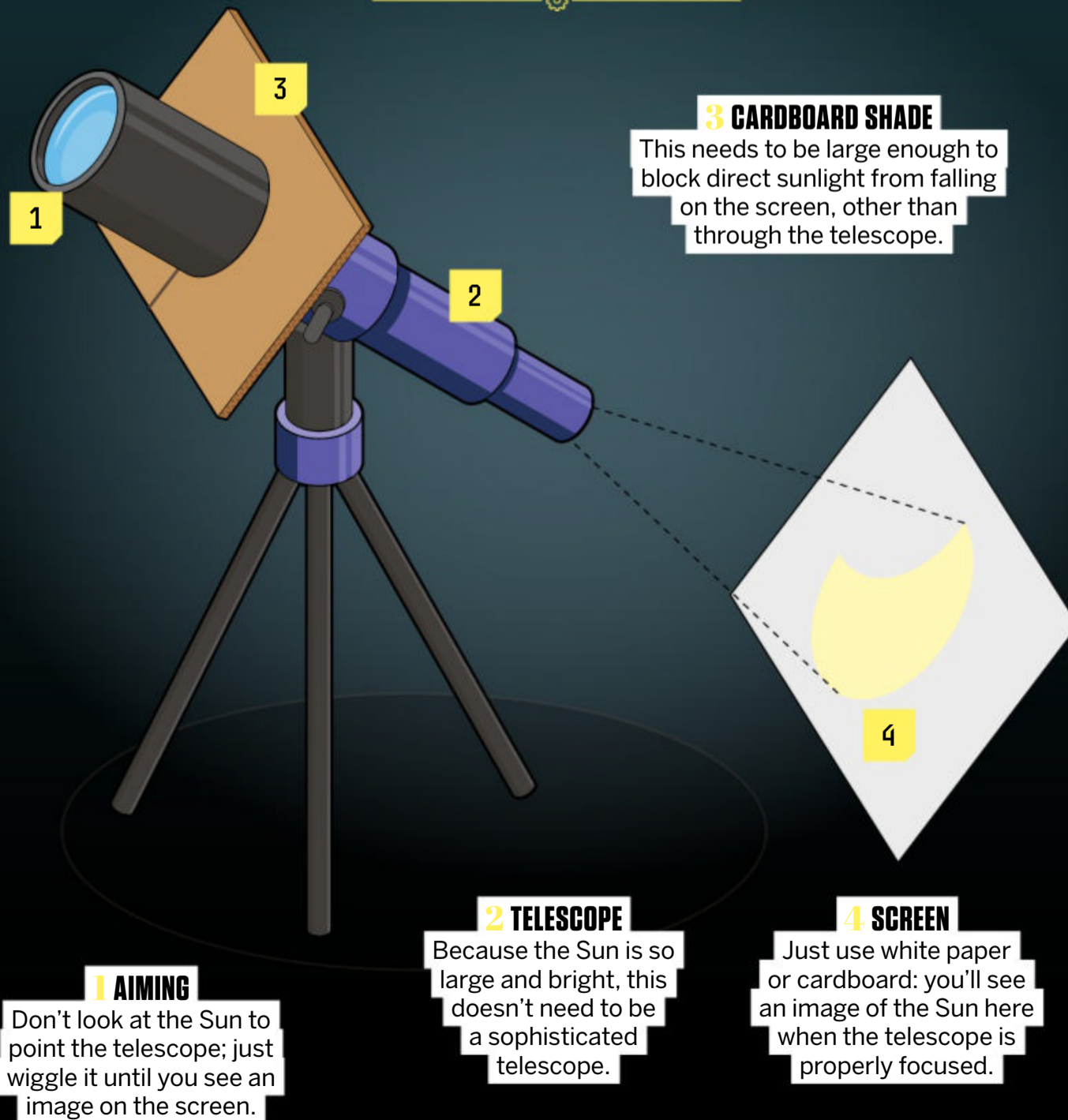
It's always dangerous to look directly at the Sun, as much during an eclipse as at any other time. It's important to take proper precautions, or you could risk permanently damaging your eyesight. NASA recommends using special 'eclipse glasses' or handheld solar viewers. But there are other options if you'd like a more magnified view. One approach involves attaching a special solar filter, typically made from aluminium-coated Mylar, over the front end of an ordinary telescope. This can be done quite cheaply by buying a sheet of filter material, then carefully following the instructions to fit it safely onto your telescope. Another option is to use a special 'solar scope' that projects a magnified image of the Sun onto a screen. These can be bought ready-made, but if you already have a suitable telescope, you can easily make one of your own.

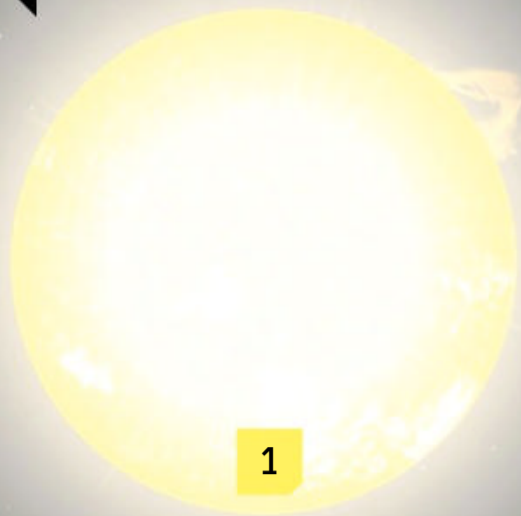


A group of eclipse-watchers using handheld solar viewers and eclipse safety glasses

A HOMEMADE 'SOLAR SCOPE'

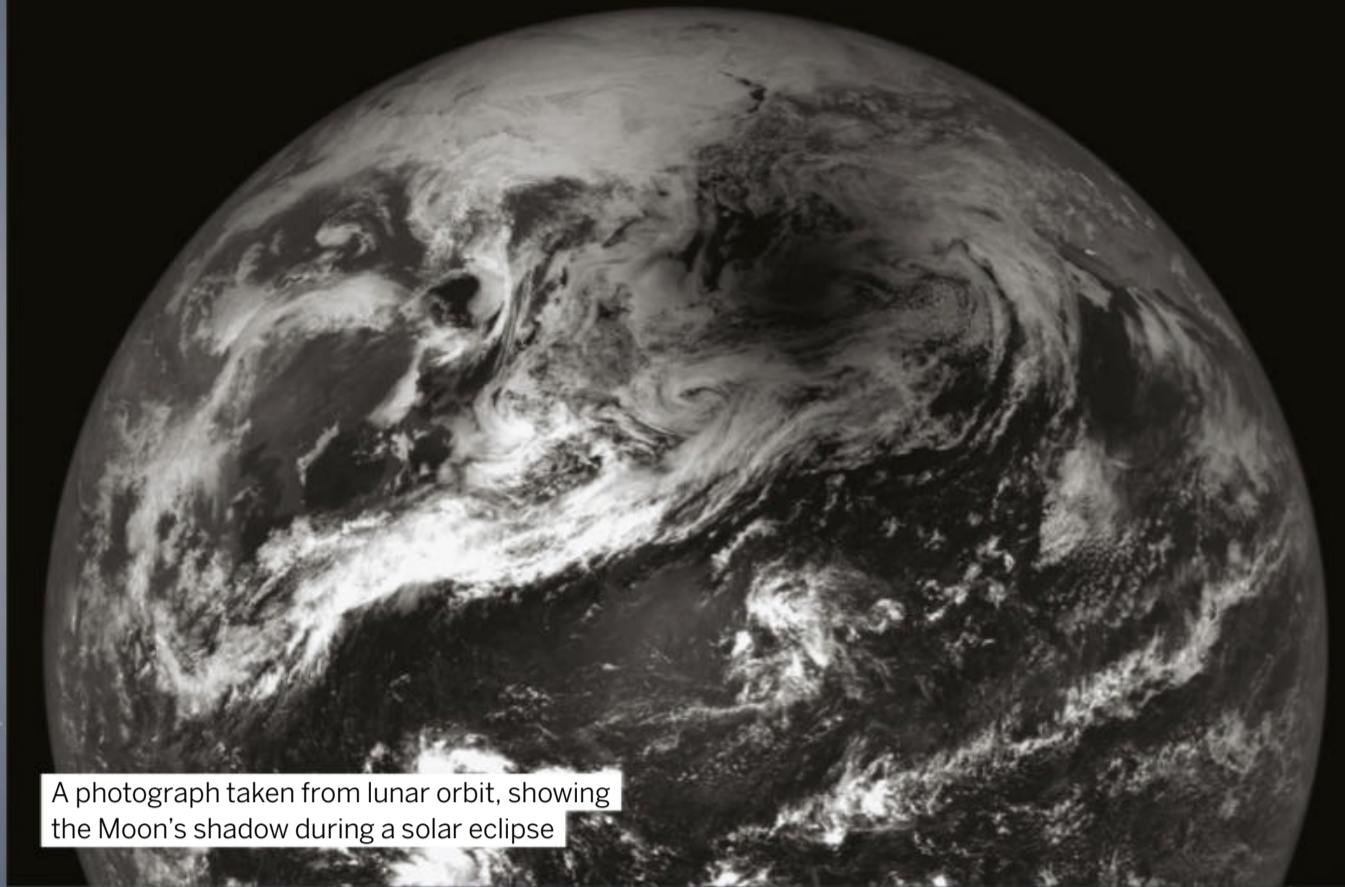
Here's a simple way to use any telescope to view the Sun safely





1 THE SUN

The two satellites, close together in Earth orbit, will form a straight line pointing at the Sun.



A photograph taken from lunar orbit, showing the Moon's shadow during a solar eclipse

ECLIPSE FROM SPACE

Space travel opens up a whole new perspective on the study of eclipses. In the broadest terms, these involve an alignment of the Sun, the observer and an obstructing object, such as the Moon. We normally think of the observer as being on the surface of Earth, but what if this isn't the case? When the Apollo 12 astronauts were returning from the Moon in 1969, they witnessed a type of eclipse no-one had ever seen before, when our own planet passed in front of the Sun.

This would have been similar to observing what we think of as a

'lunar eclipse' from the vicinity of the Moon. So what would a 'solar eclipse' look like from that perspective? It would involve the Moon's shadow passing over Earth, and this has indeed been strikingly photographed by NASA's Lunar Reconnaissance Orbiter. For scientists, a total solar eclipse is an all-too-rare opportunity to observe the solar corona. They'd much prefer if the necessary alignment could be created to order, and that's exactly what the European Space Agency is planning to do with its Proba-3 mission later this year.



2 OCCULTER SATELLITE

This satellite uses its 1.4-metre-diameter circular screen to block out the Sun as seen from the second satellite.

4

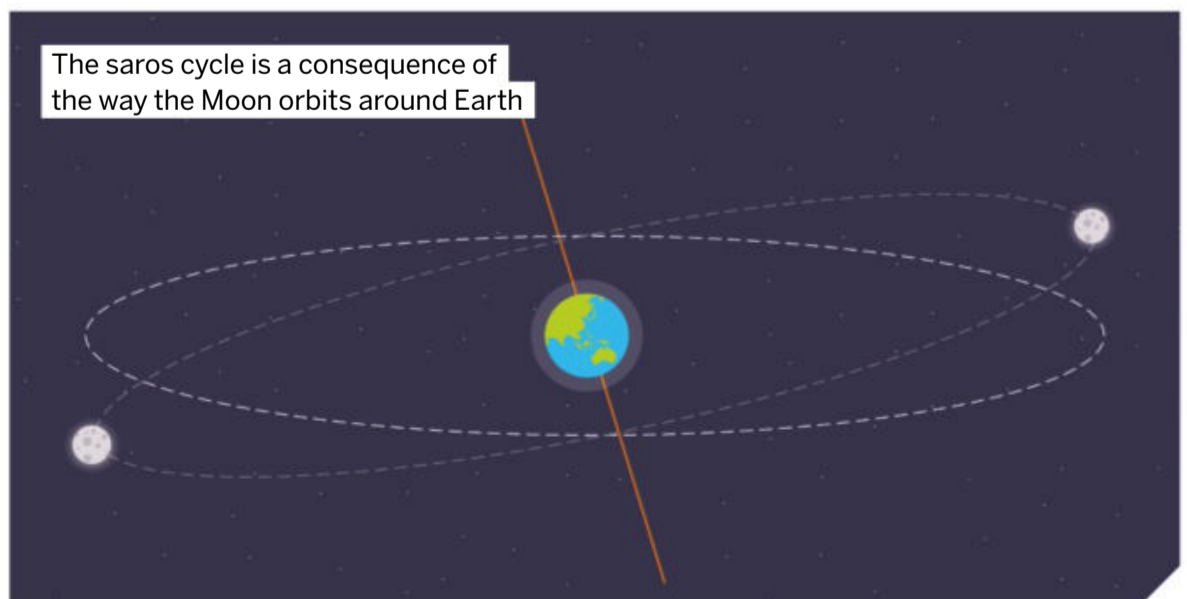
4 144 METRES

If the two satellites maintain this exact separation, the result will be a perfect 'total eclipse' of the Sun.

PREDICTING ECLIPSES

Working out the exact timing of future eclipses – and, just as importantly, where on Earth's surface they'll be visible – is a complicated mathematical problem that can only be solved using sophisticated computers. Yet even the ancients often had some idea of when an eclipse was coming up. This was thanks to something called the 'saros cycle', which was known to ancient Babylonian, Chinese and Greek astronomers. Although eclipses of some type or other happen quite often, if you look at their timing over just a few years, there isn't any obvious pattern to them. Over a longer period, however, a pattern does emerge that repeats roughly every 18 years, and that's known as the saros cycle.

The saros cycle is a consequence of the way the Moon orbits around Earth



DID YOU KNOW? International Space Station crews have seen the Moon's shadow on Earth below them during an eclipse



An eclipse of the Sun by Earth, seen from Apollo 12 in November 1969



An artist's impression of ancient Babylonians watching an eclipse in 763 BCE

5 FACTS

BLOCKING THE SUN

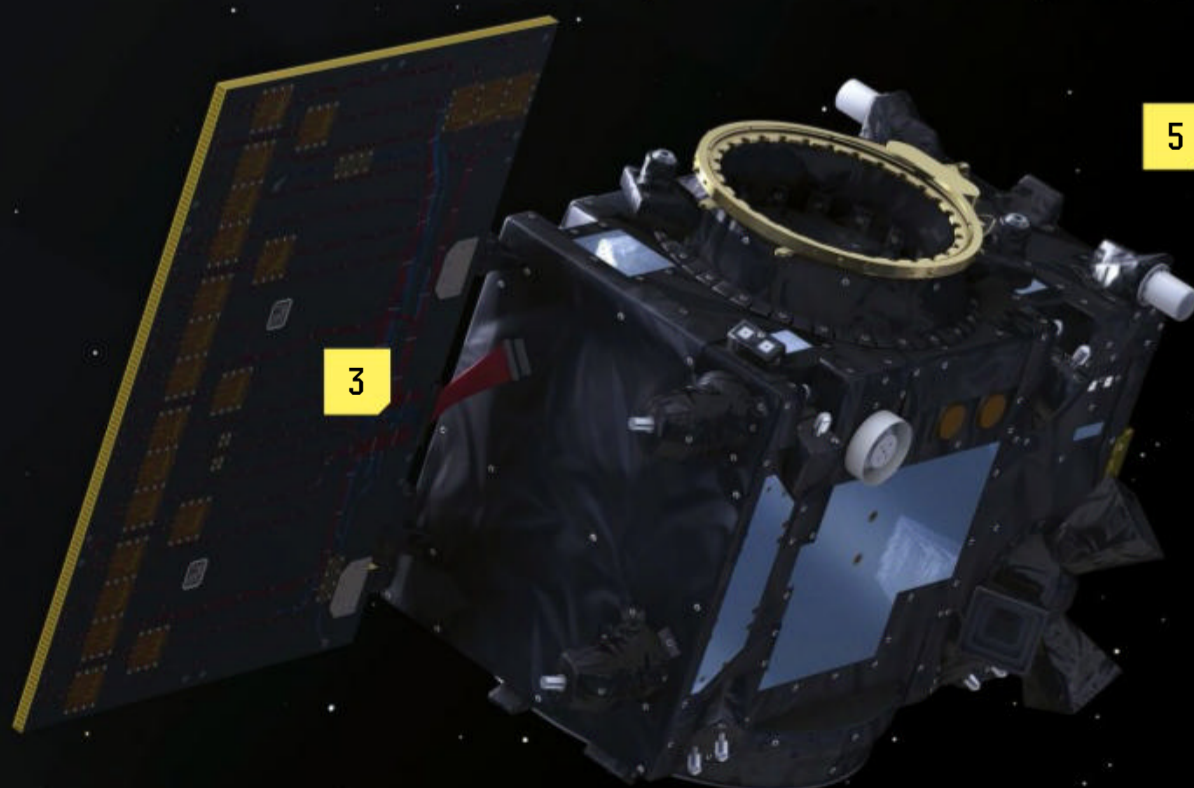
FUTURE EVENTS

17 September 2024	2 October 2024	13 March 2025	29 March 2025	7 September 2025	12 August 2026	2 August 2027	22 July 2028	25 November 2030	23 September 2090
PARTIAL LUNAR UK and elsewhere	ANNULAR SOLAR Pacific Ocean	TOTAL LUNAR North and South America	PARTIAL LUNAR UK and elsewhere	TOTAL LUNAR UK and elsewhere	TOTAL SOLAR Greenland (partial in the UK)	TOTAL SOLAR Northern Africa	TOTAL SOLAR Australia and New Zealand	PARTIAL LUNAR Southern Africa	TOTAL SOLAR UK and elsewhere

3 CORONAGRAPH SATELLITE
This carries an instrument to observe the solar corona when the Sun's disc is 'eclipsed' by the first satellite.

CREATING AN ARTIFICIAL ECLIPSE

The Proba-3 mission will consist of two satellites flying in close formation



5 FORMATION FLYING
Both satellites have thrusters and navigation sensors to keep them precisely lined up during observations.

1 SUPERSTITIONS
In the past, people often linked eclipses to major world events, such as the death of King Henry I in 1133, which was preceded by an eclipse.

2 WRITTEN THEORY
The first books describing the science behind eclipses, complete with diagrams showing the relative positions of the Earth, Moon and Sun, didn't appear until the 1600s.

3 DISCOVERY OF HELIUM
The element helium, whose name comes from the Greek word for the Sun, was first observed in the solar corona during a total eclipse in 1868.

4 LONGEST PERIOD OF TOTALITY
The theoretical maximum duration of a total solar eclipse is 7 minutes and 31 seconds, although the longest seen in recent times was 27 seconds less than this, in 1973.

5 THE END OF TOTAL ECLIPSES
Total eclipses occur because the Moon is close enough to completely cover the Sun, but it's slowly moving away, so this won't be true 50 million years from now.

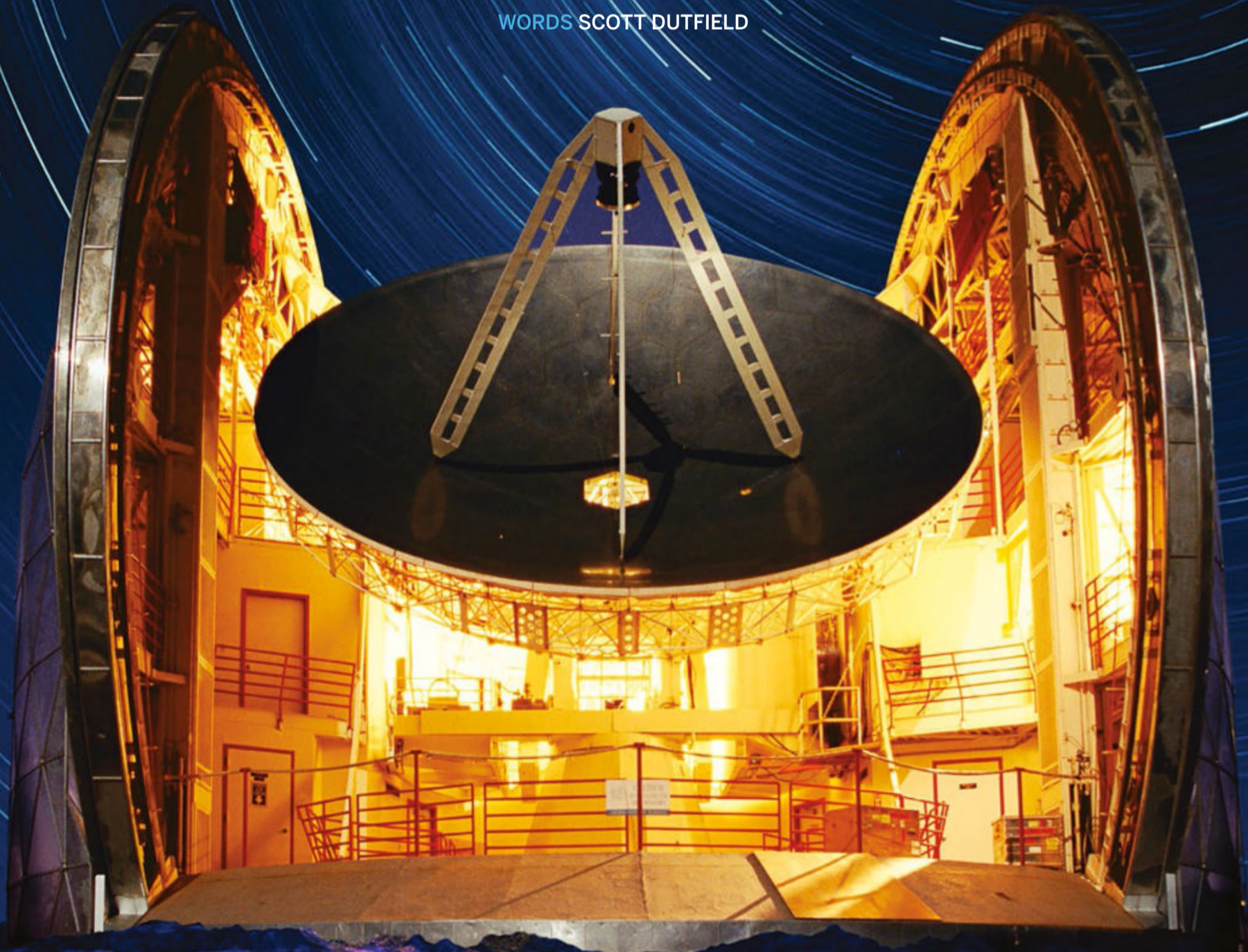
Did you know?
The saros cycle was named by Edmond Halley in 1686



DEEP-SPACE COMMUNICATION

How scientists keep tabs on spacecraft as they journey into the vast expanse of the universe

WORDS SCOTT DUTFIELD



There are thousands of satellites and spacecraft whizzing around in the Solar System. But how do scientists communicate with them? This job largely belongs to the Deep Space Network (DSN), a complex array of giant radio antennae that canvas the cosmos to stay connected with spacecraft. Operated by NASA's Jet Propulsion Laboratory (JPL), the DSN has been around since 1958, when radio tracking stations were installed in Nigeria, Singapore and California. In its debut mission, the network of dish-shaped antennae helped Earth-based controllers guide Explorer 1, the first military satellite, into orbit. Now the DSN is made up of 14 dish antennae at three stations that are spread 120 degrees apart around the globe – in Australia, the United States and Spain. Together, these sites completely cover the night sky, ready to exchange signals with spacecraft from anywhere in the Solar System – or beyond.

Each station is equipped with one 70-metre-wide dish and several smaller supporting 34-metre and 26-metre antennae. The latest addition to the DSN family, DSS 56, was

switched online in 2021. The 34-metre-wide dish, constructed in Madrid, joined the five other dishes at the Spanish station, and is used to manage data between the full catalogue of NASA spacecraft, including the James Webb Space Telescope, and future crewed missions to the Moon.

To communicate with far-flung spacecraft, the DSN uses radio waves to transmit instructions and information, as well as to receive them, known as uplink and downlink. Radio waves are used to transmit information at the speed of light – around 186,000 miles per hour – but due to the vast expanse of the Solar System, it can still take several hours for some signals to reach their targets.

The record for the most distant deep-space communication is between the DSN and the Voyager 1 spacecraft, which launched in September 1977. Originally designed to explore and examine the gas-giant planets Jupiter and Saturn, the spacecraft now ventures beyond the Solar System in interstellar space, around 15.2 billion miles away. The power of the radio signal that the DSN receives from Voyager 1 is

Did you know?
Over 300 robotic spacecraft have left Earth orbit

MAKEWAY FOR LASERS

In October 2023, NASA launched the Deep Space Optical Communications (DSOC) experiment, exploring the use of lasers as the next frontier of spacecraft communication. Hitching a ride on the Psyche spacecraft is a DSOC transceiver. A modulated laser at the Optical Communication Telescope Laboratory (OCTL) in California will transmit data to the transceiver via laser, and subsequently receive returning signals using superconducting nanowire single-photon detectors. The new technology will enable scientists to send more data over the same time frame as current radio wave communication. In November 2023, the 'first light' was received by DSOC, and successfully sent as a downlink back to the transceiver on Earth.



The Deep Space Optical Communications (DSOC) experiment on board Psyche



FORMING A NETWORK

Where in the world are the deep-space antennae?

1 CALIFORNIA
Network: DSN
Organisation: NASA
Antennae: DSS 14, 23, 24, 25 and 26

2 MADRID, SPAIN
Network: DSN
Organisation: NASA
Antennae: DSS 53, 54, 55, 56, 63 and 65

3 CANBERRA, AUSTRALIA
Network: DSN
Organisation: NASA
Antennae: DSS 34, 35, 36 and 43

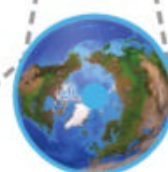
4 PERTH, AUSTRALIA
Network: DSA
Organisation: ESA
Antenna: DSA 1

5 MADRID, SPAIN
Network: DSA
Organisation: ESA
Antenna: DSA 2

6 BUENOS AIRES, ARGENTINA
Network: DSA
Organisation: ESA
Antenna: DSA 3

CALIFORNIA VIEW

AUSTRALIA VIEW



SPAIN VIEW

The three stations of the DSN cover the entire night sky

120 DEGREES



20 billion times weaker than the power required to run a digital watch.

To send and receive radio signals across great cosmic distances, a device called a modulator encodes digital data onto high-frequency radio waves, and an amplifier increases the power of the radio waves as the signal is emitted from one of the DSN antennae. These uplink signals are received by a spacecraft demodulator, and transcribed back into digital data that it can understand and act upon, such as activating its propulsion system or its camera. At the other end, when the spacecraft sends information to Earth, it encodes the information onto radio waves that are picked up by one of the many DSN dishes. Spacecraft send their radio signals in one of two ways – either using 'low-gain' antennae, which emit weaker radio waves in every direction like a terrestrial radio station, or through 'high-gain' antennae, which are stronger waves directed at Earth.

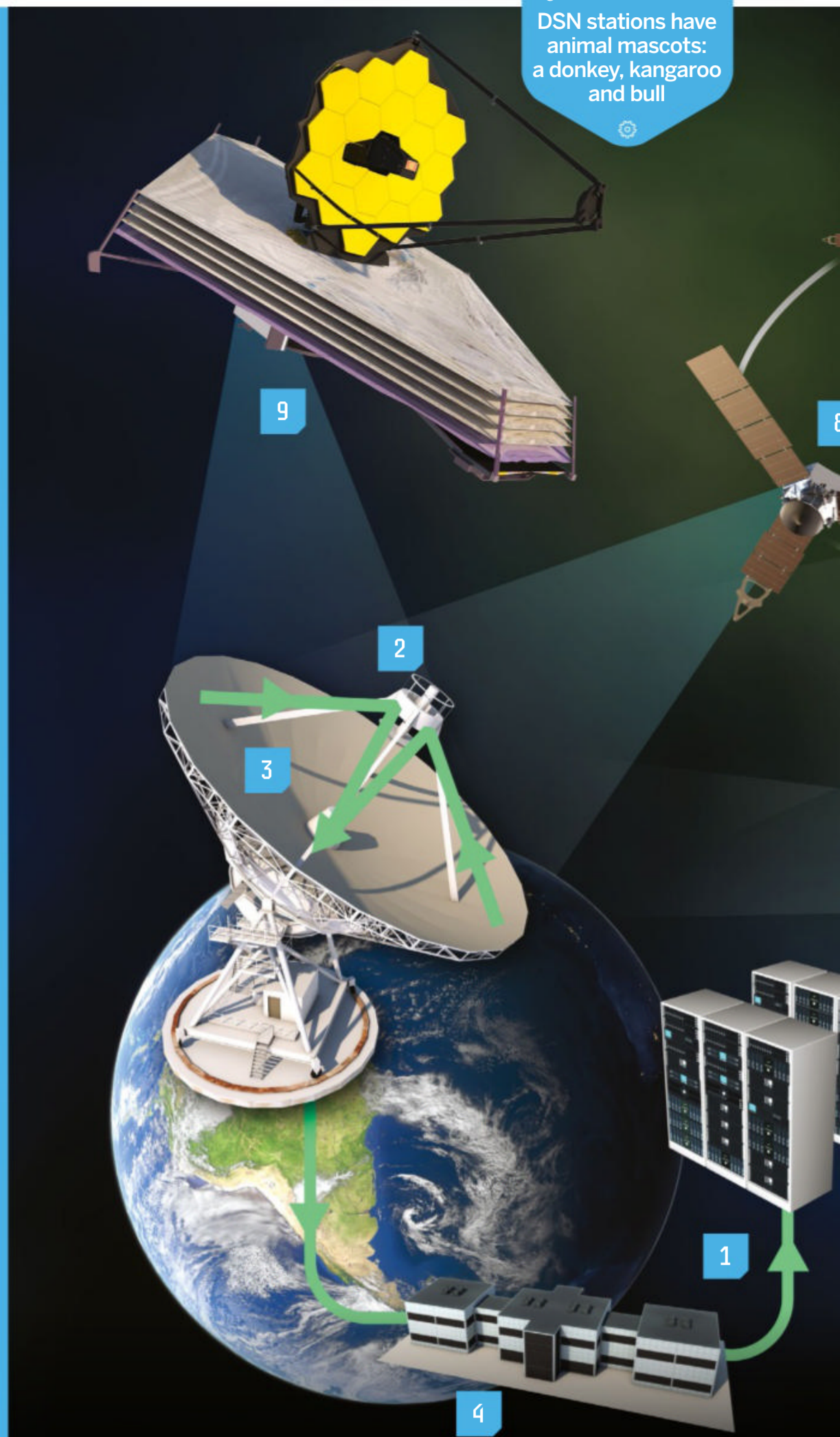
Along with communicating with spacecraft, the DSN is also used to glean valuable information about many celestial objects, such as radio-emitting sources like pulsars, throughout the universe. In 2017, the DSN tracked the 'death dive' of the Cassini spacecraft into Saturn, after more than 20 years of the spacecraft studying the planet. During its climactic descent through the largest of Saturn's rings, called the B Ring, valuable information was gathered about the planet's mass and composition.

The DSN isn't Earth's only answer to making long-distance calls to space. The European Space Agency (ESA) has its own global Deep Space Antenna (DSA) stations to form the Estrack network, which is controlled by the European Space Operations Centre (ESOC) in Germany. In a similar way to the DSN, Estrack uses radio waves to create two-way communication with spacecraft, sending them data to carry out missions.

Did you know?
DSN stations have animal mascots: a donkey, kangaroo and bull



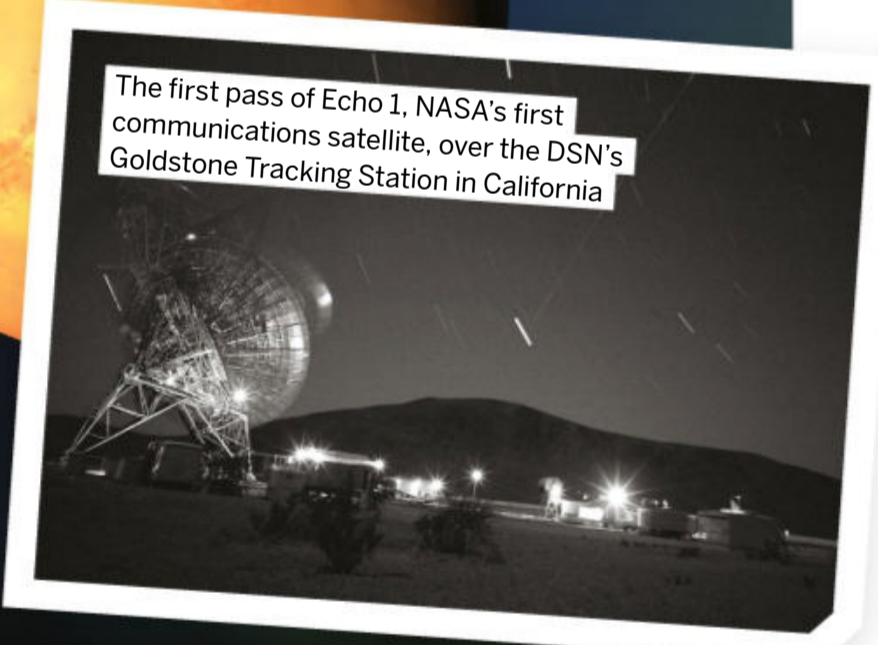
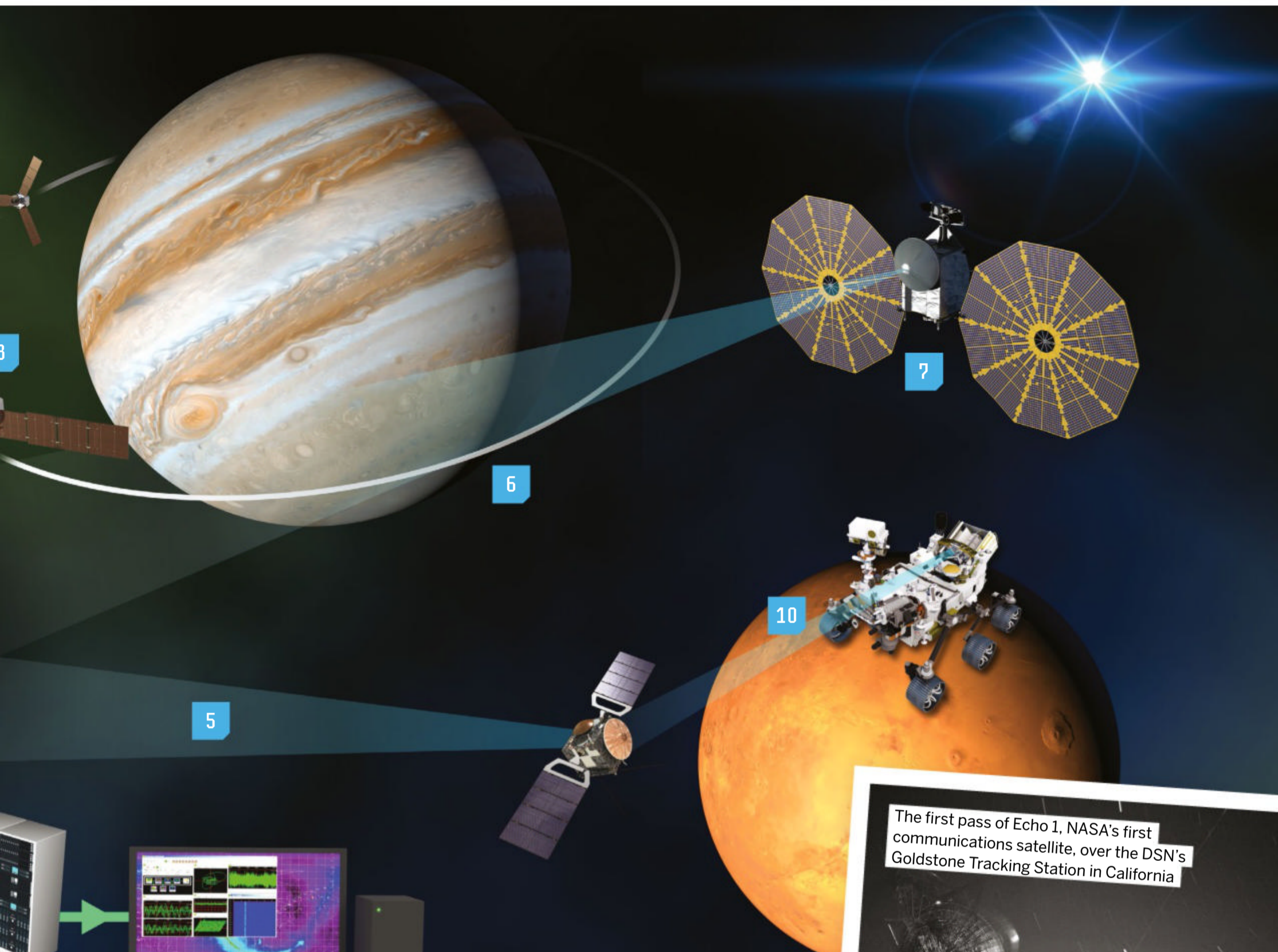
DSS 53 is a 34-metre antenna in Madrid



1 TRANSMITTERS AND RECEIVERS
Modulated radio-frequency signals are generated, received and decoded at the base of the station.

2 MIRRORS
Radio waves bounce through the antenna using a series of mirrors.

3 DISH
Incoming radio waves hit the enormous dish, are bounced towards a subreflector at its centre and reflected down into the station for processing. Outgoing waves go through the same journey in reverse.



COSMIC CALLS

How the DSN communicates with its cosmic contact list

4 AMPLIFIER

Radio signals pass through an amplifier called a maser (microwave amplification by stimulated emission of radiation) to boost their strength.

5 SPEED

Radio signals travel through space at the speed of light, but vary in power depending on their distance from Earth.

6 PLANETARY SCIENCE

The DSN can be used to conduct experiments along with a spacecraft companion. By using changes in the way radio waves travel between the two objects, scientists can study gravity and planetary atmospheres.

7 POSITIONING

Through an investigation technique called geodesy, the DSN can pinpoint the exact location of a spacecraft based on its relative position to known, fixed natural radio sources, such as quasars.

8 TRACKING

Using gravitational and propulsion data, the DSN can estimate travel velocities and trajectories and estimate their position within fractions of a millimetre per second.

9 TELEMETRY

This is the exchange of information from a spacecraft's onboard instruments, such as cameras and spectrometers.

10 HEALTH CHECK

Along with information gathered from a spacecraft's instruments, the DSN also monitors the 'health' of a spacecraft, including fuel levels and any damage.



GAS MASK EVOLUTION

What prompted the invention of a mask that could provide clean air in polluted and poisonous environments?

WORDS AILSA HARVEY

In fresh air with low pollution levels, our bodies perform the subconscious act of breathing. You inhale and exhale air continuously to stay alive, absorbing oxygen in the lungs for use in biochemical reactions around the body. The atmosphere contains around 21 per cent oxygen, but this level only has to drop below 19.5 per cent to become unhealthy. Oxygen levels between 16 and 19.5 per cent cause tissues to stop functioning properly under exertion, and between 12 and 16 per cent your ability to think clearly stops, even when resting. When the air becomes unbreathable and contaminated with pollutants, gas masks are life-saving. These situations can include large-scale fires that suck up oxygen and release smoke, chemical spills from industrial buildings or emergency situations when people are trapped in confined spaces with inadequate ventilation.

Different models of gas masks have been accredited to a handful of inventors, including African American inventor Garrett Morgan, who made an early version of a gas mask. The value of his invention – which many historians believe to be the basis of the US Army's World War I gas masks – was demonstrated by Morgan himself in a disaster in 1916. In a waterworks tunnel in his hometown of Cleveland, natural gas escaped from a lakebed and caused an explosion. Official rescue teams were unable to enter the tunnel to search for casualties, because they didn't have any breathing apparatus. Knowing that Morgan was working on gas masks, the rescue team approached him, and he was able to enter the tunnel safely and bring eight survivors to safety. Similar masks are used today for rescue operations in toxic environments, and are standard equipment in the military for soldiers in war zones.



Gas masks cover the entire face

BREATHING EASY IN WORLD WAR I

How did the iconic World War I gas mask filter out poisonous gases?

Did you know?

The M2 gas mask was used during World War I

7 CLEAR AND PROTECTIVE

Eyepieces were made of glass or a transparent plastic called celluloid. They were sometimes covered with a thin layer of gelatine to stop them fogging up.

6 FACEPIECE MATERIALS

The facepieces of these gas masks were made of rubber, leather or canvas, to make the masks airtight and impermeable to gases.

5 OUTLET VALVE

Exhaled air leaves the mask here, and speech can be heard. Flaps on the valve open when exhaling, but close when inhaling.

3 MECHANICAL FILTERS

Cotton and wire gauze layers filter out any remaining particles, such as dust and smoke.

4 CONNECTING TUBE

A flexible rubber tube connects the filter to the mask. Air leaves the filter through the top of the device.

2 CHEMICAL FILTER

Highly porous activated carbon traps chemicals and toxic gases, which cling to the high surface area as air passes through.

1 AIR ENTRANCE

When the wearer inhales, air is drawn into the box respirator through this bottom valve.

UNMASKING THE PAST

Follow the timeline of respiratory aids, from World War I to pandemic protection

Did you know?

Before gas masks, firefighters grew beards as filters



1950S Cold War threats

During the Cold War between the US and the Soviet Union, gas masks were designed to protect people against nuclear, chemical and biological threats. Designs focused on masks that could protect against a large range of harmful substances, especially in radioactive environments following a nuclear explosion.

1939 TO 1945 More efficient filtration

Gas masks made for use in World War II were more compact than the bulky filter devices of World War I. More porous materials such as chrysotile asbestos were used during World War II, before asbestos was found to be dangerous. This allowed smaller filters to be integrated in the main mask, rather than being connected by a tube.



1960S Portable respirators

Compact and lightweight canisters were introduced for gas mask filters. This made gas masks more portable. One example was the M17 mask used by the US military, which weighed around 1.3 kilograms. This had a streamlined design and also had extra tubes installed to allow soldiers to drink without removing the mask, as well as perform mouth-to-mouth emergency resuscitation.



CIVILIAN USE

The benefit of gas masks in protecting against chemical warfare had been proven in World War I. In World War II Britain, when the threat of a German blitz attack became known, the government gave out gas masks to civilians in an attempt to save as many lives as possible. This included specialised masks for babies that encased their entire bodies. Production of civilian masks started in 1938, with a goal of making 38 million of them. When they were sent out, they came with instructions to the public to carry the mask at all times. Fines were issued to those who didn't. People were also advised to tape their windows shut to seal houses off from gas attacks.



Children wore gas masks at school during World War II

1980S First-responder technology

During this decade, first-responder gas mask technology was significantly upgraded. One main improvement was in their communication systems. Integrated communication systems helped first responders speak to casualties clearly and coordinate rescues without removing masks. The technology involved integrated microphones and speakers, radio compatibility, noise reduction and voice amplification for noisy environments.



2001 Anthrax attacks

In 2001, following the 9/11 terrorist attacks, letters containing anthrax spores were posted to media outlets and US government offices. Anthrax is a serious infectious bacterial disease: five people who came into contact with the spores died, and many more were infected. Around 4.8 million gas masks were bought by postal service workers as a result.



2020S COVID impact

The COVID-19 pandemic highlighted how severe the spread of respiratory infections can become without adequate protection. Some of the mask technology used included the N95 respirator. This mask filters out 95 per cent of airborne particles, such as respiratory droplets containing the virus. These were used in all healthcare settings, while smart mask technology that monitors air quality and mask coatings that contain antimicrobial agents gained popularity for general use.

CARRYING FRESH AIR

When roaring fires steal the surrounding oxygen, firefighters breathe using a specialised self-contained breathing apparatus (SCBA)

3 HELMET COMPATIBILITY

Gas masks designed for firefighters take other protective gear into consideration so that the entire kit fits together neatly.

2 GAS CYLINDER

A SCBA mask is connected to a gas cylinder of breathable oxygen. This holds at least 1,200 litres to provide air for 30 minutes.

5 COMFORTABLE CARRYING

The oxygen cylinder straps onto the back of the firefighter with a harness.

6 AIR AND PRESSURE GAUGE

First responders need to check this gauge to make sure they can exit dangerous environments before their breathable air runs out.

7 AIR SUPPLY TUBE

When inhaling, air is drawn into the mask from the bottom. The tube connects to the air cylinder and is attached close to the body, to prevent tubes interfering with rescues.

4 FULL-FACE

Firefighters need their entire face covered. The mask doesn't just provide oxygen, but protects skin from heat, smoke and other hazards.

1 HEAT RESISTANCE

Firefighter gas masks can be made of thermoplastic rubber to withstand close proximity to flames.

5 FACTS WHICH PROFESSIONS USE GAS MASKS?

1 MILITARY

Soldiers' masks are designed to be worn for long periods during chemical, biological, radiological and nuclear threats.

2 FIRST RESPONDER

These people are the first to enter dangerous scenes. They include hazmat teams and paramedics.

3 HEALTHCARE

Healthcare professionals wear specialised respiratory masks when treating respiratory infections.

4 INDUSTRIAL SAFETY

Employees in chemical plants, welding factories or working with pesticides and asbestos often wear gas masks.

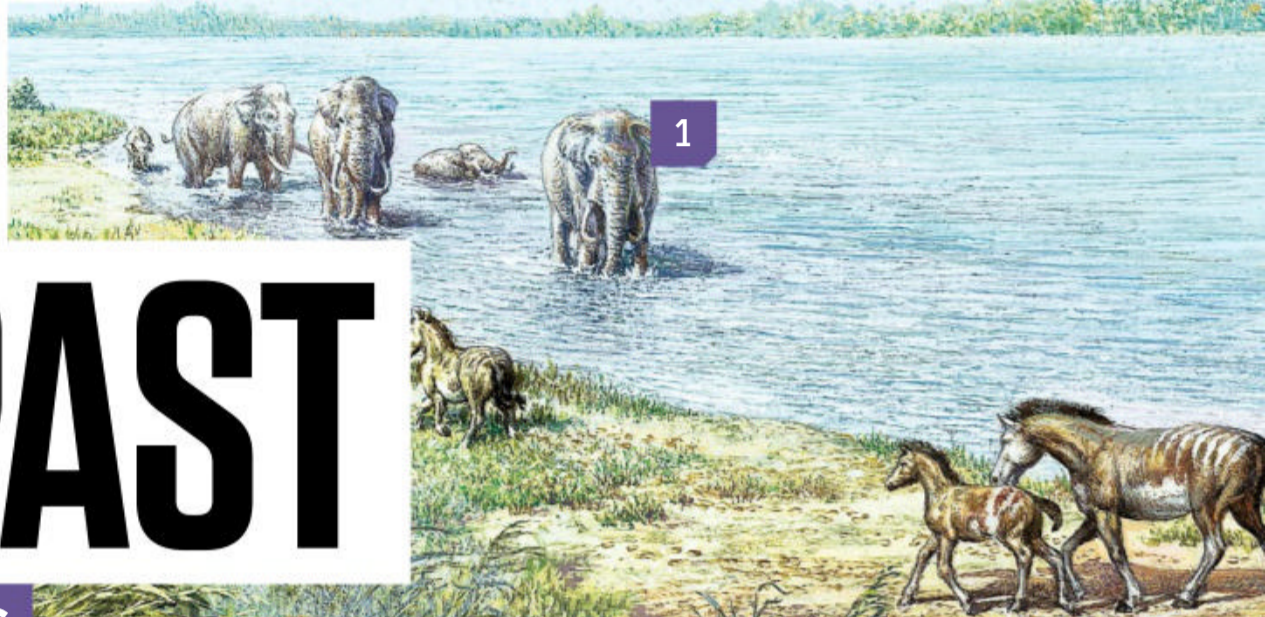
5 LAW ENFORCEMENT

Specialised law enforcement units deal with high-risk chemical agent crimes. Gas masks are essential in these cases.

UNLOCKING BRITAIN'S ANCIENT PAST

1 ANCIENT WILDLIFE

Primitive mammoths, as well as horses, would have shared life with the first settlers in Britain on the floodplain.



How a team of archaeologists, palaeontologists and earth scientists created a clear view of who our distant relatives were and how they lived

WORDS PROFESSOR CHRIS STRINGER AND ANDREW RIDGWAY

Britain has one of the richest, yet most underappreciated, records of early human history in the world. While human fossils are rare, ancient Britons left behind tools and animal bones in river deposits and caves that reveal tantalising clues about their behaviour and way of life. By analysing this trail of evidence, scientists from Britain, Europe and North America, working jointly from over 20 different research institutions, have collaborated to gain an incredible insight into the lives of our ancient relatives.

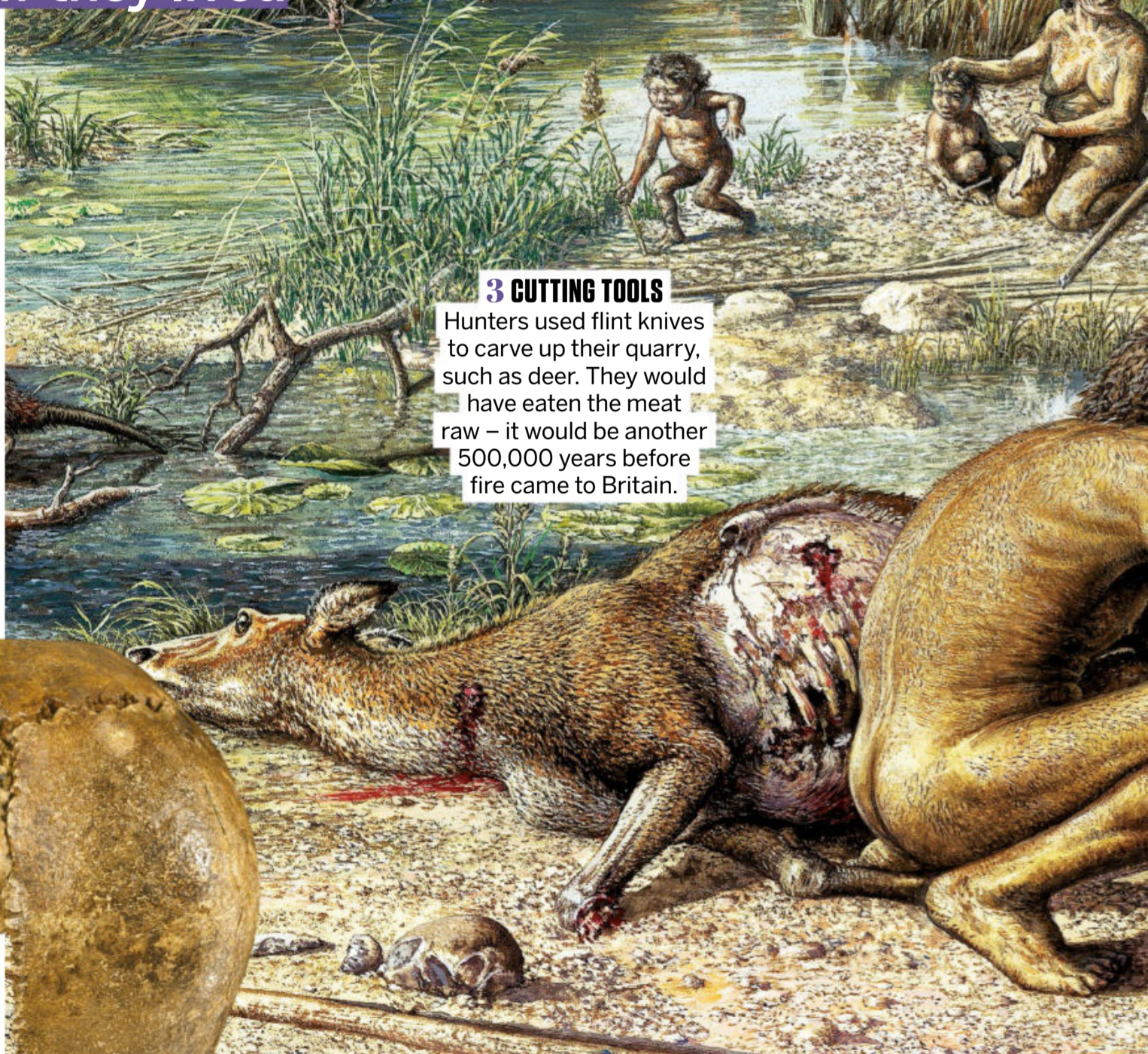
When the Ancient Human Occupation of Britain (AHOB) project was born in 2001, the researchers set out to address key questions about the early prehistory of Britain, including when people first arrived here, who they were and when Britain became an island. The idea was to reconstruct the past lives of ancient Britons by carrying out new excavations, but also by reanalysing old finds in existing collections, using state-of-the-art investigative techniques

Partial skull of a Neanderthal woman found at Swanscombe



3 CUTTING TOOLS

Hunters used flint knives to carve up their quarry, such as deer. They would have eaten the meat raw – it would be another 500,000 years before fire came to Britain.



EARLIEST SETTLERS

Life at Happisburgh in the UK 900,000 years ago

Did you know?

The exact date Neanderthals went extinct is disputed

2 MAN VERSUS BEAST

Hunters would have had to fend off hyenas, which were competitors for food.

2

3

KEY MOMENTS IN THE UK'S HUMAN HISTORY

900,000 YEARS AGO

The first known human settlement in Britain – possibly the species *Homo antecessor*. Their flint tools have been found, although no fossils have been spotted.

500,000 YEARS AGO

Britain was getting busier: evidence suggests there were larger numbers of people at this time. They were *Homo heidelbergensis*, a robust and muscular human species.

450,000 YEARS AGO

The Anglian glaciation, Britain's most severe ice age, took place. The ice sheet reached as far south as Hornchurch in northeast London, diverting the River Thames towards its present position.

400,000 YEARS AGO

Early Neanderthals occupied Britain: there have been finds of these strongly built hunters at Swanscombe in Kent. There's also the earliest evidence of fire in Britain at Beeches Pit in Suffolk.

50,000 YEARS AGO

Neanderthals returned to Britain. Immediately before this, Britain was deserted for more than 100,000 years, due first to low temperatures, then to its isolation as an island.

40,000 YEARS AGO

Homo sapiens arrived in Britain. Some of the earliest evidence of their presence comes from Kents Cavern in Devon.

20,000 YEARS AGO

The last glaciation reached its peak and people had abandoned the land. It's only when this period ended that humans were able to return.

such as scanning microscopy and isotope analysis, that weren't previously available.

In 2001, the earliest recognised evidence of humans in Britain came from artefacts and fossil remains found at Boxgrove in Sussex, dating from around 500,000 years ago. As well as restudying these prior finds, AHOB team members began work in East Anglia, where signs were beginning to emerge that stone tools and butchered bones from coastal sites might be even older than those known from Boxgrove. Four years later, AHOB researchers and their collaborators uncovered evidence from an archaeological site at Pakefield, Suffolk, that humans reached Britain 700,000 years ago, during a brief period of Mediterranean-like climate. At that time, the southeast of Britain was continuously connected to the continent by a land bridge formed of chalk, and people could have migrated north from regions such as Spain and southern France.

Then, in 2010, excavations on the foreshore at Happisburgh, Norfolk, uncovered more than 70 flint tools and flakes, pushing back the earliest date for humans in Britain to about 900,000 years ago – and making this the first known settlement in northern Europe. No human fossil remains have been uncovered so far to identify the species responsible for these early tools, but it may have been the one known from Atapuerca in Spain around 800,000 years ago, named *Homo antecessor*, or 'pioneer man'.



A Neanderthal model that was part of an exhibition at the Natural History Museum in London

WHEN BRITAIN WASN'T AN ISLAND

Doggerland allowed the return of humans from mainland Europe

Around 60,000 years ago, ice from the previous ice age retreated largely to the poles, sea levels dropped and Britain once again became a peninsula. It was joined to northern Europe by grassy plains where the English Channel and the southern part of the North Sea are found today. Scientists have named this 'Doggerland'. It was fertile land where large numbers of prey animals grazed, and it made for good hunting grounds. Now that the ice sheets and sea had gone, it was also an easy crossing from what is modern-day Normandy to Kent, which is why Neanderthals returned to Britain during this time, followed by the first *Homo sapiens* to settle in Britain.

Life must have been relatively good for humans for thousands of years during this time. But when the last ice age hit 20,000 years ago, most of Britain's human population migrated south, away from the plummeting temperatures and advancing glaciers. Scientists think that a massive tidal wave was triggered during the new interglacial period around 8,000 years ago, which washed over Doggerland. Along with rising sea levels, this finally separated Britain from the continent. Arrowheads, stone axes and other prehistoric human artefacts are still dredged up by fishermen over the Doggerland sandbanks today.



Britain around 60,000 years ago. The light-green outline shows the plains that joined Britain to the European continent

But the occupation of Britain was far from continuous. The long-term climate was unstable, and these early Britons often failed to cope with the extreme changes they had to face. Indeed, records show that at times, Britain was inhabited by warmth-loving animals. There were elephants in Yorkshire and Wales, and monkeys in Kent. Lions and rhinos would have roamed what is now Trafalgar Square, and hippos would have swum in the Thames. At other times Britain was occupied by reindeer and woolly mammoths – animals more typically associated with cooler climates. There's evidence of them in Devon.

When the environment became too harsh, with

ice sheets advancing to cover most of the land, Britain's human inhabitants either escaped south across the land bridge or died out, and it might have been tens of thousands of years before conditions improved enough for them to return.

In fact, it looks as if Britain was occupied at least ten times by waves of humans, and nine of these were unsuccessful – only the last phase, beginning around 12,000 years ago, gave rise to the present inhabitants. And there were several human species involved in this migration: the first may have been *Homo antecessor*, followed by *Homo heidelbergensis* – known from remains found at Boxgrove – and, more recently, the Neanderthals. There's evidence of their presence from Swanscombe in Kent,

Did you know?

Tools dating back 2.6 million years have been found in Ethiopia

Pontnewydd in Wales and La Cotte de St Brelade in Jersey. Finally, *Homo sapiens* came along, with evidence of early settlements at sites such as Kents Cavern in Devon, Paviland in South Wales and Gough's Cave in Somerset.

One of the questions AHOB wanted to address was when Britain first became an island, and how this affected the human occupation. Research by other earth scientists has confirmed an old idea that the English Channel was first formed during a cold stage, when a huge lake of freshwater built up where the southern North Sea is today. That lake eventually drained in a spectacular flood event that cut southwestwards through the chalk ridge that linked Britain to Europe, eroding a gully that eventually became the English Channel. The process may have begun 450,000 years ago, and it was sufficiently advanced 125,000 years ago that a high sea level managed to isolate Britain as an island.

A preceding cold stage had pushed the warmth-loving species south, and as the climate ameliorated, returning creatures such as elephants and hippos managed to get across the rising seas. The Neanderthals must have lagged behind, and without boats they were unable to reach the newly created British Isles. It would take another 60,000 years and the emergence of 'Doggerland' – a landmass in the southern North Sea connecting Great Britain to mainland Europe – before they would be able to return.

The AHOB research has demonstrated the quality of Britain's prehistoric record. It's now one of the fullest studied and best understood in the world.

5 FACTS ABOUT NEANDERTHALS

1 SHORT AND STOUT

Neanderthals grew to a maximum of around 175 centimetres, but weighed up to 82 kilograms.

2 OMNIVORES

Their diet would have been similar to *Homo sapiens* at the time: plants, meat, fungi and shellfish.

3 FIRST DISCOVERY

The species was named after the Neandertal valley in Germany, where it was first discovered in 1856.

4 SMART CAVEMEN

Despite their reputation, Neanderthals were actually quite smart, with bigger brains than modern humans.

5 EXTINCTION MYSTERY

Around 40,000 years ago, Neanderthals disappeared. Scientists suspect they couldn't compete for resources with early modern humans, and died out.



A model of a complete *Homo neanderthalensis* skeleton

“The occupation of Britain was far from continuous. The long-term climate was unstable”



Premolar of an extinct rhinoceros species found in Boxgrove, West Sussex

WHY VAPING IS BAD FOR YOU

How inhaling this flavoured aerosol affects your lungs and impacts the body

WORDS AILSA HARVEY

Billows of fruity-flavoured mist are a common scent on today's city high streets. They plume from devices called electronic cigarettes, also known as vapes or e-cigarettes, and are exhaled from the mouths of young and old alike. But the liquid in vapes contains many harmful ingredients and a total of around 2,000 different chemicals. Despite the device's name, the mist that escapes vapes is inaccurately described as vapour. A vapour is a substance in gas form, while an aerosol contains small particles of liquid – called e-liquid in vapes – that are suspended in the air.

Although e-cigarettes were invented as a cigarette substitute, feeding nicotine cravings caused by smoking without exposing the body to many deadly toxins, vapes are a new craze that come with their own set of health hazards

for a new generation of vaping addicts. Health agencies, such as those in the UK government, have previously misinformed people that vaping is a healthy alternative to smoking. Based on limited information about modern vaping devices and known ingredients, these groups promoted e-cigarettes as being 95 per cent safer than standard cigarettes. This information, which was intended to steer smokers away from tobacco products, has also steered younger non-smokers to these nicotine products.

The sweet-tasting vape flavours are marketed like candy, appealing to younger generations, while their hidden and potentially deadly chemicals can damage developing bodies. This includes your brain, which isn't fully developed until you reach your mid-20s – vaping can hinder this process. Some of the main psychological risks include severe

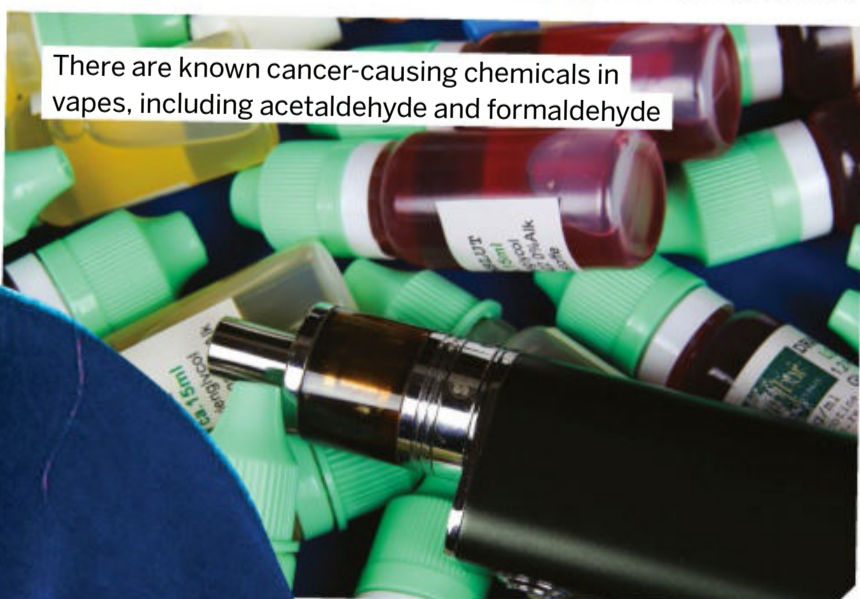
Did you know?
About 4.5 million adults in the UK use a vape



CONTENT CHECK

Unlike cigarettes, which burn tobacco, vapes only contain the nicotine that has been extracted from tobacco. This is a very addictive, toxic substance that raises your blood pressure, heart rate and adrenaline, and can hinder proper brain development in young people. Propylene glycol is a chemical added to vapes to help create mist when heated, but is known to cause respiratory irritation. It is commonly found in paint solvent and artificial smoke machines.

Not all chemicals found in the aerosol are present in the raw vape liquid. Those such as acrolein, a toxic chemical often used as a herbicide, is produced inside vapes when the device is heated and the flavouring chemicals begin to thermally decompose. Meanwhile, the chemical compound diacetyl is a yellow liquid that adds a buttery flavour to many vapes. Inhaling this chemical causes scarring to the lungs' air sacs.



There are known cancer-causing chemicals in vapes, including acetaldehyde and formaldehyde

INSIDE AN E-CIGARETTE

How does a vape heat liquid and produce an aerosol when inhaled?

1

1 MOUTHPIECE

This hollow tube connects to the cartridge, where the aerosol is produced. Inhaling through the mouthpiece activates the heating element and draws the mist into the mouth and lungs.

2

2 CARTRIDGE

The liquid, sometimes referred to as juice, is held in this compartment.

3

3 HEATING ELEMENT

This metal coil heats up the vape liquid, turning it into tiny airborne droplets. The particles absorb the heat energy, move vigorously and break molecular bonds that keep them in liquid form.

4

4 MICROPROCESSOR

Responsible for regulating much of the vape's technology, the microprocessor is activated by sensors to heat the liquid and keep temperatures within a safe consistent range.

5

5 SWITCH

Some vapes have automatic sensors for activation, while others have a switch to turn them on and off.

6

6 BATTERY

A built-in lithium-ion battery powers the device. Full charging takes three to four hours.

7

7 MIMICKING LED

The LED light at the bottom lights up to imitate a burning cigarette.

nicotine addiction, mood disorders and lowered impulse control. Those who start vaping when they're younger are more likely to pick up smoking habits later in life.

Many vapes are sold in disposable packaging that can leach hazardous chemicals into the environment when discarded carelessly. These include the plastics of the container and toxic compounds from the e-liquid remnants. The disposal of empty vapes into household bins can be just as problematic. The highly flammable lithium batteries inside the devices can easily start fires when crushed in refuse lorries. Through this process, they aren't recycled and their toxic metals enter landfills, contaminating surrounding ecosystems and water supplies. More than a million disposable vapes are thrown away every week – an indication of the scale of this increasing health and climate emergency.

CAN VAPING BE BENEFICIAL?

Vaping is considered the lesser of two evils when compared with tobacco. Cigarettes release thousands of chemicals into the body, and 70 of these are known to cause cancer. In the short term, it's better to take up vaping as a replacement to smoking rather than continuing smoking. Vapes are one of the most useful tools for stopping smoking. When an adult switches from smoking to vaping, it's also normal for them to vape more frequently than they smoked. This isn't always as harmful, as toxins in their body can still be reduced. Nicotine levels in vapes vary and don't contain the same chemicals, like tar and carbon monoxide, so the only benefit of vaping is to wean someone off their nicotine addiction by reducing the strength until they quit.



Unlike vapes, cigarettes turn healthy lungs (left) into tar-covered black tissue (right)

VAPING VS SMOKING

Discover the known and potential health impacts of inhaling vape aerosol compared with inhaling cigarette smoke

1 INFLAMMATION

Flavouring agent diacetyl causes inflammation in the branches of the lung's airways. A 2023 study suggests vapers suffer from more inflammation than smokers.

3 ACCELERATING CELL DEATH

Cell death occurs five times as often when vaping without nicotine, and ten times as much with nicotine.

11 MUCUS THICKENING

Vaping dehydrates the airways and causes thick mucus.

15 SIGNS OF EMPHYSEMA

Some studies have linked vaping with emphysema. Emphysema is damage to the lungs' air sacs, reducing gas exchange in and out of the organ.

9 IMMEDIATE INFECTIONS

Long-term infections caused by vaping are yet to be fully understood. More immediately, vaping decreases the production of antiviral protein SPLUNC1, increasing the risk of respiratory infections like the common cold.

13 SMALL AIRWAY OBSTRUCTION

The lungs' small airways are impeded by vaping, resulting in asthma-like symptoms. The extent of further damage isn't well studied.

19 FATTY IMMUNE CELLS

E-liquid contains oily substances that cigarettes lack. The fats are engulfed by immune cells called macrophages. The presence of these lipid-filled cells causes inflammation.

17 TUMOUR STUDIES

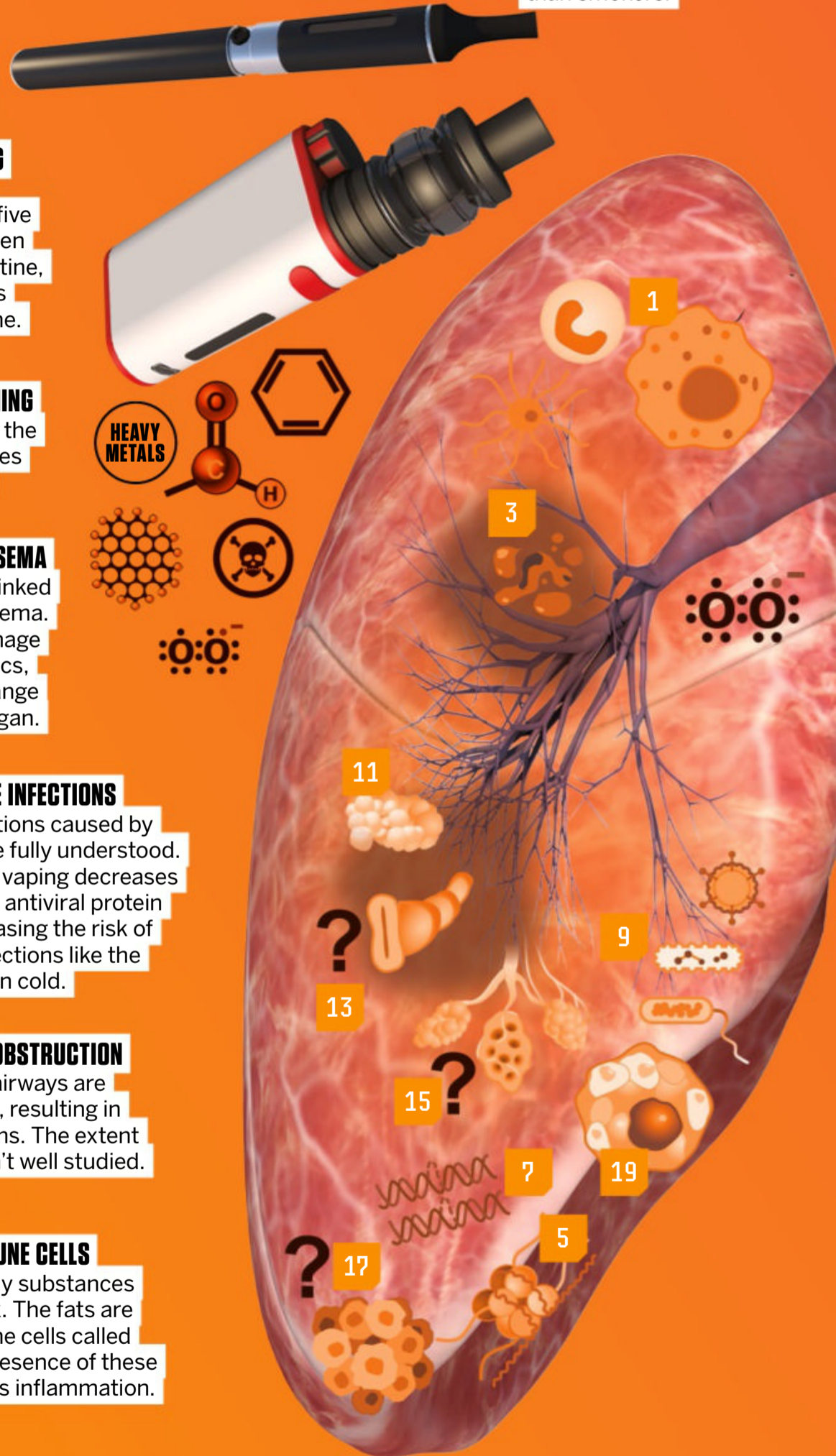
Vapes don't contain cancer-causing tobacco, and there's no significant evidence that vaping causes tumour growth.

7 DNA DAMAGE

E-liquid may stop DNA repair mechanisms, leading to DNA damage.

5 GENE EXPRESSION

E-cigarette aerosol changes the expression of non-coding RNA molecules without altering the DNA sequence. Non-coding RNA controls cell function without directly making proteins.



DID YOU KNOW? People in Australia need a prescription in order to legally buy vapes

2 CHRONIC INFLAMMATION

Smoking is known to cause severe inflammation due to containing more lung-irritating compounds like tar and carbon monoxide.

“Their hidden and potentially deadly chemicals can damage developing bodies”



5 FACTS HIDDEN DANGERS

Did you know?

Nicotine itself doesn't cause cancer or heart disease

4 IRREVERSIBLE CELL DEATH

Smoking causes more extensive cellular damage. When cells of the lungs' air sacs die, they can't regain function.

12 MUCUS BUILD UP

Smoke increases the permeability of lung tissue, which leads to too much mucus being released.

10 SEVERE INFECTIONS

Cigarette smoking is known to cause bronchitis, pneumonia and chronic obstructive pulmonary disease (COPD), and increases the risk of contracting tuberculosis.

14 AIRWAY OBSTRUCTION

COPD is a disease that restricts airflow. 80 per cent of COPD deaths are due to smoking.

16 CAUSE OF EMPHYSEMA

Smoking is the main cause of emphysema – smokers are six times more likely to develop it than non-smokers.

18 CANCER-CAUSING

Tobacco in cigarettes can damage DNA. This causes cells to begin to grow out of control and produce tumours in the lungs.

1 MISLEADING LEVELS

E-cigarette packaging can be misleading. Research shows that around half of the labels on e-cigarette containers display levels that don't actually match the contents.

2 SECOND-HAND EXPOSURE

Inhaling second-hand aerosol from others vaping in the home is linked to shortness of breath in young adults.

3 CARDIOVASCULAR CHAOS

Using vapes more than five times a week and for at least three months is enough to cause blood vessels to stop working properly and lead to cardiovascular disease. Nicotine increases your chances of suffering a heart attack.

4 MENTAL HEALTH

In a study by the American Heart Association, anxiety was 20 per cent more prevalent in vapers. 50 per cent of those who vaped experienced symptoms of depression as opposed to 25 per cent of non-vapers.

5 ALTERING IRRITANTS

Not all of the toxins are labelled on a vape's packaging. Those that are produced during the heating of the ingredients are often missed off the list.

2

4

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6 GENE SUPPRESSION

Smoking may weaken the genes that control tumour growth.

8 DNA MUTATIONS

One packet of cigarettes holds enough harmful compounds to cause two mutations in the DNA of lung cells.



Workers at a factory in Shenzhen, China, make e-cigarette pods for vaping manufacturer KangerTech

WHAT IS EVALI?

Recognised as hazy spots on the lungs in a chest X-ray and with symptoms that include shortness of breath, fever and chest pain, EVALI is a severe lung disease caused by vaping. The full name of the illness is e-cigarette or vaping use-associated lung injury, and vitamin E acetate is thought to be the main substance in e-cigarette liquid that causes this lung damage.

The disease can crop up quickly, affecting people soon after they start vaping, or it can build up over a longer period of vaping. 90 per cent of those who develop EVALI need to go to hospital, and it can be deadly in the most severe cases. Young people under the age of 35 are believed to be most at risk of EVALI. The condition has only been reported in the last few years, so scientists are researching the disease to discover how to reverse the damage it causes.



Healthy parts of the lungs usually appear dark on X-ray scans

WHERE E-CIGARETTES ARE MADE

Around 90 per cent of vape pens are manufactured in China by companies owned by entrepreneur Zhang Shengwei. Every year, hundreds of millions of vapes are shipped from China to the UK and US, but many of these factories lack quality control. This results in thousands of harmful chemicals entering the products and the lungs of those that use them. For example, studies have discovered that some vape aerosols have four times more of the hazardous metals nickel and chromium in them than standard cigarette smoke. As vapes don't contain tobacco in its full form, the

Chinese tobacco authority that regulates cigarette manufacturing and other similar products in China doesn't monitor these factories. When vapes became popular, many countries struggled to categorise the devices. They weren't classed as drugs, food or tobacco. Today the Medicines and Healthcare products Regulatory Agency (MHRA) in the UK and the Food and Drug Administration (FDA) in the US regulate vapes.

Did you know?

In 2021, thousands of unidentified chemicals were found in vapes

HOW VAPES EVOLVED

Controversy has surrounded vaping since it was invented



2003

Chinese pharmacist Hon Lik invented the modern e-cigarette to remove the smoke from the act of smoking. He was a smoker himself, and lost his father to lung cancer.



2007

Vapes entered the global market and the World Health Organization expressed health concerns.



2010

2010 is considered the year in which vaping increased greatly in popularity around the world.

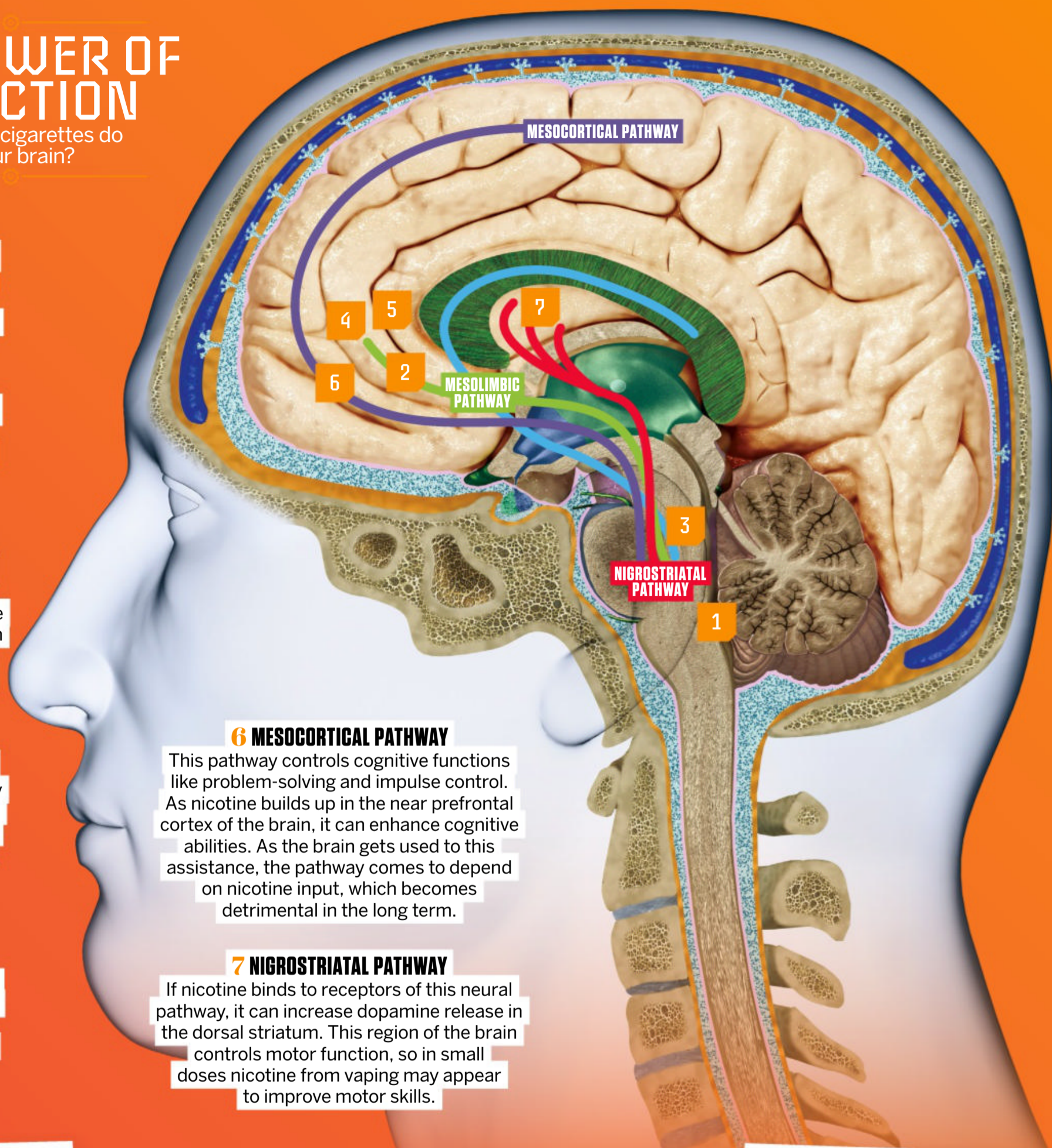
2014

Advertising and packaging became targeted at adolescents' tastes, sparking safety concerns. The term 'vaping' became popular in this year.

DID YOU KNOW? Vapes are intended for the 70 per cent of smokers who want to quit

THE POWER OF ADDICTION

What do e-cigarettes do to your brain?



1 BLOOD-BRAIN BARRIER
10 to 20 seconds after inhaling nicotine, it crosses the blood-brain barrier into the brain.

2 MESOLIMBIC PATHWAY
This neural circuit releases the feel-good chemical dopamine into the body.

3 VENTRAL TEGMENTAL AREA (VTA)
Neurons in this area have nicotine receptors. When the molecules bind to them, the mesolimbic pathway is activated.

4 NUCLEUS ACCUMBENS
The mesolimbic pathway connects the VTA to this area of the brain, where dopamine is released.

5 REWARD AND REINFORCEMENT
Dopamine, released here, creates feelings of pleasure in the brain. As the brain learns this feeling, it seeks further reward from more nicotine hits.

6 MESOCORTICAL PATHWAY
This pathway controls cognitive functions like problem-solving and impulse control. As nicotine builds up in the near prefrontal cortex of the brain, it can enhance cognitive abilities. As the brain gets used to this assistance, the pathway comes to depend on nicotine input, which becomes detrimental in the long term.

7 NIGROSTRIATAL PATHWAY
If nicotine binds to receptors of this neural pathway, it can increase dopamine release in the dorsal striatum. This region of the brain controls motor function, so in small doses nicotine from vaping may appear to improve motor skills.



2016

In the US, the FDA gained authority to regulate tobacco and vape products on 8 August.

2019

EVALI was officially identified. In the US alone, there were 2,051 cases and 39 deaths reported in four months.



2019

In the US, the legal age for purchasing vaping products was raised from 18 to 21.



2020

Amid the COVID pandemic, respiratory health entered the spotlight, re-igniting the debate around the dangers of vaping.



2024

Following a 2023 proposal to ban cigarettes for those born in 2009 or later, the UK announced plans to ban all disposable vapes.

THE POWER OF THERMITE

When iron and aluminium mix, the consequences can be explosive

WORDS SCOTT DUTFIELD

Thermite is one of the most dangerous chemical reactions humans have conceived of. Created when aluminium powder is mixed with a metal oxide (typically iron oxide) and ignited, the two metals erupt in a violent burst of light and intense heat.

This volatile reaction is the result of oxygen atoms being exchanged between a molecule of iron oxide and aluminium atoms, which means the molecular bonds that grip oxygen to its metal companion are broken and reformed. In doing so, energy is released in the form of heat, in what's known as an exothermic reaction. When reactants such as iron oxide and aluminium have a higher internal energy, known as enthalpy, than the products made by the reaction, the excess energy is released as heat or light.

In the case of a thermite reaction, this excess heat can reach up to 2,500 degrees Celsius, turning the newly separated iron atoms into molten metal. Once the volatile reaction has come to its dramatic conclusion, what remains is a lump of iron, along with some chips of an aluminium-oxide mineral called corundum.

To reap the thermal rewards of thermite, engineers have harnessed its power to weld pieces of metal together. Thermite welding is widely used in metal joining, especially in the railway industry, where thermite is poured over the two ends of rail pieces to fuse them together.

Typically, the ingredients for this are bound together with a binding agent – often a carbohydrate called dextrin – to prevent them from separating during the reaction and prolonging the exothermic release.

Did you know?

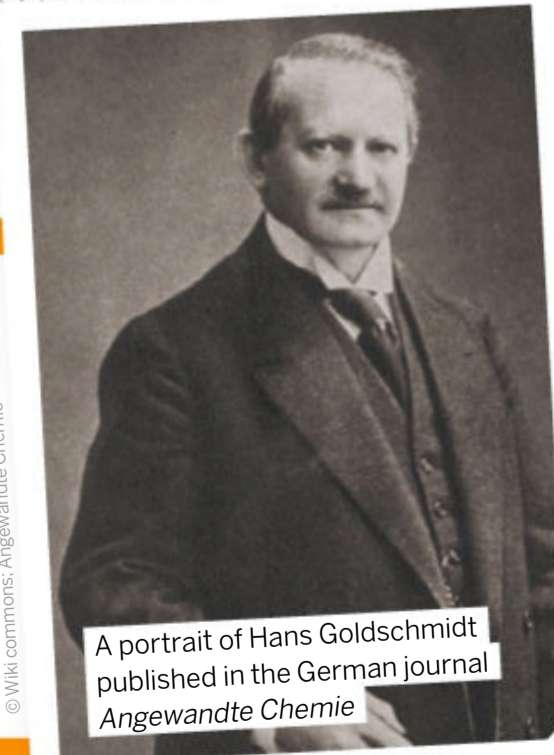
The thermite welding process was patented in 1899



GOLDSCHMIDT'S DISCOVERY

In 1893, German chemist Hans Goldschmidt came across thermite through what later became known as the Goldschmidt process, while investigating ways to extract pure metal from natural ores. At the time, Goldschmidt relied on the traditional method of obtaining iron from its ore by heating it with carbon. During this process, the carbon combines with oxygen in the iron oxide ore, releasing carbon dioxide as

a byproduct and leaving the pure iron behind. However, this method of oxygen stripping can leave carbon contaminants within the iron. It was while Goldschmidt was experimenting with aluminium as a possible alternative to carbon that he uncovered thermite's impressive exothermic reaction. Seeing its potential to be used in metal joining, Goldschmidt patented the welding compound thermite.



A portrait of Hans Goldschmidt published in the German journal *Angewandte Chemie*

© Wiki commons: Angewandte Chemie

DID YOU KNOW? Thermite typically releases four megajoules of energy per kilogram; gasoline releases 49 megajoules per kilogram

METAL JOINING

How thermite is used to repair train tracks and steel pipes

1 MOULD

A mould is used to fit over the shape and size of the tracks that will be joined together.

2 CLAMPED TOGETHER

The mould clamps the two tracks together, leaving a slight gap for the thermite.

3 PREHEATING

Before the thermite is added, the gap between the tracks is preheated to reduce the amount of shrinkage on the metal when it cools down.

4 MELTING POT

The thermite crucible is made of hardy materials such as graphite, which can handle reaction temperatures of around 3,000 degrees Celsius.

5 THERMITE MIXTURE

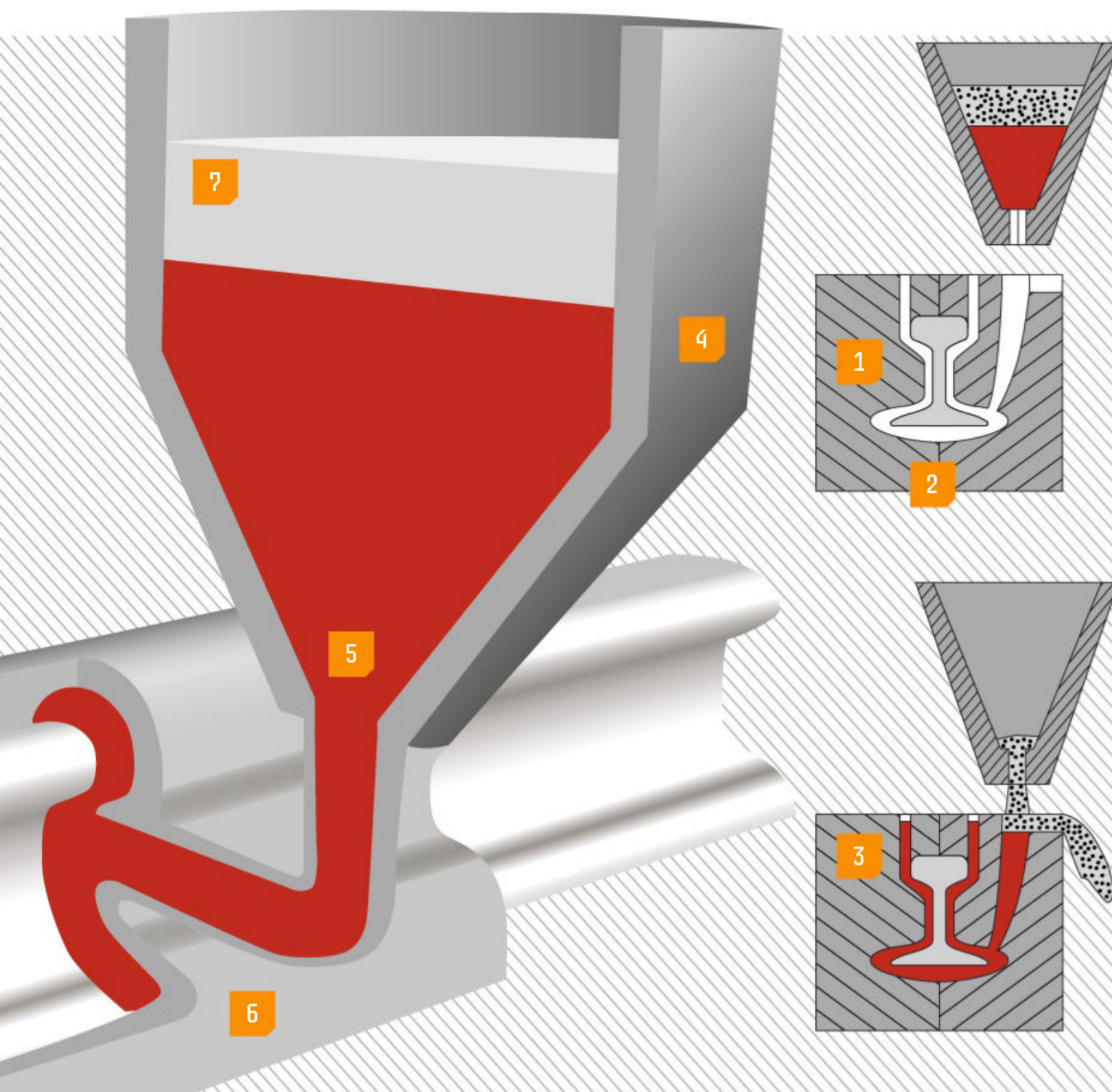
The ratio of the thermite powder is typically one part aluminium and three parts iron oxide.

6 IGNITING POWDER

Following ignition, the thermite reaction begins producing molten iron to weld the tracks together.

7 ALUMINIUM SLAG

As a byproduct of the reaction, the less dense aluminium oxide floats to the top of the crucible.



Lumps of iron are created after a thermite reaction



Thermite welding in action on a railway track in Dublin

BOMBS AWAY

The explosive nature of thermite makes it a suitable ingredient for making incendiary bombs. What's particularly devastating about thermite bombs is their ability to rain down molten metal. Following the ignition of the thermite reaction by a fuse, the burning metals erupt in a firework-like explosion, maintaining thousand-degree temperatures as they fall to the ground. Not long after the discovery of thermite, the German

military enlisted it as a weapon. In 1915, during World War I, thermite bombs were deployed by German forces in Zeppelin raids on England. During World War II, thermite bombs got an upgrade with more energetic elements, such as copper and magnesium, to maximise the damage they could cause. The use of thermite bombs is now regulated under Protocol III of the UN Convention on Certain Conventional Weapons.

A thermite explosion at a Russian arms exhibition in 2013



WHAT IS WIND CHILL?

How windy conditions can make you shiver, even on a warm day

WORDS AILSA HARVEY

When you check the predicted temperature, you may sometimes be greeted with two values: the air temperature and the 'feels like' temperature. The main temperature value represents how hot or cold the air is, but the second temperature takes the strength of the wind into account. Called wind chill, this value indicates how the air temperature will feel on your skin when you step outside. When there is more wind, heat escapes from you more quickly, lowering the wind chill temperature.

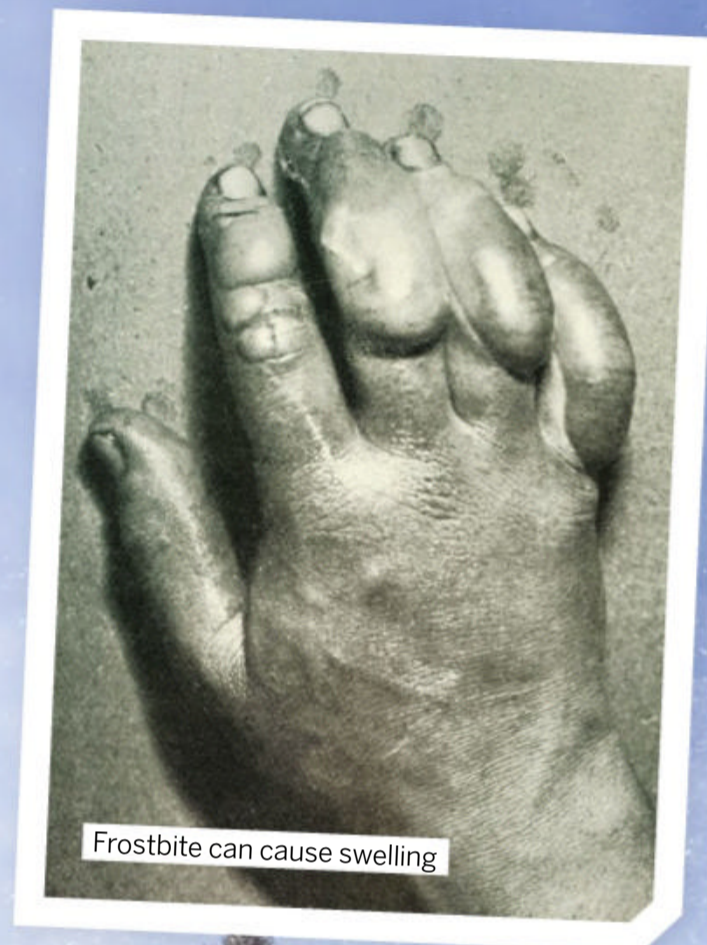
Displaying this value on forecasts means that people can make a more informed decision on what to wear and even whether to go outside. The calculation shows how cold the air would need to be outside to cause the

same rate of heat loss from your skin if there was no wind at all. When wind chill reduces the temperature far into negative values, skin temperature will decrease rapidly, followed by your internal body temperature. This increases the chances of developing hypothermia and frostbite.

Did you know?

Buildings in cities can affect wind chill

Wind chill not only impacts humans, but other animals and plants. In plants, wind chill stresses don't come from heat loss, as they don't produce heat in the same way as humans. Rather, wind chill increases the plants' rate of evaporation, whisking water away from it instead. This increases the moisture loss from leaves and dries out the plant. Whether it's in the form of drying or freezing, wind chill calculations show the drastic influence of the wind on the temperature of your environment.



Frostbite can cause swelling



Wind anemometers can calculate temperature, wind speed and wind chill

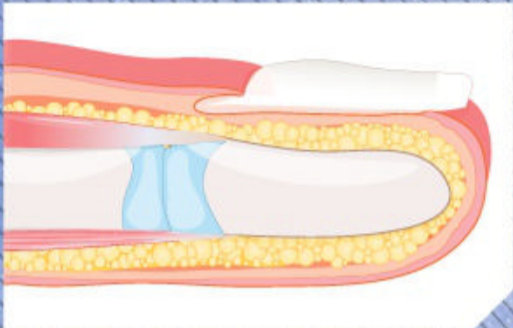
CALCULATING CHILL

In the UK, wind chill is determined by measuring how much heat is lost from a person's bare face when they walk at a speed of three miles per hour. This method of calculation is called the Joint Action Group for Temp Indices. Although this is how the calculations were first conducted, today meteorologists use a mathematical formula based on this data. There isn't a scientific instrument used to collect a value from the air

– instead air temperature and wind speed are measured and incorporated into a formula to work out wind chill. The figures in the formula were first decided by scientists Paul Siple and Charles Passel in 1945. They used a plastic bottle filled with water and a thermometer, and measured the extent that the bottle's water cooled in different wind speeds. From their findings, they derived a common mathematical relationship between the known values.

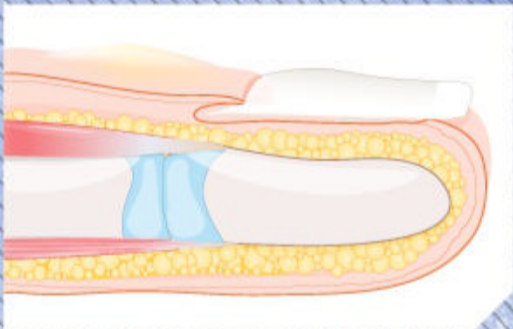
BITING COLD

In the worst cases of frostbite, limbs may be lost



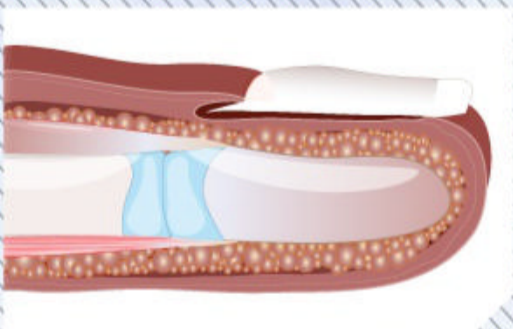
1 FROSTNIP

This is the earliest and mildest stage of frostbite. The surface of the body becomes numb, but the skin is only temporarily damaged. If the skin is warmed up after this stage, it can be painful, but full function returns.



2 SUPERFICIAL FROSTBITE

After losing feeling, the skin may also slightly change in colour, from a paler colour to blue. Oddly, the skin might begin to feel warmer as tissue damage begins and the extremities start swelling. If you rewarm the body at this stage, fluid-filled blisters are common.



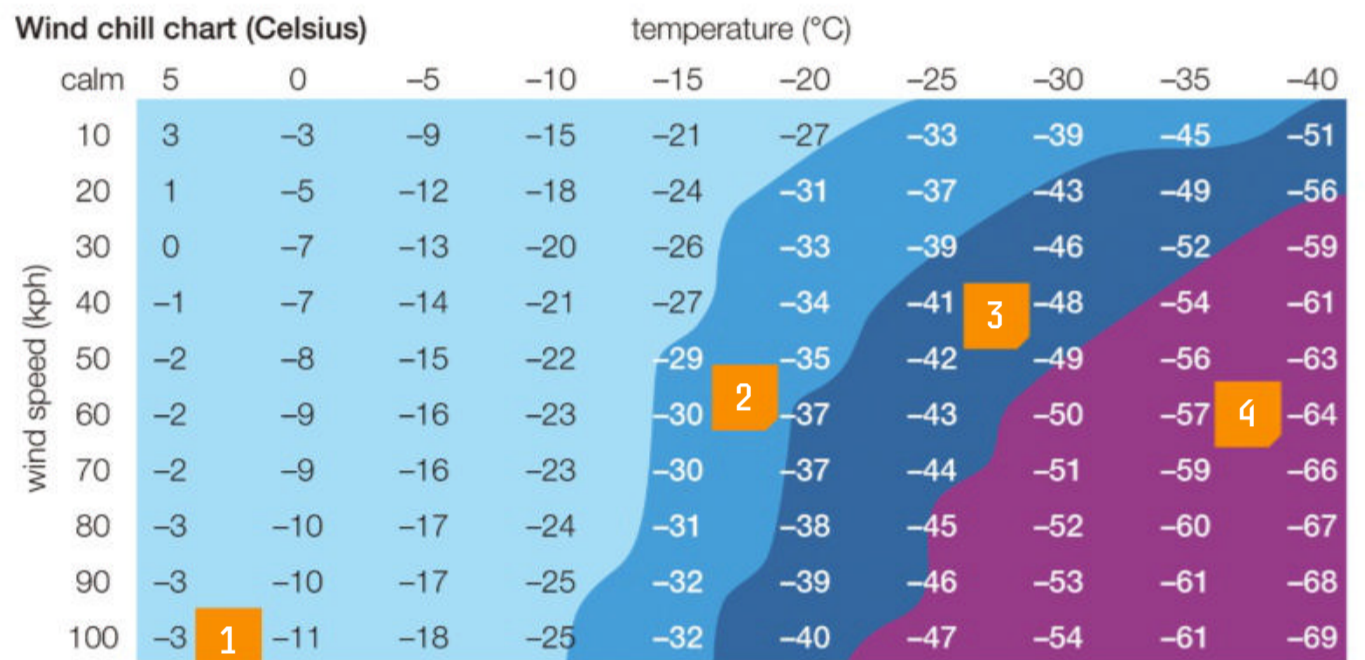
3 DEEP FROSTBITE

This is the most severe stage of frostbite, after which joints and muscles may stop working as damage extends beyond the skin. The area affected becomes darker, blue or splotchy and stops relaying cold or pain sensations. Following rewarming, the dead tissue becomes black and hard, and often needs to be removed from the body.

HOW MUCH DIFFERENCE DOES WIND MAKE?

Check this chart to see how the wind alters the temperature your body feels

- 1 WIND IMPACT**
When wind reaches 62 miles per hour (100kph), an air temperature of five degrees Celsius is felt by the skin as -3 degrees Celsius.
- 2 30 MINUTES**
Skin exposed to wind chill temperatures as low as -30 degrees Celsius will begin to experience frostbite after just half an hour.
- 3 TEN MINUTES**
For frostbite to set in within ten minutes, the air temperature needs to be at least as low as -20 degrees Celsius.
- 4 HIGH RISK**
In extreme climates, where the wind chill temperature reaches at least -50 degrees, just five minutes of skin exposure can cause frostbite.



$$\text{wind chill (°C)} = 13.12 + 0.6215T - 11.37(V^{0.16}) + 0.3965T(V^{0.16})$$

$$\text{frostbite times } \begin{cases} \text{30 minutes} \\ \text{10 minutes} \\ \text{5 minutes} \end{cases} \quad \begin{matrix} T = \text{air temperature (°C)} \\ V = \text{wind speed (kph)} \end{matrix}$$

5 HEAT LAYER

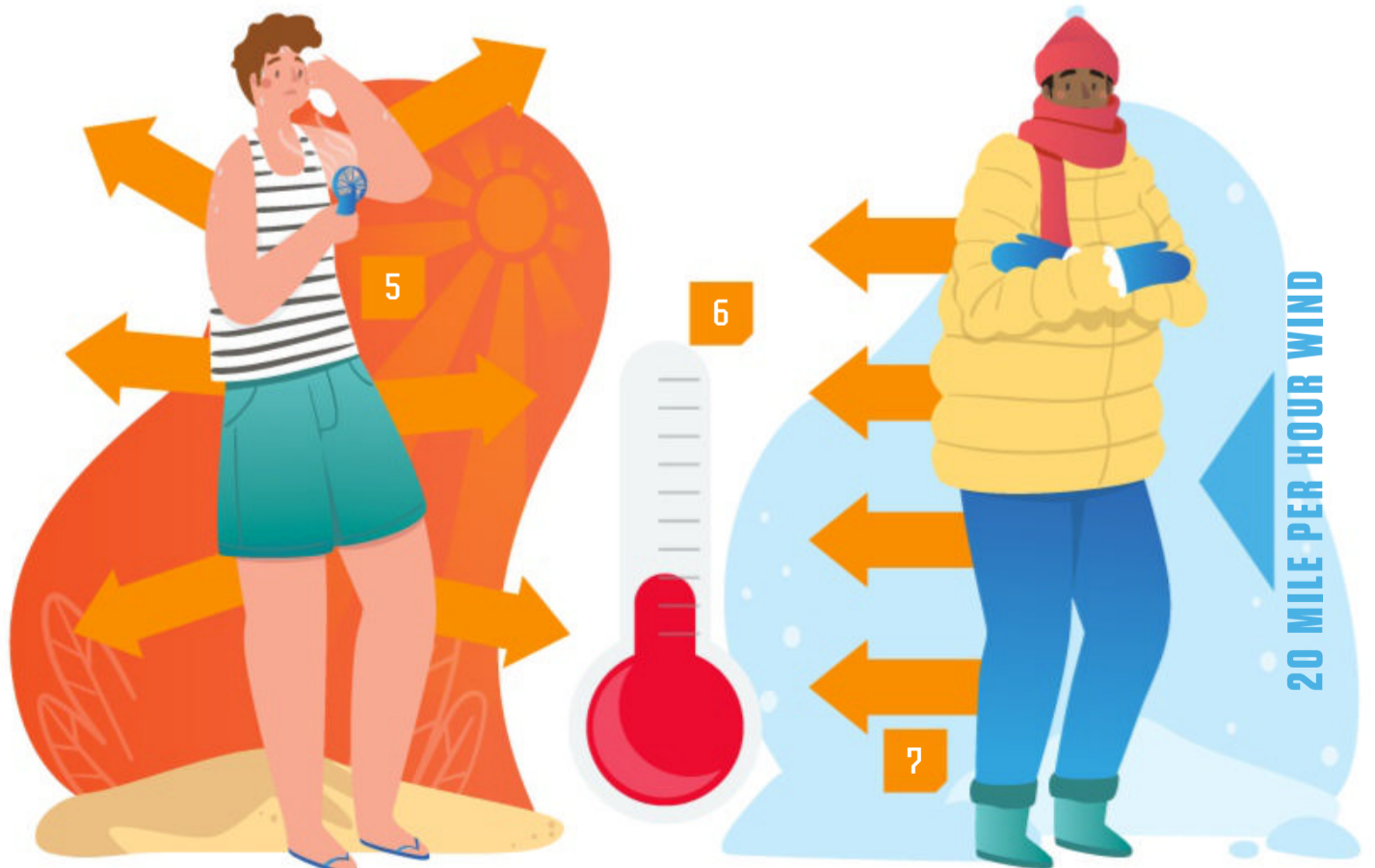
When there is no wind, the heat lost by the body stays in the air around the body for longer, maintaining the body temperature.

6 AIR TEMPERATURE

An outside air temperature of 20 degrees can feel cold or warm based on the wind conditions.

6 HEAT LOSS

On a windy day, air particles around the body are disturbed. The wind blows and carries heat released by a person away from the body. This makes you feel much colder.



12 BIG SCIENCE DISCOVERIES

These breakthroughs sent shock waves through their scientific fields



SOLAR GOOD VIBRATIONS

1 Silicon-based solar cells are relatively efficient, but expensive to produce, whereas zinc oxide-based cells are cheap but inefficient. Researchers at Queen Mary University in London and Imperial College London tried playing music to zinc oxide cells, knowing that nanoscale rods of the oxide will wobble in response to mechanical stress, such as sound, producing an electric field. This increased the efficiency of these cells by 50 per cent, showing they would be more effective in noisy places.



VOLCANO ASH SENSORS FOR AEROPLANES

3 Many aircraft are now fitted with volcanic ash detectors, after infrared technology was successfully tested using an artificial ash cloud. The Airborne Volcanic Object Imaging Detector (AVOID) uses infrared cameras to spot the silicate particles in volcanic ash. In a test carried out above the Bay of Biscay, an aircraft released ash collected from Icelandic volcanoes. Another aircraft fitted with AVOID was able to detect the ash from 37 miles away – a distance at which pilots can adjust their flight paths to avoid ash clouds. Norway's Nicarnica Aviation, which developed AVOID, as well as other airlines who were involved in the test, hope the technology will avoid a repetition of the disruption that happened when Iceland's Eyjafjallajökull volcano erupted in 2010, grounding aircraft.



2 507 YEARS OLD

The world's oldest creature, 'Ming the mollusc', was a deep-sea clam dredged from the North Atlantic. Its age was discovered by scientists at Bangor University in 2005 – but only after they froze it, killing the ancient creature.



VENOMOUS CRUSTACEAN DISCOVERED

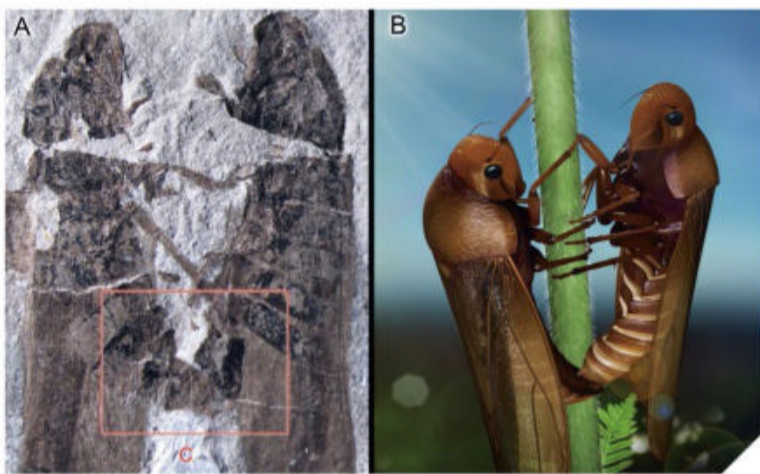
4 Meet the first venomous crustacean known to science. Biologists at the Natural History Museum in London discovered that *Xibalbanus tulumensis* has venom in reservoirs at the ends of structures on its claws

that resemble hypodermic needles. The venom contains a neurotoxin, likely to stop prey getting away, and peptidases, enzymes that help digest prey. This species dwells in cave water in Mexico and Central America.

5

THE ELECTRON IS SPHERICAL

Scientists hoping to find a 'dipole moment' for the humble electron were disappointed. A dipole moment would make an electron look squashed and support the idea of 'supersymmetry', a theoretical extension to the Standard Model of particle physics that predicts the existence of all manner of exotic particles. An ultra-sensitive experiment looking at electrons in molecules of thorium monoxide, however, found them to be boringly spherical – exactly as the Standard Model predicts.



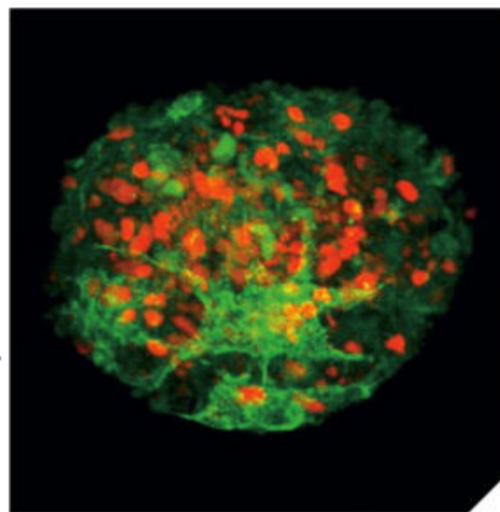
INSECTS FOSSILISED WHILE MATING

7 These 15-millimetre-long froghoppers were fossilised in the Middle Jurassic period. That's 161 to 176 million years ago, making the pair – who turned up in a study of over 1,200 specimens found in Inner Mongolia – the oldest fossilised fornicating insects yet discovered. Researchers at Capital Normal University in Beijing said the bugs' mating 'choreography' has changed little in all that time. It's speculated that a volcanic eruption released poisonous gas while the love bugs were in the act.

© Claire Higgins/Christiano Lab at Columbia University Medical Center

GRAVITY GIVES BALD PEOPLE NEW HOPE

6 A 40-year-old process that regrows hair on bald mice could finally be used on humans. The technique involves growing a culture of 'dermal papilla cells' in a Petri dish. Mouse cells clump together to form implantable hair follicles, but human cells had failed to do so. UK and US geneticists tried growing the cells in droplets of carrier medium instead of a flat dish. Forced together by gravity, they formed follicles, just like mouse cells.



© Forschungsstelle Asia Minor, Universität Münster

AMULETS UNEARTHED

9 Archaeologists in Turkey dug up more than 600 amulets, scarabs and seals dating back to between the 4th and 7th centuries BCE. The site on the Dülük Baba Tepesi mountain is thought to have been a shrine to the Roman god Jupiter Dolichenus.

MACH 1,000

10 The speed of a reverse shock wave racing towards the Tycho supernova. It's causing the star's remains to emit X-ray light as they heat up.

270 SQUARE MILES

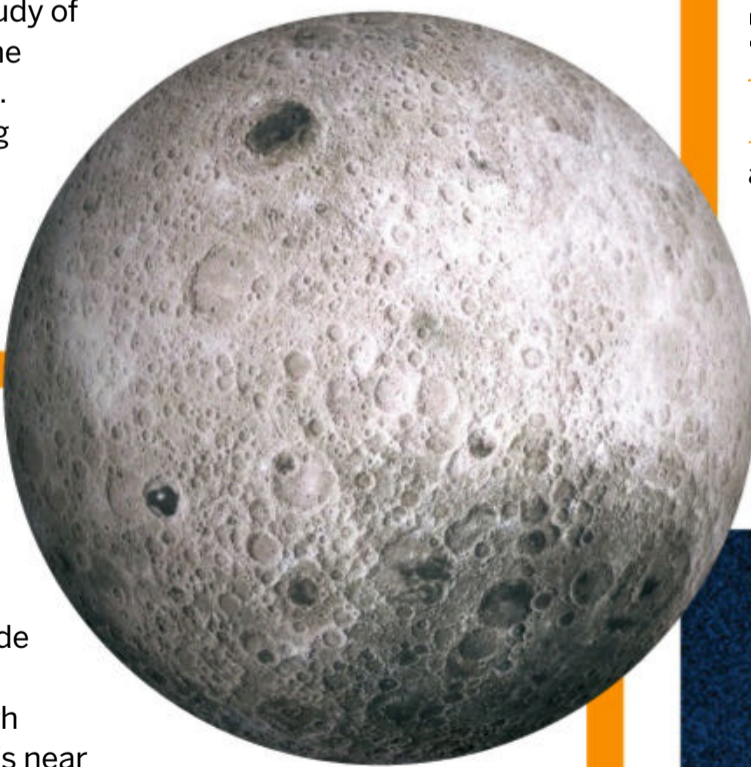
11 A massive iceberg broke off from an Antarctic glacier. Researchers at Sheffield and Southampton universities followed the ice's movements through the Southern Ocean, using satellites to check if it wandered into shipping lanes. The research involved trying to predict the glacier's path.

HUBBLE SPIED A SIX-TAILED ASTEROID

12 This sight had never been witnessed in space before – an asteroid with six tails. The asteroid, part of the Solar System's asteroid belt, was photographed using NASA's Hubble Space Telescope. It's thought that it somehow began spinning so fast that its surface started breaking apart, spraying out the tails.



© Alamy / Getty / NASA



MOON'S POCKMARKED FAR SIDE EXPLAINED

8 It's long been a mystery why the far side of the Moon has more craters than the side visible from Earth. But scientists led by Dr Katarina Miljkovic at the Paris Institute of Earth Physics found the answer: rocks on the Moon's near side may have been warmer due to higher levels of radioactive isotopes. When these hotter rocks were struck by asteroids, they melted into lava, filling in impact craters and creating the large, smooth basins that characterise the near side's landscape.

© Li S, Shih C, Wang C, Pang H, Ren D (2013) Forever Love: The Hitherto Earliest Record of Copulating Insects from the Middle Jurassic of China. PLoS ONE 8(11): e78188. doi:10.1371/journal.pone.0078188

BLOCKING OUT NOISE

How your brain tunes out the distracting sights and sounds of the outside world

WORDS SCOTT DUTFIELD

The world is full of sensory stimulation, and sometimes your brain needs to shut some of it out to tackle the task at hand.

Whether you're reading a book on a busy train or making a phone call while walking down a bustling street, your brain seems able to zone in and tune out the rest of the world.

Although this ability has no formal title, scientists have attributed its origins to one specific region of the brain: the prefrontal cortex. This complex portion of the brain is responsible for 'higher-order' cognitive functions such as decision-making and evaluative thinking. However, it doesn't directly receive sensory information from sensory organs like the eyes and ears. That responsibility lies with an egg-shaped structure in the centre of the brain called the thalamus.

Neuroscientists have long thought that a connection between the two regions holds the answer to why people can focus on one sensory stimulus, such as sight while reading a book, while simultaneously tuning out background noise. In 2019, researchers at the Massachusetts Institute of Technology (MIT)

finally made the connection through a series of experiments where mice were trained to switch their attention between two stimuli – sight and sound. They found that two parallel neural pathways acted like a circuit switch in the thalamus. When the prefrontal cortex was working on a visual task, the circuit would suppress the ability of the thalamus to process sound, and vice versa.

Did you know?

The thalamus is around 5.7 centimetres long



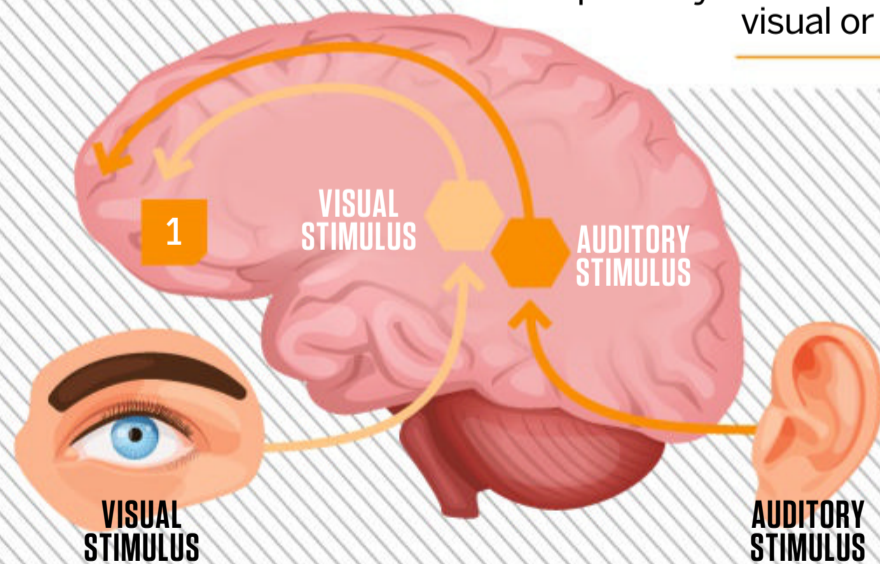
Bursts of activity in the prefrontal cortex (green) may act as a barrier for incoming distractions

BURSTS OF FOCUS

In 2023, researchers at the University of Pennsylvania uncovered a set of neurons that act as the brain's traffic controllers for distractions. Known as 'visual-movement' neurons, these cells are found in the lateral prefrontal cortex and are dedicated to keeping focus when the brain is faced with a task, shielding it from visual distractions. During animal trials, when faced with 'attentional conflict', these neurons showed bursts of activity that the researchers called beta bursts. When these occurred before the subject was shown a visual stimulus while completing a task, they were more likely to ignore it. Similarly, when visual stimuli were present while the beta bursts were weak, subjects were more likely to pay attention.

DIVERTING DISTRACTION

The pathways in the brain that helps it to cancel out either visual or auditory distraction



1 PREFRONTAL CORTEX

This region of the brain is responsible for decision-making and higher cognitive functions, receiving information from the thalamus about sensory information.

2 STRIATUM

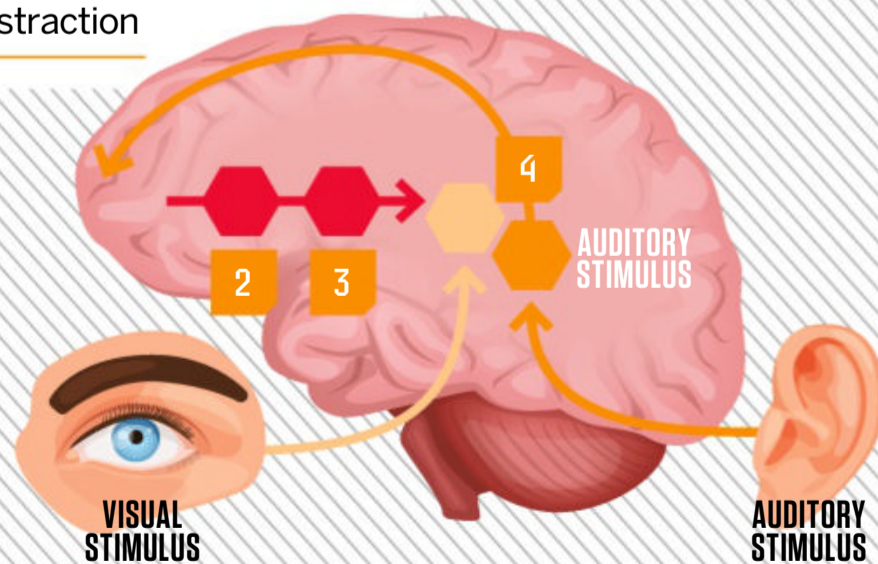
The prefrontal cortex is connected to a region called the striatum, which sends signals to another region of the brain called the basal ganglia.

3 GLOBUS PALLIDUS

Part of the basal ganglia, which receives signals from the striatum. This triggers the suppression of sensory information within the adjoining thalamus.

4 THALAMUS

Signals from the basal ganglia suppress either the visual or auditory processing abilities of the thalamus.



DISCOVER HOW THE HEAVENS MOVE AND PREPARE FOR THE 2024 ALIGNMENT

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SILENT BUT

SUPERSONIC



How NASA's latest experimental jet is designed to soften its sonic boom

Modern jet fighters are loud enough – especially when they put their afterburners on – but have you ever been startled by the thunderous boom of a plane breaking the sound barrier? This is the noisy result of some super-speed physics that engineers are now looking to quieten down.

In flight, an aircraft disrupts the air around it, creating sound waves that push ahead of the vehicle. These pressure waves travel at around 767 miles per hour – the speed of sound – and, as a result, are evenly spaced as they move away from the aircraft. Because most aircraft are subsonic, the aircraft doesn't

catch up to the sound waves as it flies. Supersonic aircraft, however, cause much more disruption. These jets travel faster than the speed of sound. As they approach the pressure waves ahead of them, the sound waves begin piling up, forming shock waves. When these combine, a thunderous roar called a sonic boom is released across the sky.

Did you know?

The X-59 was unveiled on 12 January 2024

This explosive release of sound can be as loud as 110 decibels. It's so loud that in 1974, non-military supersonic jets were banned from flying over land. 50 years later, NASA is leading the design of a supersonic jet that's able to minimise the boom. The X-59 is predicted to fly at 1.4 times the speed of sound, or 925

miles per hour. Its slender, pointed form breaks up accumulating sound waves better, and is engineered to direct sound above the aircraft rather than towards the ground. The X-59 doesn't eliminate the sonic boom, but NASA hopes it could be quiet enough to allow a return of commercial supersonic flight.

“These pressure waves travel at around 767 miles per hour – the speed of sound”

MACH?



The F414-GE-100 engine being installed into the X-59 aircraft

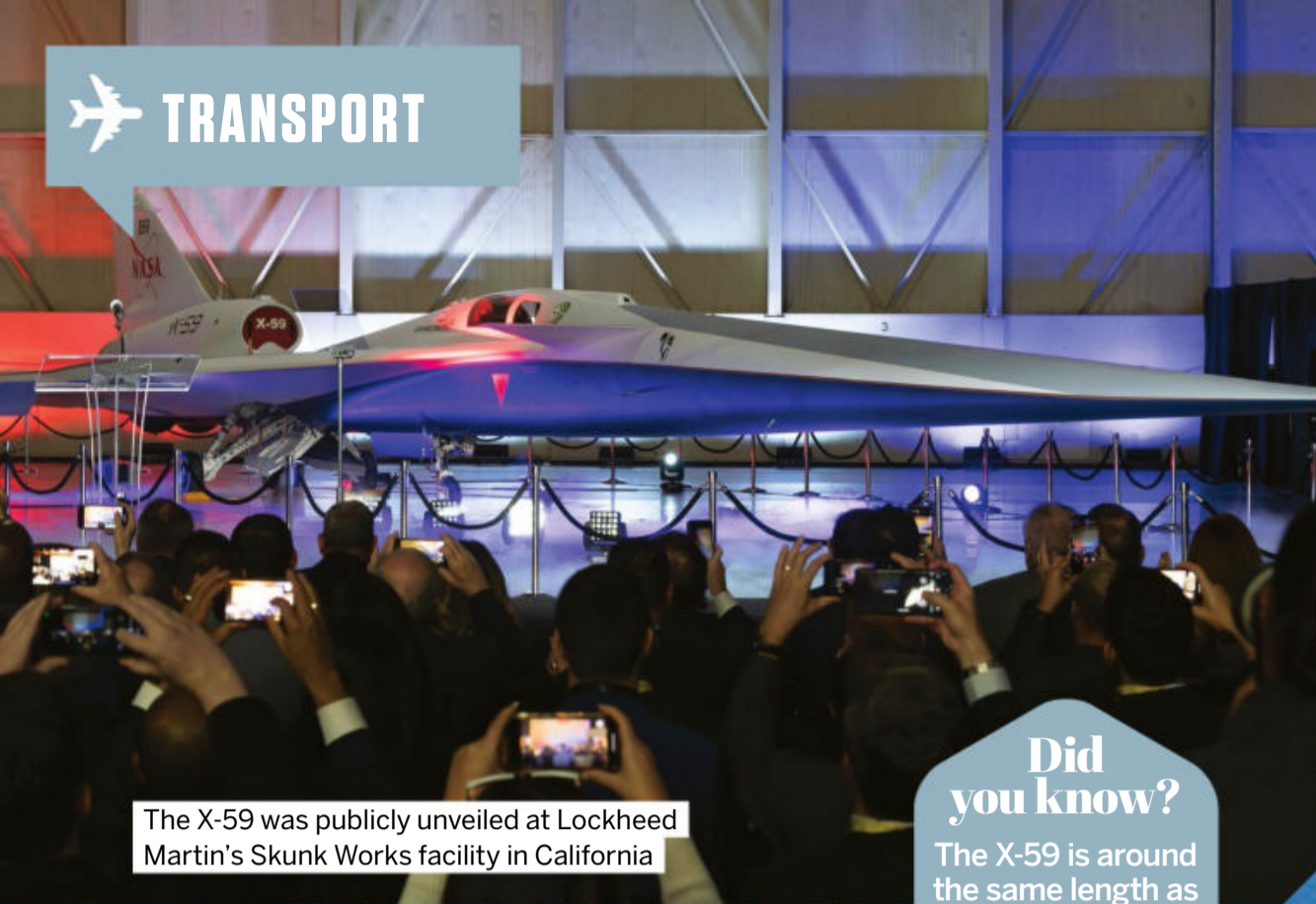
PROVING THE PEACE

In 2025, NASA plans to fly the X-59 over its Armstrong Flight Research Center at Edwards Air Force Base, California. In this controlled test area, the jet's sound levels will be monitored by ground recorders. But before this can happen, the aircraft is undergoing ground control tests to see how the engineering marvel copes with the pressures it would experience during flight. The engines are being tested, along with various other hydraulic systems and the flight control computer.

Following this, the aircraft will fly over major US cities in 2026. During this period, researchers at NASA will gather data from the public in these areas. This will serve as a community response study to judge how widely accepted or disruptive the jet is for general use. The data NASA accumulates from this public perception test will be combined with the ground-recorder data and presented to flight regulators. The aim is to lift the current ban that prevents commercial supersonic flight over land.



NASA test pilots Nils Larson (left) and Jim Less (right) and Lockheed Martin test pilot Dan Canin, pictured with the X-59 jet



The X-59 was publicly unveiled at Lockheed Martin's Skunk Works facility in California

Did you know?

The X-59 is around the same length as a basketball court

REDUCING THE BOOM

What design features help the aircraft soar through the sky?

8 WING SHAPE

The X-59 has swept wings, angled towards the back of the plane to reduce drag as it cuts through the air. The total wingspan is close to nine metres.

9 PLANE LENGTH

At 30.5 metres, the X-59 is a similar length to an average commercial airliner, but isn't designed to carry passengers.

1 T-TAIL

This horizontal stabiliser at the top of the tail minimises aft shock, or shock waves accumulating at the rear.

2 TAIL STABILITY

The conventional vertical tail maintains stability and flight control during high-speed travel.

3 HIGH-THRUST ENGINE

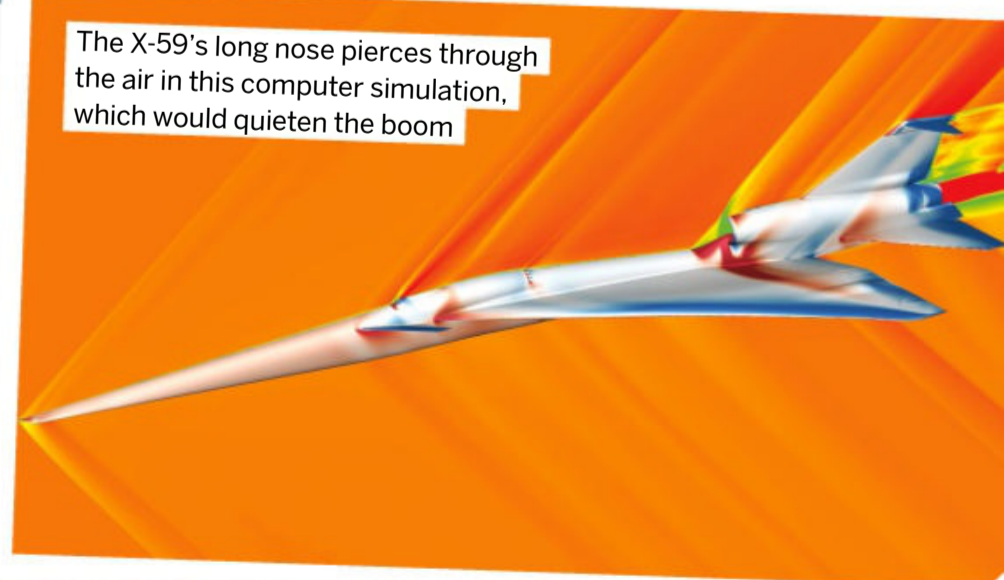
A single F414-GE-100 engine is mounted on the upper side of the jet. This keeps the bottom smooth so that shock waves don't gather at the back.

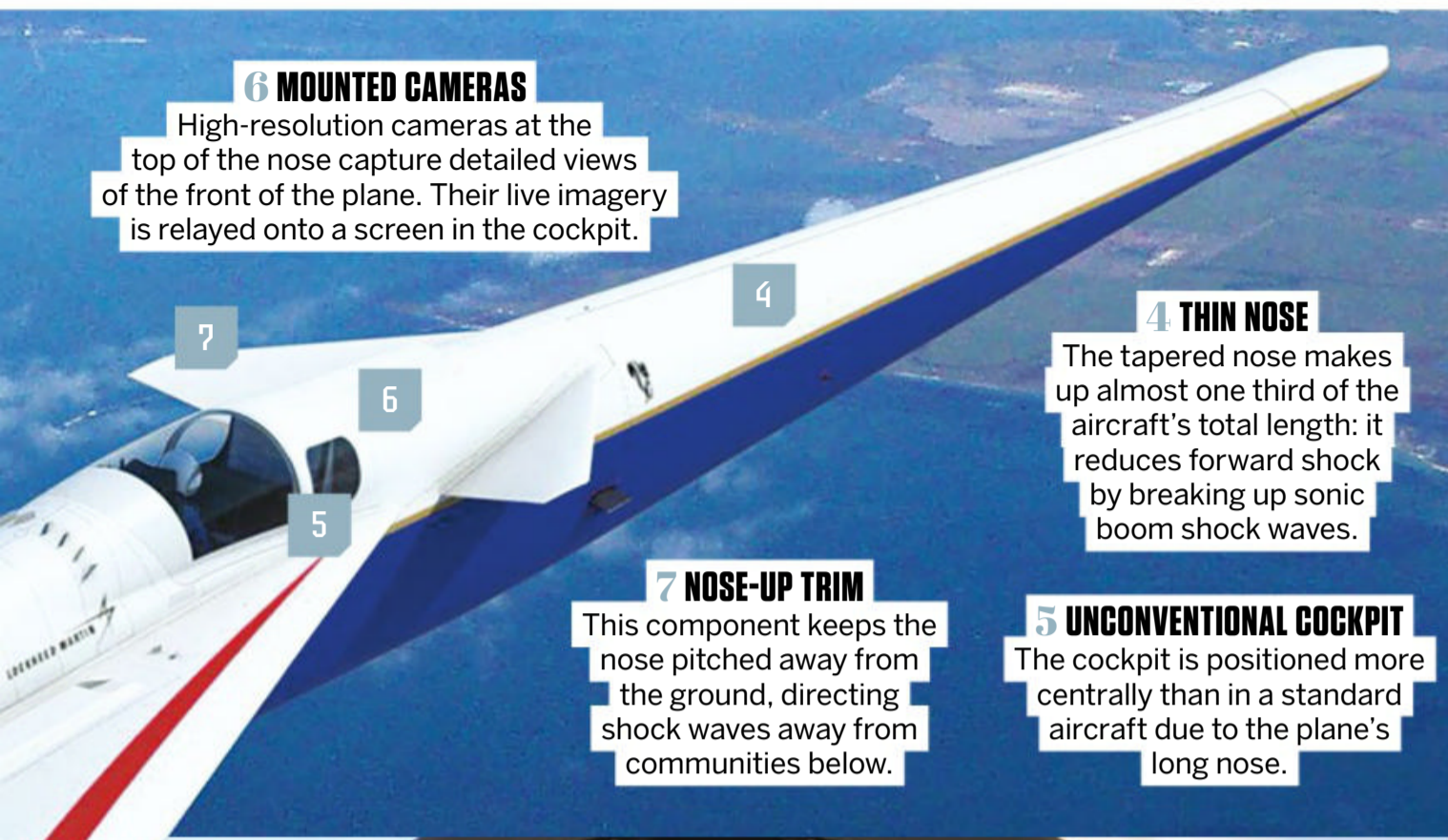


CAN SHOCK WAVES BE PREDICTED?

Before the X-59 takes to the skies, it will have to undergo a range of tests and trials. To help, NASA has its advanced supercomputers recreating conditions above the clouds. The science of fluid dynamics studies the movement of liquids and gases, and how forces affect them – for the X-59, this can be used to test how air moves around the airframe. Computer simulations can be altered based on the plane's shape, speed, air conditions and other data to create a visualisation of how shock waves form. In the computerised image, shock waves appear as parallel lines. When the lines move too close to one another and touch, this represents a supersonic boom. The direction, speed and interactions of these shock waves are analysed with each engineering variation, to determine which traits and adjustments the jet requires to reduce the boom as much as possible.

The X-59's long nose pierces through the air in this computer simulation, which would quieten the boom





6 MOUNTED CAMERAS

High-resolution cameras at the top of the nose capture detailed views of the front of the plane. Their live imagery is relayed onto a screen in the cockpit.

4

4 THIN NOSE

The tapered nose makes up almost one third of the aircraft's total length: it reduces forward shock by breaking up sonic boom shock waves.

6

7 NOSE-UP TRIM

This component keeps the nose pitched away from the ground, directing shock waves away from communities below.

5

5 UNCONVENTIONAL COCKPIT

The cockpit is positioned more centrally than in a standard aircraft due to the plane's long nose.



INSIDE THE COCKPIT

The aircraft is controlled using NASA's eXternal Vision System

A FRONT SCREEN

A 4K monitor replaces the central front window.

B WINDOWS

Traditional windows surround the screen so that the pilot can see the surrounding horizon.

C AUGMENTED REALITY (AR)

The camera view features AR overlays that show the aircraft's angle of tilt and highlight any obstacles that appear in view.

D CAMERA FUNCTIONS

The windscreen footage can be altered with these buttons. For example, night mode can be selected for optimal visibility in darker conditions.

E ORIENTATION SCREEN

This screen serves as a compass to inform the pilot of the direction of travel.

5 FACTS SUPERSONIC AIRCRAFT OF THE PAST

1 CONCORDE

Jointly operated by British Airways and Air France, Concorde was flown between 1976 and 2003. The supersonic passenger airliner had a maximum cruising speed of 1,354 miles per hour.



2 SR-71 BLACKBIRD

Lockheed Martin's reconnaissance aircraft was made in the 1960s during the Cold War. It travelled at three times the speed of sound, outrunning any weapons travelling towards it.



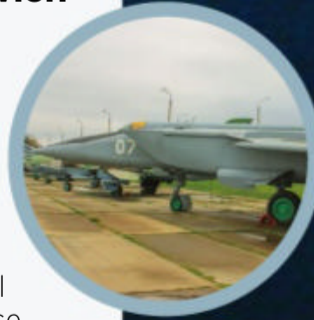
3 TUPOLEV TU-144

This Soviet airliner was a rival to Concorde. Its maiden flight on 31 December 1968 beat Concorde to the skies, but the plane broke up mid-flight at the 1973 Paris Air Show, killing all six crew and eight people on the ground.



4 MIKOYAN-GUREVICH MIG-25

This Soviet military aircraft was first used in 1970 and had a top speed of 2,171 miles per hour. On board the supersonic plane were four air-to-air missiles and a powerful radar system in the nose to detect enemy aircraft.



5 F-104 STARFIGHTER

This fighter-bomber jet was used by the US Air Force and 15 NATO countries from 1958. It could fly at around 1,550 miles per hour at altitudes above 30,000 metres. Over 2,400 were produced.



HOW HOT-AIR BALLOONS FLY

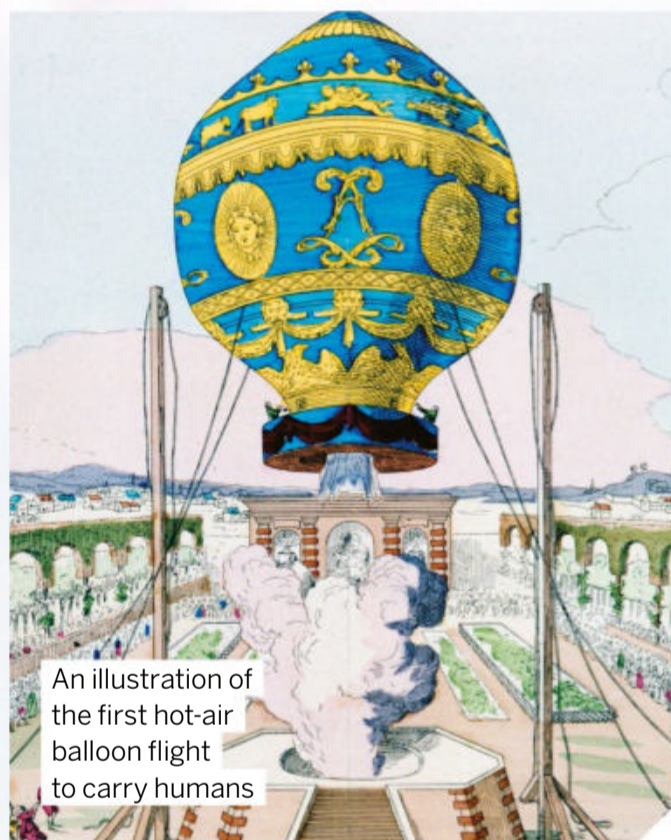
Creating changes in air density is key to getting balloons off the ground and into the skies

WORDS SCOTT DUTFIELD

The science that enables hot-air balloons to soar through the skies comes down to one fundamental principle: heat rises. To turn this fact of physics into flight, hot-air balloons are equipped with powerful burners. When fired up, these heat the air molecules inside the huge canopy. The energy and distance between each of these molecules increases with the heat, causing the air within the balloon to expand. The result is a pocket of hot air that's less dense than the colder air surrounding the balloon.

The hot air within the balloon is then displaced by colder, denser air, causing the balloon to move upwards. This upward force is known as buoyancy. Much like how a submerged rubber duck in a bathtub will rise to the surface of the water, buoyancy lifts hot-air balloons through the air.

Theoretically, a hot-air balloon would continue to rise until it reached the 'surface' of Earth's atmosphere. However, so far the highest balloon ride in the sky has only taken passengers up to around 6,700 metres, which is just a fraction of the atmosphere's 60-mile thickness. For the balloon to descend, the pilot just needs to reduce the



An illustration of the first hot-air balloon flight to carry humans

amount of heat and cool the air within the balloon, making it denser and causing it to sink through the atmosphere.

One of the challenges of flying around in a balloon is its dexterity in the air. Without propellers and wings, hot-air balloons are largely at the mercy of the wind to determine



their direction. However, pilots can skilfully alter the altitude of the balloon to meet varying wind currents in the atmosphere to guide its direction.

In 2023, Virgin announced a collaboration with pioneering hot-air balloon creator Cameron Balloons to produce the world's first steerable hot-air balloon, called the B-Wing. Along with all the whimsy of a traditional hot-air balloon, the B-Wing includes a pair of practical wings that the pilot can use to actively steer the balloon. By using rotation vents, pilots will be able to orient the balloon in the air and even control whether the aircraft moves forwards or backwards.

SOLAR-POWERED BALLOONS

It might seem like a farfetched idea, but solar-powered hot-air balloons do indeed exist. The debut of this kind of balloon occurred in 2015 at the 37th Bristol International Balloon Fiesta, and was created by Cameron Balloons. To utilise the Sun's power, the almost 4,248-cubic-metre balloon was partly made from black material specially designed to absorb the heat from sunlight, to maintain the

temperature of the hot air within. This occupied half of the balloon's overall form and was positioned towards the Sun. The half of the balloon facing away from the Sun was made using double-lined insulating silver material to reduce any heat loss during flight. The balloon wasn't entirely solar-powered; it was a hybrid aircraft, with a propane burner at its heart for takeoff and support.



Cameron Balloons' debut of a solar-powered hot-air balloon

DID YOU KNOW? The world's largest hot-air balloon is 21,238 cubic metres and can carry up to 32 passengers

3

3 GORES

The tear-drop shape of a balloon is created by long panels called gores.

6

6 ENVELOPE

The body of the hot-air balloon, typically made out of thin nylon.

4 PARACHUTE VENT

In the event that a balloon needs to descend quickly, the pilot can pull a cord attached to a vent at the top of the balloon to allow cold air to flood inside.

2

2 SKIRT

The material closest to the flame is made from flame-resistant material, commonly a textile called Nomex.

1 BURNER

Heat is supplied by burning propane, which is stored as a compressed liquid in cylinders within the balloon's basket.

5

Did you know?

The hot-air balloon was invented in 1783



4



1

UP, UP AND AWAY

The components that lift hot-air balloons into the sky

5 BASKET

Passengers are carried in a lightweight basket. Balloons can typically support a weight limit of half a tonne.

5

FACTS

RECORD-BREAKING BALLOONS

1 FASTEST FLIGHT AROUND THE GLOBE

This speedy hot-air balloon trip was made in 2016 by Russian adventurer Fedor Konyukhov, who travelled 20,829.2 miles from Northam, Australia, to Bonnie Rock, also in Australia, in 268 hours and 20 minutes.

2 FASTEST BALLOON

Not only was the Virgin Atlantic Flyer the first hot-air balloon to cross the Atlantic in 1987, it also set the speed limit for the fastest manned balloon, reaching speeds of up to 153 miles per hour.

3 FIRST NON-STOP ROUND-THE-WORLD TRIP

In 1999, Bertrand Piccard and Brian Jones became the first people to travel around the world in a hot-air balloon. The trip took 19 days, 21 hours and 55 minutes, taking the pair from Switzerland to North Africa.

4 TALLEST BALLOON

The world's tallest hot-air balloon was created in 2022 and stood just over 56 metres tall. It took the form of an enormous Coca-Cola bottle: the 'Giant of Refreshment'.

5 FIRST SOLO TRIP AROUND THE WORLD

The first solo balloonist to circumvent the globe in a hot-air balloon was Steve Fossett in 2002. After six attempts at the record, Fossett flew for 13 days over 22,100 miles to complete the record.

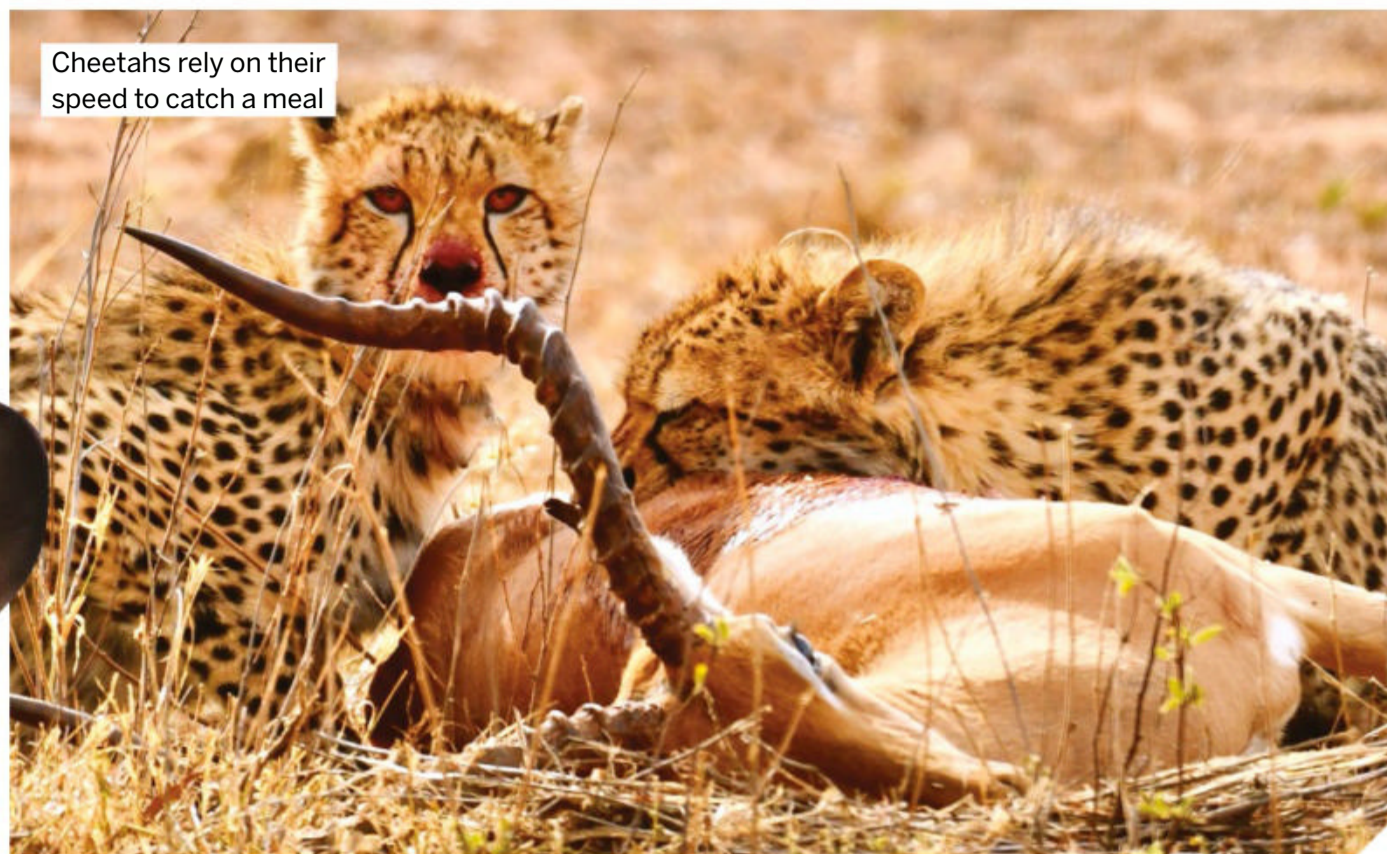
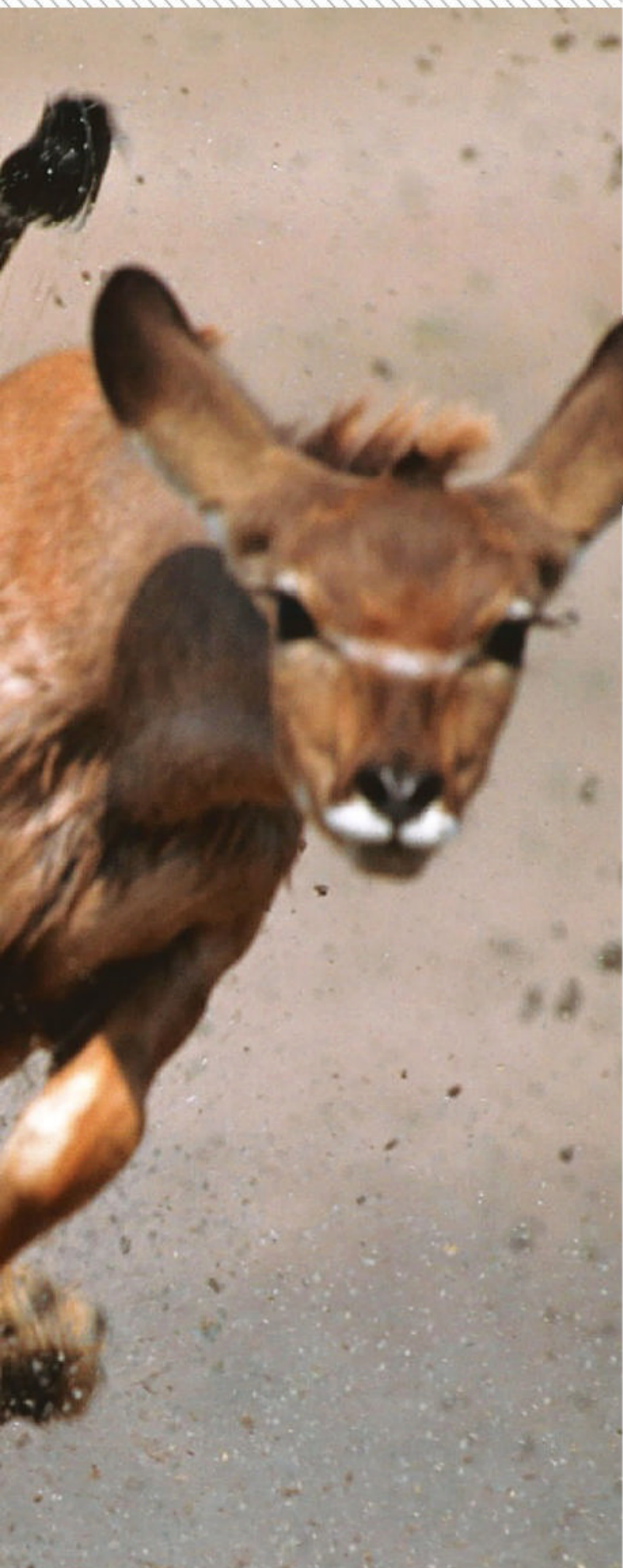


HOW ANIMALS HUNT

The strategies and techniques that the world's predators use to catch their prey

WORDS SCOTT DUTFIELD





Cheetahs rely on their speed to catch a meal

From stealthily stalking prey to launching a coordinated attack, the world's predators have evolved a multitude of techniques to find and kill their food. Many of these involve using their senses to sniff out or spot their prey from a great distance. For example, eagles have some of the best eyesight in the animal kingdom, which they use to spot prey from up to two miles away while soaring in the sky. Other species are equipped with heightened senses for hunting, such as the electricity-detecting powers of sharks. Known as electroreception, sharks have adapted pores in their snouts, called ampullae of Lorenzini, which can pick up on electrical currents that move through the water. Any movement from the muscles of fish and other sea creatures creates an electrical current which is conducted by the ocean's salty water. When sharks sense the current and its direction, they can follow their noses and catch their prey.

Making good use of their senses, hunters generally employ one of several strategies to

succeed in their pursuit of prey, such as stalking, ambushing and baiting. Others employ more deceptive methods to find and catch their food. For example, many herring gulls (*Larus argentatus*) perform a foot-tapping rain dance on the ground to call worms to the surface. It's believed that the repeated stamping on the ground mimics the vibrations of rain, which earthworms are drawn to because it makes it easier for them to move around on the surface. However, emerging from the soil under these false pretences only makes it easier for the gulls to grab a quick bite.

But for some, hunting isn't nearly as strenuous or calculated. Take the North American brown bear (*Ursus arctos*), for example. Residing in woodlands surrounding rivers and streams, these bears have situated themselves within arm's reach of their salmon prey. During the salmon's river migrations, these upstream swimmers are often faced with a furry bear sitting in wait above and below waterfalls for a salmon buffet to leap from the water, snatching them in midair.

Did you know?

Wolves can smell prey from up to a mile away

DROPPING THE BAIT

As nature's fishermen, green herons (*Butorides virescens*) have developed a nifty way to lure prey within reach. While perched on a branch, green herons will drop a small piece of bait, such as insects or feathers, into a lake and wait for nearby fish to take notice. Once a fish has fallen for the heron's bait and taken a bite, the bird quickly lunges its beak into the water and snags the fish for itself. Crocodiles and alligators employ a similar strategy by submerging themselves in the water and balancing twigs on their heads to lure nest-building birds. Unknown to them, a jaw of razor-sharp teeth is waiting below, ready to snatch them out of the air.



A green heron baiting larger fish with a smaller snack



A pride of lions taking down an African buffalo in Mana Pools National Park, Zimbabwe

FOLLOWING YOUR FOOD

How the animal kingdom's stalkers ambush their prey

Favoured as a hunting strategy among many apex predators, stalking allows an animal to wait for the precise moment prey is most vulnerable. Lions (*Panthera leo*) are one of nature's keenest stalkers. It's usually the females who are more likely to actively hunt, beginning at around two years old. While roaming the savanna, when females spot prey they quietly follow them through tall grasslands until they're within around 30 metres. Hunting is typically done in groups, with lionesses creating a formation to the left, centre and right of the prey. When the time is right, the group charges and pounces, delivering a fatal blow and bringing the animal to the ground. Stalking isn't always necessary for these apex predators, and is more likely to be reserved for large prey such as zebras and impala, not small prey like rodents and reptiles.

Tigers favour stalking their prey, but as solo predators.

Roughly once a week, an adult tiger ventures through its habitat to hunt. Its striped body is designed to assist it with remaining undetected while stalking prey. When a tiger is within around six to nine metres of its prey, it pounces, targeting the neck and delivering a fatal bite. Wolves, crocodiles and polar bears also track their prey until it's the perfect moment to pounce.

For the winged predators of the animal kingdom, stalking prey from the sky is a bit trickier without any camouflage to rely on. Raptors, such as peregrine falcons (*Falco peregrinus*), rely on sheer speed and agility to sneak up on unsuspecting prey. As the fastest-moving animals on Earth, peregrine falcons can dive through the air at speeds of up to 240 miles per hour to grab prey. While stalking prey, such as other smaller birds, peregrines can top 65 miles per hour in high-speed pursuits.

Did you know?

A lion pride has up to 40 members

WHEN LIONESSES STRIKE

The stages of hunting to take down prey much larger than yourself



1 GETTING IN POSITION

Female lions use the surrounding grassland to blend into the background and stalk their prey, while the other lionesses get into position.

2 ON THE CHASE

In a short burst of energy, lions pursue their prey at speeds of up to 45 miles per hour.

3 LEAP

When the prey is close enough to ambush, the lions leap towards their neck, sometimes jumping up to around four metres in the air.

4 TACKLE

Sometimes lions will strike the animal's legs or haunch to knock it off-balance, for an easier kill.

5 FATAL BLOW

Delivering a forceful bite to the neck, the lions bring their prey to the ground and begin to tuck into their fresh meal.



A tentacled snake, ready to engulf its fish prey

TRICKSTER SERPENT

Weaving through the waterways of Southeast Asia is an aquatic snake that has learnt to trick its prey into swimming directly into its mouth. Known as the tentacled snake (*Erpeton tentaculatum*), these sneaky serpents take on a J-shaped posture and wait for passing fish to get close. When a fish is close enough, the snake moves part of its lower body to create waves in the water in the direction of the fish. The waves signal to the fish that danger may be near and it changes direction, often swimming directly into the mouth of the snake.

DID YOU KNOW? Sidewinders are the fastest-moving snakes on Earth and can strike their prey at 18 miles per hour



A pod of orcas on the hunt for a seal meal

PREDATOR PARTNERSHIPS

The animals that work together to capture their prey

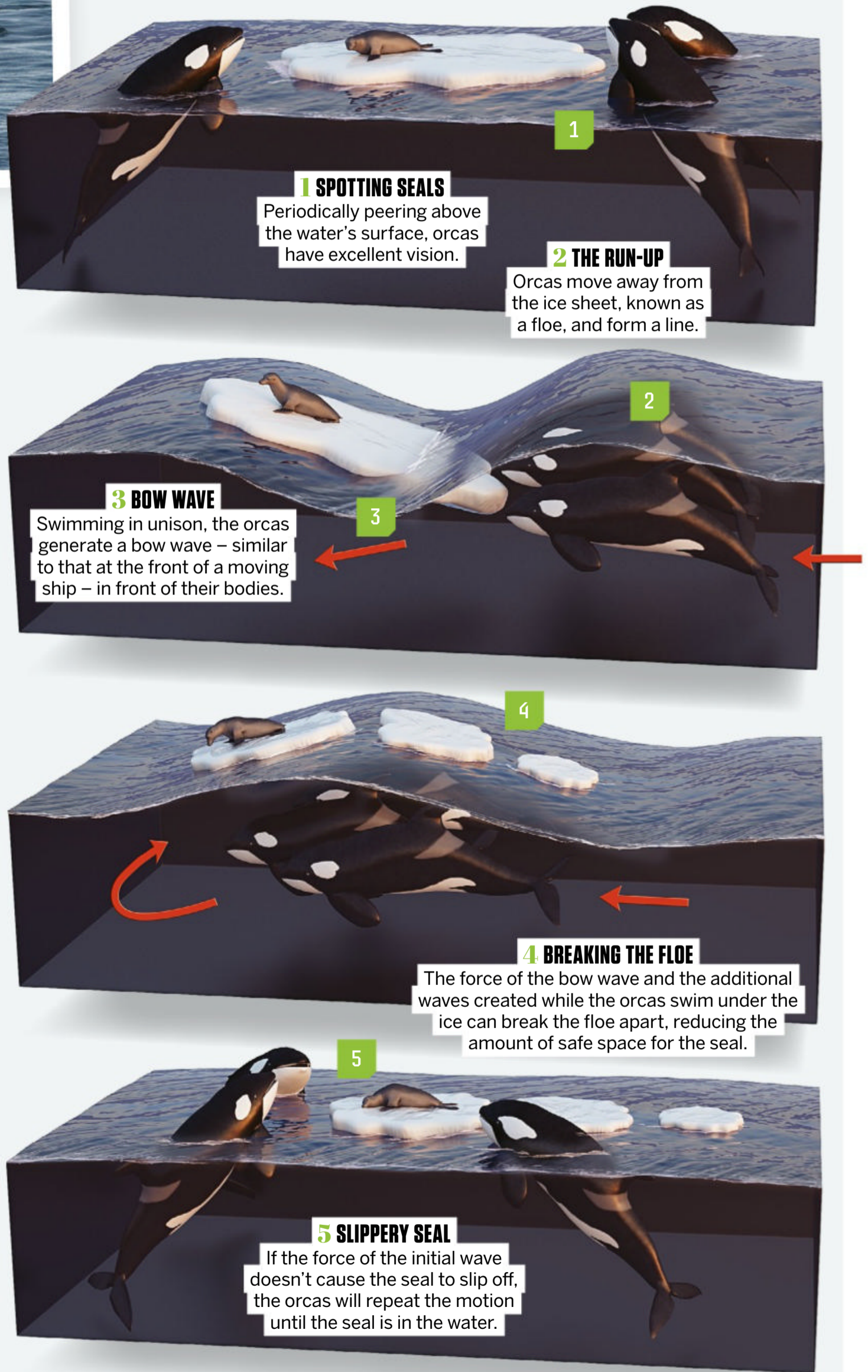
As the old saying goes, two heads are better than one, and when it comes to hunting, the more heads the better. Many mammals, such as lions, wolves and hyenas, work in teams to sniff out and take down their next meal, but none do it with such coordinated flare as orcas. Even alone, an orca is a formidable predator, striking fear into the hearts of seals and penguins around the world. However, when a pod of these marine mammals get together, they employ a coordinated assault unlike any other.

While resting on a sheet of ice, seals might be tricked into thinking they're safe from water-bound predators. However, orcas have developed a technique to generate a barrage of waves that not only break the ice apart, but also knock the seal into the water for the orcas to chase and kill. Sometimes orcas employ another hunting strategy of blowing bubbles to confuse and disorient the seal underwater, giving them the advantage to attack.

Not all hunting parties are made up of the same species. For example, in the Kalahari Desert of South Africa, meerkats (*Suricata suricatta*) and the fork-tailed drongo (*Dicrurus adsimilis*) have formed a symbiotic relationship when it comes to hunting. While meerkats are on the hunt for insects, small rodents and lizards, the drongo flies overhead, keeping a keen eye out for any potential threats that want to make the meerkat its prey. If danger should appear, the drongo will call to the meerkat like a flying alarm system, hopefully with enough time for the meerkat to escape. In return, the drongo will feed on the meerkats' uneaten food, or even steal a few morsels straight from their paws.

ORCA HUNTING PARTY

How killer whales shatter the ice that shields them from their prey





CRAZY ANT ALARMS

Ants aren't known for their predatory abilities – more for their cooperative foraging. However, a 2013 study released from the University of Sussex revealed that Brazilian longhorn crazy ants (*Paratrechina longicornis*) are not only keen hunters, but form a unique prey 'escort' back to their nests. When searching for both dead and live prey, these ants leave a pheromone trail for their fellow ants to follow, and lone ant hunters can even release a beacon-like burst of pheromones to draw other ants near. Once the call is answered, the ants will capture their prey, such as termites, and act as escorts to walk their food back to the nest. On route, the ant escorts will fight off any intruders who seek to steal their meal, and will also recapture the prey if it breaks free.



Longhorn crazy ants restraining their prey

MASTERS OF PHYSICS

Some animals hunt with science in mind

One of the most impressive hunters in the water is the archerfish (*Toxotes jaculator*). Swimming through the estuaries and mangrove swamps of Asia and northern Australia, archerfish patrol the overhanging vegetation for insect prey. When a target is in sight, they use their specially adapted mouths to draw in water and fire it beyond the surface to knock their prey from the leaves and into the water. Archerfish have been known to hit their targets from 1.5 metres away. To successfully hit their prey, archers have to account for the refraction of light between the air and water to accurately pinpoint their meal. However, if the first shot doesn't hit, the fish's unique mouth can store enough water for another six shots before it's empty.

Turning this understanding of physics on its head, the northern gannet (*Morus bassanus*) hunts its water-dwelling prey from the skies. Plunging into the water from up to 15 metres above the surface at speeds of up to 60 miles per hour, gannets must be some of the bravest birds in the world. Transitioning from sky to sea at such high speed means the impact force of their dives is around 5,000 newtons – equivalent to 510 kilograms of force hitting the water. To prevent the bird's body from breaking apart, it has evolved a few adaptations. First, the arrow-shaped body of a gannet reduces drag

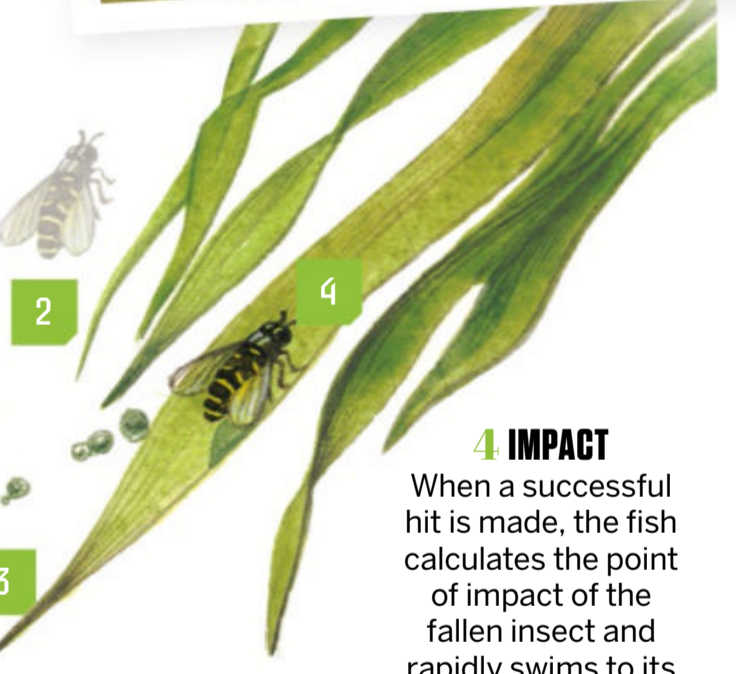
on entry and cuts into the water. The nostrils on the bird's beak are fused to prevent any water from shooting up into its head on impact. There are also lots of tiny air sacs that sit beneath the skin of the gannet's head and chest; these act like protective bubble wrap to take the brunt of the impact. Although their precision in tackling prey isn't as fine-tuned as the archerfish, these birds can estimate the position and depth of their prey very well. After the initial dive, gannets swallow their catch underwater and can use their wings like fins to swim up to 20 metres below the surface to continue the hunt.



An archerfish shooting a jet of water towards its prey

2 WHERE'S THE BUG?

Due to the refraction of light caused by the surface of the water, prey can appear up to 25 degrees off from their actual position.



4 IMPACT

When a successful hit is made, the fish calculates the point of impact of the fallen insect and rapidly swims to its location to feast.

3 FIRING WATER

Archerfish create 'pellets' by compressing the water between their tongue and the roof of their mouths, contracting their gills to fire the pellet outwards.

1 SPOTTING PREY

Sound and smell don't penetrate into the water, so archerfish rely on their acute sense of sight to find prey.

FINDING THE RIGHT ANGLE

How archerfish strike prey outside of the water



Did you know?

Tigers can eat up to 40 kilograms of food in a single sitting

SETTING A TRAP

Why stalk and chase your prey, when you can lay a trap and let the food come to you?

When it comes to setting traps in the wild, few do it better than spiders. Their silken webs are the perfect utensil for capturing unsuspecting insects and birds. However, there is one group of spiders that go the extra mile to ensnare their prey. Trapdoor spiders, of which there are hundreds of species, can be found across the globe. Unlike their web-spinning cousins, these spiders dig a burrow and thread a silken trapdoor, where they lay in wait for passing prey, typically crawling insects such as centipedes or other spiders. Tiny hairs on the legs of a trapdoor spider act like an alarm system, sensing the vibrations of outside movement. When the alarm is sounded, the spider leaps into action, pouncing from the trapdoor and biting down with its fangs to drag the body back into the burrow.

Predators' traps aren't always physical. Many species use different tactics to lure their prey into a false sense of security. Take the margay (*Leopardus wiedii*), for instance. These small jungle cats have an uncanny ability to mimic the cry of an infant monkey. Upon hearing their calls, adult monkeys scout out the supposed baby monkey, only to find the waiting margay ready to pounce.

Similarly, female *Photuris* fireflies, also known as 'femme fatale' fireflies, mimic the abdomen flashing patterns of the females of a different firefly species to lure male prey. Journeying over to what they think the flashing signal of a potential mate, the males are instead met by the mandibles of the female.

4 TRAPDOOR

Twigs and silk are piled on top of the entrance hole and attached to a silken hinge.

3 DOORWAY

The spider cuts out a circle in the webbing that covers the entrance hole.

2 WALL LINING

A mixture of soil, saliva and silk is used to line the walls of the burrow, including the entrance hole.

1 DEPTH

Trapdoor spiders use their jaws and legs to lift dirt and burrow into the ground up to 15 centimetres.

5 SECOND DOOR

Some species of trapdoor spider construct a second trap to hold prey, or for further protection for the eggs they lay inside.



A trapdoor spider waiting for its next meal to walk by

NOT ALL SPIDERS USE WEBS

What lies behind the trapdoors of these ambush predators



WHAT IS AN OASIS?

These hidden hubs sustain life in the desolate desert

WORDS AILSA HARVEY

An oasis is a contrasting area of land in an arid, inhospitable environment that is made fertile by a freshwater source. Usually, this water comes from groundwater, called an aquifer.

Oases are places where plant life thrives, becoming refuges for desert animals and humans to find food, water and shade in the unforgiving heat of desert landscapes.

Some oases have natural springs that carry water up to the surface through fractures in the ground, while in other places the water-hydrating plant life is hidden underground. Humans have tapped into this water at many oases, building wells to bring the water above ground, accessible to those who live locally and visit them. Water often needs to be pumped up from below, but in some instances the pressure beneath is so great that the water naturally shoots up from the ground. This type of well is called an artesian well.

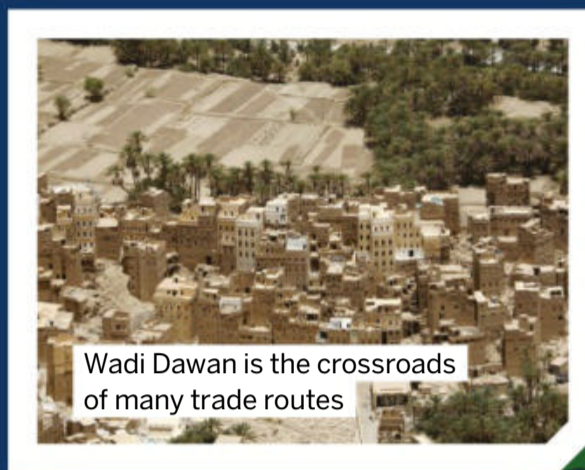
For centuries, communities that have stumbled across these fruitful lands have learned how to live in confined oases while being surrounded by extreme environments. Since the settlements were first established, people have organised agriculture to keep their oasis protected. For example, the strongest trees available may be planted around the edge of living and growing areas, stopping sandstorms from engulfing plants and spoiling wells.

One oasis community that has tailored its agricultural practice to the environment is Tozeur in Tunisia. The olive trees its people depend on are grown on terraced land – steps carved into the steep hills. Their roots strengthen the soil to prevent erosion, and the flat steps capture rare rainfall from the slopes' runoff.

In Saharan oases, one of the most important plants is the date palm. Desert oases are the perfect spot for these Sun-loving crops. Their roots need to be immersed in water, and they have evolved to thrive in extreme heat. In shaded plots around oases, fruit, vegetables, wheat and barley can also be farmed.

1 WADI DAWAN, YEMEN

Many of the buildings of Wadi Dawan are built with mud bricks and typically have wooden floors. There are a few similar small settlements across the surrounding mountains.



Wadi Dawan is the crossroads of many trade routes

2 AL-AHSA, SAUDI ARABIA

This is the largest oasis in the world, measuring around 33 square miles. Its natural springs have been present in the area for millennia. Al-Ahsa is at a lower altitude than much of Saudi Arabia, so water collects in the ground here.



Al-Ahsa is home to Saudi Arabia's largest lake

Did you know?

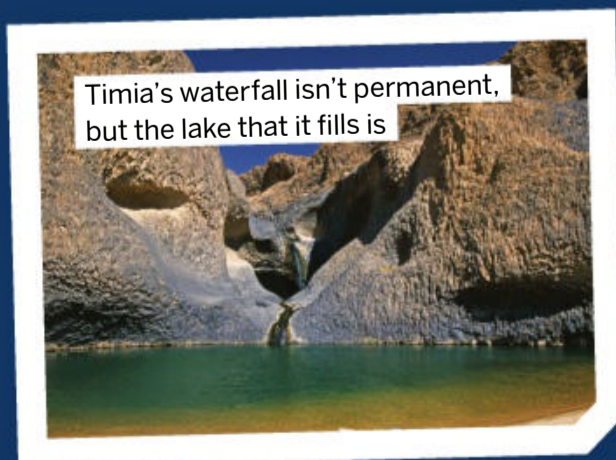
Al-Ahsa Oasis is home to 2.5 million date palms

WHERE IS THE WATER?

This desert map shows where some of these sanctuaries are located



Timia's waterfall isn't permanent, but the lake that it fills is



5 TIMIA, NIGER

The oasis town of Timia in the Air Mountains has a population of over 13,000 people. On the outskirts of the town is a waterfall that forms during the rainy season.

Tafilalt is the largest oasis in Morocco



6 TAFILALT, MOROCCO

This oasis in southeast Morocco covers 28,000 square miles. Green plant life adds a burst of colour to the dry landscape, growing in the Ziz and Ghéris valleys. The industries of this population include date farming, animal skin tanning and other crafts.

DID YOU KNOW? Two thirds of the Sahara's population live in oases

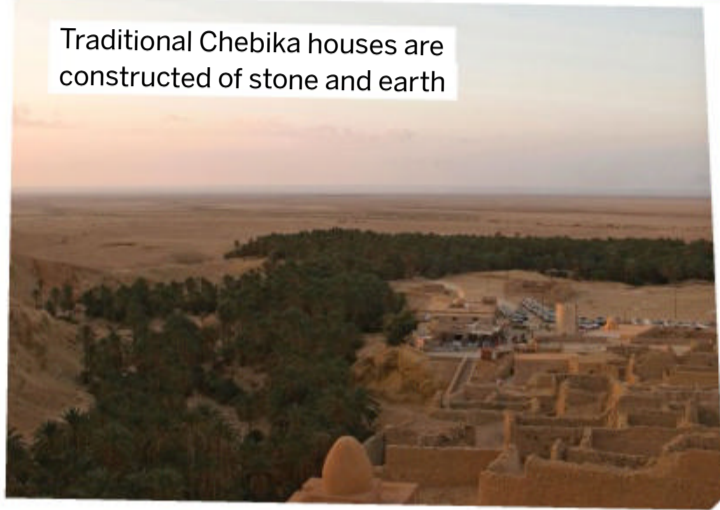
3 CHEBIKA, TUNISIA

This oasis can be found at the foot of the Djebel el Negueb mountains, near the Algerian border. The oasis was once a Roman outpost, and later became home to the Berber peoples.

4 UBARI, LIBYA

Today this pocket of life is an anomaly. But around 200,000 years ago, the surrounding sand dunes experienced abundant rainfall. In this climate, a large lake called Lake Megafezzan formed. About 5,000 years ago this lake dried out, forming the smaller oases that remain today.

Traditional Chebika houses are constructed of stone and earth



There are 20 small lakes making up the Ubari oasis



Moroccan women at the Agdz oasis, sorting dates to be sold

WHAT ARE OASES USED FOR?

The location and volume of an oasis' water supply usually determines what the area is used for. Some oases are small wells with a spattering of plant life surrounding them, while in other regions people have built sizable towns and cities around the natural resources. Where the fertile land is of considerable size, human settlements can grow enough crops to sustain bigger populations. An example of this is Al-Ahsa Oasis in Saudi Arabia, which is famous for its date palm groves. The fertile land supports over a million people who live there. Having such fertile land enables oases settlements to breed valuable livestock, giving them a place to graze and providing products like meat, milk, leather, wool and eggs.

Throughout history, oases have served as natural service stations for nomads embarking on long and often dangerous journeys. Some 2,000 years ago, trade routes, such as those in ancient Egypt, would attract sellers from around the world. In the modern day, oases are often points of interest for tourists and areas for conservation projects. Scientists strive to protect the biodiversity of oases, where unique plant species have adapted to desert regions.



This aerial image of Siwa shows the contrast of the oasis and the desert

7 SIWA, EGYPT

This 6.2-by-4.9-mile oasis is home to 200 natural springs. The main crops that thrive here are date palms and olive trees.



Huacachina is surrounded by towering sand dunes

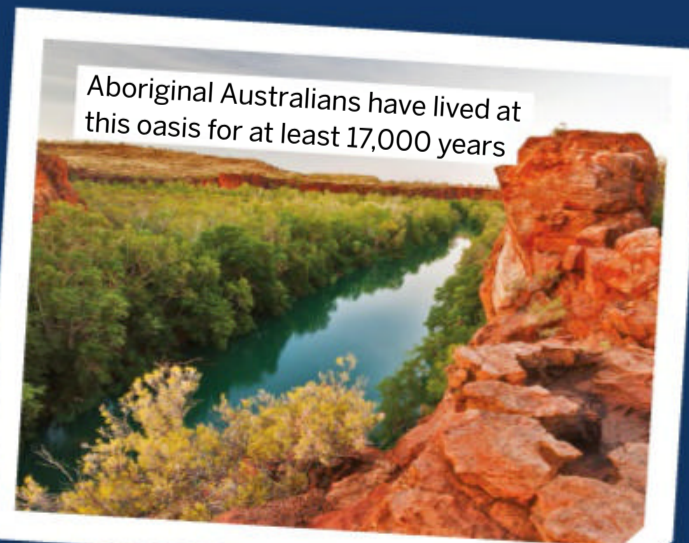
8 HUACACHINA, PERU

Only ten per cent of Peru has a desert landscape. Being just 3.1 miles from the city of Ica, tourism is the only industry for the Huacachina oasis.

9 BOODJAMULLA, AUSTRALIA

40,000 people visit this outback oasis every year.

The water at Boodjamulla's gorge is sacred to the Waanyi people of Australia because of its life-giving contents.



Aboriginal Australians have lived at this oasis for at least 17,000 years



SURPRISING WAYS NATURAL DISASTERS CAN TURN DEADLY

Forget rivers of lava and strong winds...
Earth's most furious moments claim
their victims in unexpected ways

WORDS PROFESSOR SUSAN KIEFFER



Mucor spinosus, one of the fungi that can cause the deadly mucormycosis infection

Did you know?

A tornado's damage path can be 50 miles long

TORNADOES

AIRBORNE DISEASES

Tornadoes kill primarily with 'blunt force trauma' as flying objects hit people. But these flying objects can also carry infections. In 2011, a 0.7-mile-wide tornado blasted through Joplin, Missouri. It was an EF5 storm, with winds exceeding 198 miles per hour. It killed 158 people and injured nearly 1,000. Nearly a dozen people developed mucormycosis from soil that penetrated their skin. This rare infection can be cured, but only with harsh measures: strong antifungal drugs and the removal of damaged skin. At least three of the deaths linked to the tornado were caused by this.

VOLCANOES

GLOBAL COOLING

Following the Laki volcanic eruption of 1783, winter was so cold that as many as 8,000 more people than usual in the UK may have died as a result. The sulphur particles from the eruption had major effects on conditions in Europe, leading some to speculate that it even added to the poverty and famine that led to the French Revolution of 1789. Sometimes a volcano's cooling effects go global. The 1815 eruption of Mount Tambora – the largest in the past 10,000 years – not only killed 70,000 people, but contributed to a global cooling of about 0.5 degrees Celsius by injecting sulphur particles into the atmosphere. North America and Europe experienced the 'Year Without Summer', with crops failing. Snow fell in July and August in New England.

VOLCANOES

TOXIC GASES

In 1783, Iceland's Laki volcano erupted, spewing sulphurous compounds into the atmosphere for eight months. Few Icelanders died as a result of the lava flows themselves, but other effects of the eruption proved catastrophic. Acid rain drenched the crops, and huge amounts of hydrogen fluoride were released, which poisoned both the population and livestock. It's estimated 8,000 Icelanders died as a result. The sulphur dioxide from

the eruption entered the jet stream and spread westward over Europe, through China and Russia, and then over America by way of Alaska and northern Canada. In Europe, thousands choked to death as they inhaled the poisonous cloud. It has been estimated that 23,000 people died in the British Isles alone. Scientists at the University of Leeds have estimated that a similar eruption today would kill around 142,000 people across Europe.



Swathes of land left barren



Liquefaction in Christchurch, New Zealand, after it was hit by an earthquake in 2011

EARTHQUAKES

LIQUEFACTION

When soil is saturated with water, it can turn to mush when an earthquake strikes, in a process known as liquefaction. This dramatically reduces the ability of soil to support the foundations of buildings, and accounted for much of the destruction in the harbour of Port-au-Prince during the 2010 earthquake in Haiti. Generally, but not always, liquefaction occurs near to the earthquake rupture, where the radiating seismic waves are strongest. However, the mud volcano island that formed off the southern coast of Pakistan in 2013 was hundreds of miles away from the epicentre of the magnitude 7.7 earthquake that occurred on 24 September. Geologists believe that a combination of liquefaction and methane from the pile of mud and sand that exists in the offshore region was responsible for the formation of the mud mound, which measured approximately 176 by 160 metres.



Homes toppled by a landslide

EARTHQUAKES

LANDSLIDES

The initial vibrations from an earthquake are the least of your worries if they're shaking an area with vulnerable geographical features. Particularly violent earthquakes can trigger secondary reactions – some of which prove far more deadly than the initial earthquake. The most infamous example of this phenomenon is tsunamis – huge water waves typically triggered by underwater earthquakes that can devastate coastal towns, such as the 2004 Indian Ocean tsunami, which claimed more than 230,000 lives across South Asia. But inland areas near mountains or hillsides aren't safe either. Seismic activity here can trigger chain reactions that cause massive landslides and avalanches, burying whole communities under rubble. In 2013, 100 people were killed in China's Gansu province when a magnitude 6.6 earthquake resulted in severe landslides.



OPTIMUS GOES

Automotive company Tesla is reducing the limitations of robotics with its latest humanoid reveal

WORDS AILSA HARVEY

Could you accept a piece of machinery into your life to talk to as a companion and live or work autonomously alongside you? This is the reality of one of the latest inventions by Tesla. A humanoid robot is a robot that is built to resemble a human in order to carry out various tasks that the human form is suitable for. The Optimus Gen 2 is one such robot, made with the ability to learn and perform multiple jobs, just like a human.

Some of the main roles this robot is designed for are in manufacturing, construction, healthcare and entertainment. The computerised brain of Optimus is evolving to become more advanced in order to navigate each of these working environments safely and cooperate with humans in these spaces. They can receive orders through voice-activated commands and change the force of contact with objects based on their fragility. For example, Optimus has demonstrated that the second-generation robot can lift eggs between its fingers, achieving just the right grip. Lifting an egg with enough strength to secure a hold, but without inflicting too much force to break the fragile shell, is a precision skill that humans naturally achieve, while robotic analogues have historically struggled with this task.

Humanoid robots may seem like a digression from Tesla's typical automobile products. However, much of the same technology is used in Optimus Gen 2 as in some of Tesla's latest car models. The artificial intelligence (AI) software of Optimus Gen 2 is the same that is used in the company's latest autonomous cars. The shared technology includes vision algorithms that enable the android to see and interpret the world around it, the batteries and computer chips. As one of the most valuable companies in the world, Tesla has an advantage in business scale over other humanoid manufacturing competitors. In the future, Tesla aims to have thousands of its humanoid robots working within its factories, to further grow manufacturing efficiency.

Did you know?

There are up to five additional neck joints in the Gen 2

The face screen can be adapted to the robot's role, displaying useful and relevant information

ANDROID EVOLUTION



SEPTEMBER 2022

1 BUMBLEBEE

The first prototype was called Bumblebee. When Tesla CEO Elon Musk unveiled this robot, it could walk slowly and carry out limited movements such as waving. It was later revealed that this early example of Tesla's humanoid robot was restricted in movement because it lacked balance during other gestures.



MARCH 2023

2 OPTIMUS GEN 1

Tesla engineers worked to evolve Bumblebee into a more stable and productive robot. While Bumblebee was more experimental, showing what Tesla could do using off-the-shelf components, Gen 1 used customised parts designed to optimise the humanoid's capabilities. This robot weighed 7.5 kilograms and could move at around five miles per hour.



DECEMBER 2023

3 OPTIMUS GEN 2

Some of the main improvements are its dexterity and range of motion. Its limbs and digits can move more freely. In line with the robot's eventual goal, Gen 2's appearance is tailored more towards becoming a commercial product, featuring a futuristic casing to protect joints and wires. The latest robot is 30 per cent faster and ten kilograms lighter at 62.5 kilograms.



1

1 TWO DEGREES OF FREEDOM

In the neck, there are two axes of motion, so that it can circle its head like a human and gain a wide field of view.

MEET THE MACHINE

What makes Optimus Gen 2 move and think like a human?

8 BOT BRAIN

Tesla's Dojo supercomputer provides Optimus Gen 2 with the AI needed to autonomously manipulate the near environment and make sense of its surroundings.

4 SQUATTING ABILITY

The Gen 2 robot coordinates balance across its entire body, enabling it to squat. The ability to reduce its height in this way increases Optimus' potential applications.

2 FOOT FORCE SENSING

Sensors on the bottom of the feet measure how much force is being exerted on the ground. This enhances balance and enables walking on uneven terrain.

3 ARTICULATED TOE SECTIONS

The ends of the robot's toes bend like a joint. This keeps the humanoid moving in a natural heel-toe rhythm.

2

3



9

9 LEDS

Around the robot's head is a strip of coloured LED lights. This could be used to communicate its status during a task via a colour key.

10 NAVIGATION TECHNOLOGY

Behind this panel are cameras, sensors and self-piloting software that constantly track the location of obstacles.

10

7 BATTERY PACK

The central 2.3-kilowatt-hour battery pack is designed to help the robot work long shifts.

8

7

4

Did you know?

Elon Musk claims that Optimus will one day cost less than a car



ENTERTAINMENT ELEMENT

One of the ways in which Optimus shows off its fluid and controlled movements is through visual entertainment. This robot doesn't just lift objects and carry out practical tasks – it also busts some moves on the dance floor. The robots are programmed to perceive music and dance in time in response. Two Optimus robots can carry out complex movements in synchrony. In humans, music stimulates the reward centres of the brain, and it's human nature to start moving when we hear music. By installing this reaction into the robots' software, they are being built to have human traits that could help people feel better connected to their robot companions.

To maintain control and balance, Optimus dances with both its feet on the floor. For other functions, the humanoid can balance on one leg



6

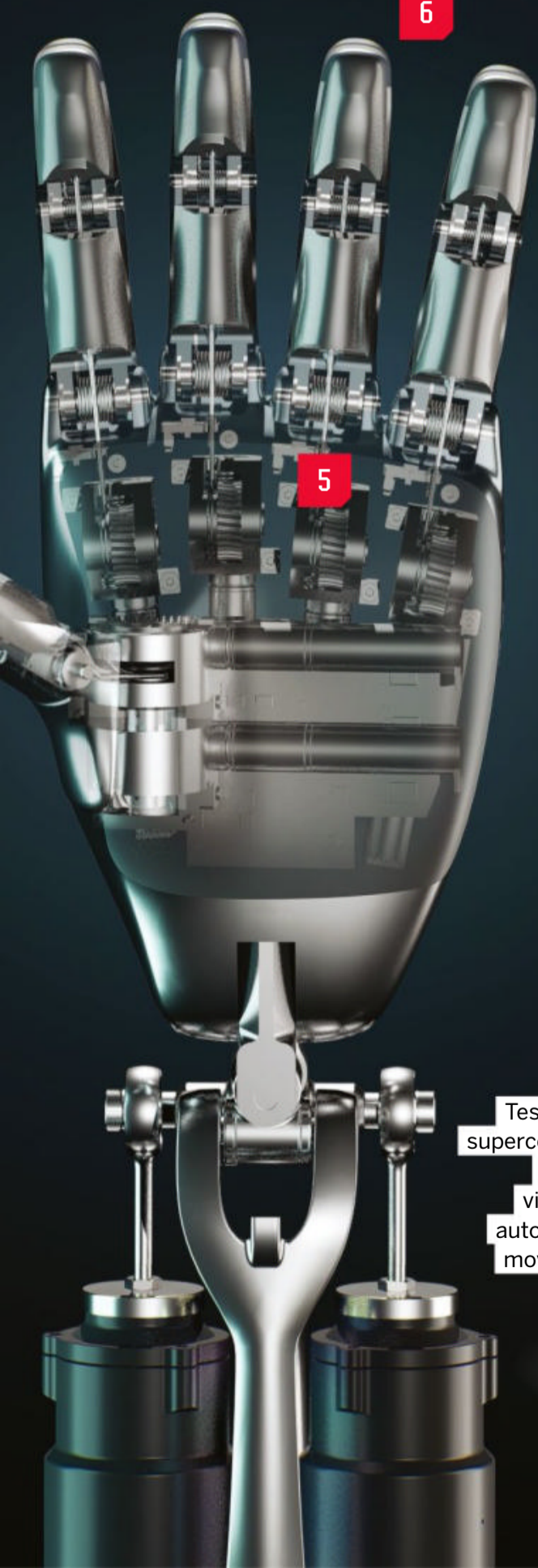
6 TACTILE SENSING

All the fingers have tactile pressure sensors that 'feel', similarly to a human hand's nerves. The sensors relay data of the force applied across the area of each fingertip.

5

5 HOLDING ON

Finger placement makes Optimus Gen 2 better than the previous generation for holding items with precision.



Tesla's Dojo supercomputer controls vision and autonomous movements



HUMANOIDS OF THE FUTURE

The great progress of Optimus demonstrates that incorporating robots into a wide range of homes and workplaces could be successful. The main industries that Tesla's latest humanoid creation is targeting are those with repetitive and dangerous tasks involved. Any laborious tasks, such as relentless factory work, often see a decrease in productivity over time. This is because human muscles get tired, and our brains

lose concentration. Repetitive tasks are ideal for robotic workers: they can keep movement at a constant rate, and precisely programmed hand movements can keep all products assembled identically. Humanoids can also assist in dangerous roles such as search-and-rescue missions. If a robot can carry out the same manoeuvres as a human rescuer, placing machinery in danger is a better option than to risk a life.



Optimus Gen 2 could work alongside Tesla's other factory robots



WORLD'S FIRST WIRELESS TRANSPARENT TV

Inside the next generation of television tech

WORDS SCOTT DUTFIELD

It's hard enough to wrap your head around the technology that brings us super-high-definition smart television displays, so the idea of a TV that's also transparent is mind-blowing. In 2011, Samsung was the first to showcase this cutting-edge technology in its transparent organic light-emitting diode (OLED) TV. But it wasn't until Chinese electronics company Xiaomi launched the Mi TV LUX in 2020 that transparent televisions became commercially produced. Now, tech giant LG has created the latest evolution in television history with the LG Signature OLED T, the world's first wireless transparent TV.

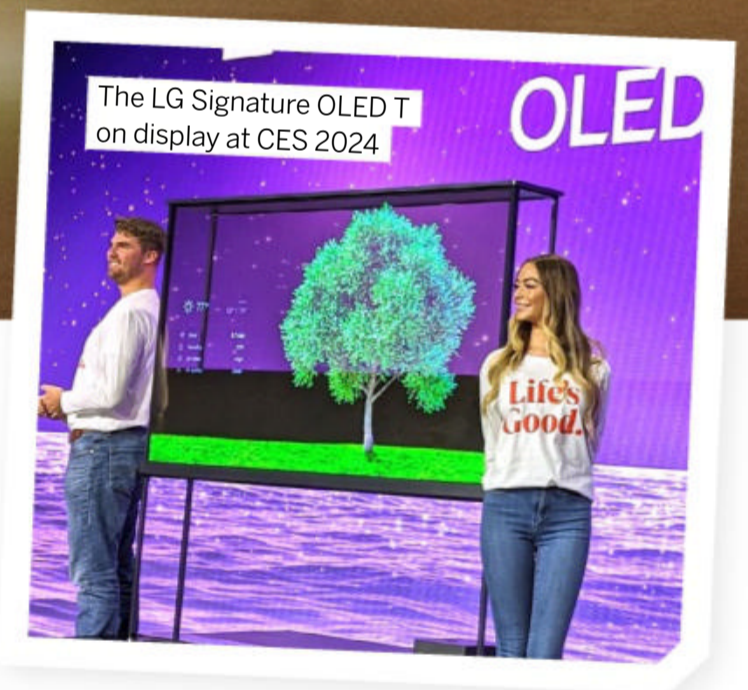
Unveiled at the 2024 Consumer Electronics Show (CES), this venture in television technology wowed crowds with its ability to switch between a traditional OLED screen and a fully transparent display. Like other OLED screens, transparent TVs, known as TOLEDs,

are made up of layers of organic and conductive material, filled with tiny diodes that emit light when electricity is passed through them. This removes the need for the backlight and colour filters commonly seen on liquid-crystal displays (LCD) and many LED TVs. The conductive layers within an OLED are typically made from minerals, carbon-based products and plastics that are transparent. To switch between television and transparency, the Signature OLED T uses a retractable contrast film behind the screen to deflect external light and increase the contrast of the on-screen image at the touch of a button.

Unlike other transparent TVs, this iteration is the first of its kind to use wireless video and audio transmission exclusively. With the exception of its power cable, there are no wires connected to the Signature OLED T display. Instead, a separate 'Zero Connect Box' wirelessly transmits picture and audio

Did you know?

Eastman Kodak made the first functional OLED device in 1987



directly to the TV, as well as providing a site for connection to external devices such as gaming consoles. An artificially intelligent processor called Alpha 11 powers the TV's 4K image quality.

This isn't the first time that LG has ventured into transparent technology. The company has long developed see-through displays for business and industry, such as its LG OLED Signage for product displays and office communication technology. However, the Signature OLED T is the first time that LG is releasing a transparent product into retail, although an exact launch date is yet to be confirmed.

DID YOU KNOW? The semiconductor substrate in an OLED TV is between 100 and 500 nanometres thick

INSIDE OLED

The layers of glass and plastic that bring your favourite TV shows to life

1 GLASS

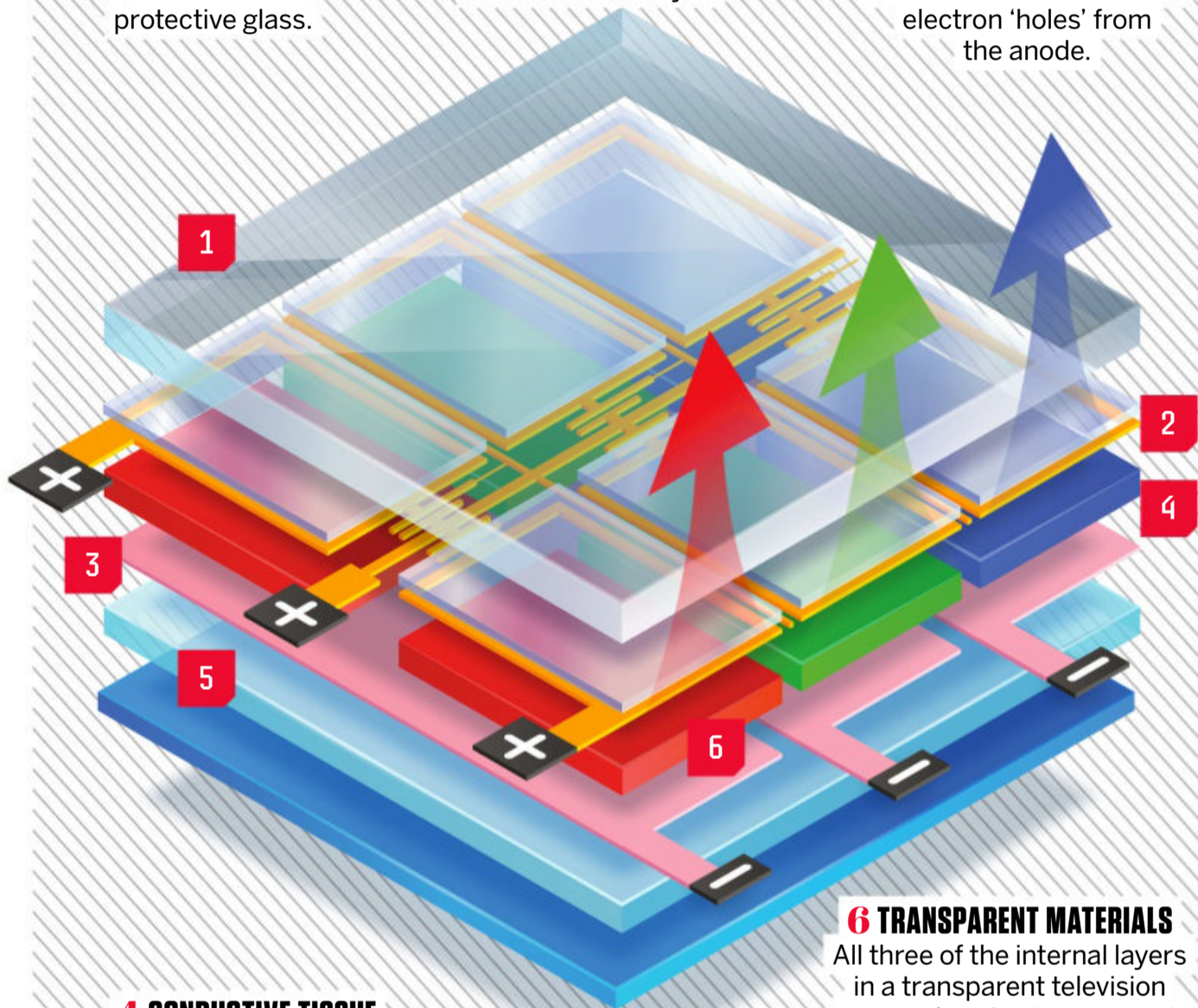
Layers of semiconducting material are contained in a thin sheet of protective glass.

2 ANODE

When electricity is passed through the anode, it loses electrons, or 'gains holes', which are filled by electrons that pass through the conductive layer.

3 CATHODE

During the flow of electricity, the cathode receives electrons and passes them off into the conductive tissue to meet electron 'holes' from the anode.



4 CONDUCTIVE TISSUE

When the electrons and holes meet each other, their opposing charges cancel each other out. In the process, they release a burst of energy in the form of light.

5 CONTRAST FILM

Because there are no backlights on an OLED TV, a film is placed behind the screen to prevent reflection from ambient light.

6 TRANSPARENT MATERIALS

All three of the internal layers in a transparent television are made using transparent materials, such as indium tin oxide for the anode, organic carbon-based materials for the conductive layer and fabricated silver and aluminium to make the cathode.



The Samsung MICRO LED display on show at CES 2024 in Las Vegas

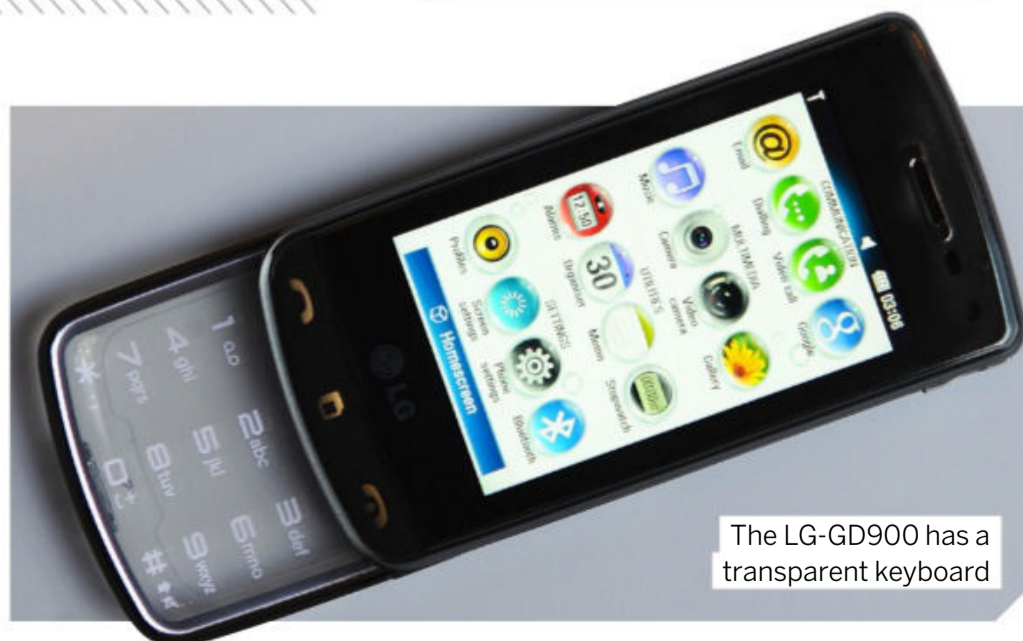
SAMSUNG'S SOLUTION

Also making an appearance at CES 2024 was Samsung's transparent MICRO LED display. Blurring the line between visual content and reality, the MICRO LED display uses layered technology similar to OLEDs; but instead of an organic substrate, they have millions of tiny transparent LEDs packed between two layers of film to make up the pixels on the screen. The MICRO LED can emit a brighter light and a clearer image on screen than OLED displays. Normally LED displays need a backlight to operate, but these MICRO LEDs are constructed with red, green and blue sub-pixels that can emit their own light, much like OLED substrate. The use of transparent MICRO LED displays is still in its infancy, with no immediate plans by Samsung to produce a transparent home TV.

“LG has created the latest evolution in television with the LG Signature OLED T”

SEE-THROUGH PHONE SCREENS

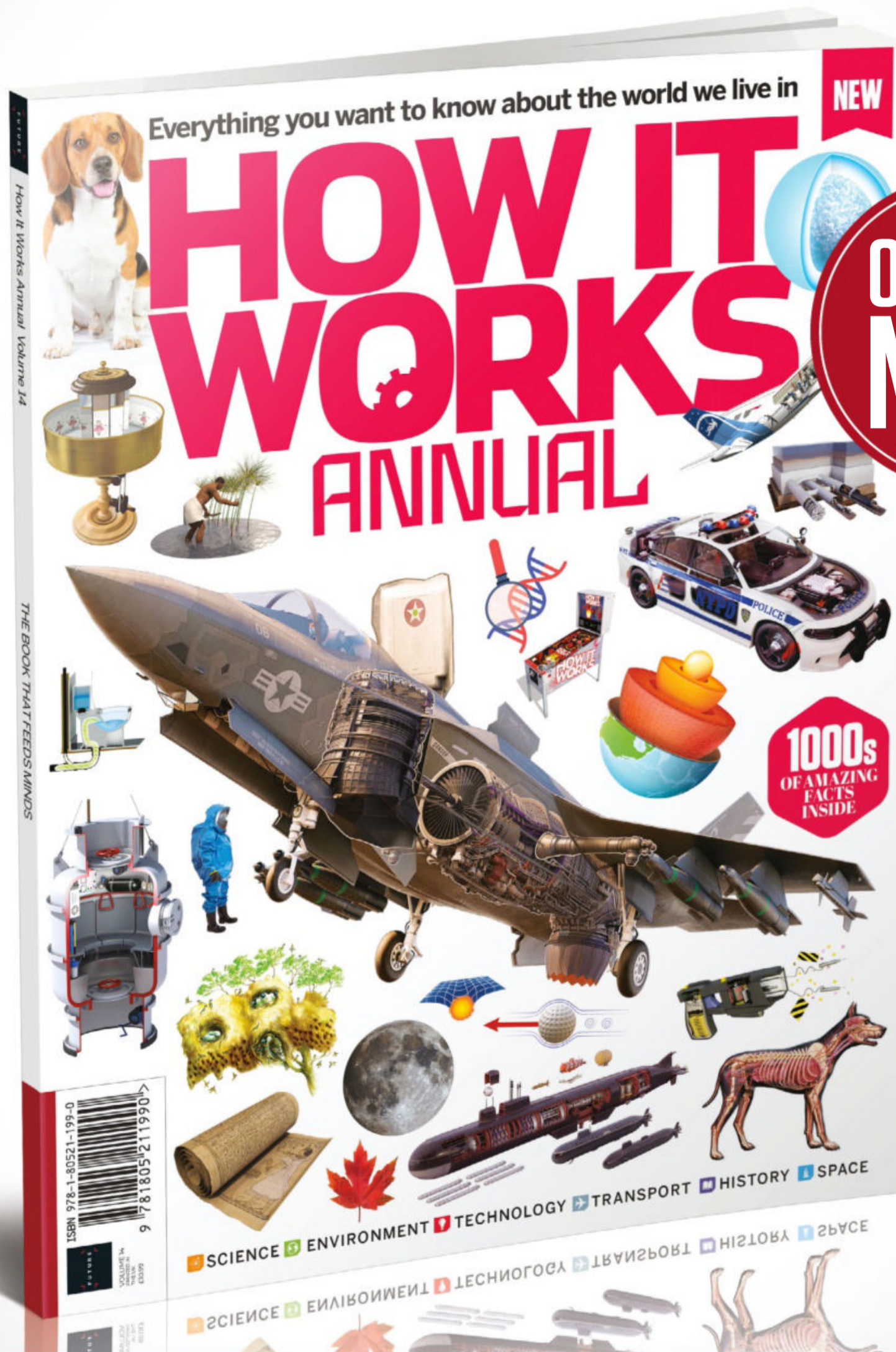
While transparent TVs are making waves in the entertainment industry, it begs the question... where are the clear-glass smartphones? The simple answer is that there are too many components, such as the camera and internal circuitry, that need to be given a transparent makeover for a completely see-through phone to become a reality. This doesn't mean that companies haven't tried to add some transparent flare to their designs. For example, in 2009 LG released the GD900, a phone with a lid that slid back to reveal a transparent touch keypad. In the last few years, Samsung has filed several patents for transparent phones, including a fully transparent mobile that can work like a standard touchscreen device. However, no official project for a transparent Samsung phone has been announced yet.



The LG-GD900 has a transparent keyboard

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Just how big can stars get?

In 2005, studies conducted by NASA using the Hubble Space Telescope showed astronomers that stars have an upper limit of about 150 times the mass of the Sun. Hubble was used to measure stars in the Arches Cluster, which is the densest group of stars found in the Milky Way and is about 25,000 light years away.

Expecting to find as many as 30 stars with masses up to 1,000 times the Sun's mass, astronomers were surprised to find that the largest ones were only about 130 solar masses. One theory is that the intense radiation from large stars blows them apart – if a star is 100 times the solar mass, that means it burns about a million times brighter than the Sun. However, the star R136a1 was found in 2010 in the R136 star cluster, around 163,000 light years away, which was 250 times the mass and 5 million times brighter than our Sun. So while we're still unsure exactly what the upper limit is, there's little doubt that there is one.

HOW DOES ANTI-VIRUS SOFTWARE WORK?

Anti-virus programs typically employ two methods to detect and eradicate their digital nemesis. The first is to check known virus signatures against a database, engineering a fix that directly matches the bug. Most anti-viral software relies on this method, drawing on the internet for its effectiveness by constantly updating the 'wild list' of known viruses, allowing patches to be developed and downloaded into your anti-virus database to keep it up to date.

The second method is simply to think like the virus coders, looking out for weaknesses in existing programs and then staking them out. Working closely with software manufacturers, anti-virus software coders can detect when a known program is behaving strangely, alerting everyone to a potential threat before developing an antidote.

1 DENTIN

A calcified tissue that sits under the enamel, with tiny tubes connecting to the central nerve. It makes up most of the tooth.

2 DENTAL PULP

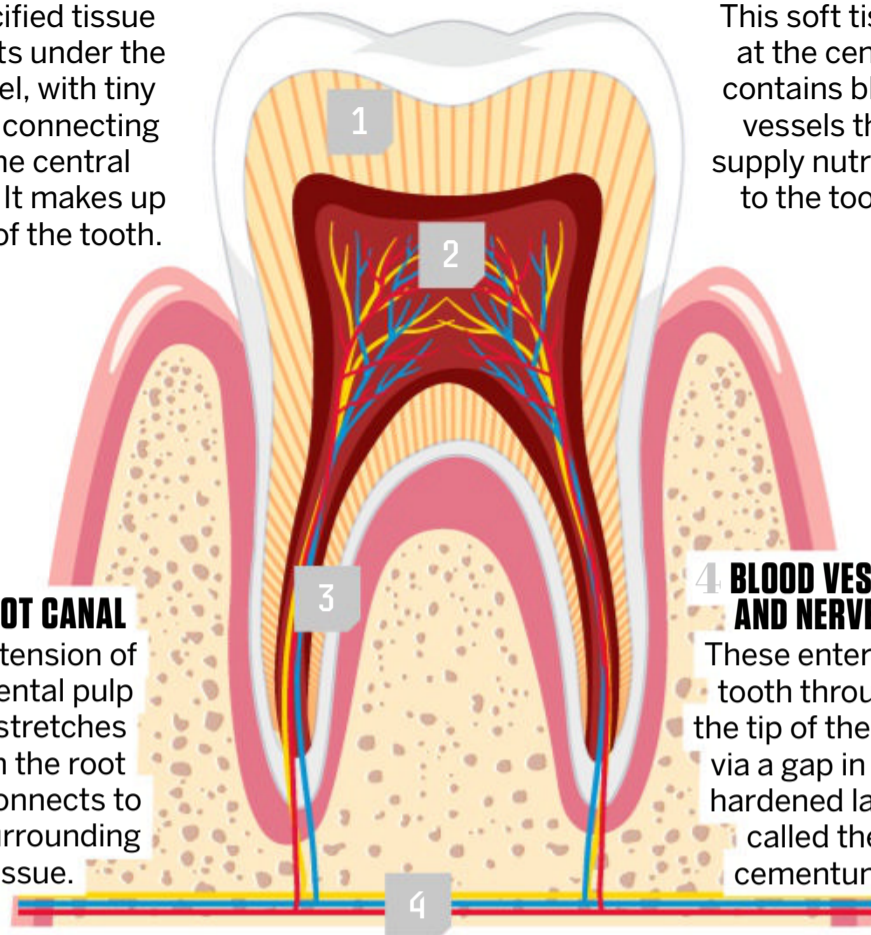
This soft tissue at the centre contains blood vessels that supply nutrients to the tooth.

3 ROOT CANAL

An extension of the dental pulp that stretches down the root and connects to the surrounding tissue.

4 BLOOD VESSELS AND NERVES

These enter the tooth through the tip of the root via a gap in the hardened layer called the cementum.



WHAT ARE ROOT CANALS?

Although they seem pretty solid, our teeth are hollow inside, all the way to the roots. The core is filled with nerves, blood vessels and a connective tissue called dental pulp. In the actual tooth, this space is known as the coronal chamber, but when you get down to the roots they're called canals. The blood vessels run through the centres like graphite in a pencil. A 'root canal' is also used to describe a dental procedure in which the pulp and other tissues are removed and replaced with a filler. This is usually done when the tooth is severely infected: while considered 'dead', the tooth can at least be preserved.

HOW DOES DESICCATING FOOD MAKE IT LAST LONGER?

Food becomes rotten for two reasons: air and water. Water encourages the growth of bacteria, yeasts and moulds, while air causes oxidation, which ages almost everything it touches, including food. Drying – whether by air, sunlight, artificial heat or salting – is designed to remove the water; the longer the process, the more water is extracted. This also affects the cellular structure of the food, often requiring it to be rehydrated before eating. Sometimes a chemical such as silica gel is used to speed up the drying – this process is known as desiccation.



Why is chocolate bad for animals but not humans?

Chocolate contains theobromine, which is an alkaloid chemical like caffeine. It causes vomiting, diarrhoea and – in high enough doses – even heart failure and seizures. The symptoms of chocolate poisoning are the same for humans as for dogs, but dogs need a much smaller dose. Dogs are carnivores, and their metabolism hasn't evolved efficient enzymes to deal with as wide a range of plant chemicals as ours. Dogs are about three times more sensitive to chocolate than humans per kilo of body weight, so two 120-gram bars of dark chocolate are enough to make a 20-kilogram dog ill, while half a kilogram could be fatal.



HOW CAN STEM CELLS BECOME ANY CELL?

The potential for adult and embryonic stem cells to contribute to a range of specialised tissues was first realised 50 years ago. Yet we still have much to learn about how they work. The process by which stem cells become specialised is called differentiation, and happens in other kinds of cells too. During differentiation, some of the genes that form the DNA within a cell are switched on or off. This causes the cell to express qualities that are needed for it to become part of an internal organ or living tissue, such as the brain or bone marrow. Most cells produced after an early stage in the growth of a multicellular organism are biologically committed to a single purpose, but stem cells are more flexible.

Finding out exactly what they can do is a long and complex process. Stem cells extracted from living tissue have to be cultured for many generations to ensure that there is little risk of mutation. Then comes



the really exciting bit: researchers attempt to stimulate differentiation, perhaps by adding specific proteins to the culture or infusing the cells with particular genes. If the cells differentiate as expected, we get one step closer to unlocking their secrets.



IS IT TRUE THAT STATIC IMAGES ON A PLASMA TV WILL 'BURN IN'?

The simple answer is yes – but if you're asking if this is something to be concerned about, it's a resounding no. 'Burn-in' is better called image retention, and it happens when the phosphors in a plasma screen become overstimulated. This causes them to continue glowing after the image has ended, creating a dim 'ghost' image of the original that can stay on the screen even after the television is switched off. This takes a long time to happen, and the image has to be both static and very bright – for instance, if you left the screen on overnight showing nothing but a channel's logo.

As soon as the screen is restimulated by a different set of moving images, you either won't notice any residual glow, or the screen will simply 'overwrite' the ghost image. These days, the idea of image retention permanently ruining a TV is an urban myth. Indeed, as screen technology improves, it's a far rarer occurrence that generally affects only types of TV sets.

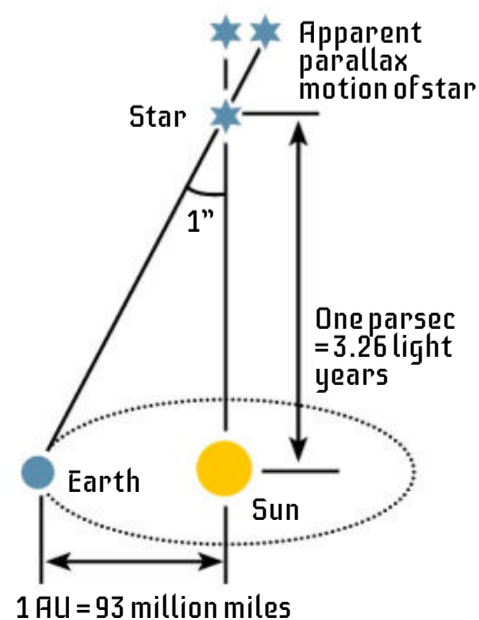
Why don't dogs see in colour like us?

Canine vision is much less rich than ours. Dogs have only two different kinds of cone cells in their retina, compared to our three. They also have far fewer of them. Where we see the rainbow as red, orange, yellow, green, blue and violet, they see only a brownish yellow that shades through yellow, grey, into light blue and blue. Our colour vision evolved to allow us to tell when fruit was ripe and help identify poisonous berries. For a carnivore, that's less important, while the space for extra rod cells allows for far more accurate spatial perception.



WHAT EXACTLY IS A PARSEC?

A parsec is a unit of length in astronomy. It's the equivalent of 19.2 trillion miles, or about 3.26 light years. It's the distance from the Sun to an object that has a parallax angle of one arcsecond. The word 'parsec' is derived from 'parallax' and 'arcsecond'. Imagine a right-angle triangle in space. The angle opposite the right angle is one arcsecond. An arcsecond is 1/60th of an arcminute, which is 1/60th of a degree in a 360-degree circle. The opposite side is one astronomical unit (AU) – the distance from Earth to the Sun. The adjacent side is a parsec long. Astronomers have long calculated the distance of stars by measuring their positions above Earth at two different points, six months apart. The difference in angle between the measurements is twice the parallax angle, an angle formed by drawing imaginary lines from the Sun and Earth that meet at the star. With this data, we can work out the distance of stars.



Is there a limit to how dense an object can be?

Density is a measure of how much mass a material has in a specific volume of space. The more squashed together an object's particles are, the denser it is. Temperature and pressure are two factors that can affect an object's density. Almost all materials become less dense as they get hotter, due to their particles moving around more and taking up more space. Likewise, when materials cool down, they tend to become denser. Almost all materials will reach their maximum density at very low temperatures and very high pressures.

Unusually, one of the densest substances we know of exists only at very high

temperatures. This is called quark-gluon plasma (QGP), and has been synthesised at the Large Hadron Collider by smashing particles of ionised gold together at extremely high energies. Temperatures 100,000 times hotter than inside the Sun force the atoms to break into their constituent quarks and gluons, and it's speculated that the universe was made entirely of QGP briefly after the Big Bang.

Black holes are the densest known objects in the cosmos and are thought to be infinitely dense – considering infinity means 'no end', maybe there are no limits to density!

CAN MOBILE PHONES REALLY MAKE US SICK?

The World Health Organization (WHO) classified mobile phone radiation as 'possibly' carcinogenic in the 1990s. Certainly, mobiles create minute spikes in both electromagnetic radiation and temperature that are absorbed by anything in close proximity, including the skull. However, to date, no study has been able

to demonstrate that this contact has any worse effect than other common forms of radiation, like Wi-Fi. There has been more concern about mobile base stations that continuously pump out electromagnetic radiation at much higher doses. However, even here there has been no conclusive evidence of an increased health risk.



When rockets lift off, why do fragments of what looks like ice fall off?

Some rockets use a combination of super-cooled liquid hydrogen and liquid oxygen as their fuel. This fuel is much colder than the temperature of the air surrounding the rocket, and the difference causes water vapour in the air to condense on the outside of the fuel tank. This is similar to the condensation that forms on the outside of a cold drink can when you take it out of the fridge. As this water vapour collects and cools further, it freezes into patches of ice, and the intense forces during launch cause the ice chunks to fall away.



IS IT POSSIBLE TO MAKE ALCOHOLIC LOLLIES OR ICE CREAM?

Yes, you can – some companies even sell them. That said, it's not simply a case of pouring a bottle of your favourite tippie into a bowl along with your favourite flavour of soft-scoop, mixing and then freezing it. Pure alcohol freezes at -114 degrees Celsius. Alcoholic drinks begin to melt at temperatures higher than that, but still much lower than water. Consequently, frozen vodka on a stick wouldn't stay in a solid state long enough on a summer's day to be suckable.

To successfully make an alcoholic ice cream or lolly you must use additives, such as gelatine or molasses, in order to bind the frozen molecules together. But remember, these aren't for kids!



WHAT IS 'PINS AND NEEDLES'?

The numb sensation of your leg 'going to sleep' isn't caused by cutting off the blood circulation. Instead it's the pressure on the nerves that is responsible. This squeezes the insulating sheath around the nerve and 'shorts it out', blocking nerve transmission. When the pressure is released, the nerves downstream from the pinch point suddenly all begin firing at once.



HOW CAN YOU RECYCLE VEGETABLE OIL INTO FUEL?

Vegetable oil can be used as fuel in an ordinary diesel engine without being altered, but impurities can damage the engine over time. A process called transesterification removes impurities and chemically alters the oil to make biodiesel, which is more suitable. Biodiesel is purer and less viscous, and has a lower boiling point than straight vegetable oil.

ARE MELANIN AND MELAMINE RELATED IN ANY WAY?

In a word, no. Melanin is a brown pigment found in virtually every animal group – spiders are a rare exception. In humans, it's made in the skin, eyes and hair, in cells called melanocytes. You have 1,000 to 2,000 melanocytes for every square millimetre of skin, regardless of its colour. But the amount of melanin each one produces depends on your ethnicity and the amount of ultraviolet light exposure you receive. There are different forms of melanin with slightly different chemical compositions, but the most common is eumelanin, a long chain of dihydroxyindole carboxylic acid groups. There are about a dozen steps in the synthesis of melanin; one of the intermediate steps is the neurotransmitter serotonin.

Melamine, meanwhile, is an organic molecule that looks like a ring of three nitrogen atoms with an NH_2 group attached to each one. This molecule can be polymerised with formaldehyde to produce a thermoplastic, usually called melamine. It's used to make a wide range of products, from dishwasher-proof kitchenware to garden furniture.



WHY DOES THE FOLDED STEEL IN SAMURAI SWORDS MAKE THEM SO SHARP?

Samurai swords are made with soft steel in the core and hard steel on the outside. Hard steels are produced when a relatively high amount of carbon is dissolved in molten iron during smelting. A low

carbon content results in softer steel. Bladesmiths beat the layers of steel together and fold them up to 20 times to remove impurities and spread the carbon more evenly through the layers. At the

atomic level, carbon atoms fill gaps in the iron's crystal lattice, strengthening fracture points. This produces a strong, flexible sword with an edge that's hard enough for sharpening to a fine point.



Is it possible for humans to have an allergy to water?

A rare condition called aquagenic urticaria is often referred to as an allergy to water. Symptoms are painful, but generally not fatal. Contact with water-containing substances can bring out sore hives on the surface of the skin, cause a burning sensation and induce headaches. Death could occur when water is swallowed if the throat swells up, blocking the airway. The root cause is unknown. One hypothesis is that water generates a toxic compound in the outer layers of the skin, prompting the release of histamines. There is no cure, but the reactions can sometimes be controlled with antihistamines.

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The latest book releases for curious minds

EYES IN THE SKY

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Most of us will take certain truths about space and astronomy for granted, without really questioning why or how. We'll scan NASA press releases for the latest space news and watch documentaries, but never consider why we measure astronomical distances in light years, or how the Hubble Space Telescope can take detailed photos of celestial objects trillions of miles away that we can't even see with the naked eye. What we need is to sit down with an expert, pick their brains and have them explain everything in layman's terms. That's what we've got in the form of the latest book from astronomer, astrophysicist and *How It Works* contributor Dr Andrew May.

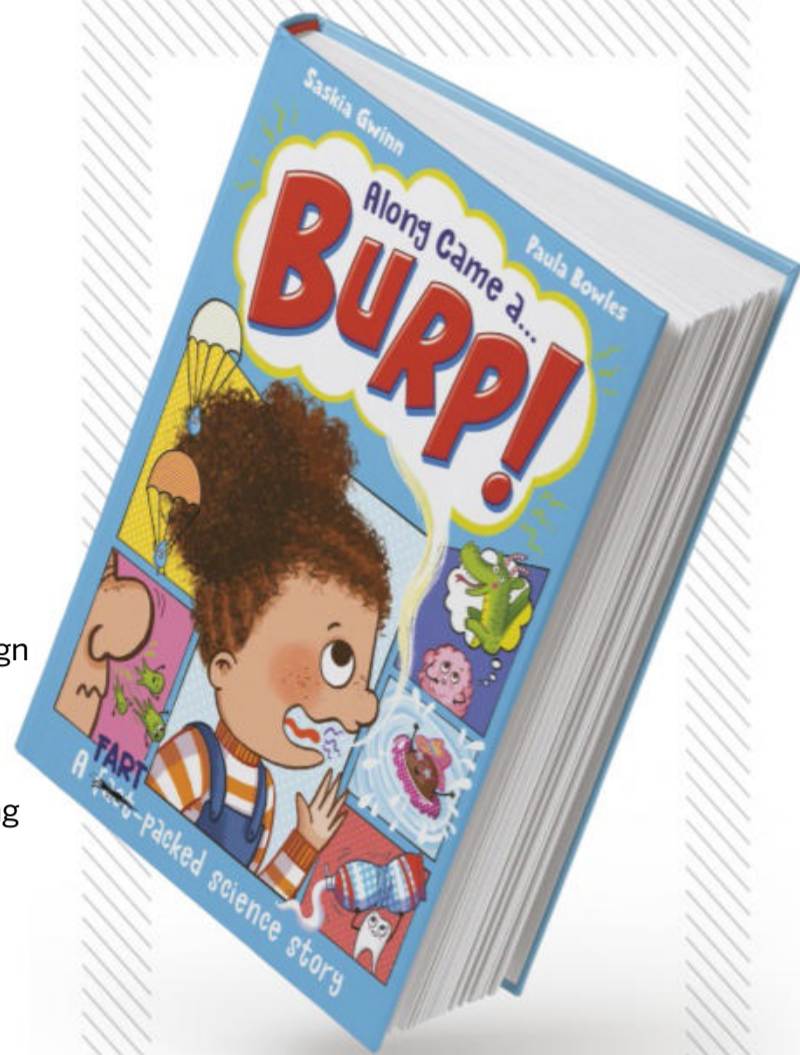
Eyes in the Sky is about the greatest space telescopes launched by space agencies – but mostly NASA – over the last 40 years or so. It's broken down into eight chapters that largely deal with the different flavours of telescopes for different types of astronomy. This includes Hubble, of course, the venerable visible-light telescope whose glory days are behind it. There's also Planck, which explored the origins of the universe and the esoteric sphere of the cosmic microwave background, and Kepler, the exoplanet hunter that scanned nearby stars and found orbiting planets using a very specialist technique. Last but not least, there's the new kid on the block – the James Webb Space Telescope.

This is no mere space history book, though. May boils a huge number of complicated concepts down into something much more easily digested, such as describing what arcseconds are and how parallax works in relation to the way the Gaia space telescope – which has the exciting task of mapping the Milky Way and all its contents – calculates the distance to a celestial object. If you're a science-fiction fan, you might have bumped up against the word 'parsec' a few times, which May also explains, then goes on to question this unnecessarily confusing term. It's nice to know that an actual astrophysicist doesn't understand why some use this instead

of light years either. He also dips into the design decisions and politics behind some of the space telescopes, particularly Hubble, which nearly never happened, and the James Webb Space Telescope, with its controversial naming after a bureaucrat with a dark past.

Eyes in the Sky answers many of the questions we had about space telescopes – and many more that we didn't even realise we had. It's a fairly easy and fascinating read, suitable for teens and adults with a keen interest in space.

"This is no mere space history book"



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PRICE £9.99 (APPROX. \$12.70)

RELEASE 4 JULY

Told through the eyes of an inquisitive young girl with lots of questions, this informative book has heaps of answers to the curious questions she and no doubt lots of children have about their bodies... Where do burps come from? Why are sneezes so loud? Where is wee made? Why do we yawn? Tackling each question with humour and fun, what's most impressive about this book is its comical and joyful illustrations, such as a poop waiting room, kidney-powered water slides and muscle workout routines to tackle the shivering cold. This laugh-out-loud science book will be a superb way to teach your little ones about the funnier side of human biology.

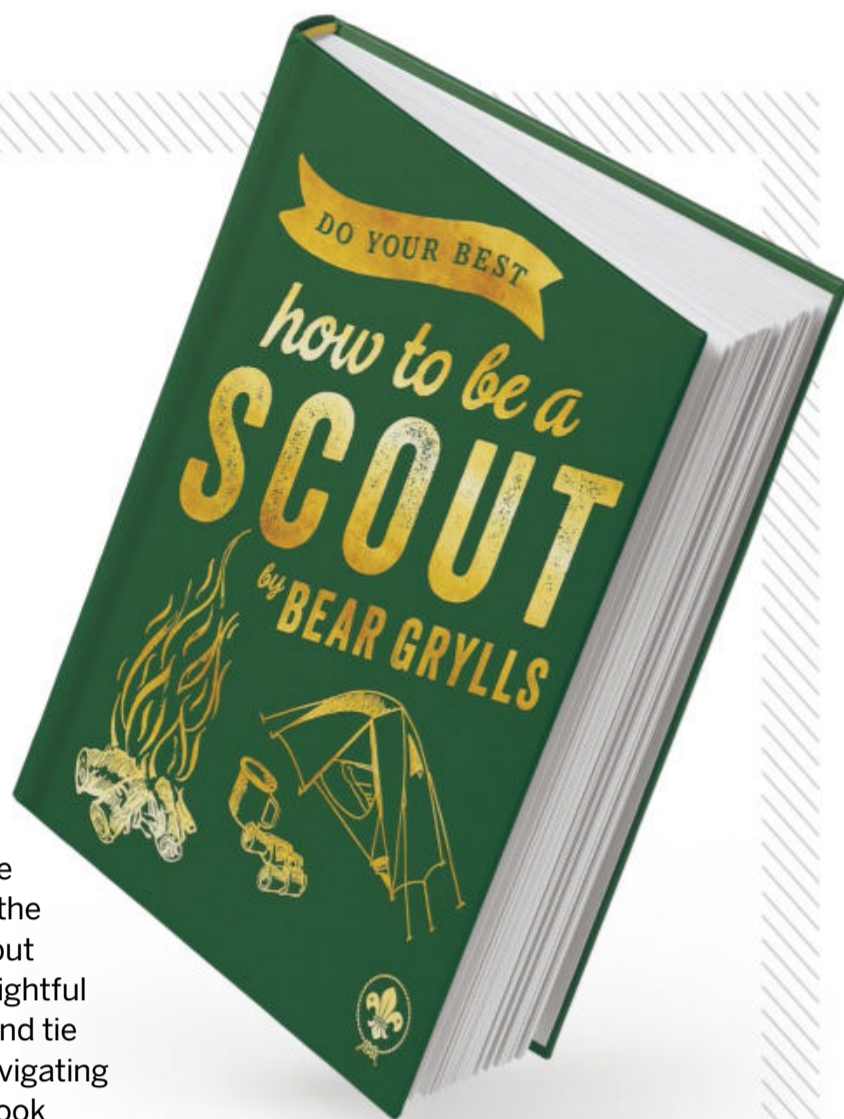
DO YOUR BEST: HOW TO BE A SCOUT

BEAR GRYLLS' TIPS AND TRICKS TO BRAVING THE OUTDOORS

AUTHOR BEAR GRYLLS
PUBLISHER HODDER & STOUGHTON
PRICE £20 / \$24.99
RELEASE OUT NOW

Whether you've been a Scout, want to become a Scout or you're just looking to learn more about the great outdoors, Bear Grylls has put together this informative and insightful guide. From how to pitch a tent and tie knots to tracking animals and navigating the stars, there isn't much this book doesn't cover. There are also heaps of helpful illustrated identification guides for wildlife, such as trees and birds, to help you get to know your surroundings.

Along with all of the practical advice you might expect from a Bear Grylls



how-to guide, this book is also packed with inspirational stories and motivational tips, to help the next generation of Scouts overcome every hurdle they might face in the wilderness and at home.

PLANT PETS

27 COOL HOUSEPLANTS TO GROW AND LOVE

AUTHORS BEATRICE BOGGS ALLEN AND BELLE BOGGS
PUBLISHER WORKMAN PUBLISHING
PRICE £14.99 / \$16.99
RELEASE 19 SEPTEMBER

Just like the animal pets that some readers may care for, plant pets are living things that have specific needs and require consistent attention. This conversational-styled book is written for pre-teen children who want to grow their own plant pets. Knowing where to place a plant, how much water to give it and which are safe to grow around animal pets can be difficult. For example, lilies are toxic to cats, as are sago palms to dogs.

This book will answer many of your questions about plants, and inform you about some of the coolest and most affordable plants you can choose from. Included are instructions for carrying out light tests around the home so that you can pinpoint areas of direct sunlight, indirect light and low light.

Looking after plants requires science, and readers are introduced to basic biological



concepts in this book. In one chapter, you will hear about plant scientist Dr Anju Manandhar to explore the possibility of turning your plant passion into a career. From plants you can train to climb to carnivorous marvels and those that grow without soil, this book is perfect for children to discover the right plant for them, and embark on a journey to grow their own.

OCEAN ANATOMY ACTIVITY BOOK

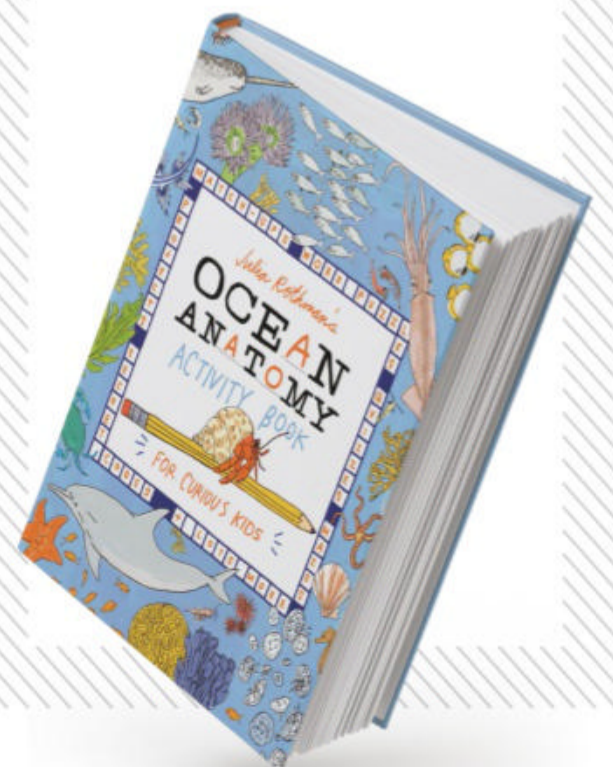
PUZZLES, QUIZZES, PROJECTS AND MORE

AUTHOR AND ILLUSTRATOR JULIA ROTHMAN
PUBLISHER WORKMAN PUBLISHING
PRICE £9.99 / \$12.99
RELEASE 21 MARCH

Following on from *Ocean Anatomy*, this activity version is an entertaining and interactive sequel. Whether you enjoy mazes, crafty projects, word puzzles or drawing, you are sure to find something to excite your mind and stimulate your imagination. The activities are targeted at ages eight and over, with varying levels of difficulty and skills required.

By opening this book, you unlock the tools to learn about the marine world. Master the art of drawing realistic sea creatures through simple guides, get crafty as you make kinetic sand or carry out your own beach survey on your next trip to the seaside with the colour-in counting graph.

Dispersed throughout the beautifully illustrated book are fascinating facts, while on other pages you can test your growing knowledge of marine life. As a result, this book is an ideal combination of learning resources, amusing games and information recall activities.



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

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

MEDIUM

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

HARD

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

Word search

Find the following words

- | | | |
|---------|----------|-------|
| ECLIPSE | SOUND | LUNG |
| GAS | BALLOON | SUN |
| OASIS | THERMITE | WIND |
| ROBOT | VAPE | BRAIN |

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

What is it?

Hint:
Mud-eater

A



Spot the difference

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



Answers Find the solutions to last issue's puzzle pages

- Q1 MASS
- Q2 OXYGEN
- Q3 PLIOSAUR
- Q4 DARK ENERGY
- Q5 URINE
- Q6 1 BILLION



What is it?
ICEBERG LETTUCE

Spot the difference



QUICKFIRE QUESTIONS

Q1 1,900-year-old evidence of which parasite was recently found at Hadrian's Wall?

- Fleas
- Bedbugs
- Ticks
- Mosquitos

Q2 What was the top speed of the Saturn V rocket?

- 25 miles per hour
- 250 miles per hour
- 2,500 miles per hour
- 25,000 miles per hour

Q3 What year was the computer hard disk drive invented?

- 1895
- 1954
- 1976
- 1992

Q4 How heavy is a typical adult bee hummingbird?

- Two grams
- Five grams
- Ten grams
- 15 grams

Q5 A teaspoon of neutron star weighs as much as...?

- A teaspoon of water
- An elephant
- The human population
- Earth

Q6 Honey is the only spread that will never...?

- Contain sugar
- Be vegan
- Be processed
- Spoil

HOW TO...

Practical projects to try at home

MAKE SPRINKLES DANCE WITH SOUND

These colourful cake decorations can really bounce to the beat

SEND YOUR IDEAS TO: [f](#) HOW IT WORKS MAGAZINE [x](#) @HOWITWORKSMAG [@](#)HOWITWORKS@FUTURENET.COM [i](#) HOWITWORKSMAG



1 GATHER YOUR MATERIALS

A small portable speaker is ideal for this experiment, although a mobile phone with a loud speaker will also work.



2 PLACE THE DEVICE

Put the phone or speaker onto the bowl or plate. If you're using a phone, play some loud music on it now. If you're using a speaker, switch it on and pair it with your phone.



3 WRAP IT UP

Place a piece of cling film across the top of your container and wrap it around the sides.



4 SPRINKLE TIME

Pour a small handful of sprinkles into the sandwich bag.



5 SEAL IT UP

Zip the sandwich bag up all the way so that no sprinkles can escape the bag.



6 LAY IT FLAT

Put the sealed sandwich bag flat on top of the cling-filmed dish with the phone or speaker.

KIT LIST

Ziploc sandwich bag

Mobile phone

Portable speaker (optional)

Bowl or dish big and deep enough to hold the device

Cling film

Elastic band

Sprinkles



7 LET THEM DANCE

If you're using a speaker, play some bassy music on it using your phone's Bluetooth connection. You should see the sprinkles 'dance' to the beat.



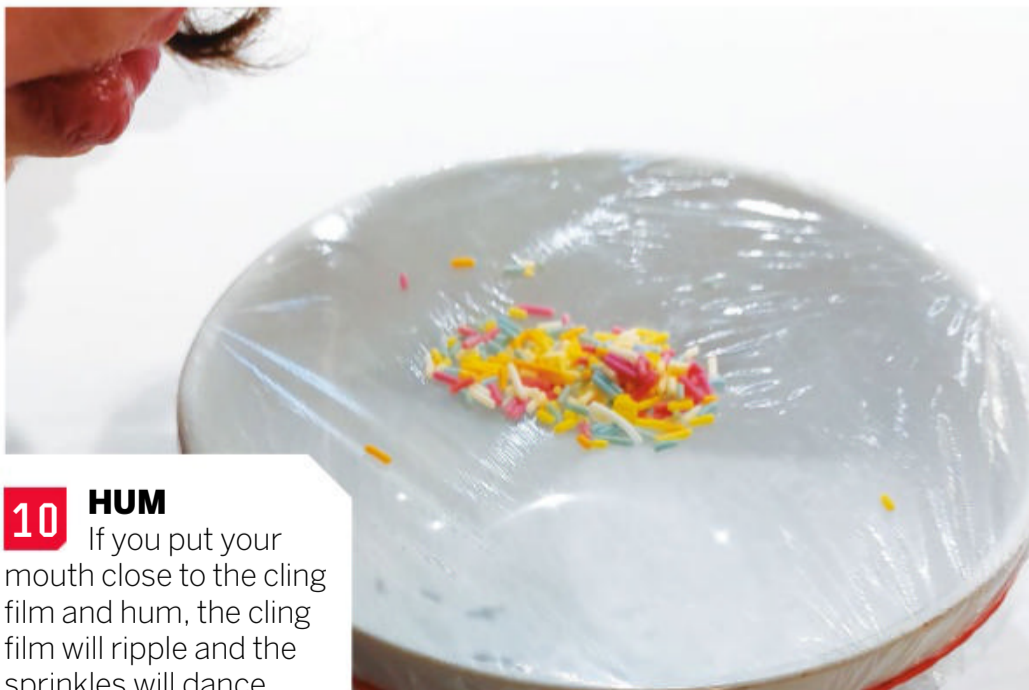
8 LOW-TECH ALTERNATIVE

You can perform this experiment without any electronic devices. First place the cling film over a dish; put a rubber band around the edge to get it really tight.



9 SPRINKLING

Place the sprinkles directly onto the cling film.



10 HUM

If you put your mouth close to the cling film and hum, the cling film will ripple and the sprinkles will dance.

SUMMARY

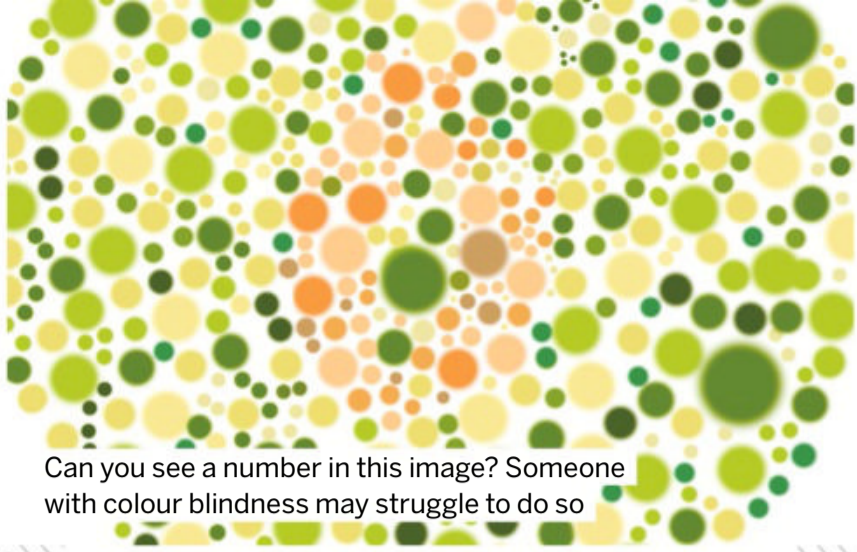
Sound waves are air that's vibrating, and any object that vibrates will make a sound – whether you can hear it or not – by vibrating the air around it. The vibrations that are sent through the air from your device or lips move through the cling film, causing this thin material to move and push the sprinkles around. The louder the volume, the bigger the ripples and the more the sprinkles will dance. Playing music or humming in different tones will result in a different kind of 'dance' from the speakers, as will maintaining a single note versus a tune that skips around a lot.

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.

DISCLAIMER

Neither Future Publishing nor its employees can accept any liability for any adverse effects experienced during the course of carrying out these projects or at any time after. Always take care when handling potentially hazardous equipment or when working with electronics, and follow the manufacturer's instructions.



Can you see a number in this image? Someone with colour blindness may struggle to do so

QUESTIONING COLOUR BLINDNESS

Dear HIW,

Nobody knows what someone else's sight looks like, so how does a person become aware that they are colour blind?

Ethan Thompson

There are many different types of colour blindness, altering the way an individual sees colour. The most common types are related to the colours red and green. People with red-green colour blindness might not be able to differentiate between these two colours, or other colours in which red and green make up parts of the whole colour. It's easy to be unaware that you are colour blind, and around 40 per cent of students with colour blindness leave school not knowing that they are.

EARPHONE INTELLIGENCE

Dear HIW,

How do some earphones know when they're in an ear? Mine stop playing music when one is taken out.

Noah Lewis

Many earphones have optical sensors on them that measure the presence of light. When the earphones are in or against your ear, it blocks the light and music plays. Taking one out exposes it to light and alerts the headphones to pause the audio. Accelerometers are also sometimes used, which are sensors that detect earphone movement. They are programmed to recognise the precise movements required to place earphones into the ear and adjust them to fit, as well as tracking the earpiece's orientation. The two sensors are used together to make this function effective.



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WE ASKED YOU

This month on social media, we asked you:
What are your views on an increased robot population in the future?

JENNIFER DODD

THEY WILL MAKE FACTORIES MUCH MORE EFFICIENT

@DOODLENEWS

I THINK AI IS GETTING SO SOPHISTICATED THAT THE NEXT GENERATION OF ROBOTS WILL BE SCARILY HUMAN-LIKE

@DEFINITELY.NOTMAX

I THINK ROBOTS CAN DO MORE GOOD THAN BAD, FROM HELPING IN DAILY TASKS TO MEDICAL OPERATIONS

ALEX NGUYEN

I THINK EVERYONE WILL HAVE ONE IN THE FUTURE, LIKE A PET, HOUSEWORK HELPER OR TO COMBAT LONELINESS

@????FATEMEH????

DETRIMENTAL BECAUSE THEY WILL REPLACE HUMANS AND THEY LACK HUMANITY

EMILY T

I THINK THEY WILL BOOST PRODUCTIVITY, BUT WE NEED TO MAKE SURE HUMANS REMAIN IN CONTROL

NEXT ISSUE

ISSUE 189 ON SALE 11 APR 2024

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FAST FACTS

Amazing trivia that will blow your mind

13.7 MILES

A mountain on the asteroid Vesta is nearly three times as tall as Everest



EAR WAX ISN'T WAX AT ALL – IT'S A TYPE OF SWEAT

40,000 LITRES

You will produce enough saliva in your lifetime to fill 500 bathtubs



\$135 MILLION

The world's most expensive car sold for the equivalent of £114.4 million in 2022

2029

In five years, there will be four solar eclipses in a single year



38 SQUARE MILES

The ancient Chinese emperor Qin Shi Huang's tomb is spread over a huge area



One centimetre

You are a little bit taller in the morning than you are when you go to bed

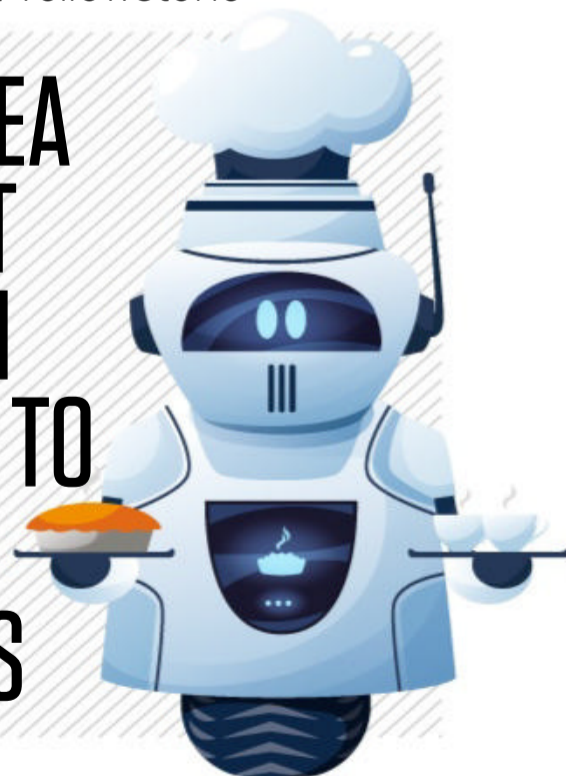
In 1897, Rudolf Diesel created an engine that could run on peanut oil



1 IN 730,000

The yearly probability of a supervolcano erupting at Yellowstone

SOUTH KOREA IS THE FIRST COUNTRY IN THE WORLD TO HAVE LAWS FOR ROBOTS





PAPER REVOLUTION

74% of paper and 83% of paper-based packaging is recycled into new products; one of the highest recycling rates of any material in Europe!

Sources: Confederation of European Paper Industries (CEPI), 2020 and Eurostat, 2018.
Europe: EU27 + Norway, Switzerland and the UK.



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blogs and much more!



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