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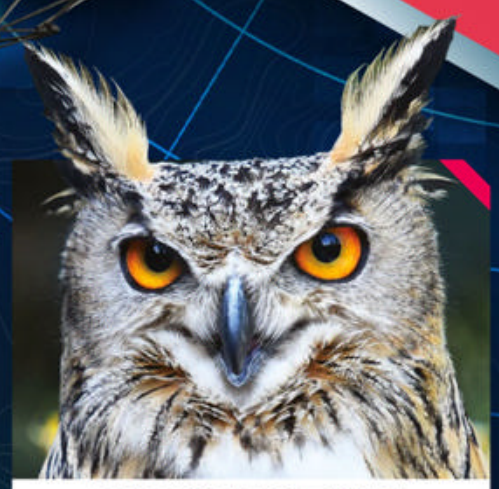

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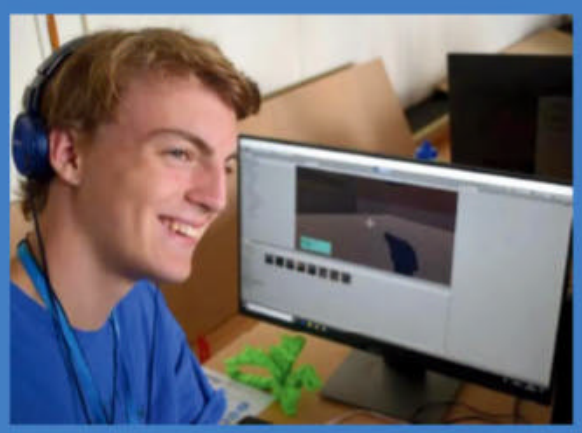

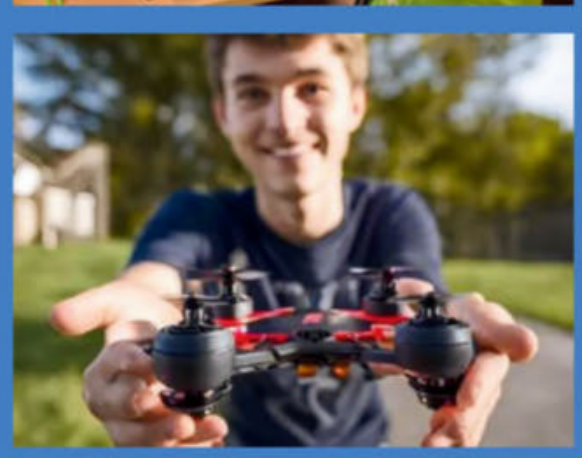

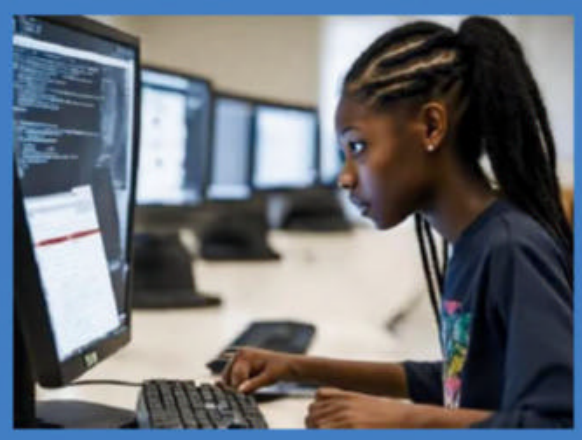

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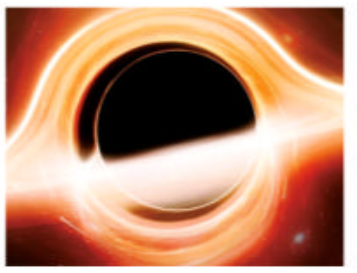
"Today there are more than 885,000 drones registered in the US alone"

HIGHLIGHTS



Future drones
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The drone revolution has been simmering for the last decade or so, and has only recently begun to boil over into our everyday lives. Armed forces around the world have been using them for decades, but now unmanned aerial vehicles of all shapes and sizes are being used in many different industries as the technology becomes cheaper and more accessible. In this issue of **How It Works**, we look at the latest drones used by explorers, filmmakers, couriers, the military and, of course, your everyday drone enthusiast. We'll be looking at how they work, how they can improve our lives and also what kind of drones we'll have in the future. Enjoy!

Ben Biggs
EDITOR

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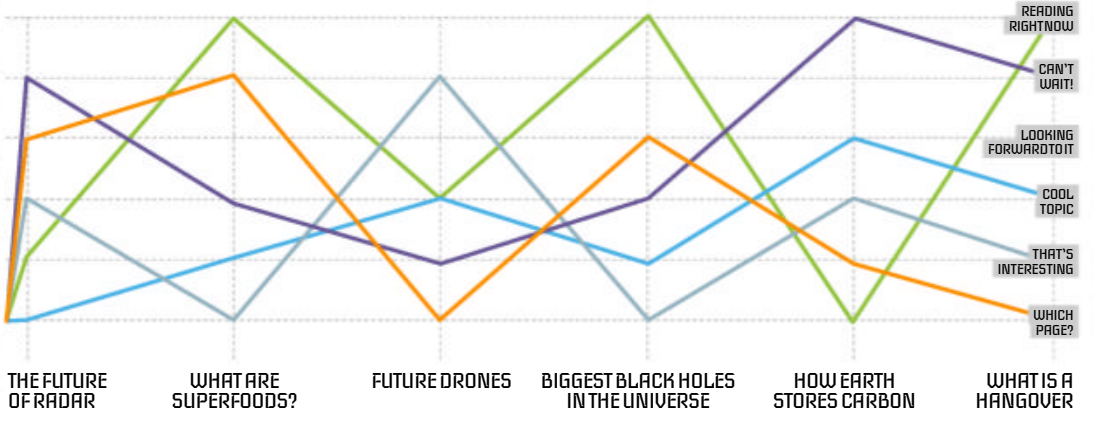

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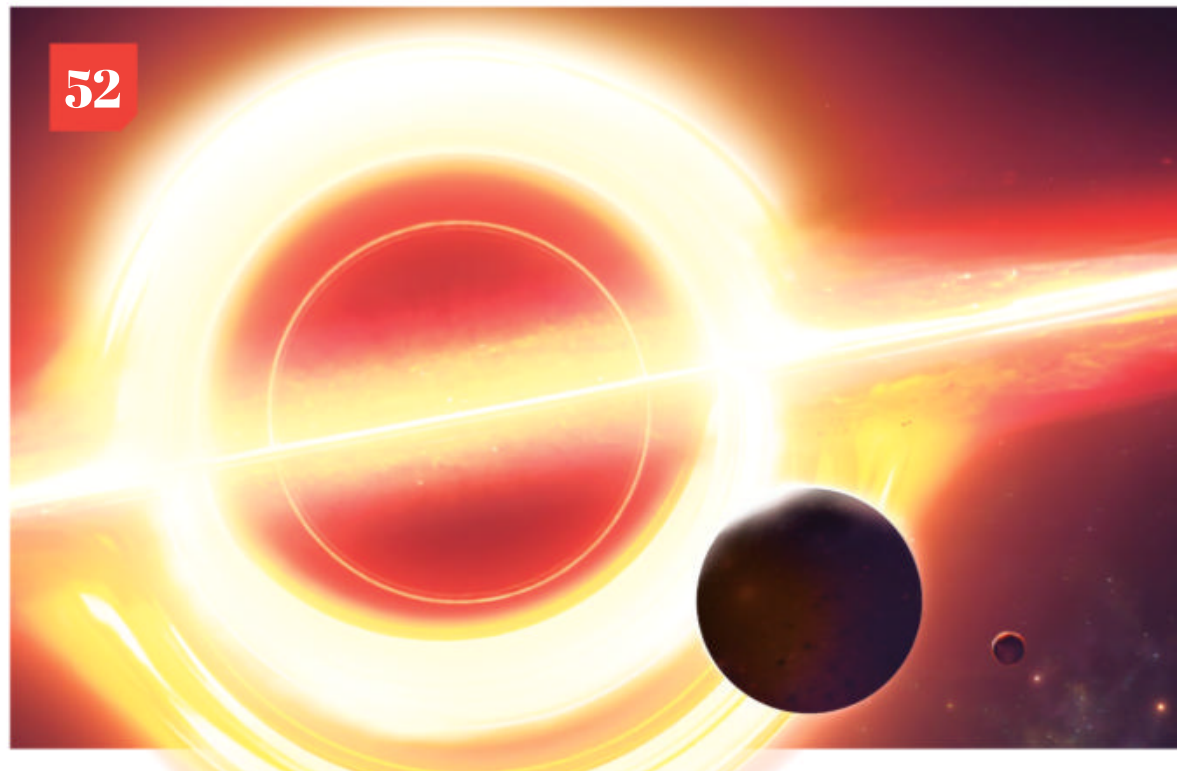
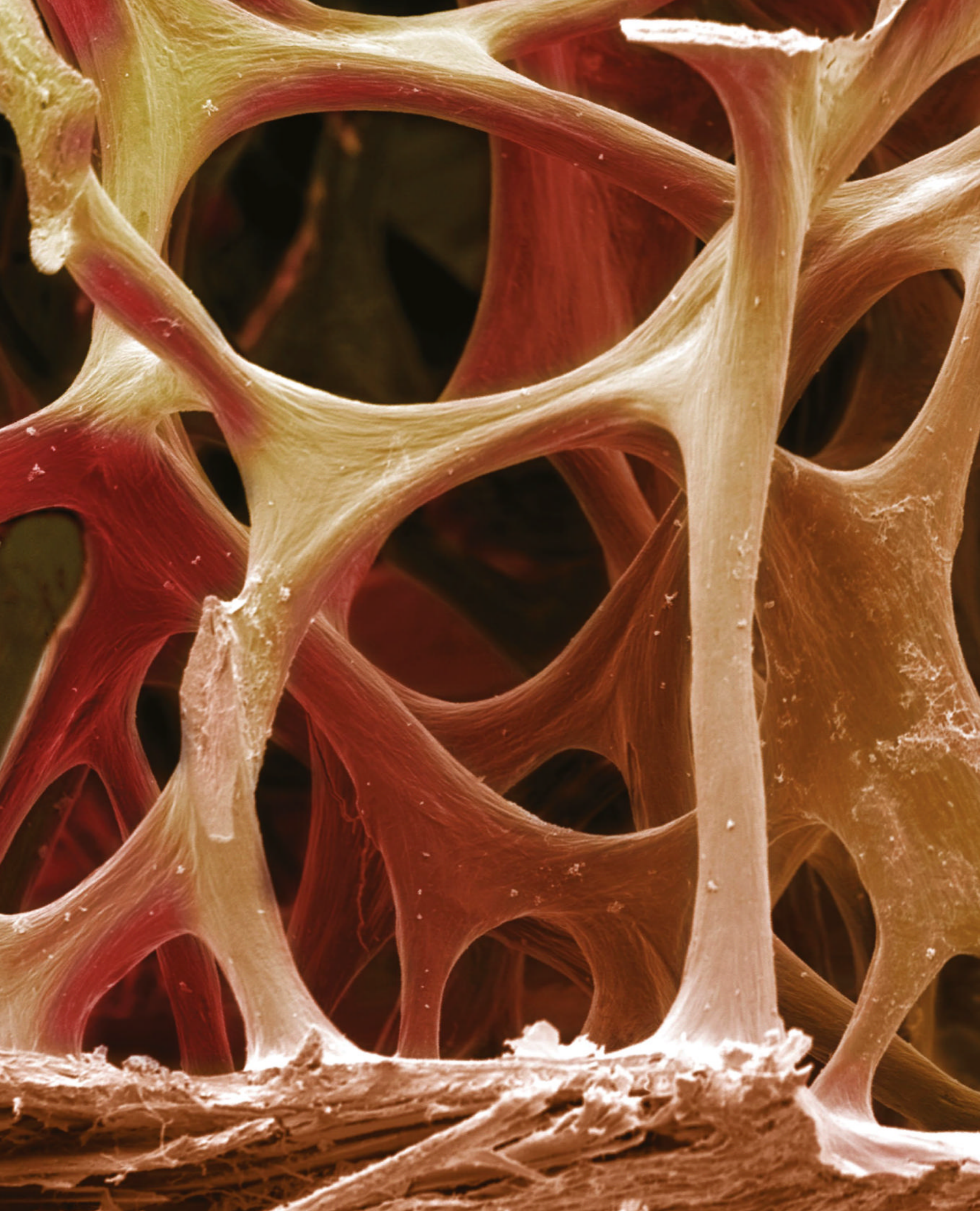


Mad honey hunting

Each spring, honey hunters suspend themselves off the tops of cliffsides in pursuit of ‘mad honey’. Nepal and Turkey are the two main producers of the world’s mad honey supply. Named because the honey is filled with a hallucinogenic grayanotoxin, the *Apis laboriosa* bees which produce the honey use nectar from vibrant rhododendron plants, which contain the toxin.



Beneath bone

Here is a scanning electron microscope image of the bones of a robin. Known as cancellous bone, this tissue is found on the interior of the bird's bones, as well as in the bones of many other animals, and has a honeycomb arrangement of columns called trabeculae. The arrangement of the trabeculae provides support and rigidity and dampens any sudden physical stress applied to the bone.

April's eclipse up close

On 8 April 2024, many people across North America caught sight of the most recent total solar eclipse to grace the sky. The next total eclipse over North America won't be seen until 23 August 2044. This image, taken from Florida, highlights the chromosphere of the Sun, which is the thin layer of plasma sitting between the Sun's surface and its upper atmosphere, called the corona.

Buildings of Barcelona

The creation of Barcelona's iconic gridded region began in the 1850s, following the demolition of the city's encompassing walls in response to its overgrowing population. It was designed by Spanish engineer Ildefons Cerdà and is known as the Eixample, which means extension in Catalan. At the heart of this image is the 172.5-metre-tall Sagrada Familia, designed by Anton Gaudi.

Artificial intelligence trained by citizen scientists helped uncover more than 1,000 new asteroids from old Hubble photos

SPACE

Scientists find more than 1,000 new objects in the Solar System

WORDS **HARRY BAKER**

Over 1,000 never-before-seen space rocks have been discovered after secretly photobombing images of the cosmos for decades. A combination of artificial intelligence and citizen scientists helped uncover the asteroids hiding in archival photos from the Hubble Space Telescope. Our cosmic neighbourhood is littered with asteroids of varying size. Scientists have already discovered more than 1.3 million of the space rocks, most of which lie in the asteroid belt between Mars and Jupiter. There are likely hundreds of thousands – if not millions – more asteroids waiting to be discovered. However, these remaining space rocks are likely the smallest and therefore faintest bodies in the Solar System, which makes them very hard to spot.

In a new study, researchers highlighted 1,031 previously uncategorised asteroids from archival Hubble data. They were identified by artificial intelligence (AI) that was trained by thousands of citizen scientists to spot faint streaks of light left behind by the tiny space rocks. "We were surprised to see such a large number of candidate objects," said Pablo García-Martín, a researcher at the Autonomous University of Madrid in Spain. Although these asteroids were discovered randomly, their projected orbits suggest that most of them belong to a single population within the asteroid belt, which makes them even more valuable to researchers. "There was some hint that this population existed, but now we are confirming it," García-Martín said. "This is important for providing insights into the evolutionary models of our Solar System."

The asteroid streaks in the Hubble photos are the result of the space telescope racing around Earth as it takes long-exposure images of distant galaxies. The asteroids would normally go unnoticed in images like this because the space rocks are millions of times fainter than the faintest stars in the night sky. However, the streaks make them much more noticeable and enable astronomers to infer information on their size and orbital characteristics. Since 2019, more than 11,000 citizen scientists have been combing through images in search of these streaks. This project, known as Hubble Asteroid Hunter (HAH), has massively helped astronomers who would otherwise have had to sift through the images themselves.

In the new study, researchers gave HAH members a group of Hubble images to sort through and then used the results as a training set for an AI to help it learn how to detect the streaking space rocks. The team then used this AI to comb through 37,000 Hubble images taken over a 19-year period in search of new asteroids. The AI identified a total of 1,701 candidates, of which 1,031 had never been seen before. The researchers were surprised by how well the AI identified the asteroids and are now hoping to use similar methods to search through different kinds of archival datasets to pull out other hidden gems from these astronomical treasure troves.

The superconducting quantum cloud platform at QuantumCTek that will utilise the new chip

Did you know?

The world's largest quantum chip is 1,125 qubits

TECHNOLOGY

China creates the largest ever quantum computing chip

WORDS **OWEN HUGHES**

Scientists in China have developed a 504-qubit quantum computing chip that will be made available to researchers worldwide via a new quantum computing cloud platform. The new chip, called 'Xiaohong', is the biggest built by China to date and is designed to improve systems that manage the behaviour and interaction of quantum bits, or qubits, in quantum computers. The scientists hope that the chip will help scale up existing quantum computers so they can handle more complex tasks.

Xiaohong was developed by scientists at the Center for Excellence in Quantum Information and Quantum Physics, part of the Chinese Academy of Sciences (CAS). Chinese quantum computing company QuantumCTek, which received the first Xiaohong chip, will now reportedly work alongside China Telecom Quantum Group to integrate the 504-qubit chip into a new quantum computer. This system will then be made available to researchers worldwide via a quantum computing cloud platform also developed by China Telecom Quantum Group. Wang Zhen, deputy general manager of China Telecom Quantum Group, said the new system would "allow users in various fields to conduct research on problems and algorithms of practical value efficiently and accelerate the application of quantum computing in actual scenarios."

"The new chip, called 'Xiaohong', is the biggest built by China to date"

Xiaohong is designed to meet the performance standards of cloud-enabled quantum computing platforms like those made by IBM or Amazon Web Services. But it's not intended as a technical rival to cutting-edge US technology such as the 1,121-qubit IBM Condor chip, said Gong Ming, a researcher at the Center for Excellence in Quantum Information and Quantum Physics. Instead, the scientists hope access to Xiaohong via the cloud will promote the development of large-scale quantum computing measurement and control systems (QCMCSs). Quantum computers work fundamentally differently from classical computers. Unlike classical bits, which can only be represented as zero or one, qubits can exist in multiple states simultaneously. This enables quantum computers to perform calculations in parallel and at near-unimaginable speeds if qubits are stitched together through quantum entanglement.

QCMCSs, meanwhile, are components that play a crucial role in quantum computing, acting as a bridge that connects traditional computers with quantum computers. This connection enables quantum computers to interpret commands received from classical computing environments and manage the state of qubits accordingly. QuantumCTek will use Xiaohong to test the 'kilo-qubit' quantum computing measurement and control systems developed in-house. This would "greatly influence the overall performance of quantum computers," said Liang Futian, an associate professor at the Center for Excellence in Quantum Information and Quantum Physics.

ANIMALS

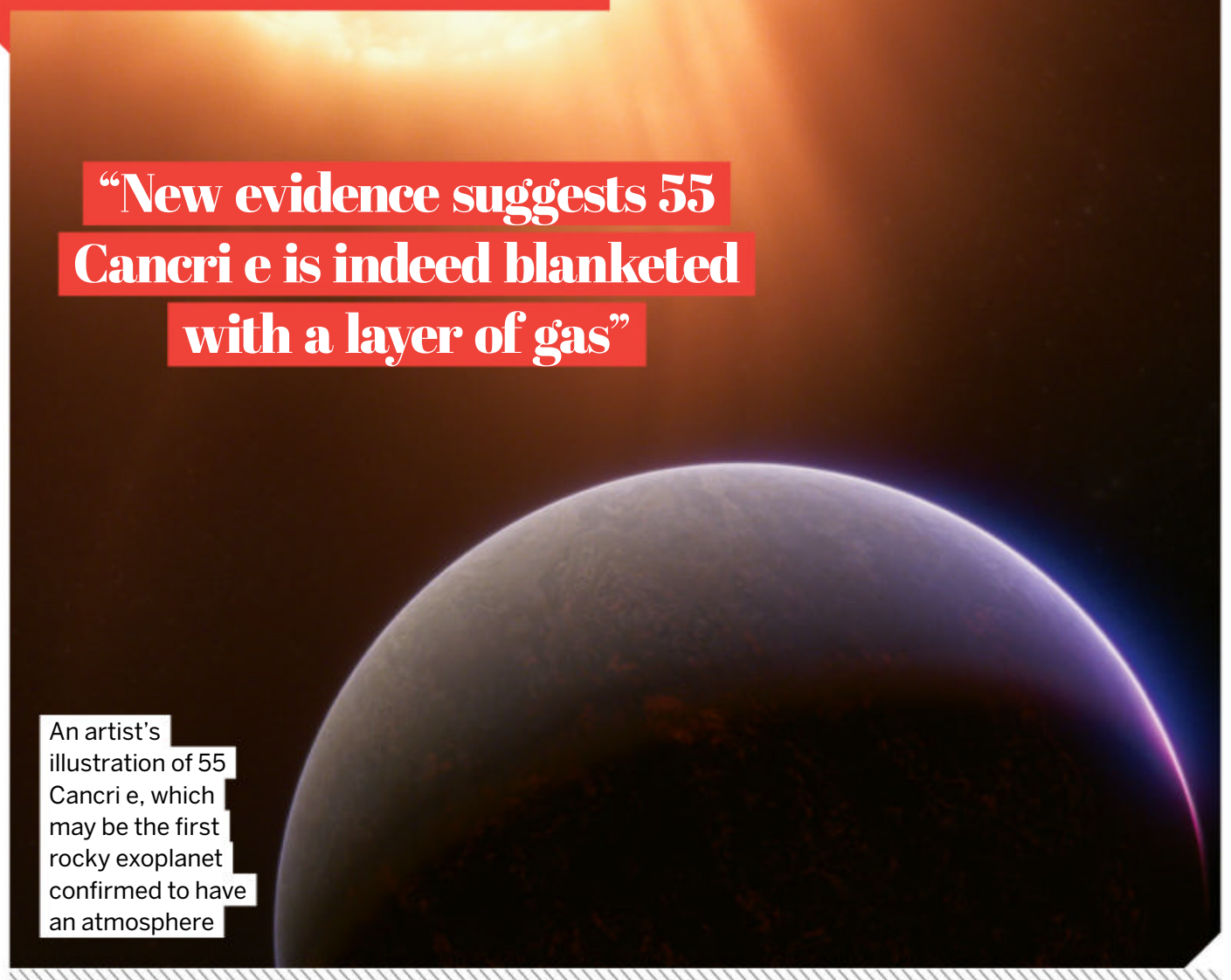
A 65-MILLION-YEAR-OLD COW RELATIVE LOOKED LIKE A CHINCHILLA

WORDS **PATRICK PESTER**

Researchers in Colorado have discovered the fossilised skull of a tiny, now-extinct mammal that lived around 65 million years ago. The newly identified species, *Militocodon lydae*, was around the size of a chinchilla and weighed up to 455 grams, yet it was part of a group that likely gave rise to modern hoofed mammals, such as cows, deer and pigs. *M. lydae* helps researchers understand how mammals evolved into different forms after non-avian dinosaurs disappeared during the Cretaceous-Paleogene mass extinction event 66 million years ago.

***M. lydae* lived around 65.43 million years ago for about 610,000 years, which is not long in geological terms. Researchers identified *M. lydae* from skull and jaw fossils collected in the Corral Bluffs area near Colorado Springs in 2016 and 2020. The team used high-resolution X-rays to create 3D reconstructions of the fossils as part of their analysis. *M. lydae* belongs to the Periptychidae family, and its teeth are similar to those of other periptychids. Researchers still have a lot to learn about periptychids and other Paleocene mammals. However, *M. lydae* appears to be an intermediate form between some of the early members of the group.**

An artist's reconstruction of *Militocodon lydae*



An artist’s illustration of 55 Cancri e, which may be the first rocky exoplanet confirmed to have an atmosphere

SPACE

Webb detects a one-of-a-kind atmosphere around a ‘hell planet’

WORDS **JOANNA THOMPSON**

Can a ‘hell planet’ have an atmosphere? In a new paper, researchers using the James Webb Space Telescope may have finally cracked this decades-old exoplanetary mystery, and in doing so detected the best evidence of an atmosphere around a rocky world outside our Solar System. 55 Cancri e is a fiery world. Classified as a rocky ‘super-Earth’, this exoplanet is twice the diameter of Earth and orbits its star at a mere four per cent of the distance between Mercury and the Sun. Its surface is probably covered in a sea of molten magma, with ambient temperatures hot enough to melt iron.

Ever since 55 Cancri e was discovered in 2004, scientists have been puzzling over various aspects of its existence: its orbital period, its density and most of all, its atmosphere. Initially, researchers weren’t sure whether the exoplanet could even support an atmosphere; some believed it was simply too hot and too close to its star. But new evidence from Webb suggests that 55 Cancri e is indeed blanketed with a layer of gas – albeit an unusual one.

The first hint that this superhot super-Earth had an atmosphere came from a weird temperature measurement. Using Webb’s Mid-Infrared Instrument (MIRI), researchers measured the thermal emissions from 55 Cancri e’s dayside. If the planet had no atmosphere, its daytime temperature would spike to around 2,200 degrees Celsius. But that’s not what MIRI found. “Instead, the MIRI data showed a relatively low temperature of about 2,800 degrees Fahrenheit [1,500 degrees Celsius],” said Renyu Hu, an astronomer at NASA’s Jet Propulsion Laboratory. This reading indicates that something – likely an atmospheric current – was moving heat from the dayside to the nightside of the planet.

Next, Hu’s team used Webb’s Near-Infrared Camera (NIRCam) instrument to determine what elements might be present in this suspected atmosphere. They found evidence of carbon dioxide or carbon monoxide gas swirling around the planet’s molten rock surface. But the researchers suspect that this gaseous layer has not been present since the planet’s formation, as such an atmosphere would be quickly and violently stripped by solar wind from its nearby star. They think that the carbon-rich ‘secondary atmosphere’ is bubbling out from the planet’s interior. This would allow the atmosphere to continually replenish itself, even as the gases boil away.

SPACE

NASA’S TESS RESUMES ITS EXOPLANET HUNT AFTER A GLITCH

WORDS **ROBERT LEA**

NASA’s planet-hunting Transiting Exoplanet Survey Satellite (TESS) is back in action, searching for worlds beyond the Solar System’s limits. TESS came out of ‘safe mode’ on 3 May, resuming its search for worlds known as exoplanets. The satellite had gone into safe mode when it halted operations on 23 April. The TESS operating team has determined that the safe mode was triggered when momentum started building in the spacecraft’s reaction wheels, which are responsible for properly orienting TESS as it makes its observations. This shutdown was related to a separate safe mode event. TESS went offline on 8 April, resuming operations after that glitch on 17 April, only to go back into safe mode six days later. NASA said that the second shutdown happened because when the 8 April safe mode event was resolved, the propulsion system of TESS had failed to successfully repressurise. This system is responsible for offloading momentum from the reaction wheels.

TESS was returned to full capacity when its operations team depressurised its propulsion system. Yet despite TESS again returning to full operation, the cause of the spacecraft’s first safe mode event still remains a mystery.

An illustration of NASA’s Transiting Exoplanet Survey Satellite at work

PLANET EARTH

‘Biosphere’ of microbes found beneath the Atacama Desert’s surface

WORDS SASCHA PARE

A rich microbial ‘biosphere’ lies buried four metres beneath the surface of Chile’s Atacama Desert. The hidden world of bacteria is one of the deepest found in Atacama soils and could inform the search for life on Mars. Microbial life has been recorded down to depths of 80 centimetres in the Atacama Desert, but the new biosphere, in the region’s Yungas Valley, is isolated from the surface.

The newly discovered community inhabits soils between two and at least four metres deep. It is dominated by Actinobacteria, a diverse group of bacteria found in other extreme environments, including the Arctic, boiling hot springs and salty seas. “Little is known about microbial life in deeper sediment layers,” researchers wrote in a new study. “Communities described in this study could represent the upper extent of a deep biosphere underneath hyperarid desert soils.”

The researchers also found Actinobacteria living closer to the surface, between two to five centimetres deep. Digging deeper, the team found bacteria belonging to the phylum Firmicutes, which are resilient to high concentrations of salt and do not require oxygen to survive. The Atacama Desert is the driest hot desert in the world, receiving as much sunshine as Venus. While only a handful of animals survive the harsh conditions, some bacteria thrive in the desert’s salty, mineral-rich soils.

To find out more about these microscopic inhabitants, researchers extracted soil samples from a pit in the Yungas Valley and extracted any DNA fragments they could find. Previous work has not differentiated between DNA from living and dead microbes, so the researchers designed a method to separate DNA still contained in living cells, known as intracellular DNA, from free-floating, or extracellular DNA. “This approach provides a significant improvement for microbial diversity studies of extreme environments as it effectively eliminates bias from DNA derived from dead cells,” the researchers wrote.

Bacteria were abundant in the top 80 centimetres of soil, but they were virtually absent between 80 centimetres and two metres deep, where salt concentrations were too high for even the sturdiest microbes. But at the lower depth, the researchers discovered a ‘transition zone’ to a stable microbial community. This transition zone coincided with a change from clay-rich soils known as playa deposits to ancient river deposits.

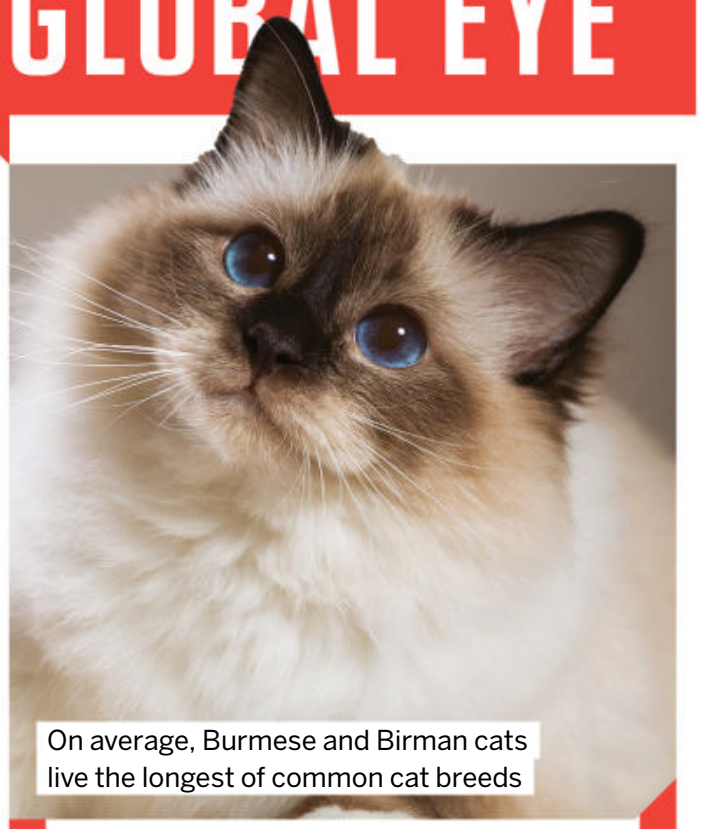
The team suggests Actinobacteria colonised the river deposits around 19,000 years ago and became buried beneath playa sediments over thousands of years. They also proposed that the microbes survive at depth by extracting water from gypsum, which forms when the mineral anhydrite is exposed to water. This reaction is reversible at high temperatures, which could release water. The Atacama Desert is often used as an analogue for studying the harsh conditions of Mars, where the surface is lifeless, but may hide evidence of microbial life below. The new research could further inform the search for life on the Red Planet, as Mars also has gypsum deposits that could potentially serve as a water source for extraterrestrial life.

Did you know?

The Atacama Desert’s average annual rainfall is 15 millimetres

Microbes were found in the Yungas Valley region of the Atacama Desert

© NASA, ESA, CSA, Ralf Crawford (STScI) / Getty



On average, Burmese and Birman cats live the longest of common cat breeds

ANIMALS

A STUDY OF 8,000 CATS REVEALS THE BREEDS THAT LIVE THE LONGEST

WORDS **SKYLAR WARE**

Burmese and Birman cats have the longest average life expectancies among common pet cat breeds. Sphynx cats, meanwhile, die the youngest on average. A new study examined data from nearly 8,000 pet cats in the UK that died between January 2019 and March 2021.

A breed's average life expectancy can be a useful metric, but it doesn't tell the whole story. To get a better picture of cats' projected life spans, the researchers developed 'life tables', which estimate cats' average remaining life expectancy at any given age by excluding data on cats that died before reaching that age. Pet cats in the UK had an average life expectancy of 11.7 years at birth. On the whole, crossbred cats lived about 1.5 years longer than purebred ones. Burmese and Birman cats had the longest life expectancies at birth, each averaging 14.4 years. Sphynx cats' life expectancies were less than half as long, a mere 6.7 years.

Other factors besides breed contributed. Female cats lived an average of 1.3 years longer than male cats, while spayed and neutered cats lived 1.1 years longer than intact cats. Whether cats should be kept indoors or allowed outside could also influence a cat's estimated life span.

Did you know?

There are 350 million pet cats in the world

PLANET EARTH

Weird blobs near Earth's core may have been dragged from the surface

WORDS **STEPHANIE PAPPAS**

Strange 'blobs' deep in Earth's middle layer may be chunks of ancient continental crust that have been dragged down by tectonic forces. These blobs, known as ultra-low velocity zones (ULVZs), have long puzzled scientists. They're deep in the mantle, near the boundary with Earth's core, so researchers can only glimpse them by studying earthquake waves as they reverberate around the planet's interior. These waves slow down significantly in the blob regions, which indicates they are different from the mantle around them. In a new study, researchers suggest that these regions might be more widespread than previously believed, and that composition varies dramatically from blob to blob. "There's more of that material down there," said Samantha Hansen, a geologist at the University of Alabama. "Whatever that material is."

In 2012, Hansen and her team began a project to study the upper mantle via a network of seismic monitors in Antarctica, but they soon realised they had a unique dataset. To image the lower mantle with earthquake waves, scientists need the right combination of earthquake locations and sensors, and Antarctica offered a new window into structures beneath the Southern Hemisphere. When the scientists analysed the data, they found widespread ULVZs. They also modelled global subduction, the phenomenon of oceanic crust sinking into the mantle. Currently, this occurs in subduction zones such as those around the Pacific 'Ring of Fire', where earthquakes and volcanoes are common. The ULVZs seemed to be in the positions that would be expected if they were ancient oceanic crust brought down towards Earth's centre by subduction.

There are other hypotheses for ULVZs, including that they are simply mantle regions with temperature variations that cause partial melting, which could change the way earthquake waves move through them. Another hypothesis holds that they're remnants of the planetary collision that created the Moon. But subduction might explain why ULVZs are not all created equal.

Scientists studied the upper mantle via a network of seismic monitors in Antarctica

A composite image of the superbubble DEM L50, taken by NASA's Chandra X-ray Observatory

PHYSICS

Cosmic 'superbubbles' might be throwing entire galaxies into chaos

WORDS PAUL SUTTER

The worlds of dark matter and regular matter connect only through their gravity, and astronomers hope that giant cavities in space known as 'superbubbles' might hold the key to understanding that connection. Our galaxy, like almost all others, is filled with an invisible substance known as dark matter. There is a wealth of evidence for dark matter, but the exact nature of the elusive substance remains a cosmic mystery. Astronomers desperately want to identify dark matter, and one way they can understand more about it is by observing its gravitational influence on normal matter. But galaxies are complex, busy places, with all sorts of interactions, events and energetic explosions happening all the time, so it's difficult to separate dark matter's influence from the normal behaviour of regular matter.

Now, astronomers at the University of Tartu in Estonia may have found a clever connection point: superbubbles. As described in a recent paper, superbubbles are giant cavities that powerful stellar explosions called supernovae carve out of the interstellar medium – the loose bits of charged particles and dust that drift between stars. It takes more than one supernova to make a superbubble, but giant stars are often born together in large clusters. They tend to have similar life spans, and they also tend to explode together at the ends of their lives. When multiple supernovae go off, their blast waves create a high-density region within the interstellar medium stretching up to thousands of light years across: a superbubble.

Because a superbubble has a slightly lower density than its surroundings, it creates tiny gravitational differences in the regions around it. Using simulations of superbubbles and their environments, the researchers discovered that the gravitational differences within the superbubbles influence both the stars and the dark matter that passes through them, acting as a source of friction that slows the rate of rotation of both kinds of matter. The researchers found that the presence of superbubbles can affect the overall rotation rate of stars and galaxies by about four per cent per billion years. Over the lifetime of a galaxy, that can mean sapping about half of the total rotational energy of a galaxy, greatly affecting the orbits of both stars and dark matter.

But the superbubbles affect the dark matter and the stars in different ways. The superbubbles slow down the dark matter, but not as much as the stars, which creates a disconnect in their evolution. The properties of dark matter inside galaxies – most importantly, its rotational energy – also change in response to the superbubble friction, which in turn influences the gravitational connection between dark matter and normal matter in ways that could potentially be detectable.

This is an intriguing clue. While their results are based only on simulations, the researchers think future studies will better reveal how superbubbles can be used to disentangle the relationship between dark matter and normal matter. This will ultimately allow astronomers to map the positions and velocities of stars near superbubbles to look for signs of how the underlying dark matter is behaving.

ANIMALS

Elephants say ‘hello’ by flapping their ears and making noises

WORDS MEG DUFF

When elephants reunite with friends, they greet each other with ear flaps, rumbles and other deliberate sounds and gestures. A new study suggests that elephants are communicating intentionally and that they tailor their greeting depending on what other elephants are doing. For example, when another elephant was already paying attention, elephants were more likely to use visual gestures, otherwise they were more likely to use touch. “For me, it was really exciting to finally do this, to finally understand how they use their bodies to communicate,” said Vesta Eleuteri, a graduate student at the University of Vienna. “It’s just mind-blowing that they do rely on it so much, but it’s so overlooked.”

Scientists already knew that elephants communicate from up to miles away using deep rumbles that are too low for humans to hear, but that their species’ massive ears pick up with ease. And their long trunks come with an excellent sense of smell: elephants can sniff out age, kinship and even social groups, among both elephants and people. Compared with humans, though, elephants’ eyesight is relatively poor. Previous elephant communication research has tended to focus on sound and smell separately, rather than on how those and other senses might work together.

Eleuteri and her team took a different approach, counting visual gestures, such as ear flapping and trunk reaching, along with vocalisations, touches and scent-related behaviours. They tracked which gestures and sounds occurred together, noting that low rumble noises often accompanied ear flapping. This combination was the most common greeting they documented. The recurring combination suggested the elephants wanted to communicate, Eleuteri said. The elephants also usually looked at each other before gesturing, further reinforcing that idea.

For years, researchers had documented a cacophony of greeting behaviours when groups of elephants came together. It just wasn’t clear which behaviours, if any, were intended as communication and which were unthinking. To answer that question, the researchers in the new study worked with a group of nine semi-wild elephants in Zimbabwe, separating them for ten minutes at a time and then bringing them back together in order to observe their greetings.

Elephants only tend to greet other elephants that they know and like, so an important first step was to figure out which elephants in the group were already close. Elephant caretakers already had some sense of the elephants’ social dynamics. To quantify them, they used a proxy for elephant friendship: the ‘nearest neighbour index’. Twice a month, elephant carers checked to see which elephants were standing closest to each other. They eventually chose to study six elephants that were closely bonded.

The study emphasises that elephants live in complex social worlds, with family groups separating, coming together and keeping track of complex relationships over time. “They have long lives like humans. They can live up to 70 years and they have a similar trajectory,” Eleuteri said, suggesting that having many social partners could push animals to develop complex communication.

“They tailor their greeting depending on what other elephants are doing”

Elephants use a variety of gestures, sounds and visual cues to communicate

Newly discovered cells help shed light on how the liver repairs itself

HEALTH

Scientists discover a new type of liver cell

WORDS **EMILY COOKE**

Scientists have discovered a new type of cell in the liver that plays a critical role in repairing damage. These 'leader cells' are responsible for dragging healthy tissue into wounds as they heal after injury, essentially filling the gap and allowing cellular regeneration to occur. This newfound knowledge could be used to create novel treatments for liver disease. "Cutting-edge technologies have allowed us to study human liver regeneration in high definition for the first time, facilitating the identification of a cell type that is critical for liver repair," said Dr Neil Henderson, a professor at the Centre for Inflammation Research at the University of Edinburgh in Scotland. "We hope that our findings will accelerate the discovery of much needed new treatments for patients with liver disease."

The liver helps remove toxins from our blood, produces bile to remove waste products of digestion and metabolises drugs. The liver also has the remarkable ability to repair itself after damage, for instance due to viral infections such as hepatitis, drug-induced injury and alcoholic liver disease. However, sometimes the liver is so damaged that it can't heal quickly enough, leading to acute liver failure, which affects more than 2,000 Americans a year. The condition can happen within 48 hours, potentially causing symptoms such as yellowing of the skin, excessive bleeding, brain swelling and multi-organ dysfunction.

Did you know?

The liver is the largest gland in the body

Depending on the cause, some cases of acute liver failure – for example those induced by poisoning – can be reversed with drugs. However, in severe cases the only cure is an emergency liver transplant. There's therefore an urgent need for new therapies that enhance the liver's natural ability to heal itself. To better characterise this healing process, Henderson and his colleagues studied liver tissue from patients with acute liver failure who'd gone on to receive transplants. Although many liver cells from these patients could multiply, their livers still showed signs of significant damage. The team wondered whether repairing the liver required more than simply making new cells to replace the damaged ones.

The team sequenced the genes of every liver cell, comparing those from patients with acute liver failure to ones from healthy individuals. This allowed them to generate an 'atlas' of liver regeneration, showcasing which cells were active and when during the repair process, including the freshly found leader cells. The team also viewed these cells in mice as they helped repair the liver after acetaminophen-induced injury. They noticed that during wound healing, leader cells emerged first to rapidly close the wound before cell proliferation helped further seal the gap. This suggests that the liver prioritises wound closure before new tissue is made to prevent bacteria entering the organ from the gut and causing widespread infection.

ARCHAEOLOGY

1,900-year-old Roman legionary fortress unearthed

WORDS **JENNIFER NALEWICKI**

Archaeologists have discovered several Roman ruins buried next to a cathedral in Exeter, UK. The structures, built between 50 and 75 CE, include a street and wooden buildings that were once part of a Roman legionary fortress. The construction was likely part of a "long barrack building," said John Allan, a cathedral archaeologist with the University of Exeter. Romans built the fortress around the same time as a bathhouse discovered near the cathedral in 1971.

Roman troops, whose legions boasted 5,000 soldiers apiece, were a common sight. Britain was one of the most heavily militarised regions in the Roman Empire. Archaeologists at the cathedral also unearthed what was left of a stone wall that once belonged to a Roman townhouse built sometime in the 3rd and 4th centuries CE. The archaeological excavation work is part of a much larger project that involves building a new cloister gallery at the cathedral, replacing the medieval cloisters that were demolished in 1656. The new construction will be built on the original cloisters' foundations. Exeter Cathedral is located in a region of Devon County that was conquered by the Roman Empire in 50 CE.

Excavations occurred at Exeter Cathedral's cloister garden

WISH LIST

The latest tech for SLEEP

YOGASLEEP DREAMCENTER

£34.95 / $29.99

YOGASLEEP.COM

For those who enjoy listening to the sound of rain or chirping birds while they fall asleep, the Yogasleep Dreamcenter is packed with background noises to snooze to. There are 29 sounds available, including white noise, brown noise and nature sounds. There are even womb noises to help newborns drift off to sleep. The Dreamcenter can be played continuously throughout the night or be set to a timer of either 45 minutes, 90 minutes or eight hours. Along with its various sounds, the Dreamcenter comes with a colour-customisable ring night light.

WIIM WAKE-UP LIGHT

$129 (APPROX. £101.50) **WIIMHOME.COM**

The WiiM Wake-Up Light lets you bring a natural sunrise and sunset into your bedroom whenever you're ready to fall asleep. With the help of an integrated Alexa, you can use all the features of WiiM with voice activation, as well as the light's companion app. You can personalise nighttime and morning routines to fall asleep and wake up with naturally shifting light levels that mimic the Sun's movements and support your circadian rhythm. The colour of the WiiM Wake-Up Light is completely customisable to suit your mood and pair with specific music for different occasions and activities, such as for study or meditation. Along with its many light features, WiiM comes with a clock display and Alexa-enabled alarm.

CHILIPAD DOCK PRO

FROM $1,149 (APPROX. £904.50)

SLEEP.ME

If you're always fighting to find the right temperature for your bed, the Chilipad Dock Pro could be the perfect addition to your bedroom. This water-based cooling and warming mattress topper lets you tailor the temperature under the sheets using your smartphone. You can set nighttime temperatures between 12 and 46 degrees Celsius using the companion app. The Chilipad Dock Pro is also designed for one or two sleepers, allowing each person to pick their preferred temperature without affecting the other. There's even an AI adjustment feature that works with your sleep metrics to change the temperature throughout the night in real time.

SOMNOX 2

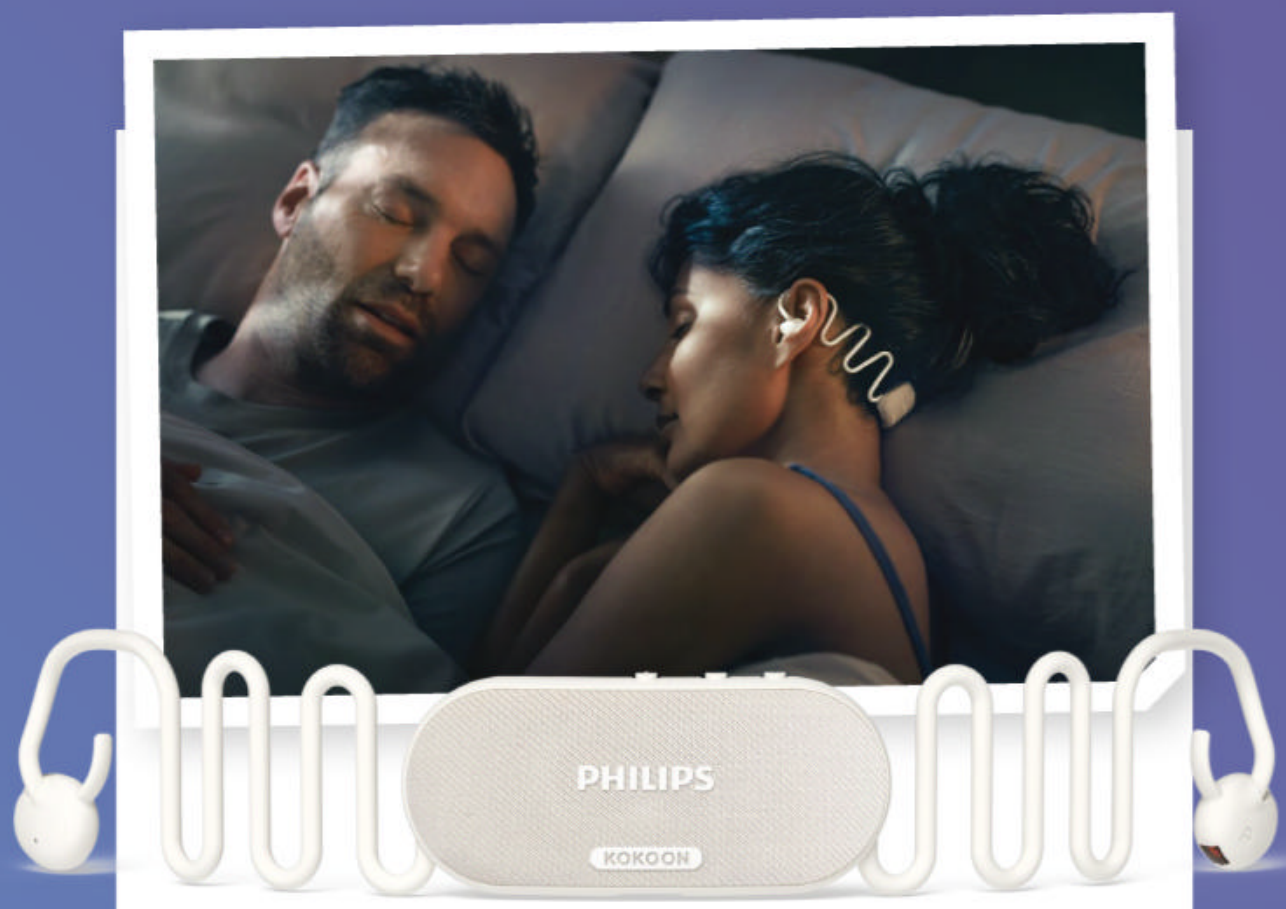
$599 (APPROX. £471.55) SOMNOX.COM

The Somnox is a snuggly sleep companion that's designed to help you fall asleep and have a peaceful rest. This sleep robot works by simulating natural breathing in the hope of syncing up the rhythm of your breathing with its own. While holding the Somnox 2, the robot will mimic the rise and fall of a breathing chest. While you're initially holding the Somnox 2, its 'breathing' will match up automatically with your own using a built-in smart sensor. Gradually, that rhythm will slow down to a sleep-inducing pace, which your body will hopefully mimic. Along with its breathing rhythm feature, the Somnox can stream white noise or music from your smartphone to aid your journey into dreamland.

MUSE S HEADBAND

$399 / €419.98 (APPROX. £359.40)
CHOOSEMUSE.COM

Muse uses electroencephalogram (EEG) technology to monitor your brain's activity. With the help of its companion app, the device will track your sleep patterns and stages, give you feedback on your deep sleep and even track your sleeping position. Muse will also use the EGG data to personalise soundscapes to guide you into a restful slumber, including moments when you've reawakened, helping you drift back to sleep. Tracking sleep is just one of the many aspects of your life that this band monitors. Heart rate detection, breathing monitoring and guided meditation are just some of the ways the Muse headband can keep you informed about your body.



PHILIPS SLEEP HEADPHONES WITH KOKOON

£249.99 / $250 KOKOON.IO

In a collaboration between Philips and the Kokoon app, these sleep headphones are designed to be the whole package when it comes to a sound night's sleep. There's a vast library of different audio tracks, such as soundscapes and relaxation techniques, to discover through the Kookoon app. If you sleep next to an avid snorer, then these headphones can also block out external sounds using their 'SnoreProtect' technology.

Along with supplying relaxing sounds while blocking jarring sounds out, these headphones gather data on your sleeping patterns using thier built-in sensors, which the Kookoon app can analyse to give you daily summaries of your previous night's slumber. According to Philips, these headphones also have the world's thinnest earbuds for optimal comfort while you sleep.

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SPECIAL

WORDS AILSA HARVEY

FUTURE DRONES

DID YOU KNOW? The first US drone permit was issued by the Federal Aviation Administration in 2006

DISCOVER THE FLYING MACHINES THAT CAN DELIVER GOODS, EVACUATE INJURED SOLDIERS FROM THE BATTLEFIELD, HELP FARMERS GROW CROPS AND MORE

The de Havilland DH82B Queen Bee could be flown crewed or uncrewed

Drones are uncrewed aerial vehicles (UAVs) that can be either autonomous or remotely controlled. While many of their modern applications could have them mistaken for new inventions, drones have existed for many decades. In 1935, between World War I and II, the British Army invented a radio-controlled aircraft to be used for military target practice. The aircraft was called the de Havilland DH82B Queen Bee, but was nicknamed a 'drone' and is believed to be the first modern drone. Today, armies own fleets of drones in the tens of thousands, and they have become increasingly popular for private use too.

It wasn't until the 21st century that drones began to be used by civilians for recreational purposes, but today there are more than 885,000 drones registered in the US alone. Smaller drones with high-quality cameras began to be used in film-making, with the first drone scene in a major Hollywood film shot in 2006 for *Miami Vice*. Since then, aerial shots have become commonplace in setting movie scenes, providing new and artistic perspectives.

These same aesthetic shots can be captured by recreational drone users thanks to the invention of the smartphone. As smartphones became mass produced, the prices of accelerometers, microcontrollers and camera technology reduced, making drones more affordable over time.

An increase in drones comes with increased surveillance, but there are many laws in place surrounding the private use of drones. Every drone owner must register their device and display their unique drone number on the aircraft at all times. There are also laws and distance restrictions preventing flight over private and residential land to maintain privacy.

Did you know?

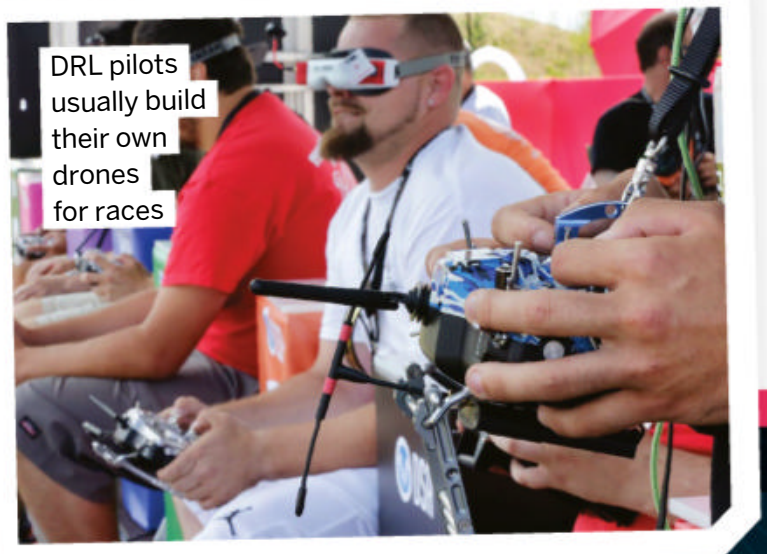
In Europe, drone users must be 16 years old

WORLD RACERS

Drone flying has been adopted as a professional sport in a tournament called the Drone Racing League (DRL). Millions of DRL fans can watch live footage straight from the drones of the world's best drone pilots through streaming platforms such as YouTube and TikTok.

They're flown at over 80 miles per hour, and competitions take place in stadiums around the world or as virtual races in simulators. In real-life races, these need to be operated in first person – as if the pilot was sitting in a cockpit. The drones have a camera that the pilot can connect to in order to watch live footage and steer. Usually, this is viewed through a headset, like a virtual-reality game.

The first amateur drone racing began in New Zealand and Australia, but as it grew in popularity, the DRL was established in 2015. This sport will once again take place at the 2025 World Games in Chengdu, China – an event it has featured in since 2022.



DRL pilots usually build their own drones for races

FAST-FLYING COURIERS

Amazon hopes to speed up its delivery times with its latest Prime Air MK30 drone

1 PARCEL PICKUP
The MK30 can carry packages up to 2.2 kilograms.

2 VERTICAL CLIMB
From Amazon's fulfilment centre launch pad, the drone climbs to 40 to 120 metres at a maximum speed of 65 miles per hour.

3 AUTONOMOUS FLIGHT
The drone's computer directs travel to the recipient in one hour or less.

4 OBSTACLE AVOIDANCE
Built-in cameras and sensors help the drones detect obstacles and alter their altitude to avoid collisions.

5 MARKER SEARCH
The customer has to place an Amazon landing pad on the ground near their property before the drone's arrival.

6 CUSTOMER DELIVERY
When the drone sees the landing pad, it descends from just above it, opens its doors and releases the package onto the pad.

Did you know?
Amazon's delivery drone is quieter than traffic

BEST YOU CAN BUY

MOST COMPACT
With a weight of 249 grams, the DJI Mini 4 Pro is a compact drone that can maintain high-quality footage in flight. Its frame can be folded inwards to fit on the palm of your hand when not in use.

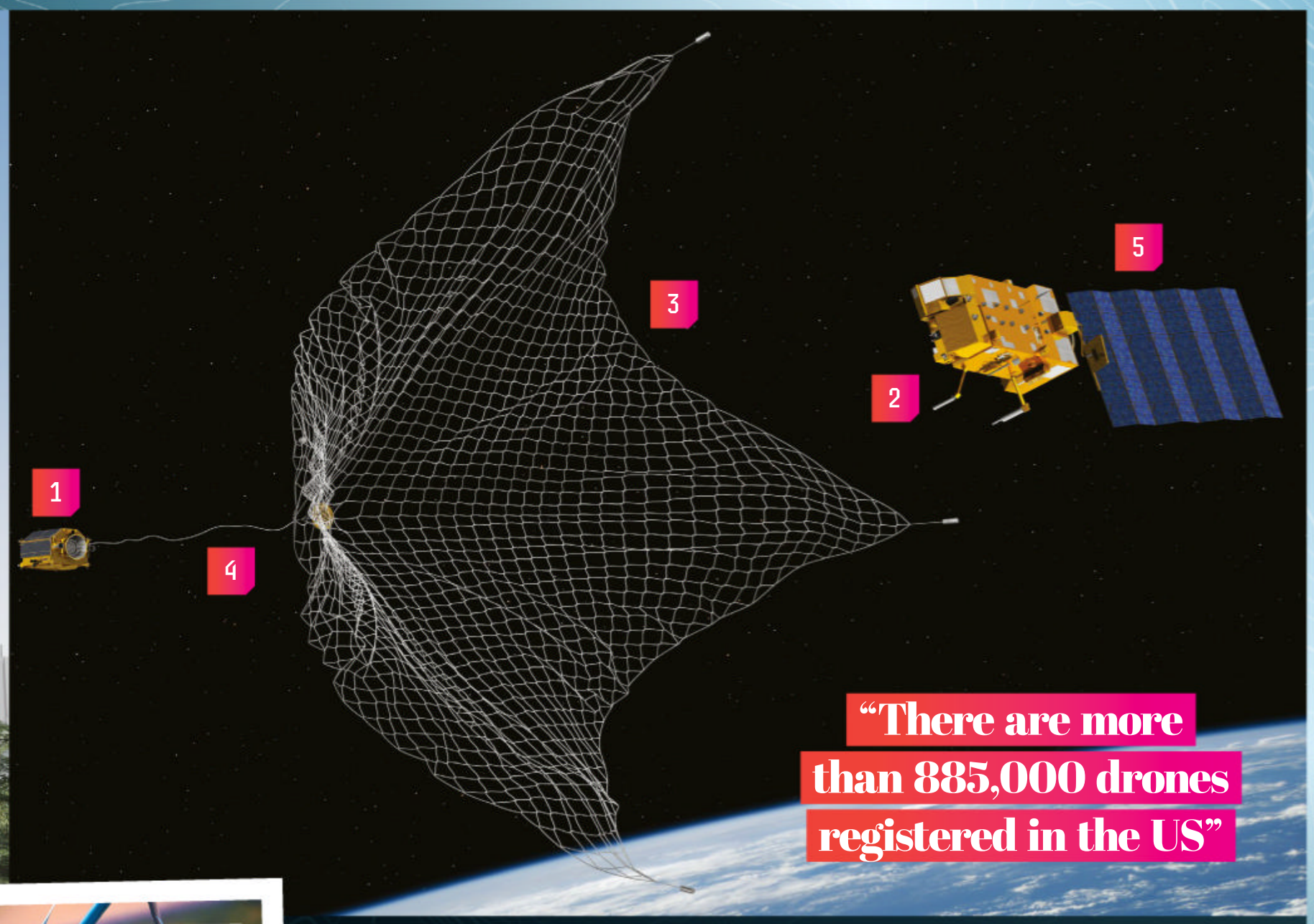
BEST CAMERA QUALITY
The DJI Mavic 3 Pro is the first consumer drone with three cameras. The drone can capture 5.1K-pixel resolution at 50 frames per second, or 4K at 120 frames per second.

MOST ACROBATIC
A first-person view (FPV) drone relays footage of what the drone 'sees' in real time. The DJI Avata 2 is one of the best consumer FPV drones with an easy acrobatic mode for manoeuvres.

AMAZING AUTOMATION
The Skydio 2+ has six 4K 200-degree cameras that help it spot obstacles all around it, enabling safe autonomous flight. Its AI-operated computer can process 1.3 trillion operations per second.

HIGH ENDURANCE
The Autel Evo Lite+ drone's battery can provide 40 minutes of flight time. Most commercial drones can only last up to 20 or 30 minutes before they need to be recharged.

DID YOU KNOW? Delivery drones have been tested in the UK, mainland Europe and Australia



"There are more than 885,000 drones registered in the US"

Amazon's MK30 Prime Air drone on display at one of its fulfilment centres in Washington, US

DRONE INTERCEPTORS

How net-firing guns collect space debris and illegal drones

1 NET-FIRING GUN
These guns can be deployed on satellites in space or fixed structures and drones on Earth.

2 TARGET
Whether the target is a rogue drone or orbiting space debris, the gun's camera tracks the target to keep the net lined up.

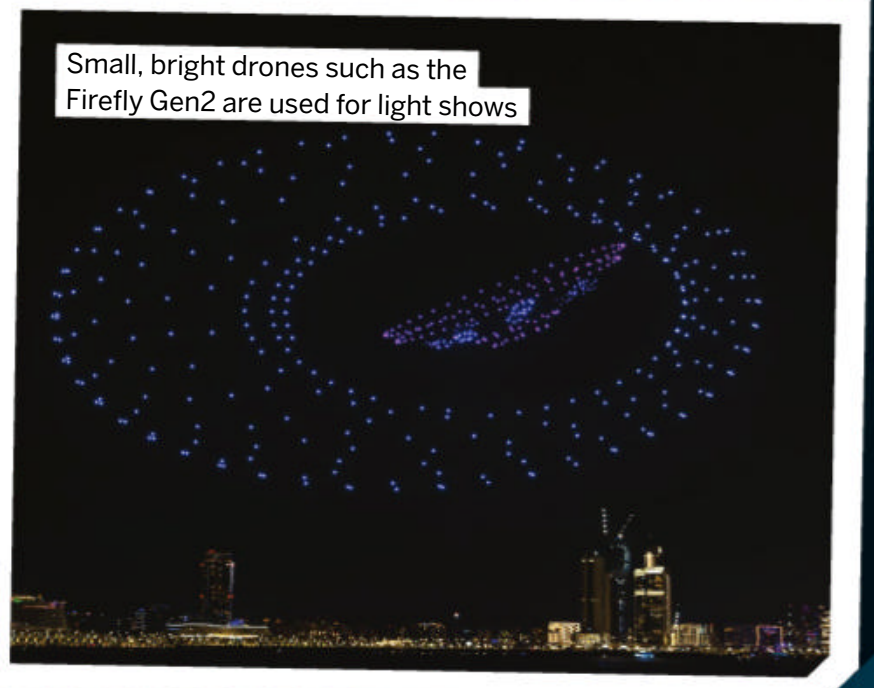
3 CAPTURE
When the drone comes within reach, the gun launches the net. Four weights wrap around the drone, catching it in the netting.

4 RETRIEVAL
A motor pulls the net back. For drones retrieving other drones close to Earth, this prevents the drone hitting the ground.

5 DAMAGE PREVENTION
Satellites can be retrieved and illegal drones examined as the netting captures devices without damaging them.

TEAM PERFORMERS

Drones can be used for entertainment as well as high-priority jobs. For example, to welcome in 2024, the city of Ras Al-Khaimah in the United Arab Emirates launched a spectacular light show using 1,050 drones. The eight-minute show broke the world record for its runtime and stretched 1.2 miles across the sky. The LED-lit drones moved in synchrony to form shapes, words and patterns. Drones that work together like this are called swarms. In drone shows, each drone is programmed by a computer to follow its own flight path, carefully avoiding the surrounding drones. They communicate with neighbouring drones and use proximity sensors to keep a specific distance apart. The position and LED colours change throughout the performance to depict different objects in the night sky.



Small, bright drones such as the Firefly Gen2 are used for light shows

SPECIAL

MILITARY DRONES

BATTLEFIELD CARGO

The electric T-650 drone can airlift injured soldiers and deliver essential supplies

3 MILITARY SUPPLIES
With a maximum payload of 300 kilograms, it can deliver additional military supplies to troops during long missions.

6 FLIGHT COMPUTER
The computer processes live flight data, such as altitude and speed, as well as receiving obstacle-detection data from sensors so it can autonomously control the drone.

5 POWERFUL BATTERIES
Lithium-polymer batteries have the highest power-to-weight ratio. They can be easily and quickly replaced with charged ones between flights.

8 PROPELLER
There are four sets of stacked propellers so that if one fails or is damaged, the drone can still land safely.

1 CASEVAC
For short-range airlifts, a casualty evacuation payload can be attached to the drone.

7 DRIVETRAIN
As the propellers rotate, the drone is powered to a maximum speed of 87 miles per hour.

Engineer and helicopter pilot Chris Malloy founded the company behind the T-650, Malloy Aeronautics

A lithium-polymer battery for a commercial drone. The T-650 is powered by the same technology

DID YOU KNOW? Google launched a food drone delivery service in Australia in 2019

2 TORPEDO
An anti-submarine lightweight torpedo called Sting Ray has been tested with the drone as a payload option.

Did you know?
Racing drones can go from 0 to 90 miles per hour in one second

4 CARBON-FIBRE CHASSIS
The drone has a carbon-fibre layer, making it lightweight and long-lasting even against corrosive chemical weapons.

Even the T-650's little brother, the T-400, is capable of lifting heavy loads

NEIL APPLETON

BAE Systems' Malloy Aeronautics has developed a series of heavy-lift drones, including the T-650. The company's CEO explains the value of these drones in the military

What makes drones good for resupply missions?
In ship-to-ship resupplies, typically you would start moving things from one ship to another with an expensive helicopter. That is very much like using a sledgehammer to crack a nut. If you imagine the capability of a helicopter, it can loiter for hours, it can carry tonnage, it can do all kinds of complex electronic warfare or submarine hunting, and instead you're using it to move bags from one ship to another. That's not a good use of that platform, and it's the only solution customers have today. Our drones allow them to use a simpler and cheaper platform – from £20,000 [$25,181.95] to around £100 [$125.90] per hour.

How is the T-650 designed to work in all weather?
The drone itself has a vehicle management system that adjusts the platform to strong winds and gusts to stabilise itself. Beyond that, we've taken the platform to the desert and the Arctic, in temperatures of -20 and 40 degrees Celsius. They don't like the cold. But that doesn't mean you need a complicated system to keep them warm prior to deployment. When our platforms were deployed to the Arctic, the batteries were kept warm in a vehicle and then installed to the aircraft just before flying with no deterioration in performance. During flight, when the batteries are generating heat because they are being used, it helps compensate for the fact it's -20.

Is it safe to carry injured soldiers by drone?
Casualty evacuation is designed around the vehicle of opportunity, which means if you've got an injured soldier on a battlefield, you don't necessarily want to wait for an ambulance. You use whatever vehicle you've got in the area to get them out in that golden hour – the first hour of an injured soldier is key for survival. If you're an injured soldier, would you want to climb underneath a drone? We've had some soldiers say, "Absolutely. I'm injured, get me out of there," and other soldiers say no. There's very much a different perception among the military community on this, and what we're trying to do is stimulate that conversation.

"Technology evolves and autonomy gets better"

How do you see uncrewed drone technology shaping the future?
As technology evolves, autonomy gets better. In the future you could have one individual flying ten drones almost like an air-traffic controller, rather than on a one-to-one basis. And all they're doing is monitoring that the missions are taking place as designed. It's a different skill set which will reduce the burden on frontline people.

MILITARY DRONES

Concept 2 is described as a medium-sized UAS

UNCREWED ATTACKER

BAE Systems' Uncrewed Air System (UAS) Concept 2 drone has been designed to demonstrate how autonomous technology can be utilised on the battlefield for efficiency and safety. It can fly at altitudes above 12,000 metres for up to five hours at a time in order to engage fighter jets at this high altitude. With a maximum takeoff weight of 3,500 kilograms and an internal payload of 500 kilograms, the drone can launch air-to-air and air-to-ground missiles. It also allows for electronic attacks by carrying payloads that block radio signals. UAS Concept 2 has a fixed-wing design with a V-shaped tail, which requires a runway for traditional takeoff and landing and is powered by a jet engine that can reach speeds of 575 miles per hour.

PHASA stands for Persistent High Altitude Solar Aircraft

HIGH FLYER

In June 2023, BAE System's PHASA-35 drone achieved stratospheric flight by travelling at an altitude over 20,000 metres. The high-altitude aircraft can be used for long-term surveillance as it doesn't rely on jet fuel. Instead, it's powered by the Sun. PHASA-35's photovoltaic arrays power it throughout the day, as well as storing excess electrical energy in its rechargeable batteries to use during hours of darkness. Commercial aircraft fly in the troposphere, the lowest layer of Earth's atmosphere, at altitudes of around 6.2 to 8.0 miles. The stratosphere begins at around 12.4 miles, making PHASA-35's height a safer space for military surveillance.

A XAG P100 on display at the DroneX exhibition 2023

FIVE FARM ROLES

There are multiple ways in which the XAG P100 drone can help farmers

1 LIVESTOCK COUNTING
High-resolution cameras can capture detailed field surveillance. With machine learning, cameras can detect specific animals.

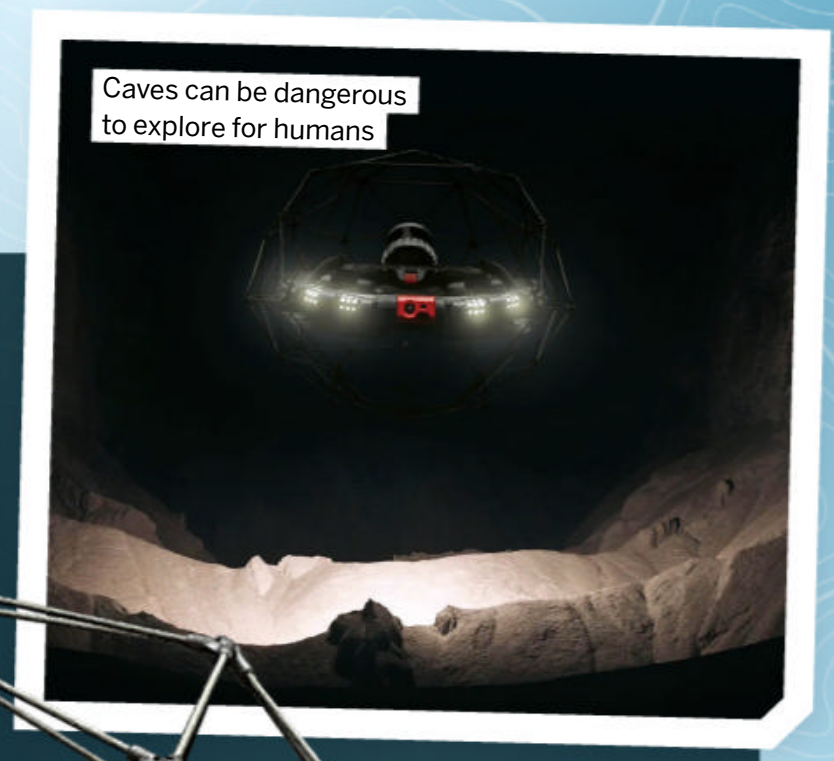
2 PRECISION SPRAYING
The XAG P100 can target crops with pesticides with precision from an aerial position. Its droplet size is 60 to 400 micrometres.

3 FIELD MAPPING
Accurate aerial field maps can be composed using drone imagery. These are analysed to detect weeds and track crop yield and location.

4 AUTONOMOUS PROGRAMMING
Based on the field map, the drone is programmed to follow specific routes around the farm to attend to crops.

5 DISEASE DETECTION
The drone flags any visible signs of disease, enabling farmers to locate the exact site of the affected crops before the disease spreads.

DID YOU KNOW? Lifeguards in Australia started using drones to detect sharks in 2020


Caves can be dangerous to explore for humans

INDOOR SURVEYOR

From exploring caves to mapping industrial sites, Elios 3 carries out safer inspections of enclosed spaces


The cage prevents collisions

1 LIDAR
Elios 3 uses a pulsed laser to map out the perimeter of enclosed spaces. This is saved as a 3D digital file.

2 RESILIENT CAGE
The drone is surrounded by a carbon-fibre cage, which is hard yet elastic, to withstand collisions.

3 THERMAL CAMERA
Heat anomalies in industrial sites can be detected with the thermal camera's data.

4 4K VISION
The front camera relays live footage to workers, covering a 180-degree field of view.

5 DISTANCE SENSORS
A time-of-flight distance sensor measures how close surrounding obstacles are so that operators can change direction and avoid collisions.

6 SMART LIGHTING
These LED panels can be operated independently to create the optimal lighting for analysing different environments and details in varying dust levels.

Did you know?
Elios 3 can produce a centimetre-accurate map

7 PROPELLER
The four propellers are replaced every ten flight hours.

8 NAVIGATION LIGHT
Coloured LED lighting is used at the rear of the drone to show the orientation of the drone and display warnings such as low battery status.

9 MOTOR
When the drone reaches a wall, it uses its reversible motors to back itself up.

"A distance sensor measures how close surrounding obstacles are"

RESURRECTING DINOSAURS

Does the discovery of their cells – and possibly even DNA – mean we stand a chance of bringing these long-lost beasts back to life?

WORDS **HAYLEY BIRCH**

Staring at the screen in the darkened theatre of the visitor centre, Dr Ellie Sattler shakes her head and whispers, "Palaeo-DNA, from what source? Where do you get 100-million-year-old dinosaur blood?" We all know the scene. It's 'the science bit' in *Jurassic Park* – the part apparently so convincing that it's led science-fiction fans the world over to wonder why we can't just patch together a dinosaur via the miracle of cloning. And wonder we might because, as it turns out, 100-million-year-old dinosaur blood may not be impossible to come by.

Since before *Jurassic Park*, Mary Schweitzer, a palaeontologist at North Carolina State University, has been finding traces of blood in the fossilised bones of dinosaurs. Textbooks tell us that blood and bone cells decay too readily to be found in the fossil record. But in 2005 in the journal *Science*, Schweitzer published pictures showing what looked like blood vessels and bone cells in the leg bone of a *Tyrannosaurus rex*. "We had all this soft tissue that was consistent with blood and bone cells in every way," says Schweitzer. "I knew it completely went against what I had been taught."

The pictures whipped up a scientific storm. If it could be proved that the round structures Schweitzer had found were cells belonging to a dinosaur that had been dead for millions of years, then our ideas about fossilisation must be wrong. We'd also have answered Dr Sattler's question. For science-fiction fans, it was just a short leap from dinosaur blood to DNA, and resurrecting a living, breathing *T rex*. Just rip out the DNA, stick it in an ostrich egg and hey presto! A dinosaur! Right?

Did you know?

***Stegosaurus* had a brain the size of a walnut**

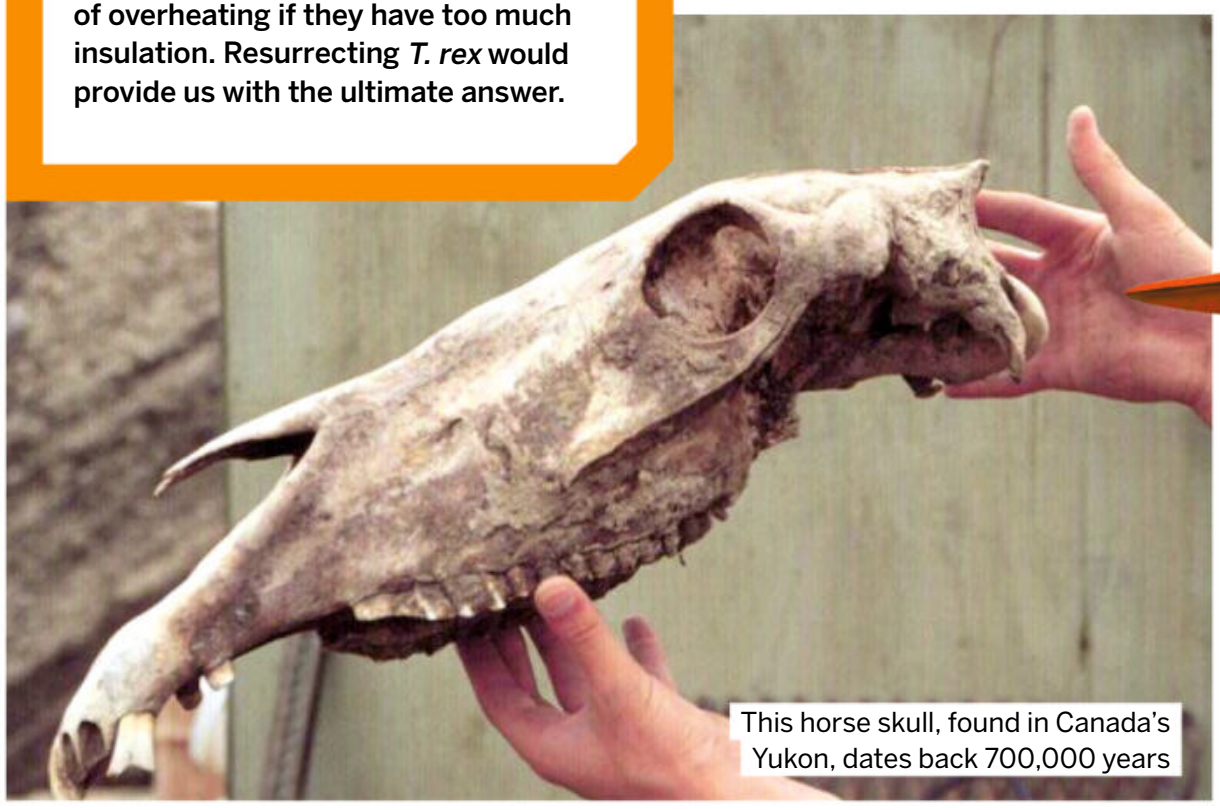
Not so fast. As Dr Patrick Orr, a fossil expert at University College Dublin, explains, there's a difference between the presence of soft tissue and the molecular signatures of proteins and DNA that once resided within that tissue. While Orr's own studies have unearthed bone marrow in 10-million-year-old rocks, his investigations don't extend to the chemical constituents. "There's no question, as far as I'm concerned, that decay-prone tissues, such as the blood vessels that were reported originally, can and do make it into the geological record," says Orr. "But it was quite clear as the discussion

DID YOU KNOW? 700 dinosaur species have been discovered, and more than 100 have been found in Britain

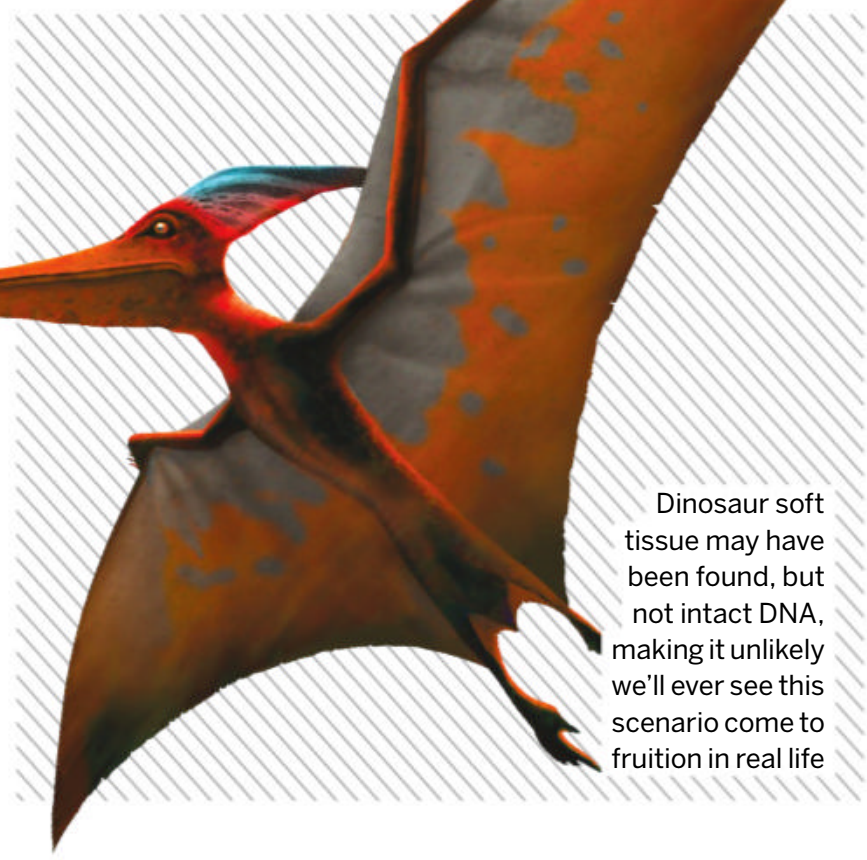
SCALING DOWN THE *T. REX*

Could the most iconic dinosaur have been a feathered beast? Not content with robbing the *T. rex* of its upright stance, palaeontologists now have mounting evidence that the world's most famous dinosaur could have been coated not in scales, but in a range of flamboyant feathers. Scientists have long established a link between modern birds and dinosaurs, and in the past 20 years, well-preserved specimens of two of the *T. rex*'s closest relatives – *Yutyrannus* and *Dilong* – have been found coated in a layer of feathers. This is compelling evidence that feathers were the standard for carnivorous dinosaurs, but if *T. rex* did have feathers they would likely have been sparse – larger animals are in danger of overheating if they have too much insulation. Resurrecting *T. rex* would provide us with the ultimate answer.

Yutyrannus' fuzzy plumage was an early precursor to modern feathers



This horse skull, found in Canada's Yukon, dates back 700,000 years



Dinosaur soft tissue may have been found, but not intact DNA, making it unlikely we'll ever see this scenario come to fruition in real life

A team of researchers was able to sequence the horse's DNA from bone marrow

evolved that it was the actual chemical fidelity that Mary was commenting on. That's a completely separate field."

Schweitzer, who has faced a torrent of criticism from other scientists about her molecular analyses, remains sanguine. After subjecting her blood vessels to "a million methods" she can conclude only that what she's finding are dinosaur proteins. On DNA, though, she's a little more cagey. "I don't work on DNA," she says. "I don't have an appropriate lab." Still, in a paper, Schweitzer's team reported how they had tested for DNA, alongside proteins, in cell-like structures from *T. rex* fossils. The study claims to show antibodies sticking to "material consistent with DNA" in the same way they do to ostrich DNA.

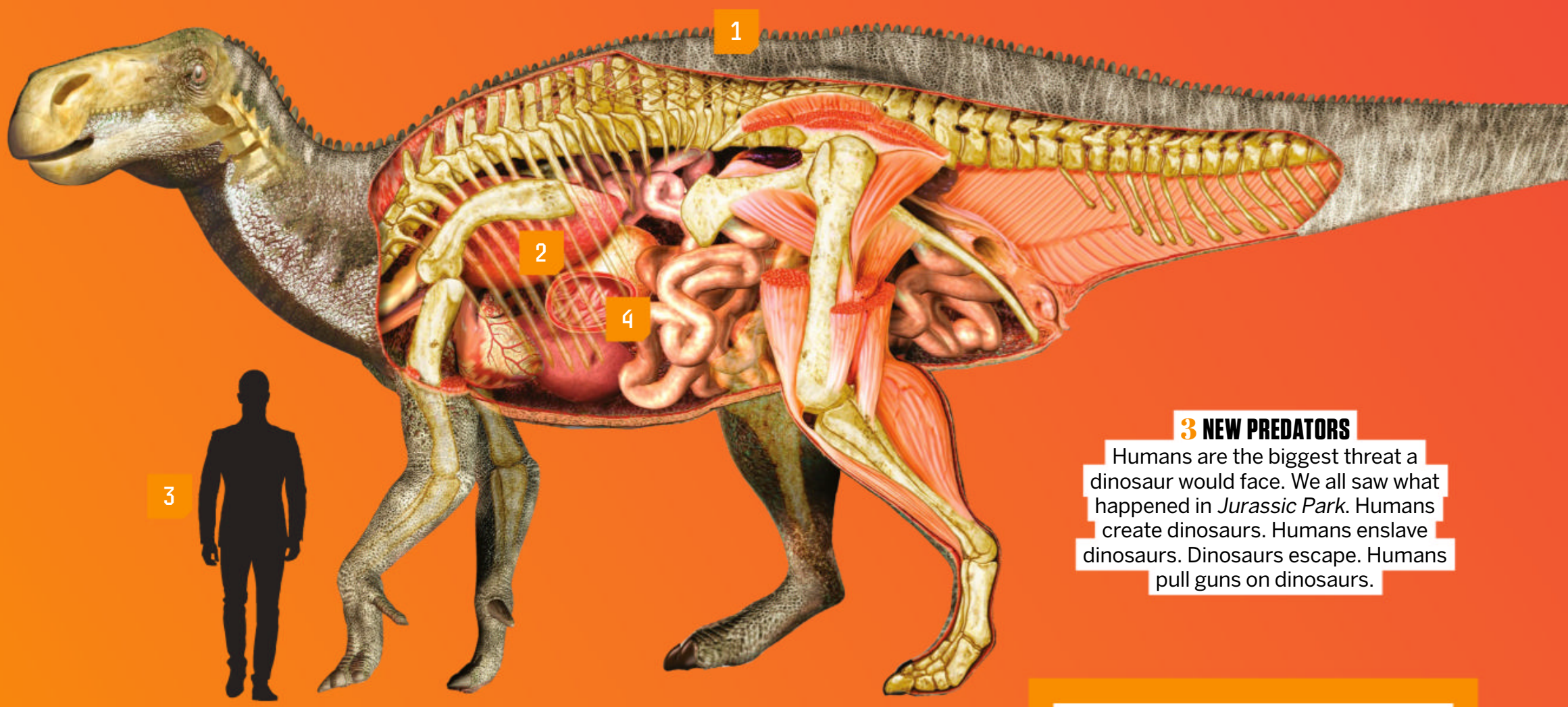
So, do we have dinosaur DNA or not? Since palaeontologists generally try to avoid talk of DNA, it's a difficult question to answer. But Dr Jakob Vinther at the University of Bristol is one palaeontologist who is thinking about DNA. He's one member of a 56-strong team that published the genome of a 700,000-year-old horse whose bones were found frozen in the permafrost of Yukon, Canada. They beat the record for sequencing a genome from ancient DNA by more than 600,000 years.

As Vinther explains, the ancient molecules were badly degraded. "Basically, the DNA had fallen apart," he says. "But we found lots of little fragments, and the fragments were long enough for us to be able to patch them together and then reconstruct the genome of this old horse." They used genome sequences from modern horse DNA as a template. But piecing together a dinosaur genome would be much trickier – like a puzzle without a picture

DID YOU KNOW? *T. rex* had a 1.5-metre-long skull. It used it to bore into prey with the help of its serrated teeth

SURVIVING IN A CHANGED WORLD

Could dinosaurs live in today's very different conditions?



1 COLDER CLIMES
During the Jurassic and Cretaceous periods, it was a lot warmer than today. Ice sheets had not yet formed at the poles, which were covered by thick forests. If dinosaurs were cold-blooded, they might find our climate a little chilly.

2 LOWER CARBON DIOXIDE
The hot climate of the Cretaceous seems to have been related to high atmospheric carbon dioxide levels. In this period, they were off the scale: 1,000 parts per million versus 400 today. Dinosaurs must have adapted to breathing this stifling air. How would they fare now?

3 NEW PREDATORS
Humans are the biggest threat a dinosaur would face. We all saw what happened in *Jurassic Park*. Humans create dinosaurs. Humans enslave dinosaurs. Dinosaurs escape. Humans pull guns on dinosaurs.

4 DIFFERENT FOOD
We can't say what plants dinosaurs ate, but scientists have suggested many didn't chew their food. They swallowed it and let stomach stones or plant-digesting enzymes do their work. Those enzymes would have been adapted to the plants of the era, only some of which survive today.

THE IDEAL CONDITIONS FOR TISSUE SURVIVAL

As we all know, freezing slows down bacterial growth – that's why we keep food in the freezer. The permafrost of Siberia is so effective at preserving tissue that some mammoth specimens extracted from the ice there are incredibly well-preserved. And yes, scientists have found mammoth blood, along with muscle, skin and hairs. Each successive discovery has led to new excitement about the prospect of decoding the beast's DNA.

When it comes to keeping tissue intact, the colder the better

to work from and no indication of whether there should be 2,000, 20,000 or 200,000 pieces. Besides which, it would mean finding much older DNA, at least tens of millions of years old. So while Vinther thinks Schweitzer has made some fascinating discoveries, he says she's probably over-interpreting her data.

Even Schweitzer is cynical about assembling a complete dinosaur genome. "Even if we had the complete genome, we don't know how many chromosomes dinosaurs had," she says. On its own, the string of code that makes up a genome doesn't tell us anything about how that code is arranged on the chromosomes inside a cell.

The number of chromosomes, Schweitzer points out, is one of the defining aspects of a species. Human DNA is packaged up into 46 chromosomes, and if just one is deleted or duplicated, it can be devastating, hinting at what might happen if we try to force an entire *T. rex* genome – if we could ever get one – into the wrong package.

Did you know?
T. rex's tiny arms were likely used for holding prey

So the prospects for a dinosaur resurrection project don't look rosy. Dr Dave Hone, a biologist and dinosaur expert at Queen Mary University of London, says he's not sure why anyone is taking the idea seriously. When we suggest it might be due to a certain science-fiction film, he's quick to reply: "It's a film! I've seen *Aliens* as well, but that doesn't mean that we've got interstellar ships that are going to start landing on other planets and we should start worrying about whether we need to quarantine them."

He adds that putting together a full dinosaur genome is just the first in a long line of problems – getting that into a cell and then to grow into an embryonic dinosaur is virtually inconceivable, especially given the gargantuan effort it took to clone a solitary sheep, an animal we're pretty familiar with. About other proposed de-extinction projects, such as the passenger pigeon, Hone is slightly more optimistic. Given that we have passenger pigeons in museum collections and close living relatives in modern pigeons, it's less of a stretch to think about cloning one.

Schweitzer, meanwhile, continues her studies – she's eager to learn all she can about the evolution of dinosaurs, but not, she says, to clone a *T. rex*. "Is it really worth doing if you're only going to bring back one? I mean, it takes 5,000 organisms to make a viable population. Where are you going to get 5,000? And where are you going to put them if you did?"

Did you know?

Fossilisation is a very rare process

The *T. rex* would be many people's first choice for resurrection

"Putting together a full dinosaur genome is just the first in a long line of problems"

The chances of a real-life *Jurassic Park* scenario are incredibly slim

DNA AND DEAD MOSQUITOES

Can we really find dinosaur blood encased in tree sap? In *Jurassic Park*, they didn't get their dinosaur DNA from fossilised bones... They got it from mosquitoes that had gorged themselves on dinosaur blood and then got stuck in tree sap. So why don't we just do that? A study published in the journal *PLOS One* demonstrates why.

When trying to extract DNA from two bees entombed in resin – one 10,600 years old and one just 60 years old – University of Manchester researchers failed both times, leading to the conclusion that DNA isn't preserved in insect samples from our own Anthropocene epoch, let alone the reign of the dinosaurs. Their results suggest that previous studies claiming to have achieved the feat were contaminated with microbial DNA.

DID YOU KNOW? One of the first discoveries was the Bristol dinosaur. *Thecodontosaurus* was found in 1834 and lived 210 million years ago

TOP-FIVE CANDIDATES FOR DE-EXTINCTION

Dinosaurs might be out of the question for now, but which species are more likely?

It isn't just a case of time elapsed. There are many reasons why it's more feasible to bring back a species that has become extinct relatively recently. They may have close living relatives, or in the case of the Pyrenean ibex, the only animal so far to have survived de-extinction – even if only for ten minutes – we can begin the process by collecting DNA before extinction.

TASMANIAN TIGER

EXTINCT 1936

A short DNA segment from this species – a relative of Tasmanian devils – was given a second lease of life in 2008. To demonstrate a way of learning more about species that died out long ago, scientists used it to switch on a gene controlling cartilage production in mouse embryos.

GASTRIC BROODING FROG

EXTINCT 1981

Females of this strange species had the ability to turn their own stomachs into wombs. Keen to study them, scientists at the University of New South Wales convinced living frogs' eggs to accept the DNA of their dead cousins, but so far the embryos haven't turned into tadpoles.

PYRENEAN IBEX

EXTINCT 2000

A type of Iberian wild goat, this is the only animal to have been verifiably de-extincted – albeit for a few breathless moments. In 2009, a cloned kid was resurrected using DNA from scraps of cryopreserved skin, but died from lung defects shortly after birth.

PASSENGER PIGEON

EXTINCT 1914

Ben Novak sequenced fragments of their DNA as a side project during his time at McMaster University's Ancient DNA Centre in Ontario. He plans to combine passenger and band-tailed pigeon DNA in rock pigeon eggs to make a passenger pigeon mash-up.

MAMMOTH

EXTINCT 1650 BC

Frozen bone marrow, hair and skin samples recovered from Siberian ice have been scrutinised for surviving cells and cell nuclei – the DNA-containing control centres of cells. But even if the search throws up one measly nucleus, harvesting an elephant egg into which to transplant it may prove to be impossible.

What are SUPERFOODS?

How you fuel your body has a direct impact on your health, and some foods are considered far superior to others

WORDS AILSA HARVEY

Describing a food as a 'superfood' gives the impression that one berry or legume could be a miracle worker. In reality, we need a combination of lots of healthy foods to keep our bodies functioning optimally. Different items on your plate might be considered 'superfoods' due to high levels of a vital nutrient. This could be considered its power, but a team of food heroes is required to deliver all the nutrients your body needs.

The term superfood doesn't have an official scientific definition – it's a general term for foods with an exceptional nutrient density or wide range of benefits. Often this term will be used on food product packaging to sell particular items or ingredients. Whole foods are the most worthy of the superfood title, being lightly processed or not at all. If a processed product claims to contain a superfood, the benefits of this ingredient are often cancelled out by the added sugar, salt and fat content.

The first food considered a 'superfood' was the banana. During a World War I advertising campaign, the United Fruit Company sold the fruit as a cheap and nutritious option for everyone. Soon after, the American Medical Association released scientific findings linking banana consumption to the relief of diabetes and celiac disease, before the cause of these conditions was better understood. It is true that a diet can work as a lifestyle treatment for some medical conditions, and the term superfood is still used to highlight some of the healthier and nutrient-packed options available.

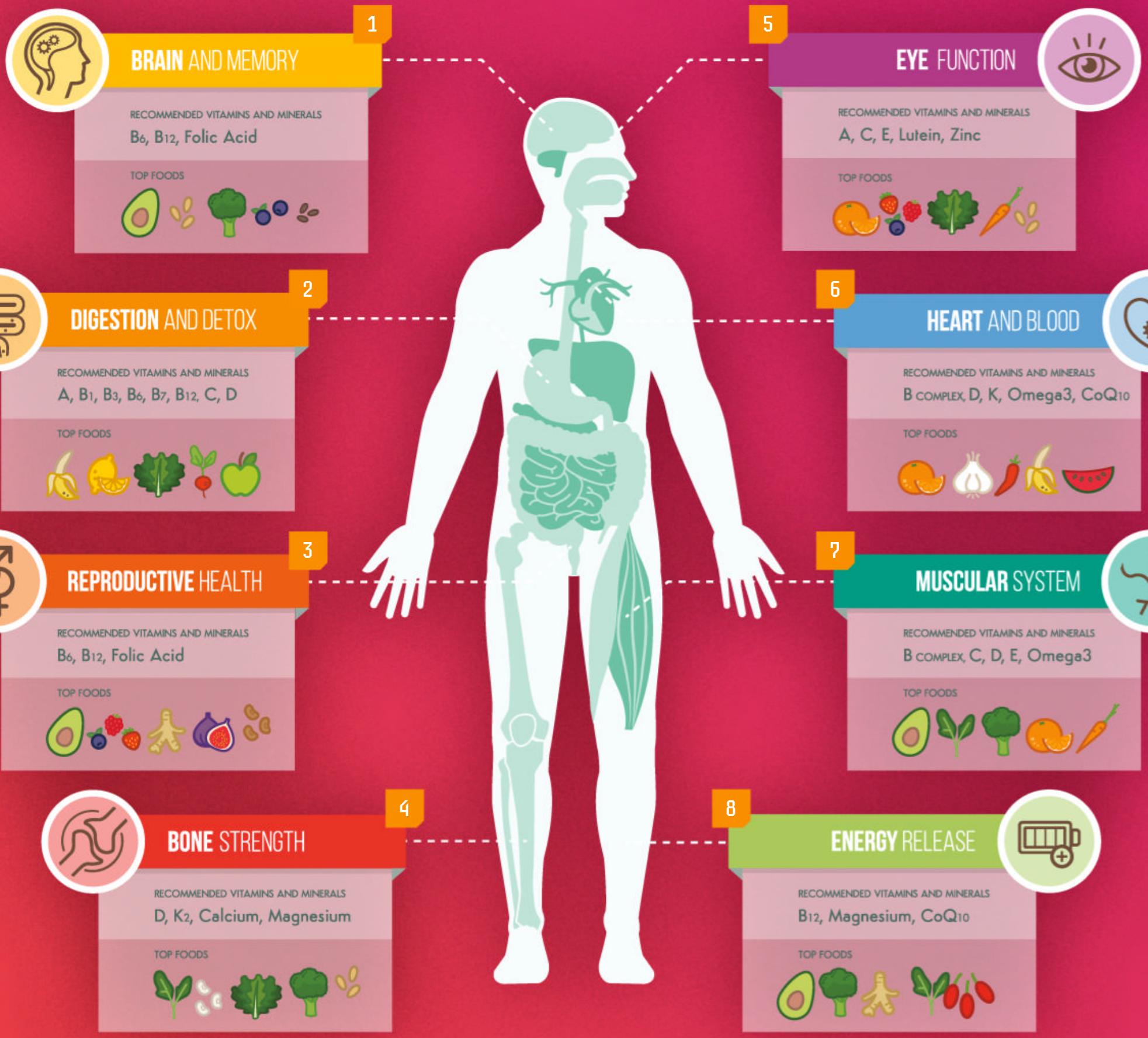
Did you know?

Ginger can relieve pain and nausea

DID YOU KNOW? Egg antioxidants zeaxanthin and lutein improve eye health

BODY BENEFITS

How can superfoods be chosen to meet specific health goals?



1 BRAIN AND MEMORY

60 per cent of your brain is made of fat. Fats in nuts and fatty fish help in brain and nerve growth.

2 DIGESTIVE HEALTH

Ginger helps increase movement in digestion while also reducing gas to prevent bloating.

3 REPRODUCTIVE BENEFITS

Green, leafy vegetables contain the B vitamin folate. This vitamin supports healthy cell division in reproduction.

4 STRONG BONES

Sweet potatoes are high in potassium and magnesium. Magnesium helps harden bones, while potassium neutralises acid to prevent calcium leaching from bones.

5 EYE FUNCTION

Nuts and legumes, such as lentils and cashews, have omega-3 to prevent drying eyes and vitamin E to prevent age-related damage.

6 HEALTHY HEART

Beetroots contain high levels of nitrates, which work to dilate blood vessels and keep the heart pumping healthily.

7 MUSCLE MAINTENANCE

Eggs are high in protein, phospholipids, omega-3 fatty acids, cholesterol and vitamin D for muscle building.

8 ENERGY RELEASE

To keep energy levels high for long periods, avocados have potassium and healthy fats.

ESSENTIAL NUTRIENTS

THE VITAMINS AND MINERALS THAT SUPPORT HEALTHY BODILY FUNCTIONS

B6 Vitamin B6 helps manage mood regulation in the brain.

B12 This vitamin is needed to make red blood cells and DNA and keeps nerve cells healthy.

Fot Without enough folate, red blood cells are reduced in number, become enlarged and oval in shape.

Ca The mineral calcium builds strong bones and teeth, as well as enabling blood clotting.

P Phosphorus keeps the blood's pH in a normal range and helps with kidney filtration.

K Potassium moves nutrients around the body's cells and regulates your heartbeat.

Fe Iron is required to make the protein in red blood cells called haemoglobin. This carries oxygen around the body.

Zn Almost 100 enzymes rely on zinc to work, but it is only needed in trace amounts.

A Vitamin A helps form soft tissue, mucus membranes and skin. It also produces pigment in the eye, maintaining good eyesight.

D Without this vitamin, the body can't absorb or regulate calcium well.

E Vitamin E keeps the eyes and skin healthy and strengthens the immune system.

C Vitamin C helps your body heal. It is used to grow skin, cartilage, bone and teeth.

Nia Niacin prevents inflammation and improves circulation.

FIVE NUTRIENT-DENSE FOODS

KALE
Kale can lower the risk of type 2 diabetes and heart disease.

BLUEBERRIES
Blueberries have the most antioxidants of all common fruits and vegetables.

QUINOA
Quinoa contains twice as much protein as white rice.

LIVER
100 grams of beef liver has over 2,000 per cent the daily recommended value of vitamin B12.

SALMON
Salmon's high omega-3 content reduces the risk of heart disease, depression and arthritis.

DID YOU KNOW? B vitamins are water soluble. They can't be stored in the body, so need to be a regular part of your diet

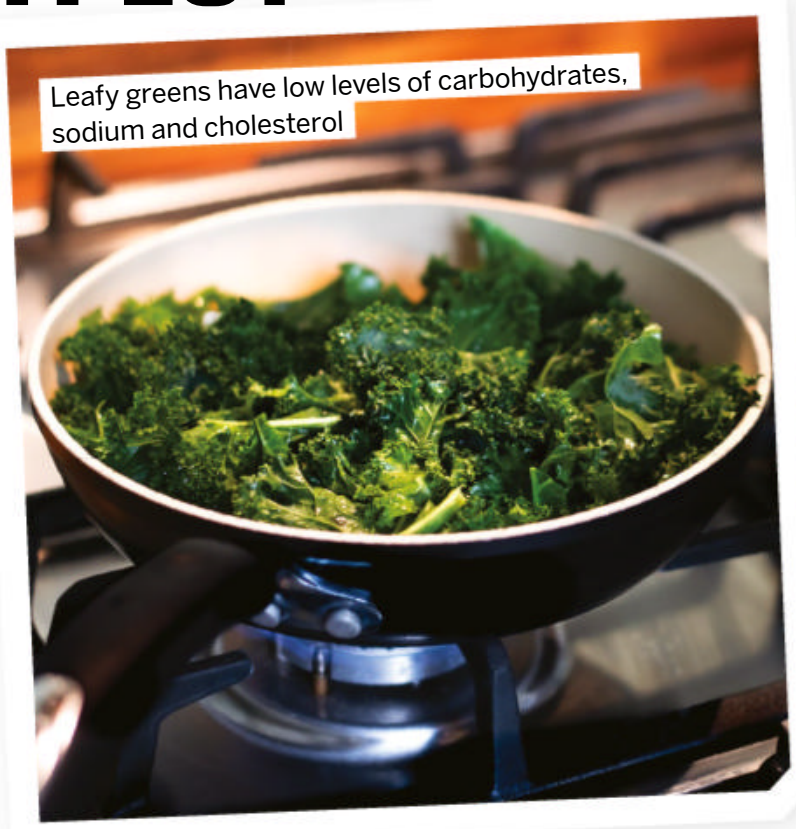
Fermented foods like kimchi are considered superfoods due to the beneficial bacteria, as well as the vitamins and minerals it contains

WHAT ARE THE DIFFERENT TYPES?

Did you know?

Legumes are rich in B vitamins

A diverse diet is key in maintaining health across the body. There are multiple superfood categories serving different biological purposes. The first superfood type is dark-green leafy vegetables, like kale and spinach. These leafy vegetables usually have high levels of calcium, iron, magnesium, vitamin C, fibre, zinc and folate. Many berries are also considered superfoods due to their high antioxidant, vitamin, mineral and fibre content. Berries also reduce the risk of inflammatory and immune conditions. Nuts and seeds are another type of superfood, usually high in protein, fibre and antioxidants, while whole grains, which are those that contain all the germ, endosperm and bran, hold onto all the vitamins and minerals that are usually lost in the refining process.



Leafy greens have low levels of carbohydrates, sodium and cholesterol

COMMON MYTHS

There are many myths surrounding how you should consume superfoods. For example, you might think that because they are so nutritious, you should eat superfoods in large quantities. But eating too much of anything cancels out the positive body response. By consuming too many antioxidants, instead of reducing the risk of disease, an overload can inhibit cells' defence mechanisms. Another common misconception is that superfoods also need to be super expensive. However, many cheaper food items have high nutritional value, from tinned beans packed with protein to tuna, carrots and eggs.

Not all superfoods are consumed as a whole foodstuff – some are taken as supplements

WHAT IS A HANGOVER?

The biochemistry behind your body's backlash after a night of heavy drinking

WORDS SCOTT DUTFIELD

Did you know?

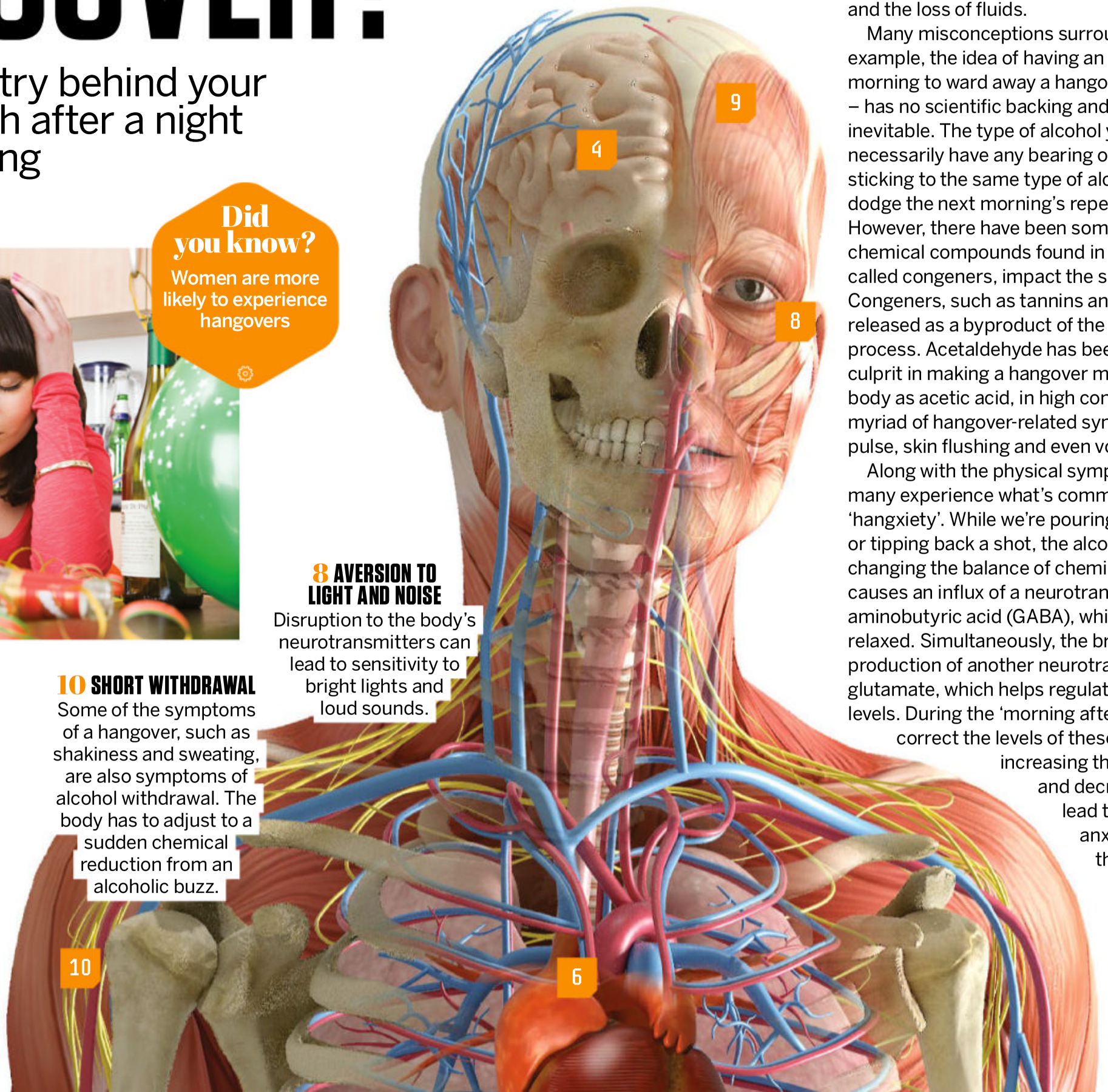
Women are more likely to experience hangovers

THE MORNING AFTER

How the body is affected by alcohol and the consequences of overindulging

4 HEADACHES
The expansion and contraction of blood vessels caused by alcohol consumption can lead to headaches.

9 BAD SLEEP
A hangover comes hand in hand with tiredness due to an interrupted sleep cycle.



8 AVERSION TO LIGHT AND NOISE
Disruption to the body's neurotransmitters can lead to sensitivity to bright lights and loud sounds.

10 SHORT WITHDRAWAL
Some of the symptoms of a hangover, such as shakiness and sweating, are also symptoms of alcohol withdrawal. The body has to adjust to a sudden chemical reduction from an alcoholic buzz.

Headaches, nausea and fatigue are just some of the reminders of last night's boozy antics. Commonly known as a hangover, 'veisalgia' is the medical term for the group of unpleasant symptoms that follow a period of excessive alcohol consumption. One of the main causes of its symptoms is related to dehydration. Vasopressin is a vital hormone that is sent to the kidneys from the brain, signalling that they retain fluid. But consuming alcohol suppresses the release of vasopressin, which causes an increase in urination and the loss of fluids.

Many misconceptions surround hangovers. For example, the idea of having an alcoholic drink in the morning to ward away a hangover – the 'hair of the dog' – has no scientific backing and likely just delays the inevitable. The type of alcohol you consume doesn't necessarily have any bearing on a hangover, and sticking to the same type of alcohol won't help you dodge the next morning's repercussions either. However, there have been some studies that suggest chemical compounds found in alcoholic beverages, called congeners, impact the severity of a hangover. Congeners, such as tannins and acetaldehyde, are released as a byproduct of the alcohol fermentation process. Acetaldehyde has been found to be a prime culprit in making a hangover more severe. Found in the body as acetic acid, in high concentrations it causes a myriad of hangover-related symptoms, such as a rapid pulse, skin flushing and even vomiting.

Along with the physical symptoms of a hangover, many experience what's commonly referred to as 'hangxiety'. While we're pouring another glass of wine or tipping back a shot, the alcohol in our bodies is changing the balance of chemicals in the brain. Alcohol causes an influx of a neurotransmitter called gamma-aminobutyric acid (GABA), which helps the body feel relaxed. Simultaneously, the brain starts to reduce the production of another neurotransmitter called glutamate, which helps regulate mood and anxiety levels. During the 'morning after', the brain works to correct the levels of these two neurotransmitters, increasing the levels of glutamate and decreasing GABA, which can lead to a prolonged period of anxiety. Unfortunately, there are no scientifically backed remedies or hacks that can prevent a hangover. You'll just have to stay hydrated and wait out the rough ride, which can last for up to 72 hours after drinking.

FEELING FRESH

For around 20 to 25 per cent of alcohol drinkers, hangovers aren't such a big deal. Known as 'hangover resistant', many people claim to be able to enjoy alcohol without feeling the negative aftereffects. Some studies have attributed genetics to such an ability. For example, a 2014 study in the scientific journal *Addiction* found that 43 per cent of hangover resistance in study patients was attributed to genetic influences. Scientists have found several genetic variants that appear to bestow hangover resistance, help flush alcohol out of the blood and dampen inflammation.

A link between a person's estimated blood alcohol concentration (eBAC) has also been made in connection with hangover resistance. In 2015, a group of international scientists found that almost 80 per cent of people who claimed hangover resistance paced their drinking and didn't pass an eBAC of 0.10 per cent, despite drinking the same volume of alcohol as other study participants.

For a lucky few, a night of drinking doesn't result in a hangover

5 EXCESSIVE THIRST
After a bout of dehydration, the body experiences excessive thirst to replenish what was lost.

7 DIARRHOEA
Due to the lack of water absorption while drinking, stools may pass loosely during a hangover.

1 NAUSEA
The lining of the stomach and gastrointestinal tract become irritated by alcohol, and the production of acid increases.

6 INCREASED HEART RATE
An increased heartbeat, called tachycardia, and increased blood pressure are common symptoms during a hangover. Excess drinking can lead to atrial fibrillation, also known as holiday heart, which can cause irregular heartbeats and damage.

2 INFLAMMATION
Alcohol increases the release of cytokines from the liver, increasing inflammation within the body. This contributes to the general discomfort or sense of illness experienced during a hangover.

3 LOW BLOOD SUGAR
Blood sugar declines, causing you to feel more tired and weak, as well as your affecting mood.

Darker alcoholic drinks contain high levels of congeners

DID YOU KNOW?

On average, Britons spend 315 days of their lives battling a hangover

HOW ACUPUNCTURE WORKS

WORDS AILSA HARVEY

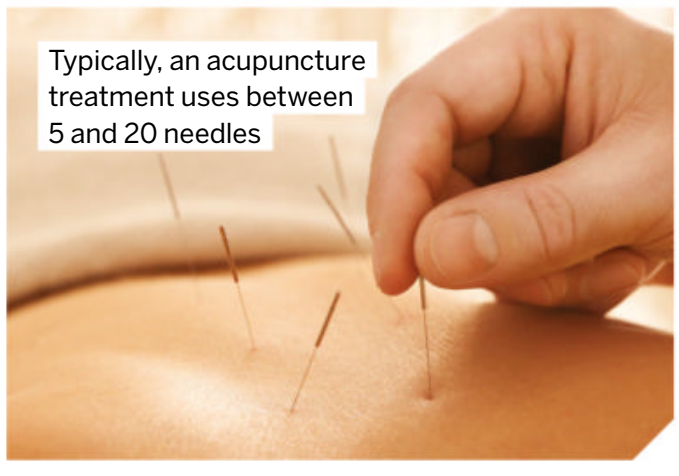
Fine needles have been inserted into the skin for centuries as a traditional medicine that can have full-body benefits

Did you know?

There are over 300 acupuncture points

In Western medicine, chemical painkillers and other lab-produced drugs are often prescribed for common ailments. However, an ancient Chinese medical practice involves the controlled insertion of needles beneath the skin – an alternative medicine that prompts the body to release its own natural remedies. This includes endorphins, which are pain-relieving hormones. The production of endorphins can be manipulated by stimulating sensory nerves across the body in a process called acupuncture.

Compared to other modern treatments, there's less significant scientific evidence detailing the benefits of acupuncture. However, it is often recommended alongside modern medicine for chronic pain and tension headaches. Most acupuncture patients seek private companies for this treatment. During a session, the patient will sit or lie down while the practitioner inserts needles a few centimetres in length into precise points across the body. The areas and number of inserted needles depend on a person's symptoms. Initially, the acupuncture process creates a tingling or aching sensation, which is left in the body for between 5 and 30 minutes.



Typically, an acupuncture treatment uses between 5 and 20 needles

ANCIENT ORIGINS

In the year 6000 BCE, acupuncture was practised in China using long animal bones and carved stones. Traditionally, the procedure was carried out to control an energy in the body called qi, with the benefits felt from acupuncture credited to the balancing of qi. Traditional acupuncture practitioners carry out this treatment following the belief that the interrupted flow of qi causes illness. The 12 main channels of qi are detailed in the oldest document to mention acupuncture, *The Yellow Emperor's Classic of Internal Medicine*, from 100 BCE. Between 1368 and 1644, when acupuncture became a widespread practice across China, 365 acupuncture points were documented. As Western medicine adopted acupuncture, it referred less to the channels of qi and instead became centred around physiology and muscle relaxation.

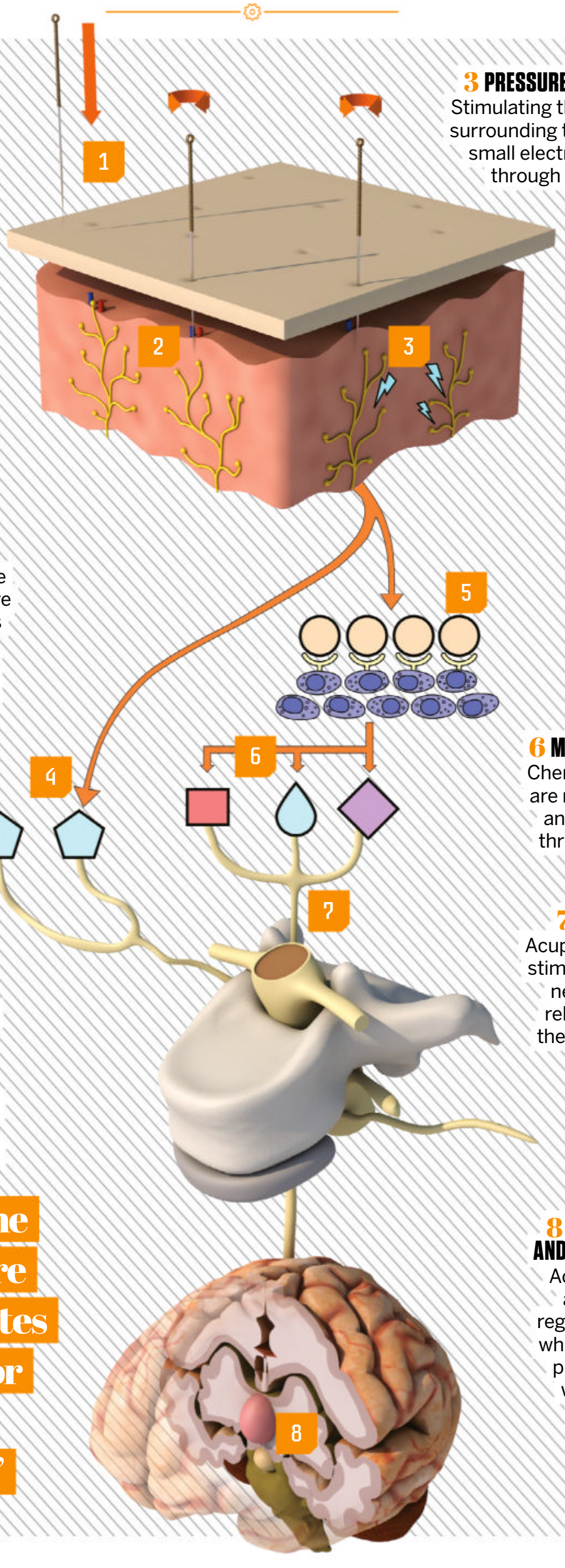
© Wikimedia Commons: Hua Shou

This drawing from 1716 shows the main acupuncture points

DID YOU KNOW? Acupuncture has been used to treat over 200 health symptoms

NEEDLE STIMULATION

How does acupuncture interact with the central nervous system?



1 ACUPUNCTURE POINT
The needles are inserted underneath the skin – from a few millimetres deep on the forehead to two to three centimetres at the back of the neck.

2 NERVE ENDINGS
Acupuncture points are close to peripheral nerve endings, blood vessels and mast cells – the white blood cells that trigger inflammation.

3 PRESSURE SENSATIONS
Stimulating the nerves and surrounding tissue triggers small electric impulses through the body.

4 ENDORPHIN RESPONSE
Nerve stimulation can cause the body to release hormones called endorphins, which are the body's natural painkillers.

5 SUBSTANCE P
This protein binds to mast cells and may help regulate pain during acupuncture.

6 MESSENGER RELEASE
Chemical messengers are released to create an electrical signal through the nerves.

7 NERVE SIGNAL
Acupuncture pressure stimulates the central nervous system, relaying signals to the brain and spine.

8 HYPOTHALAMUS AND PITUITARY GLAND
Acupuncture can activate these regions of the brain, which impact blood pressure, mood, wound healing and anxiety.

"Initially, the acupuncture process creates a tingling or aching sensation"

5 FACTS ACUPOINTS

1 LI4 (HEGU)
Found between the thumb and index finger at the back of the hand, pressure at this point can relieve headaches.

2 LV3 (TAI CHONG)
This point, at the top of the foot between the big toe and second toe, relieves stress, menstrual pain and insomnia.

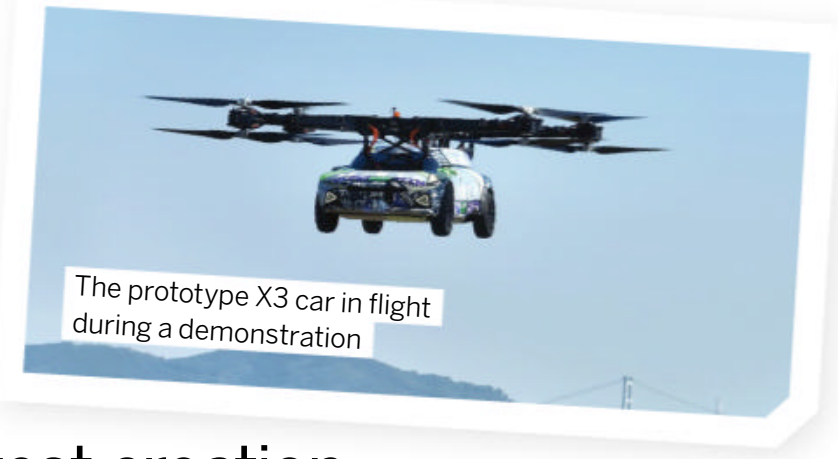
3 PC6 (NEIGUAN)
On the inner forearm, about three fingerbreadths beneath the wrist, this acupressure point soothes nausea.

4 SP6 (SANYINJIAO)
Just above the ankle bone, this point on the calf has been used in acupuncture to relieve digestive pain.

5 GV20 (BAIHUI)
At the top of the head, GV20 stops headaches and is said to help with mental clarity.

NEXT-GENERATION FLYING CAR

Could XPeng's latest creation be the future of eVTOL cars?


The prototype X3 car in flight during a demonstration

WORDS **SCOTT DUTFIELD**

At the 2024 Consumer Electronics Show (CES), XPeng AeroHT, a Chinese electric vehicle company, unveiled its electric vertical takeoff and landing (eVTOL) flying car. Unlike other eVTOL vehicles, the XPeng creation looks like it's jumped straight from a work of science fiction as a road-worthy car that can sprout wings and fly. But this eVTOL can indeed do just that. In drive mode, it looks like any other aerodynamic supercar. However, at the touch of a button, the steering wheel disappears and the rotary blades begin to emerge, like a space-age Chitty Chitty Bang Bang. At the same time, a hidden compartment at the rear of the car opens up and a set of drone-like propellers emerge, fanning out ready for takeoff.

Like other rotary drones, this flying car uses a set of blades that alternate their direction as they spin to generate a balanced lift for takeoff and landing. The vehicle is designed for short-distance, low-altitude flight and can ascend to an altitude of around 100 metres. In 2022 the prototype of the eVTOL, known as the X3, completed a successful test flight, lifting its around two tonnes of weight into the air. As part of the test, engineers also performed multiple single-propeller failure tests, which the vehicle passed. XPeng has also developed a multi-parachute rescue system for its flying vehicles, which has been successfully deployed at altitudes of just 50 metres.

XPeng's flying car remains a concept vehicle, so its top speed, power and performance are yet to be determined. However, the company estimates that models could be available as soon as 2030. Whether they will ever be road worthy remains to be seen.

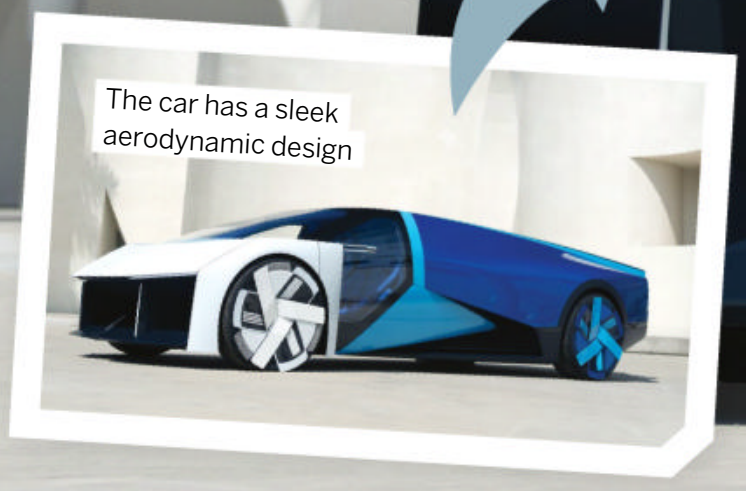

The XPeng flying car on display at Beijing Auto Show in April 2024

eVTOL ANATOMY

Inside this futuristic flying concept car

2 BLADES
Eight rotary propellers extended from four booms generate enough lift for takeoff.

4 MIRRORLESS
Instead of typical wing mirrors, the eVTOL uses backwards-facing cameras on each door to display a rear view on the internal dash.

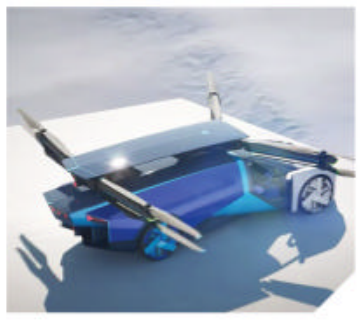

The car has a sleek aerodynamic design

DID YOU KNOW? The flying car market could be worth over £700 billion ($889 billion) by 2040

TRANSFORMERS

How XPeng's eVTOL transforms from a car into a flying machine

1 TUCKED AWAY
The rotary blades, along with the arms that support them, are folded away within a compartment beneath the roof.



2 EXTENDED ARMS
From the storage compartment, four booms fan out – two at the front and two at the rear.

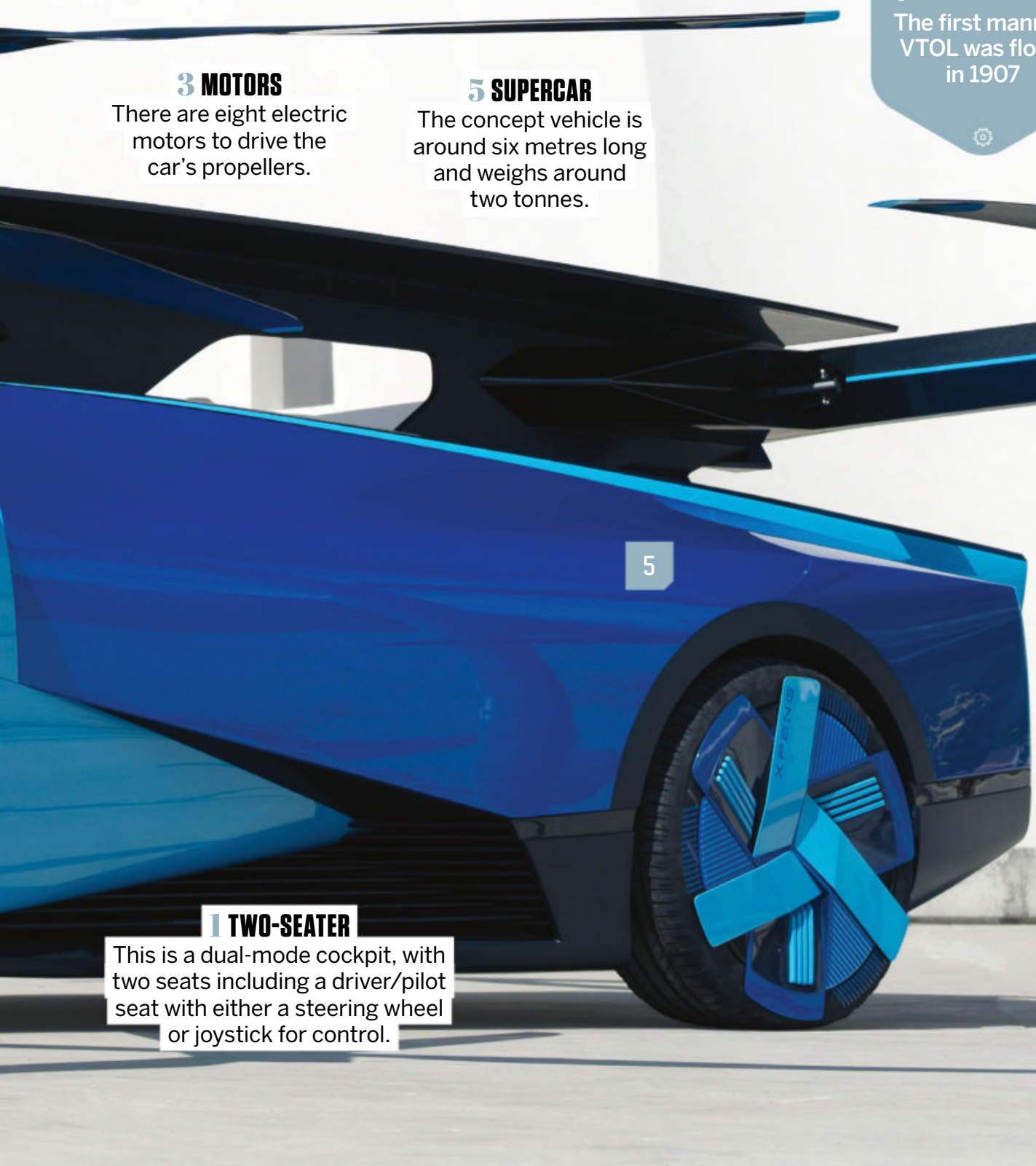
3 BLADES EMERGE
Using the joystick controls in the cockpit, the two alternating blades on each boom spin to generate lift.

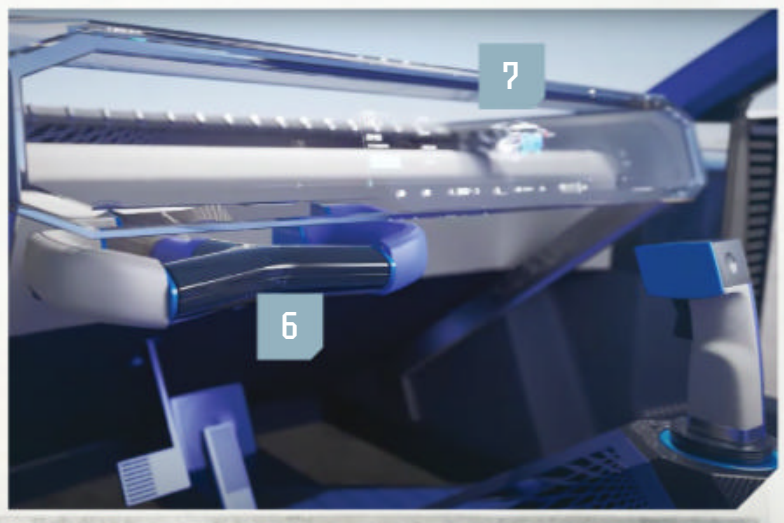
4 TAKEOFF
The car begins to lift off vertically before the blades are tilted by the control to adjust the vehicle's trajectory.

Did you know?
The first manned VTOL was flown in 1907

3 MOTORS
There are eight electric motors to drive the car's propellers.

5 SUPERCAR
The concept vehicle is around six metres long and weighs around two tonnes.





1 TWO-SEATER
This is a dual-mode cockpit, with two seats including a driver/pilot seat with either a steering wheel or joystick for control.

6 SWITCHING STEERING
In fly mode, the gear selector becomes the aircraft's flight stick, while the steering yoke retracts under the dashboard.

7 DASHBOARD
The vehicle's vital statistics, such as speed and battery, are displayed on a panoramic glass dashboard.

The ground module can carry up to five passengers, while the air module can seat two

VEHICLE WITHIN A VEHICLE

You might see a flying XPeng vehicle on the roads even sooner than the eVTOL flying car. The Land Aircraft Carrier modular flying car is a vehicle within a vehicle: an all-electric, six-wheeled truck that contains an eVTOL vehicle. It's a foldable quadcopter with a 270-degree panoramic cockpit that can be flown manually or by using one of its automatic driving modes. When the driver is ready to switch between the two modules, the ground unit will automatically eject the air module and leave it standing on the ground, ready for takeoff. Much like the XPeng flying car, the air unit is also designed for low-altitude flight. The Land Aircraft Carrier is heading for mass production and XPeng expects it to roll out by the end of 2025.

BUILDING THE FAROE ISLAND TUNNELS

At up to 189 metres below the surface, these subsea tunnels connect the islands, their people and economies

WORDS **AILSA HARVEY**

The Faroe Islands is an archipelago between Iceland and Norway. The land is mostly mountainous, with deep fjords that make cross-country travel complicated and time consuming. Today, thanks to a huge long-term construction project, the route to island connectivity lies beneath the ground and sea. There are more than 20 tunnels that the 53,000 residents can travel through by car, both across and between islands, with multiple more still under construction. Currently, more than 90 per cent of Faroe's inhabitants are connected by these tunnels. Use of the mountain tunnels is free of charge, but the undersea tunnels are toll roads.

Though the network is fairly new, opening in December 2020, the islanders built their first road tunnel in 1963, cutting through a large mountain on the island of Suðuroy. To create these tunnels, workers use the drill-and-blast method. This involves drilling holes deep into the ground and filling them with explosives to blast away the rock. The debris is then cleared and the watertight walls shored up with concrete.

The process of drilling and blasting the undersea tunnels took around 2.5 years, followed by 1.5 years of further construction. This includes adding electrical systems and pipework. In the event of a water leak, a series of pumps and pipes direct water out of the tunnels.

Did you know?

Eysturoyartunnilin is the second-longest road tunnel

THE FIRST SUBSEA ROUNDABOUT

The Eysturoy tunnel connects the two largest islands, Streymoy and Eysturoy. Construction of the seven-mile tunnel took four years and includes the world's first undersea roundabout, built 72 metres below the surface. A Faroese artist, Tróndur Patursson, designed it, featuring a large, central pillar lit with projections. The pillar is made of natural rock that remained in place after blasting the tunnels, and around it is a steel ring carved into human figures. It only takes 15 minutes to travel between the two islands– a journey which once took over an hour.

The undersea roundabout is called the jellyfish roundabout

ISLAND INFRASTRUCTURE

Which islands are connected by these subsea routes?

1 SANDOYARTUNNILIN
This 6.7-mile tunnel connects Streymoy to Sandoy. It was the fourth underwater tunnel, opening on 21 December 2023.

2 NORÐOYATUNNILIN
Norðoyatunnilin is 3.8 miles long. It's built under the Leirvíksfjørður strait, connecting Eysturoy and Borðoy.

3 VÁGATUNNILIN
Those who fly into the Faroe Islands need to travel this three-mile tunnel to leave Vágar Island, where the only airport is located.

4 HOVSTUNNILIN
Hovstunnilin is a 1.5-mile mountain tunnel that links the north and south of Suðuroy island, bypassing a large mountain range between Øravík and Hov.

5 KOLLAFJARÐARTUNNILIN
This 1.7-mile mountain tunnel connects Streymoy to the capital, Tórshavn.

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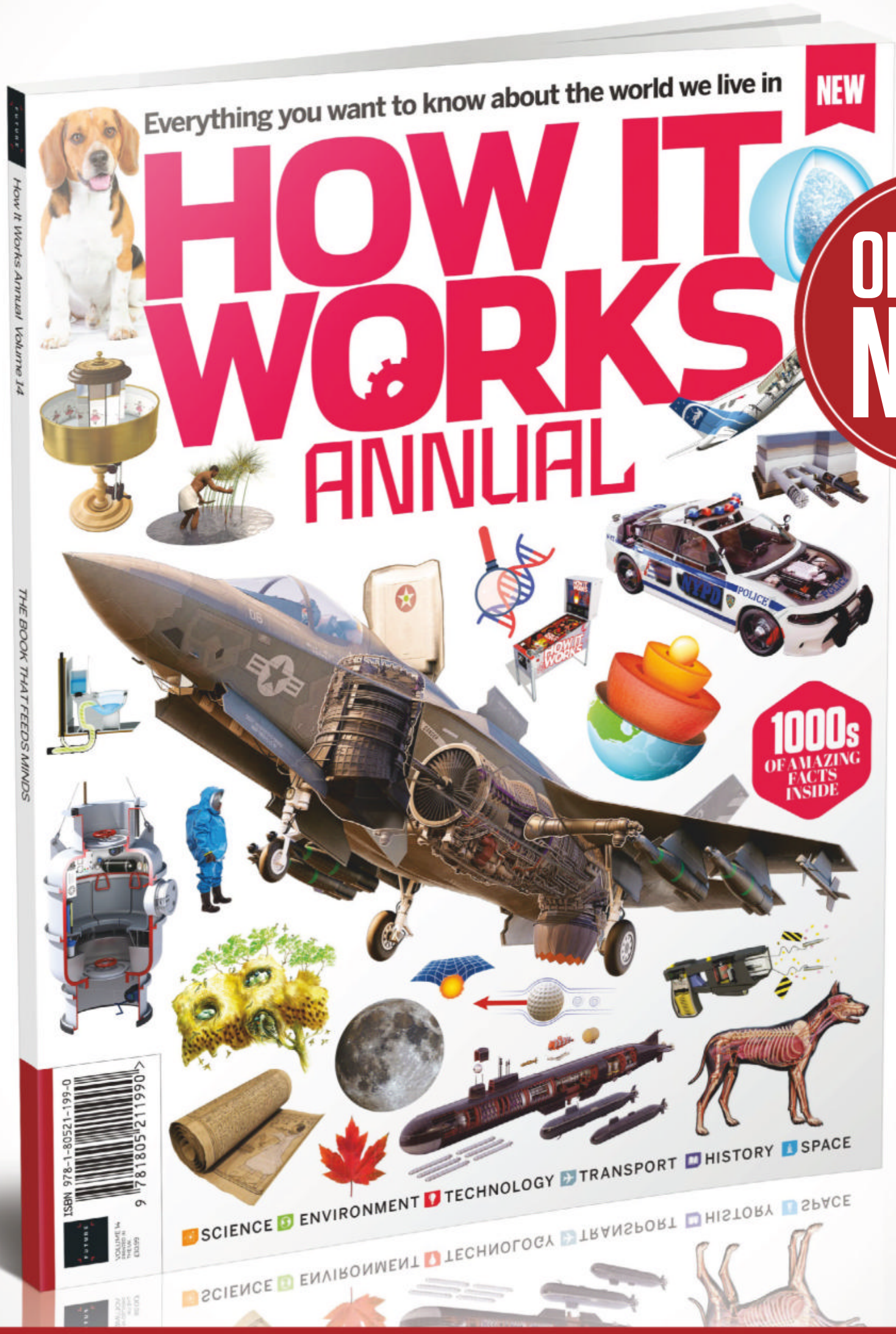

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BIGGEST BLACK HOLES IN THE UNIVERSE

WORDS ANDREW MAY

There's a giant black hole with the mass of 4 million Suns at the centre of the Milky Way. But that's still tiny compared to its counterparts in other galaxies

DID YOU KNOW? Atomic bomb scientist Robert Oppenheimer worked on black hole theory prior to World War II

Black holes are the most extreme astrophysical phenomena in the universe. And there's a good chance they're the best known, too. Not everyone has heard of neutron stars, planetary nebulae or brown dwarfs, but most people have come across the idea of a black hole, even if it was only in a science-fiction film. Part of the fascination lies in the way black holes seem to break – or at least twist beyond recognition – all the common-sense laws of physics. Looked at more closely, though, they're really just an inevitable consequence of these laws.

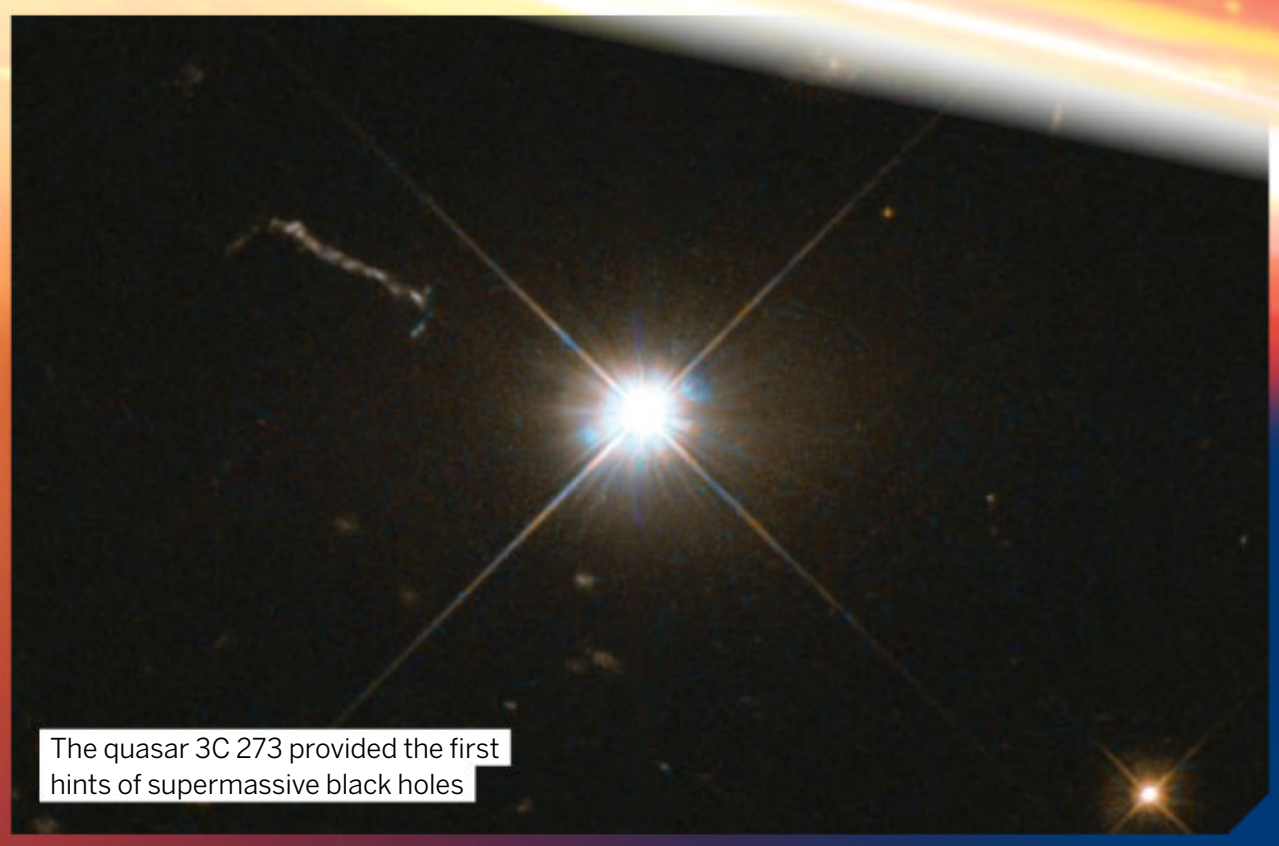
As a theoretical concept, black holes first made their appearance when scientists were thinking about gravity, particularly in the context of large objects such as stars. Gravity is a force that acts between particles of matter, tending to pull them closer and closer together. In everyday objects in the world around us, the force of gravity is counterbalanced by other physical effects such as electrostatic and nuclear forces – with the result that things maintain a finite size rather than collapsing down to a point. The same is true of stars like the Sun, where gravity is counteracted by fluid pressure. Even in an ultra-compact star like a white dwarf, where a mass similar to that of the Sun is squashed down to a planet-sized volume, there are other more exotic forces that come into play to stop them collapsing forever.

By the middle of the 20th century, however, scientists knew there was an upper limit to the amount of gravity that these exotic forces could resist. If a star was sufficiently massive to start with, it would eventually collapse all the way down to an infinitesimally small point. All the original mass would still be there, but compressed down to a state of infinitely high density. This sounded so impossible – particularly to mathematicians, who dislike having 'infinity' in their equations – that many thought some new kind of physics would come to the rescue to prevent the infinite collapse. But it didn't, and by the 1960s it was generally accepted that these mind-bending phenomena really were a possibility. It was around this time that they acquired the name by which we know them now: black holes.

13 BILLION LIGHT YEARS

The most distant known black hole is nearly at the edge of the observable universe

It may seem like a rather big leap to go from the idea of matter being compressed down to an infinitesimally small point to talking about a 'hole' in space – one that it's possible to fall into, but never climb out of. Yet this really is a logical step to take if we think about how gravity works. In the familiar case of Earth, we know that its gravitational pull gets stronger the closer an object is to its surface. That's why the International Space Station, 250 miles above the surface, has to whiz around at a very high speed in order to remain in orbit, completing a revolution in just 90 minutes. However, satellites at the geosynchronous altitude of 22,000 miles can move much more slowly,



The quasar 3C 273 provided the first hints of supermassive black holes

SUPERMASSIVE BLACK HOLES CAN ACCELERATE PARTICLES ALMOST TO LIGHT SPEED

taking a whole day to complete an orbit. There's another speed, around 40 per cent greater than orbital velocity, that's also of interest to spacecraft engineers. Known as 'escape velocity', it's the speed with which an object has to travel in order to break free of Earth's gravitational pull and head into space. And this doesn't only apply to Earth – all other astronomical objects have their own escape velocities. It's a quantity that, like orbital speed, increases the closer you are to the object, as well as increasing in proportion to the object's mass.

If black holes have a reputation for being 'dangerous', we can now see why this is. They have a lot of mass compressed into an infinitesimally tiny volume, which means that if we're not careful we can get very, very close to them. Being at such a short distance from such a massive object means that its escape velocity will be extremely high. In fact, there will be one particular distance at which the escape velocity equals the speed of light. Since nothing can travel faster than this speed, it means that the black hole is surrounded by a sphere of this radius, known as the 'event horizon', within which objects are trapped forever. Nothing can ever escape from inside the event horizon, not even light, and that's why black holes are called 'black'. As to why they're called 'holes'? We can imagine a three-dimensional hole, with a diameter equal to the event horizon, into which an object can fall with no hope of ever getting out again.

When people talk about the size of a black hole, they're almost always referring to the diameter of the event horizon. The thing that actually creates the black hole, the enormous concentration of mass at its centre that's sometimes called the 'singularity', actually has no size. But that's really only a technicality because you

Did you know?

The discoverers of Sgr A* won a Nobel Prize for it

The Event Horizon Telescope's first image of Sgr A*, released in 2022

TYPES OF BLACK HOLE

STELLAR-MASS BLACK HOLE

1 SOLAR MASS
RANGE: 5 to 100

These are classic black holes as they were originally theorised, resulting from the gravitational collapse of very massive stars at the end of their lives. There may be millions of these in the Milky Way alone, though they're usually only detectable when part of a binary system.

INTERMEDIATE-MASS BLACK HOLE

2 SOLAR MASS
RANGE: 100 to 10,000

Scientists believe that black holes in this mass range should exist, formed as a result of the merger of two or more stellar-mass black holes. Little is known about them because they're difficult to detect, but around 300 candidates have been observed.

SUPERMASSIVE BLACK HOLE

3 SOLAR MASS
RANGE: 10,000 to 1,000,000,000+

It's now known that the majority of galaxies have a single black hole of this type at or near their centres. These probably formed very early in the history of the universe and have subsequently grown in size by accreting surrounding stars and other objects.

SUPERMASSIVE COMPARISON

A look at some of the largest supermassive black holes that have been discovered so far

5 3C 273
Mass: **0.9 billion solar masses**
Distance from Earth: **2.4 billion light years**
The first quasar ever discovered, this is still the brightest one visible in our skies, bright enough to be seen even with a simple telescope, making it the most distant object observable by amateur astronomers.

4 CYGNUS A
Mass: **1 billion solar masses**
Distance from Earth: **760 million light years**
This galaxy is one of the strongest radio sources in the sky. As such, it was first observed by the earliest radio telescopes as far back as 1939, long before its true nature was understood.

3 MESSIER 87
Mass: **7 billion solar masses**
Distance from Earth: **53 million light years**
This supergiant elliptical galaxy is the largest member of the Virgo Cluster. Its central black hole made headlines in 2019 as the first black hole to be imaged by the Event Horizon Telescope.

WHEN BLACK HOLES PULL STARS APART, IT'S CALLED SPAGHETTIFICATION

DID YOU KNOW? When astronomers describe an object as 'massive', they're talking about its mass, not its physical size

1,500 LIGHT YEARS

Distance to the closest known black hole, Gaia BH1

1 TON 618

Mass: **40 billion solar masses**

Distance from Earth: **18.2 billion light years**

Tonantzintla 618, to give it its full name, is one of the most distant known quasars. Blasting out 40 decillion megawatts, or 140 trillion times as much power as the Sun, it's one of the brightest objects in the universe.

1

11 SOLAR SYSTEMS WIDE

2

2 OJ 287

Mass: **18 billion solar masses**

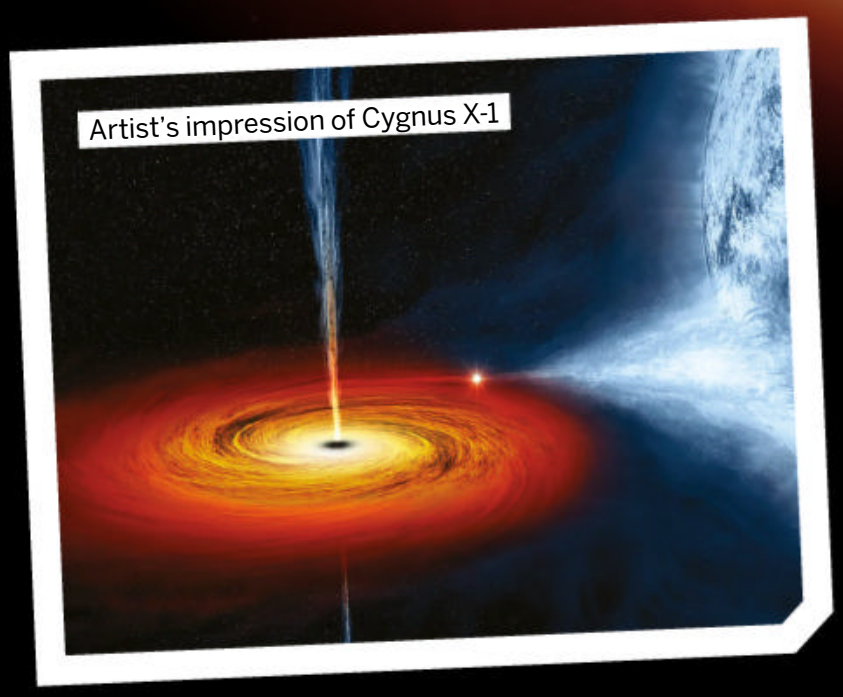
Distance from Earth: **3.5 billion light years**

This is another type of active galaxy, related to a quasar but more highly variable, called a BL Lacertae object. It actually contains two supermassive black holes, the second one a 'mere' 150 million times the mass of the Sun.

MILKY WAY MONSTER

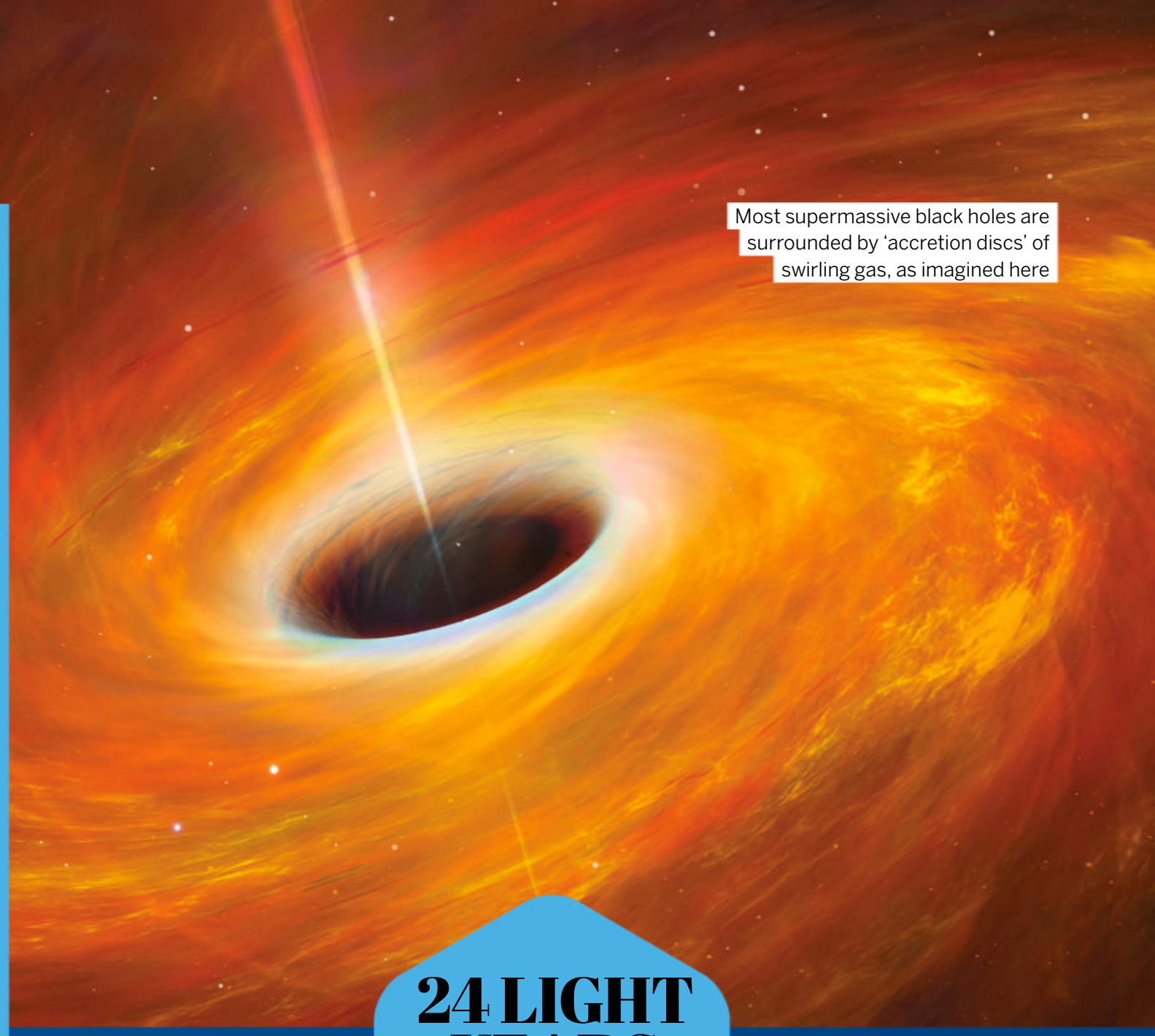
The Milky Way is fairly typical of the spiral galaxies we see in the universe around us. One characteristic shared by most galaxies is that the density of stars and other matter rises steeply towards the centre. This means there's always going to be a huge mass concentrated right in the centre, but it can be difficult to establish if this is a black hole or simply a very dense conglomeration of stars. The presence of a strong radio source, called Sagittarius A* or Sgr A*, right at the centre of the Milky Way implied there probably was a black hole there, but its existence was only clinched when astronomers noticed stars in that region orbiting around an invisible object at a third the speed of light.

Sgr A* is around 4,000,000 solar masses, with an event horizon 16,000,000 miles across


Artist's impression of Cygnus X-1

150+

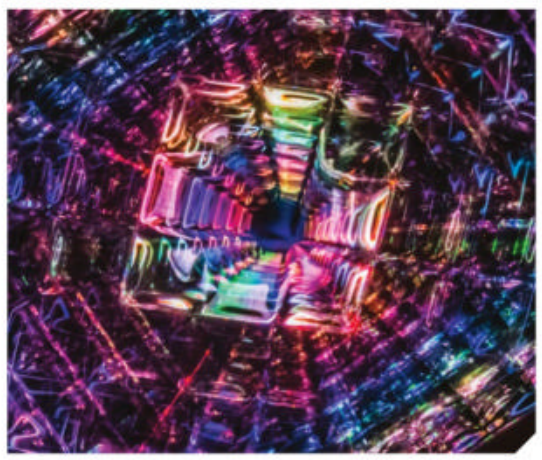
There are plenty of confirmed supermassive black holes with direct mass measurements



Most supermassive black holes are surrounded by ‘accretion discs’ of swirling gas, as imagined here

THE SMALLEST BLACK HOLES

Although no one has ever found one, it’s possible that very low-mass black holes exist in the universe. According to standard theories of cosmology, black holes of almost any mass might have been created in the first second after the Big Bang. Referred to as ‘primordial black holes’, the very smallest of these would have been unable to survive to the present day, but those above a trillion kilograms or so may well have done. This is roughly the mass of a typical asteroid, or of a mountain on Earth, yet a black hole of that mass would have an event horizon smaller than the size of a proton – the subatomic particle found in the nuclei of atoms. This is small enough that it would be subject to quantum-mechanical effects, and black holes of this size are sometimes referred to as ‘quantum black holes’.



Artist’s impression of a microscopically small quantum black hole

can never get anywhere near it. Even the event horizon itself isn’t a particularly large thing when compared to any ordinary object containing the same amount of mass. We can see this by trying to imagine what an escape velocity equal to the speed of light means. NASA’s Parker Solar Probe is currently orbiting about three solar diameters above the Sun’s surface at a speed approaching half a million miles per hour – and its escape velocity would be almost 50 percent faster than that. But even this is only around a thousandth of the speed of light.

It turns out that for a hypothetical black hole with the same mass as the Sun, the event horizon would be less than four miles across. If you were unlucky enough to be orbiting it at that distance, you’d have the entire mass of the Sun pulling you down into that small volume of space, and you’d have to travel faster than light if you wanted to escape from it.

Did you know?

An Earth-mass black hole would be 1.75 centimetres across

Up to this point, everything we’ve said about black holes has been purely theoretical. It’s a well-established theory that gives us strong reasons for believing that black holes can indeed exist... but if they do, how are we ever going to see them? After all, one of their defining characteristics is that no light, or any other form of radiation, can escape from them. Fortunately, though, there are a couple of ways in which a black hole can be detected, even if we can’t see it directly. One is by its gravitational effect on nearby stars, which will orbit around the black hole in a way that gives its presence away. Secondly, there’s the black hole’s effect on any gas and dust in its vicinity – while they won’t be instantly sucked into it in the manner of a Hollywood movie, they will swirl around it at high speed, becoming heated up to a very high temperature in the process. This superhot material then emits X-rays and other high-energy radiation, which can be detected using suitable instruments. It was in this latter way that the first serious black hole suspect, Cygnus X-1, was discovered in 1965. Years later, after a lot more data had been collected, it was confirmed to be one.

With a mass ten or more times that of the Sun and an event horizon around 50 miles across, Cygnus X-1 was a perfect match to theoretical predictions of what a black hole might look like if it was formed from the collapse of a high-mass star.

24 LIGHT YEARS

A relatively small distance separates two supermassive black holes in the galaxy B2 0402+379

But back in 1963, even before Cygnus X-1 was discovered, astronomers found a much more distant object, 3C 273, that they couldn’t explain at all. This turned out to be a quasar – a type of galaxy with an unimaginably powerful source of energy at its centre. After many years of study, it was eventually realised that this too had to be a black hole – but one of incredible size. It wasn’t merely ten times the mass of the Sun, it was getting on for a billion times its mass. Astronomers had discovered a supermassive black hole.

Quasars are one of several types of active galaxy, all of which blast out so much energy from their central regions that astronomers have known for some time that they must harbour giant black holes in order to power them. A more recent discovery, however, is that even an ordinary galaxy can have a large central black hole. In these cases there isn’t enough material falling into the black hole to generate the kind of radiation we see from active galaxies. Instead, that other method of detecting black holes comes into play, by observing the motion of stars orbiting around the black hole. By observing stars in the centres of ‘normal’ galaxies, super-powerful telescopes like Hubble and the James Webb Space Telescope can show that there must be supermassive black holes there too.

DID YOU KNOW? If a proton-sized, asteroid-mass black hole hit Earth, it would whiz right through it almost harmlessly

THE EHT'S GLOBAL NETWORK

Telescopes around the world working together

1 Atacama Desert, Chile 2 Pico de Valeta, Spain
3 Mauna Kea, Hawaii 4 Sierra Negra, Mexico
5 Mount Graham, Arizona 6 South Pole Station

60,000 ROTATIONS PER MINUTE

Black hole GRS 1915+105 spins on its axis at a terrific speed

SUPERMASSIVE MYTHS BUSTED

We bust some common misconceptions about these monstrous celestial objects

1 THEY'RE INSATIABLE EATERS

Black holes only swallow stars and other objects that get close enough to be pulled in by gravity; they don't go out of their way to find material to 'eat'. Plenty of stars happily orbit close to the black hole for millions of years without getting swallowed up.

2 THEY ARE INVISIBLE

While no light emerges from inside the black hole itself, they're far from invisible. Just outside the event horizon, there's often a disc of super-heated gas that can be a strong source of electromagnetic radiation. In fact, some black holes are among the brightest objects in the universe.

3 THEY'RE HUGE

This myth comes from misinterpreting the term 'supermassive', which refers to a black hole's mass rather than its size. In fact, black holes are very compact in size – much more so than any ordinary object, such as a dense star cluster, having the same mass.

4 THEY WILL SUCK EVERYTHING IN

This is probably the most prevalent myth of all, and is completely false. Black holes only interact with other matter through their gravitational pull, which until you get close to the event horizon works in exactly the same way as the gravity of any other object of the same mass.

5 THEY ARE SPACE-TIME PORTALS

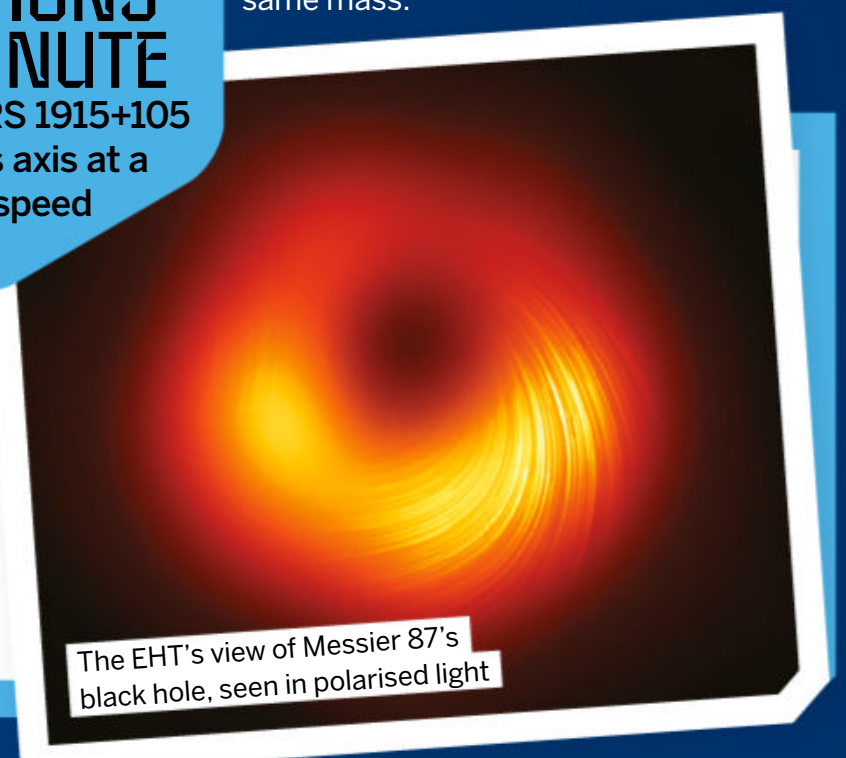
This myth has become popular through its appearance in numerous science-fiction movies. It's true that some scientists have proposed something like this in the past, but these are fringe theories for which there's no observational evidence, and thus they aren't widely accepted.

6 THEY CRUSH INFALLING OBJECTS

Paradoxically, falling objects don't feel the force of gravity, even the huge gravity of a black hole. But if you fell in feet first, the force on your feet would be much stronger than on your head – rather than being crushed, you'd be stretched and pulled apart.

THE EVENT HORIZON TELESCOPE

These days, it's not too difficult for astronomers to establish the existence of a supermassive black hole by observing its effects on the stars and other material surrounding it. But obtaining a direct image of a black hole is another matter. The biggest problem relates to what astronomers call 'angular resolution' – the ability of a telescope to see physically small objects a long way away. An example would be trying to image an orange on the surface of the Moon. It turns out that even the 'easiest' supermassive black holes – such as Sgr A* in our own galaxy or the giant one in Messier 87 – are about that level of difficulty. In order to take pictures of them, astronomers have to employ not just a single radio telescope, but a whole network of them all over the planet. This network is called the Event Horizon Telescope, or EHT.



The EHT's view of Messier 87's black hole, seen in polarised light

ENVIRONMENT

HOW EARTH STORES CARBON

Dive into Earth's carbon sinks and find out where the world's carbon comes from

WORDS SCOTT DUTFIELD

DID YOU KNOW? Carbon is the fourth most abundant element in the known universe

Carbon is one of the fundamental elements of life on Earth. It can be found in the atmosphere, forms part of the biological building blocks of every living organism on Earth and is trapped in the structures of rocks that form our planet's crust. Scientists estimate that Earth contains 1.85 quintillion tonnes of carbon, all of which moves through what's known as the carbon cycle. Through countless mechanisms of carbon storage and release, the planet has evolved a complex exchange system that continually cycles this essential element to sustain life.

During the billions of years that our planet has existed, this complex and intricate carbon cycle has formed to maintain atmospheric harmony. Several major players in the carbon cycle keep the exchange of 'carbon stock' ticking over. 'Carbon sinks', such as forests and oceans, commonly exchange carbon atoms in the form of atmospheric carbon dioxide. A carbon sink becomes a 'carbon pool' when it absorbs more carbon stock than it releases into the atmosphere. When the release of carbon is greater than its absorption, this is known as a 'carbon source' – a volcano being a good example. The process of taking carbon from one source and storing it for long periods is called carbon sequestration.

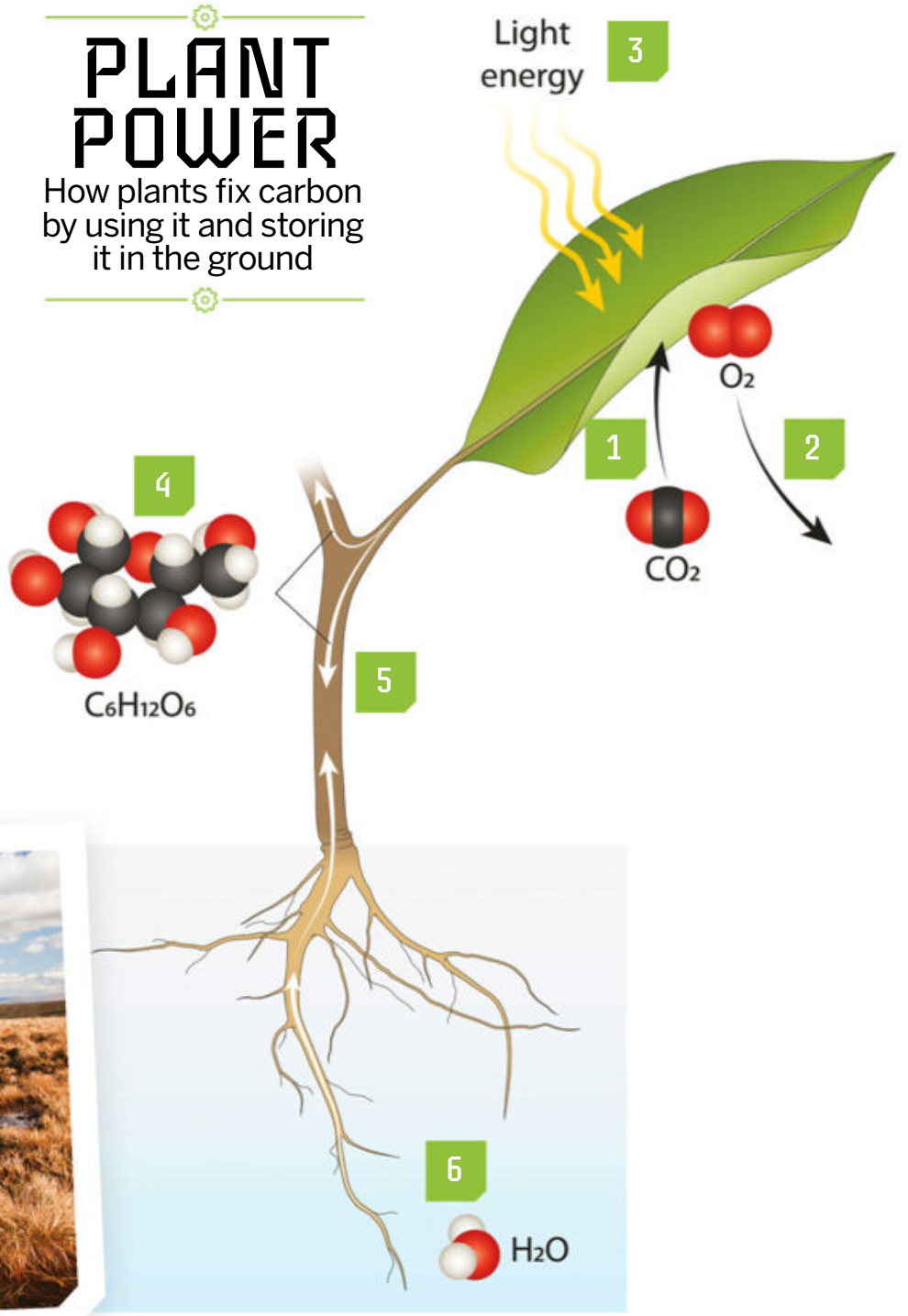
There are several ways that the world sequesters carbon. For example, one of the most well-known examples of carbon exchange is through photosynthesis and respiration. Plants extract carbon from the atmosphere, in the form of carbon dioxide, and use it to build more plant cells to grow. Similarly, when they need to break down sugars for energy, plants release carbon dioxide through respiration. Plants, like all life, hold onto the carbon in their biomass until they die and it is released into the soil through decomposition, or is passed into the bodies of other organisms that eat them. One plant can't store that much carbon, but together the world's forests absorb around 15.6 billion tonnes of carbon dioxide each year. Congo's tropical rainforest alone sequesters 600 million tonnes of carbon dioxide each year.

Did you know?
You are around 18 per cent carbon

Plants aren't the only living things with carbon-fixing powers. Phytoplankton drifting through the world's oceans also trap carbon

PLANT POWER

How plants fix carbon by using it and storing it in the ground



1 UPTAKE
Carbon dioxide enters plants through tiny holes on the underside of leaves called stomata.

2 OXYGEN RELEASE
As a byproduct of photosynthesis, oxygen is released into the atmosphere.

3 LIGHT ENERGY
The energy of sunlight stimulates tiny organelles called chloroplasts in the plants to convert the carbon dioxide and water into sugar.

4 GLUCOSE
Glucose is a simple sugar, each molecule of which contains six carbon atoms.

5 STORAGE
Glucose is used to build the bodies of plants, in which carbon atoms are stored.

6 ROOTS
When roots die or leaves fall to the ground and decay, carbon is released into the soil and becomes sequestered.

A peat hag at Loadpot Hill in the Lake District, UK

through photosynthesis. Plankton are part of a marine carbon storage system called the 'biological carbon pump', whereby the carbon they collect is passed through a chain of other organisms, gradually filtering down to the bottom of the ocean where it is stored. The world's oceans make up the largest carbon sink on the planet and hold a whopping 60 times more carbon dioxide than the atmosphere. All in all, it's estimated that around 100 billion tonnes of carbon is released and recaptured annually through the planet's different carbon sinks.

Maintaining harmonious levels of carbon stock in the global cycle is essential for life on Earth, especially in our atmosphere. Although the concentration of carbon dioxide in the atmosphere is just 0.04 per cent, it's our planet's most important greenhouse gas, absorbing radiation from the Sun for warmth. However, when levels of carbon dioxide become unbalanced, Earth's climate drastically changes. Should the world's supply of carbon dioxide suddenly be depleted, then Earth would be plunged into freezing temperatures of around -18 degrees Celsius at the surface. Too much carbon dioxide and Earth would burn up with an atmosphere of around 400 degrees Celsius, similar to the surface of Venus.

Levels of carbon stock at each point in the cycle can naturally fluctuate. However, since the Industrial Revolution in the 18th century, human activity has offset the balance in the carbon cycle. By tapping into the world's underground carbon pools in the form of fossil fuels, humankind has become an additional and prolific carbon source. Oil and coal are packed with the carbon from decayed prehistoric animals that died millions of years ago. When these materials are burned, the trapped carbon is released into the carbon cycle.

Industrial gas pollution isn't the only way that humans have been increasing atmospheric

The bodies of plankton send trapped carbon down to the depths of the ocean floor

3 ANIMALS
As living organisms, animals store carbon as biomass while they're alive and release it through respiration, waste and when their bodies decay.

2 FORESTS
The world's forests have around 861 billion tonnes of carbon sequestered.

4 MANTLE
The viscous layer of molten rock under the Earth's crust is called the upper mantle. It contains more than 10,000 times the carbon in Earth's atmosphere.

5 HYDROTHERMAL VENTS
Heat from pools of deep magma is released at hydrothermal vents. This causes dissolved carbon in the ocean to bind with oxygen to form carbon dioxide.

Did you know?
From 2000 to 2022, global tree coverage shrank by an eighth

BLUE VERSUS GREEN

The plants and trees that build the world's forests are often referred to as 'green' carbon sinks, relating to their ability to store carbon in their green biomass. But in recent years marine scientists have discovered the importance of 'blue' carbon sinks. Along tropical coastlines near the equator, mangrove forests act as a blue carbon sink. Unlike green carbon forests, these plants store the majority of their carbon in the soil and sediment around them. Scientists estimate that mangrove forests can store up to five times more carbon than some tropical forests and currently store around 10 billion tonnes of carbon globally.

Mangrove forests, along with seagrass and salt marshes, can store more carbon that tropical and boreal forests

DID YOU KNOW? Carbon makes up just 0.032 per cent of Earth's crust and upper mantle

WHERE IS IT CAPTURED?

The sources, sinks and pools that keep carbon moving through the world

CARBON DIOXIDE TRANSFER

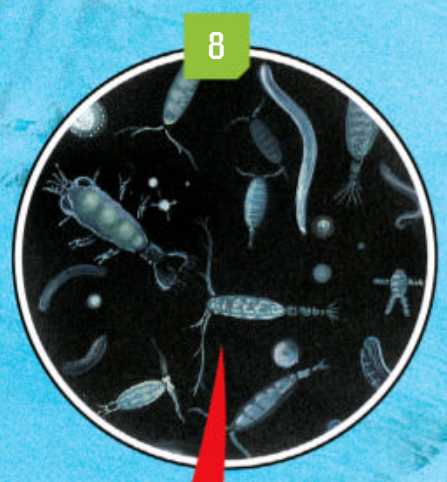
PHOTOSYNTHESIS

1 OCEANS
More than 40,000 billion tonnes of carbon is stored in the ocean.

10 INDUSTRY
Globally, humans release around 37 billion tonnes of carbon dioxide into the atmosphere by burning fossil fuels.

8 PLANKTON
Carbon-capturing phytoplankton, along with the zooplankton that consume them, fall to the seafloor and store carbon as sediment.

7 VOLCANOES
Carbon-rich molten rock is ejected through Earth's crust as volcanoes, releasing carbon dioxide into the atmosphere.



6 INTO THE EARTH
The carbon trapped in rocks and sediments on the seafloor is fed beneath the Earth's crust into the mantle at points where tectonic plates pass over each other.

9 FROZEN SINKS
Around 6 billion tonnes of carbon is locked up in the world's frozen ice sheets and glaciers.

11 SOIL
There are 1,500 billion tonnes of carbon in the first metre of soil worldwide, in the form of organic matter.

"Levels of carbon stock at each point in the cycle can naturally fluctuate"

One of the world's largest forest carbon sinks, the Amazon

carbon dioxide. By removing or altering carbon pools, humans prevent them from doing their job and leaving carbon in the air. For example, the world's peatlands are some of the most efficient carbon sinks around. Formed from waterlogged land and humid rainforests, these boggy areas create an environment in which plant matter doesn't completely decay, trapping all the plant's carbon with it. For peatlands to remain as carbon pools, they need to stay wet. However, deforestation in the tropical peatlands especially causes peatlands to dry up and release their carbon back into the atmosphere. Similarly, due to its high carbon content, peat has been used as a fuel source and burned, releasing fossil fuel levels of carbon into the atmosphere.

The world's natural carbon sinks can't keep up with the excess of carbon dioxide being released into the atmosphere, currently around 47 per cent higher than levels before the Industrial Revolution. The consequences of this are changing climates and increasing global temperatures due to carbon dioxide's warming greenhouse effect. Scientists have estimated that we would theoretically need an additional billion hectares of trees to store excess carbon and stop the global temperature increasing beyond 1.5 degrees Celsius by 2050. If the average global temperature exceeds that of pre-industrial times by more than 1.5 degrees Celsius, the world would face drastic climatic changes, such as increases in extreme weather and rising sea levels.

To combat the effects of human-produced carbon dioxide and reduce its levels in the atmosphere, scientists have made many attempts to artificially sequester carbon. In 1999, the Southern Ocean Iron RElease Experiment (SOIREE) explored the impact of iron fertilisation on phytoplankton growth and subsequently increased carbon capture. Iron fertilisation naturally occurs when strong winds blow sediment from arid deserts into coastal waters. Phytoplankton use iron as a micronutrient to grow and reproduce. However, the phytoplankton off in the South Ocean near Antarctica aren't exposed to natural iron fertilisation, something

THE IMPORTANCE OF PEAT

The consequences of peatland destruction

1 PEAT BOGS

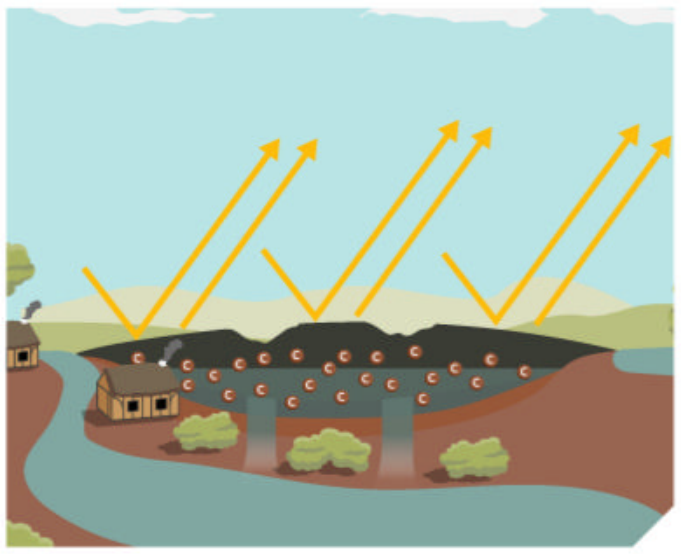
Peat is formed from partially decayed plants and other organic matter accumulating over thousands of years.

2 DESTRUCTION

Peat bogs are destroyed for fuel or for agricultural space. In some parts of the world, such as Indonesia, peatland relies on trees to shelter it from sunlight's heat.

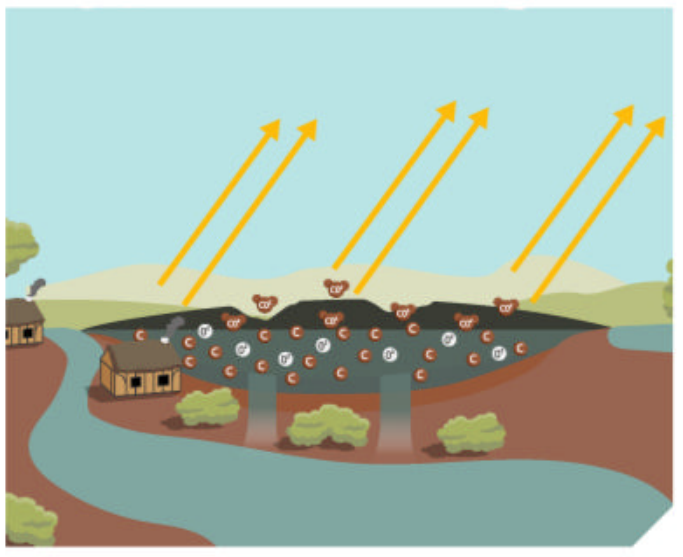
3 DRAINAGE

The removal of plant life and intentional drainage of peatlands leaves them dry and exposed to the Sun.



4 WARMING UP

Exposed and dry peatland heats up under direct sunlight. An increase in temperature allows atmospheric oxygen to enter the peatland and bind with the locked-up carbon.



5 RE-IGNITING DECOMPOSITION

The newly introduced oxygen causes the undecayed plant life to restart decomposition and release the carbon as carbon dioxide.

6 PEAT FIRES

The combustible nature of carbon-packed peatlands means they are also at risk of igniting, accelerating the release of carbon dioxide.

DID YOU KNOW? The word ‘carbon’ comes from the Latin word ‘carbo’, which means ‘charcoal’

scientists saw as an opportunity to increase plankton populations.

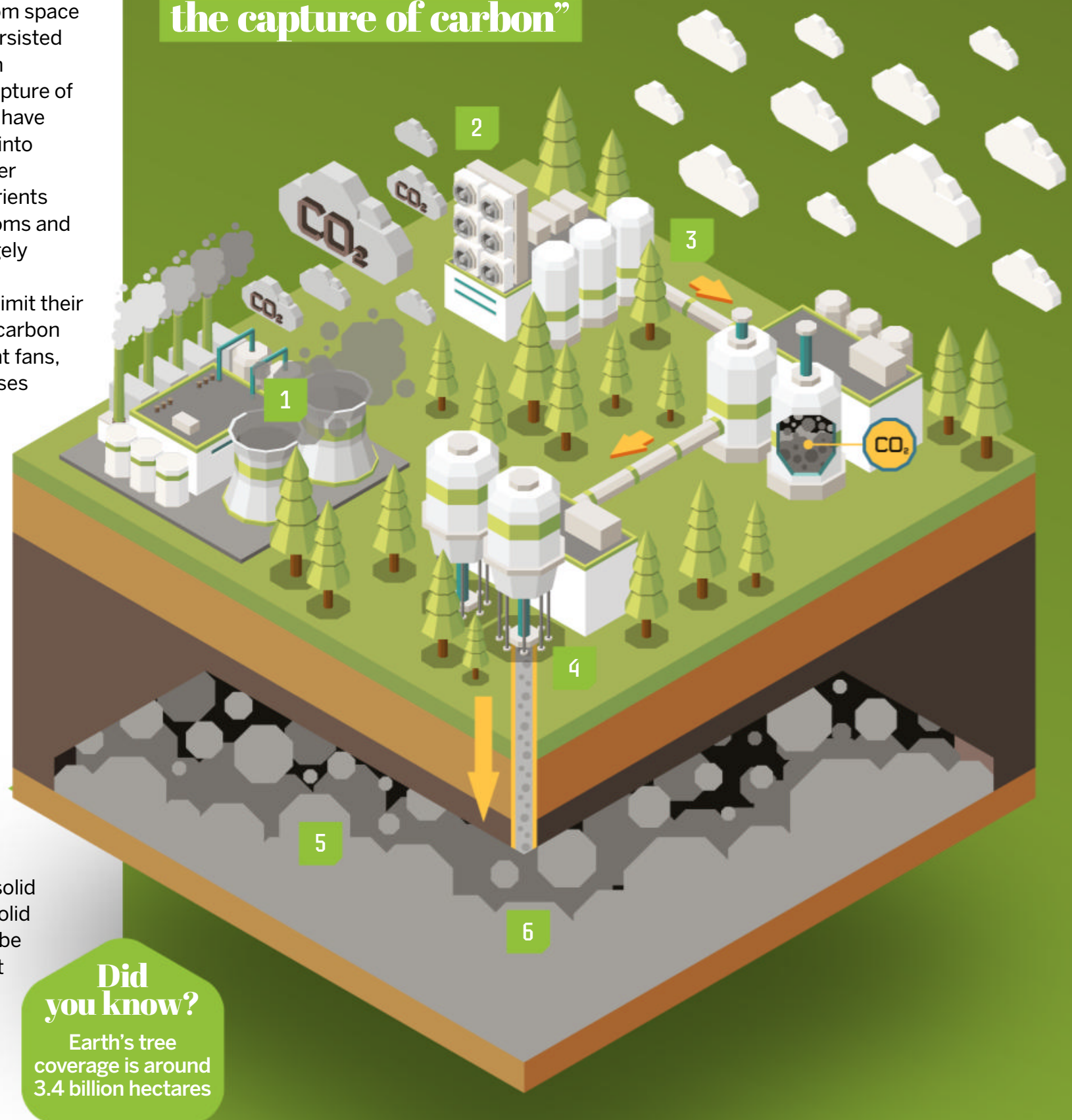
The experiment involved dumping large amounts of iron into the polar waters of the Southern Ocean and watching a plankton bloom. A bloom that could be seen from space formed in the Antarctic waters and persisted for 40 days, which suggested that iron fertilisation could help facilitate the capture of carbon. However, subsequent studies have called the practice of iron fertilisation into question. Fears over its impact on other ecosystems that rely on the micronutrients guzzled up by artificially fertilised blooms and their carbon-fixing efficiency have largely halted further iron fertilisation.

Heavy industries are attempting to limit their environmental impact through direct carbon capture and storage (CCS). Using giant fans, air is pumped into containers and passes through a material called a sorbent. Sorbents are designed to absorb specific molecules in liquids and gases, such as carbon dioxide, and hold onto them. Once the sorbent is saturated with carbon dioxide it is heated up to 100 degrees Celsius. By heating the sorbent, the trapped carbon dioxide is released and re-directed into storage tanks. The stored carbon dioxide can either be permanently stored underground or used as an ingredient in other industries, such as making plastics and graphene construction.

Similarly, emerging ‘calcium looping’ technology uses calcium oxide sorbents in the flues of cement plants to convert carbon dioxide into solid calcium carbonate. Not only can the solid carbonate be physically stored, it can be converted back into a gas by heating it to around 950 degrees Celsius. In 2023 there were around 395 CCS facility projects in the works globally, with just 43 fully operational. The largest is the Alberta Carbon Trunk Line (ACTL) in Canada, which can capture and store 14.6 million tonnes of carbon each year.

Shell’s carbon capture and storage facility in Alberta, Canada

“Iron fertilisation could help facilitate the capture of carbon”



Did you know?

Earth’s tree coverage is around 3.4 billion hectares

ARTIFICIAL STORAGE

How humans are mimicking carbon sinks

1 INDUSTRY
Burning fossil fuels for energy production and metal manufacturing are among the largest emitters of carbon dioxide in the world.

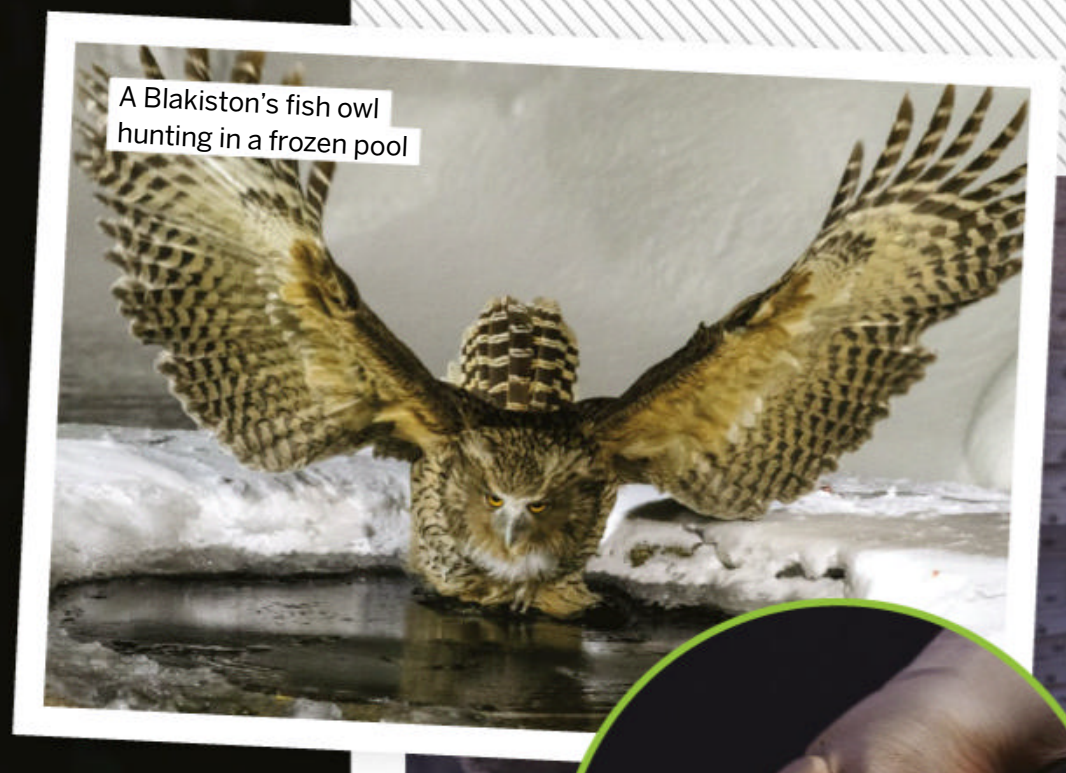
2 CAPTURE
Fans around industrial areas gather carbon dioxide and ‘capture’ the molecules in filters called sorbents.

3 COMPRESSION
Once the carbon dioxide is released from the fan’s sorbents, it’s heated and compressed to a fluid state for transport.

4 INJECTION
Through a network of pipes, pressurised carbon dioxide is injected into rock formations underground.

5 STORAGE
Carbon dioxide is often stored in natural gas reservoirs, saline aquifers or depleted oil stores.

6 DEPTH
Captured carbon is typically stored at least 0.62 miles underground.



A Blakiston's fish owl hunting in a frozen pool

HOW OWLS HUNT

Why these birds are among the most precise predators in the world

WORDS SCOTT DUTFIELD

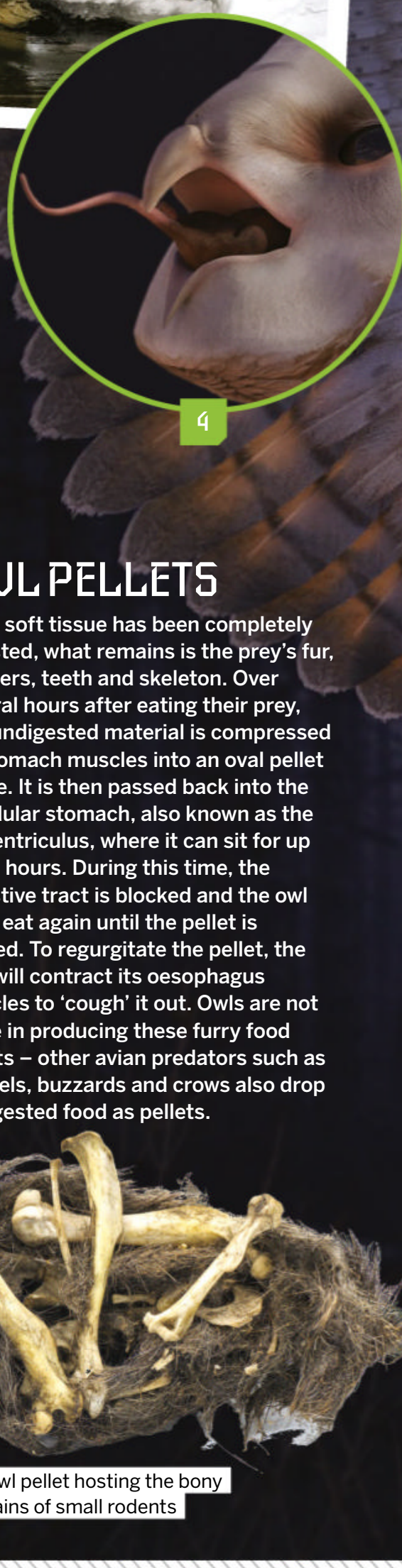
Known as a symbol of wisdom and intellect, owls are some of the most clued-up killers in the animal kingdom. The majority of owls are nocturnal ambush hunters. Waiting perched on a low branch or fence post, owls use their amazing sight and hearing to locate prey, such as small mammals, before quickly swooping to the ground to snatch them up, or grabbing flying prey, such as insects or small birds, in midair. Hunting during the night means that owls have to be equipped with night vision. Like the human eye, owls have optical cells called rods and cones. Rods recognise light, while cones capture colour. However, in an owl's eye there are far more rods than cones so they can spot their prey in very low light.

But what can razor-sharp talons and superb night vision amount to if prey can hear a predator coming from a mile away? Unlike other birds of prey, owls have evolved wings with feathers that have comb-like serrations on the leading edge of each feather, which break up the air as it flies. They also have a fringed tailend to streamline the air as it moves over the wings, absorbing some of the sound. Each of the feathers also has a velvety, compact structure that can dampen the sound of their wings as they flap them in the air. These sound-reducing adaptations make some species, such as the great horned owl (*Bubo virginianus*), virtually silent while it flies.

Did you know?

Owls first appeared around 60 million years ago

Along with ambushing their prey from a perch, some owl species will employ slightly different hunting techniques. For example, barn owls (*Tyto alba*) hunt using a technique called 'quartering' during the day, where the bird flies over fields in methodical lines to spot panicked mammal prey below. Meanwhile, the Blakiston's fish owl (*Ketupa blakistoni*) seeks water-bound prey. Found only in select areas of northeast Asia, these owls inhabit areas near year-round open water sources that are neighboured by woodlands. To snap up a fish supper, these owls swoop from the sky and use their talons to snatch fish from near the surface and have even been seen wading through the water to find food.



4

OWL PELLETS

Once soft tissue has been completely digested, what remains is the prey's fur, feathers, teeth and skeleton. Over several hours after eating their prey, this undigested material is compressed by stomach muscles into an oval pellet shape. It is then passed back into the glandular stomach, also known as the proventriculus, where it can sit for up to 20 hours. During this time, the digestive tract is blocked and the owl can't eat again until the pellet is passed. To regurgitate the pellet, the bird will contract its oesophagus muscles to 'cough' it out. Owls are not alone in producing these furry food pellets – other avian predators such as kestrels, buzzards and crows also drop undigested food as pellets.

An owl pellet hosting the bony remains of small rodents

DID YOU KNOW? There are more than 200 different species of owl in the world

A WISE PREDATOR

Discover the tools that make owls formidable hunters and see how they digest their food

1 EYES
Instead of spherical eyes, owls have large 'eye tubes' that extend far into their skull, letting in heaps of light for great night vision.

4 PIERCING BEAK
The beak of an owl is curved downwards, not only to increase the bird's field of view, but also to hook into the bodies of its prey.

3 SOUND BUSTERS
Velvety feathers with serrated edges give these birds silent passage through the air.

5 CROPLESS
Unlike many birds, owls do not have a crop, which is a thinly walled pouch of tissue that allows birds to store food quickly and digest it later.

8 ABSORPTION
The digested food passes through the bird's small and large intestines where nutrients and water are absorbed.

2 CLAWS
Owls have zygodactyl feet, meaning they have two toes on the front and two on the back – perfect for wrapping around the bodies of small animals.

6 GLANDULAR STOMACH
Food passes through the oesophagus and into the glandular stomach, where enzymes are released that begin to break down soft tissue.

7 GIZZARD
This 'second stomach' is where the majority of digestion takes place. It acts like a sieve, leaving the non-digestible material behind.

The ear tufts of the long-eared owl are more for decoration than sound detection

ASYMMETRICAL HEARING

Famed for their ability to move their heads 270 degrees, owls swivel their heads in response to different sounds detected by their asymmetrical ears to pinpoint their prey. Looking a little lopsided, an owl's ears are positioned at different heights, with the left much lower than the right. The left ear is more adept at picking up sounds emanating from the ground, while the right can detect sound more readily from up above. There's also a delay between the two ears, meaning a sound made on the left is heard by the left ear slightly before the right. The owl then moves its head towards the sound, and when the sound is heard without a delay, the bird knows the noise is dead ahead. There are also many species, such as the long-eared owl (*Asio otus*), which present long feathers on either side of their heads, called ear tufts or 'horns'. Although these feathers look like they are a part of the animal's ears, they are mainly used in communication with other owls and as part of camouflage.

WHY IS THE DEAD SEA DEAD?

This huge body of water is largely lifeless because of one crucial factor

WORDS **AILSA HARVEY**

The Dead Sea, located between Israel and Jordan, is a landlocked lake with a salt concentration so high that it holds no visible life. It has the lowest elevation of any body of water on Earth at more than 400 metres below sea level. It began its formation around 3 million years ago, when Earth's tectonic plates moved apart beneath the region. This caused a depression in the land, which filled up with seawater as it was connected to the Mediterranean Sea. However, over the next million years, further tectonic activity caused the land to the west of the Dead Sea to lift upwards, separating the Dead Sea from the coastline and turning it into a lake. Being isolated meant that the Dead Sea's water was now trapped. Water could evaporate out of the basin, but the salt was left behind.

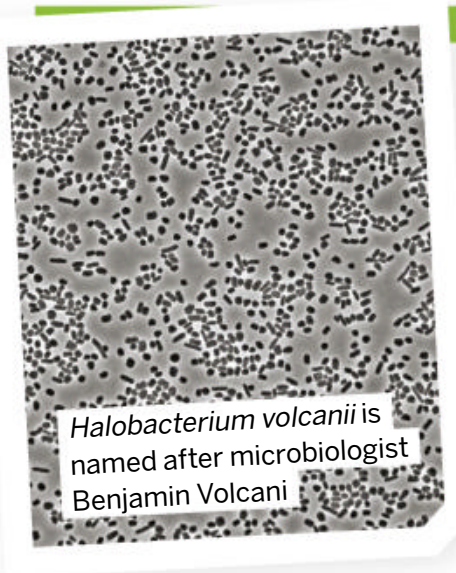
The Jordan River, which connects to the Dead Sea, deposits minerals into the basin. With low rainfall and high evaporation rates, over time the salt level has accumulated and become hypersaline. This means it is much saltier than the other seas, killing any fish, plants and other animals that end up in its waters. In this incredibly salty water, bathing tourists find that they are extremely buoyant. This happens because the salt makes the water much more dense than their bodies and holds them up in the water.

SEA SEPARATION

How the Dead Sea has changed over recent years

1 1972: UNIFIED BASIN

The water level of the Dead Sea has fluctuated over time. In these images, the darker shades of blue show deeper water. In 1972 the Dead Sea comprised one basin, with the southern part beginning to split into a separate basin.



Halobacterium volcanii is named after microbiologist Benjamin Volcani

© Wikimedia Commons/Granitehead1

EXTREMOPHILES ONLY

Not many life forms can survive in the Dead Sea, but it's not completely dead. Some single-celled microorganisms thrive in the high-salt environment. These are called halophilic organisms, and they have evolved to survive in places where other life can't. Many halophilic bacteria produce organic compounds called osmolytes that prevent water loss from their cells. One species of bacteria that has been found in a sample from the Dead Sea is *Halobacterium volcanii*. This bacterium contains proteins that remain stable in high-salt conditions.

DID YOU KNOW? The Dead Sea's salt concentration is ten times higher than the ocean's

3 2011: PLOTTING SALT PANS

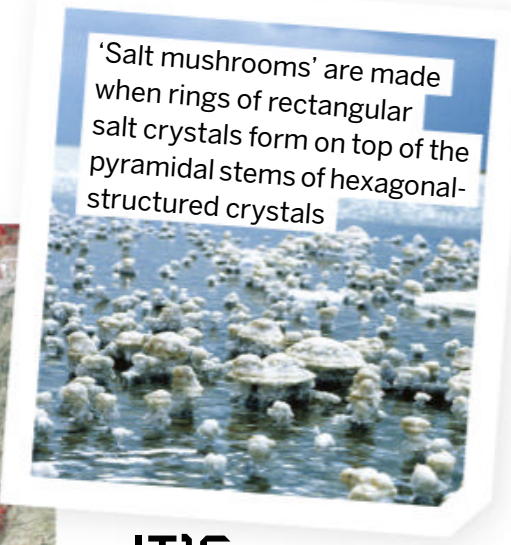
People turned the southern basin into salt evaporation pools for the mining of sodium chloride and potassium salts. These salts can be used to make widely used materials such as polyvinyl chloride, a high-strength synthetic plastic.

Did you know?

The Dead Sea has 34 per cent salinity

2 1989: BASIN SEPARATION

The Dead Sea lies over a tectonic plate boundary, where the African and Arabian plates meet. The tectonic activity, caused by Africa and Asia slowly pulling apart from each other, altered the shape of Earth's crust in this region. This, alongside a reduction in water level, caused a southern basin to split from the Dead Sea.

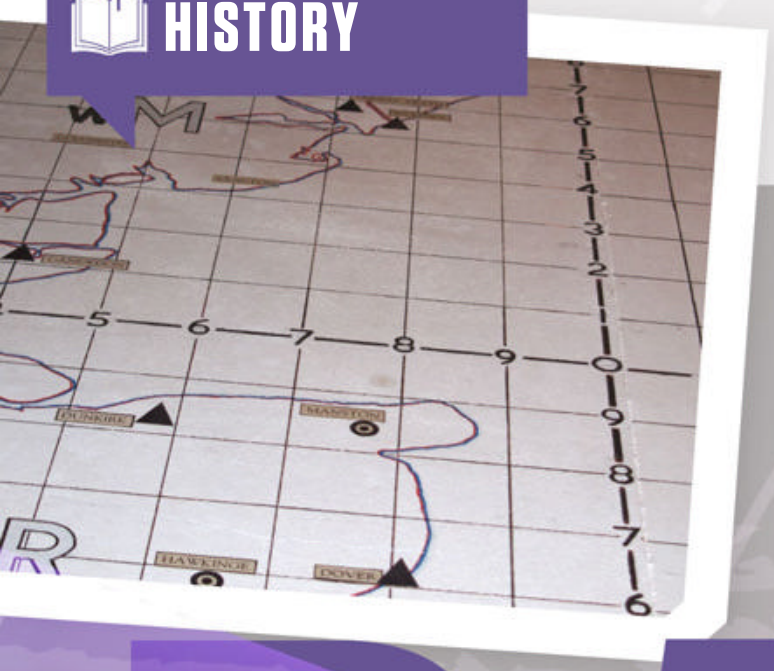


'Salt mushrooms' are made when rings of rectangular salt crystals form on top of the pyramidal stems of hexagonal-structured crystals

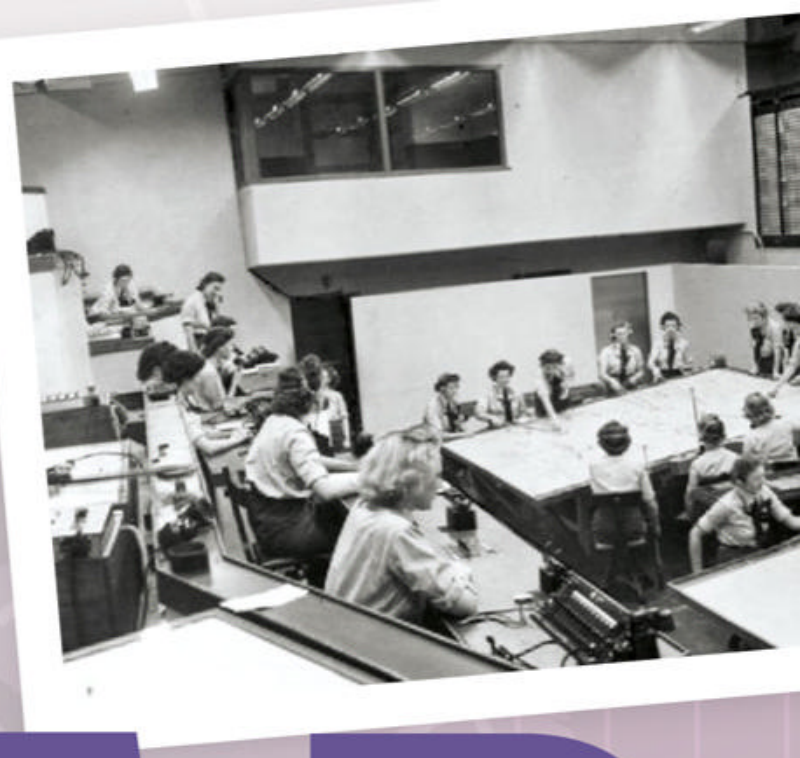
IT'S SHRINKING

The Dead Sea itself is dying, with the water level dropping around one metre every year. Compared to its condition just 50 years ago, the sea is about 15 per cent shallower and has a third of the surface area. Part of this change is human-impacted as water that would naturally replenish the Dead Sea is diverted elsewhere. The surrounding areas of Israel, Jordan and Syria are largely dry landscapes, so the region's natural water sources are needed for irrigation and drinking water. At the edges of the Dead Sea, where salty water used to lie, there are mesmerising salt sculptures that have dried in place, including pebble and chimney shapes. The different mineral ions in the Dead Sea cause salts to naturally crystallise into a range of structures.

The Dead Sea is so buoyant, visitors feel as if they're sitting on the water



HOW RADAR WAS INVENTED



WORDS SCOTT DUTFIELD

The scientific discoveries and mechanical milestones that led to the creation of one of the world's most revolutionary technologies

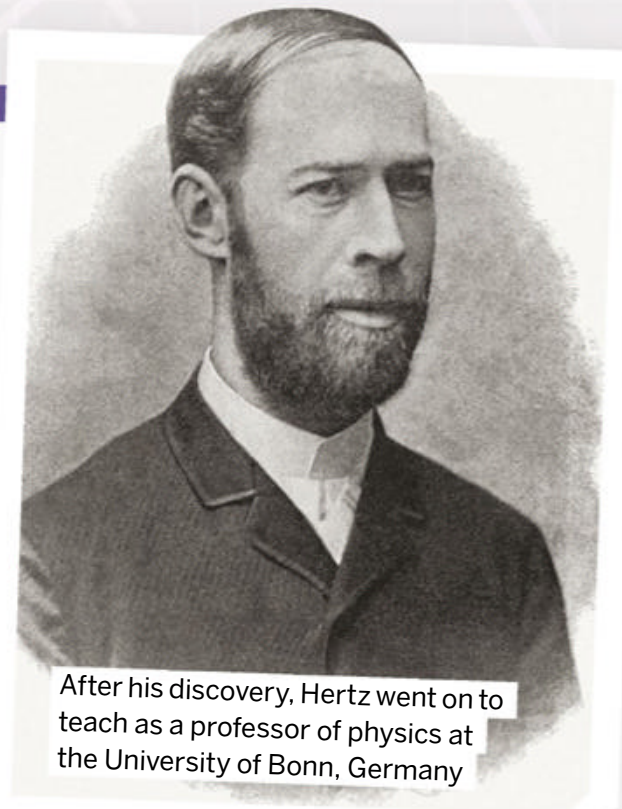
FINDING RADIO WAVES

1865 In the late 1800s, German physicist Heinrich Hertz made a discovery that would change the world forever. Before Hertz' discovery, Scottish physicist James Clerk Maxwell had predicted the existence of electromagnetic radiation in 1865 in his paper *A Dynamical Theory of the Electromagnetic Field*, in which he described electric and magnetic fields moving in waves at equal speeds.

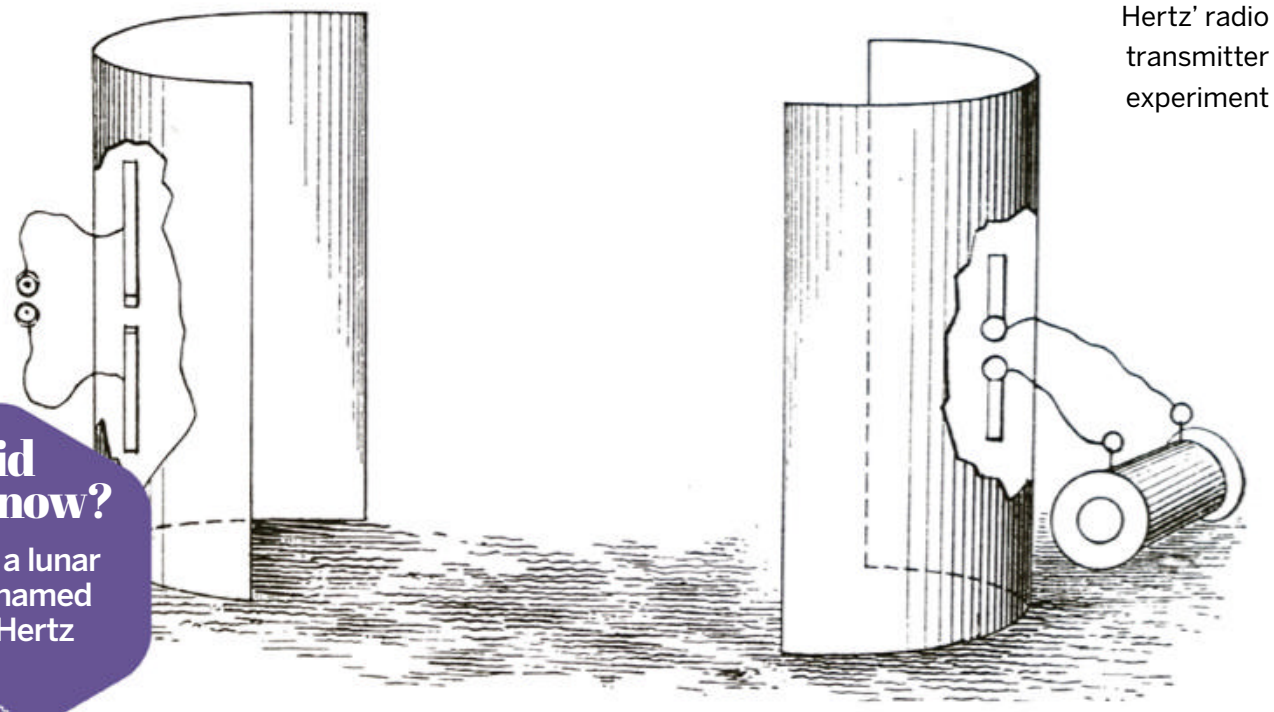
To put Maxwell's theory to the test, Hertz set up a simple home experiment to produce electromagnetic waves. Hertz used an induction coil, a type of electrical transformer, and a Leyden jar as the first capacitor to create an electrical current. The induction coil and Leyden jar were then connected to a pair of copper wires attached to two metal plates. Along each wire and sitting between the metal plates were two metal spheres. A short gap of air, called a spark gap, was left between the two spheres.

When a current was passed through the copper wire, the air in the spark gap became ionised and generated an electrical spark that jumped between the two spheres. Along with the spark, Hertz discovered that the predicted electromagnetic waves had also been released by using a receiver made from a metal loop with a similar spark gap. When the waves reached the loop, another spark was generated in the receiver's spark gap. This signified the existence of electromagnetic waves, which at the time became known as Hertzian waves, later renamed radio waves.

"Hertz discovered that electromagnetic waves had also been released"



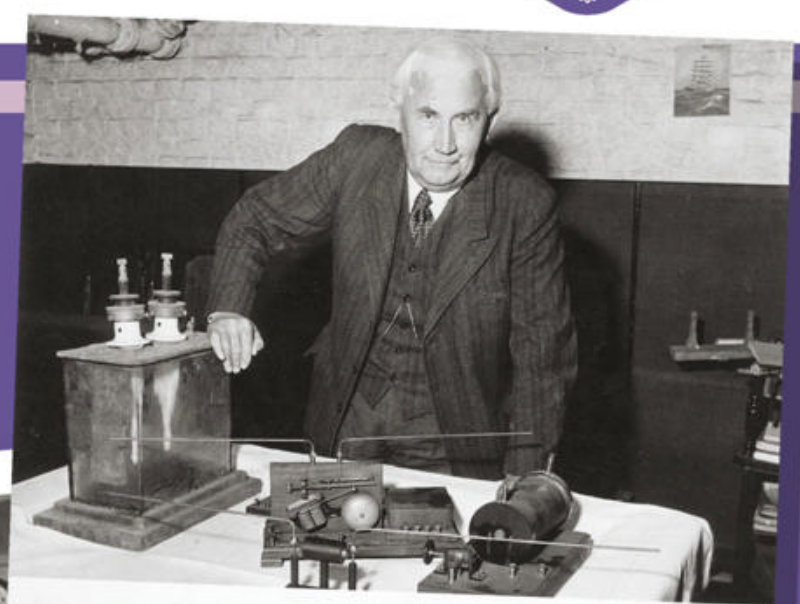
After his discovery, Hertz went on to teach as a professor of physics at the University of Bonn, Germany



An illustration of Hertz' radio transmitter experiment

Did you know?

There's a lunar crater named after Hertz



THE FIRST 'TELEMOBILOSCOPE'

1903 Armed with the knowledge of radio waves and how to find them, German inventor Christian Hülsmeyer created the first device that used radio waves to detect an object's distance and position.

In 1903, Hülsmeyer patented the 'telemobiloscope', a transmitter-receiver system that could detect the presence of large metallic objects such as ships. The telemobiloscope used two spark gaps and an induction coil to emit a radio frequency. The radio waves were directed using an antenna that could be moved 360 degrees. The returning radio waves were received by a circular antenna that was connected to a device called a 'coherer'. This was a glass tube packed with metal filings. When a current was passed through the tube, these filings clumped together, completing an electrical circuit and ringing an attached bell.

Hülsmeyer intended for the device to be used as a way of preventing ships from colliding with one another. When the telemobiloscope was pointing towards a river, the emitted radio waves would bounce off the metal hulls of passing ships and return to the antenna, causing the bell to ring. But although Hülsmeyer's invention could detect the presence of a ship, it couldn't be used to measure its distance from the transmitter.

A pair of acoustic mirrors in Kent, UK

ACOUSTIC MIRRORS

1916 While early radar technology was still finding its feet, much of Europe had been catapulted into World War I. The need for a technology that could detect advancing enemy aircraft had never been so crucial. As the precursor to radar, the British Armed Forces invested in 'listening ears' known as acoustic mirrors.

Invented by Major William Sandome Tucker, the director of acoustical research for the Air Force, acoustic mirrors were giant concrete half-spheres used to pick up the sound waves of flying engines, amplify them and bounce them to a microphone. Like electromagnetic waves, sound waves can be reflected and focused to a partial point. The shape of the mirrors caused the sound waves to reflect off the back of the half-sphere and hit the microphone situated in its centre. A vigilant soldier would then sound the alarm when the mirrors tuned in to the sound of enemy threats in the sky.

Acoustic mirrors could give the military a 15-minute head start to prepare for an oncoming attack. However, on the precipice of a second world war, the acoustic mirrors that lined part of England's south coast were abandoned to give way for the very first military radar stations.

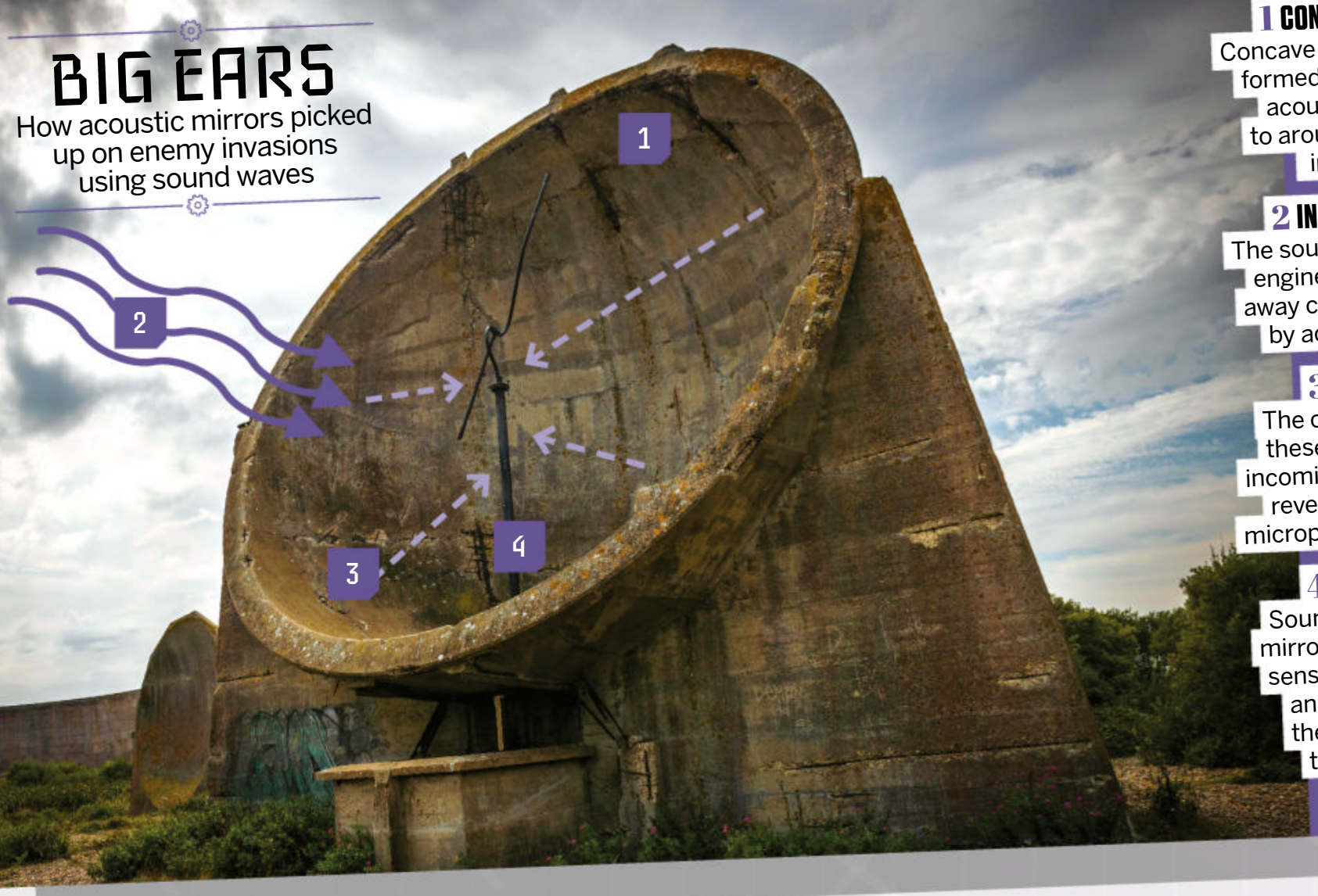
THE DAVENTRY EXPERIMENT

1935 Hülsmeyer had already proven the ability of radio waves to detect ships, but its use in detecting flying objects was yet to be seen – until British inventors Robert Watson-Watt and Arnold Wilkins conducted a pioneering experiment in Daventry, UK. Watson-Watt was head of the Radio Research Station in Slough. During his time at the station, he and Wilkins showcased how radio waves could be used to detect aircraft. In a field experiment, the pair built several posts suspending wires connected to a receiver in the back of a van. The radio waves came from BBC broadcast transmitters near Daventry. When a Handley Page Heyford bomber flew by, the field-bound receiver not only detected its flight, but its eight-mile distance. Watson-Watt and Wilkins' achievement ignited radar research in Britain, and the government approved the construction of new coastal radar stations to detect invading aircraft.

Watson-Watt experimenting with a kite and a wireless radio transmitter

BIG EARS

How acoustic mirrors picked up on enemy invasions using sound waves



1 CONCRETE MIRROR
Concave bowls of concrete formed the shape of an acoustic mirror, up to around four metres in diameter.

2 INCOMING SOUND
The sound of fighter plane engines up to 25 miles away could be picked up by acoustic mirrors.

3 REFLECTION
The concave shape of these mirrors caused incoming sound waves to reverberate and hit a microphone at the centre.

4 MICROPHONE
Sound detected in the mirror was picked up by sensitive microphones and transmitted to the headphones of their operators.

DID YOU KNOW? In 1940 the United States Navy coined the term radio detection and ranging, shortened to radar

CODENAME CHAIN HOME

1935 to 1941

With word that the German military might bring 'death-ray' radio technology aboard their fighter planes to a second world war, Britain quickly constructed coastal radar stations to spot aircraft before they crossed its shores. Known under the codename 'Chain Home', it was a network of transmitter antennae and receiver stations for a giant radar system that could detect incoming aircraft from around 100 miles away. The transmitter antennae sent long pulses out into the English Channel to bounce off any incoming enemy aircraft and return to the receiver station. The encounter would then appear on a radar display, alerting the operator to the presence of the aircraft. This helped give the Royal Air Force enough time – around 20 minutes – to jump into fighter planes and face the enemy before they had the chance to reach land. By 1939 Britain had 18 Chain Home radar stations, and by the end of World War II, 53 had been constructed.

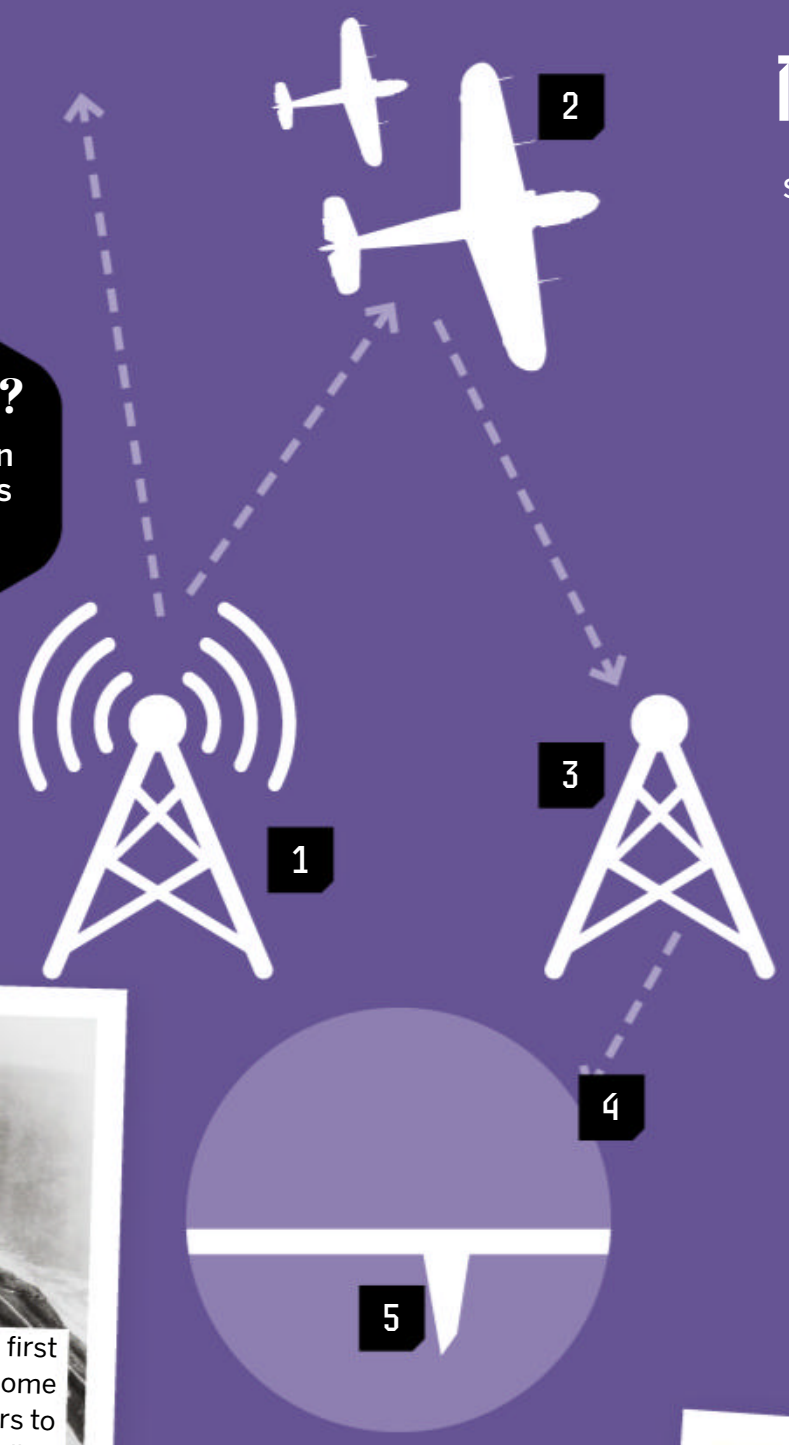
Did you know?

By 1938, Chain Home stations operated 24 hours a day

One of the first Chain Home radar towers to be installed

RADIO BLIPS

How the Chain Home radar system spotted enemy aircraft



1 TRANSMISSION
Pulses emitted from 110-metre transmitter towers flooded large areas of the coast of England towards continental Europe with radio waves.

2 BOUNCED WAVES
When the radio waves hit enemy aircraft, they were reflected and bounced back towards the station.

3 RECEIVER
The radio waves were detected by receiving aerials at the Chain Home stations.

4 BLIP
When an aircraft was detected by radio waves it appeared on a display screen as a spike on a horizontal line, called a 'blip'.

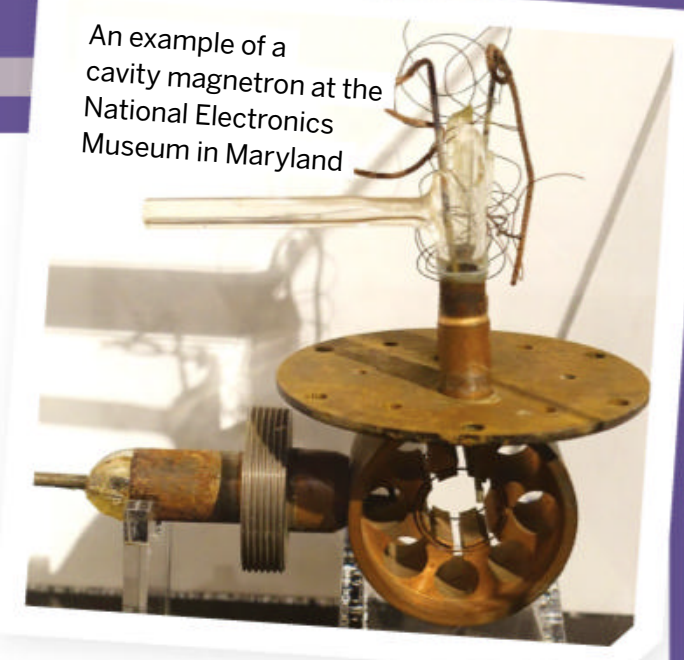
5 POSITION
Operators used the position of the blip on the line, along with its size, to determine its distance and placement in the sky.

MOVE ASIDE FOR THE MAGNETRON

1940 Although revolutionary, Chain Home wasn't without its limits, especially its range of detection. Looking for a way to extend the reach of radar, British physicists John Randall and Henry Boot of the University of Birmingham invented a new type of radar called the cavity magnetron.

The device was made from a piece of cylindrical metal with a negatively charged electrode, or cathode, running through a central hole. Surrounding the cathode was an anode – positively charged electrodes in a series of holes, or 'cavities'. When power was passed through the cathode, a magnetic field emerged around the device and electromagnetic waves radiated from the anodes. These were microwaves, which were much shorter in length than radio waves – just ten centimetres compared to the up to 13-metre wavelength of radio wave radar. For radar, transmitters that use shorter wavelengths are sensitive to detecting targets at longer ranges, and they can be produced in smaller and less expensive devices.

The cavity magnetron was small and mighty. However, Britain's manufacturing industry at the time couldn't sustain mass production of the device. Looking across the pond, Britain turned to America, which had not yet entered the war, for help. Having made the trip on a ship safely across the Atlantic, a Welsh physicist named Edward Bowen revealed the magnetron technology to the Americans. Seeing the potential for the device and its impact on military success, President Franklin D. Roosevelt approved funds to establish the Radiation Laboratory at the Massachusetts Institute of Technology (MIT) to replicate the new microwave radar. These new radars were adapted for compact units installed on aircraft or large truck-mounted devices for long-range detection.



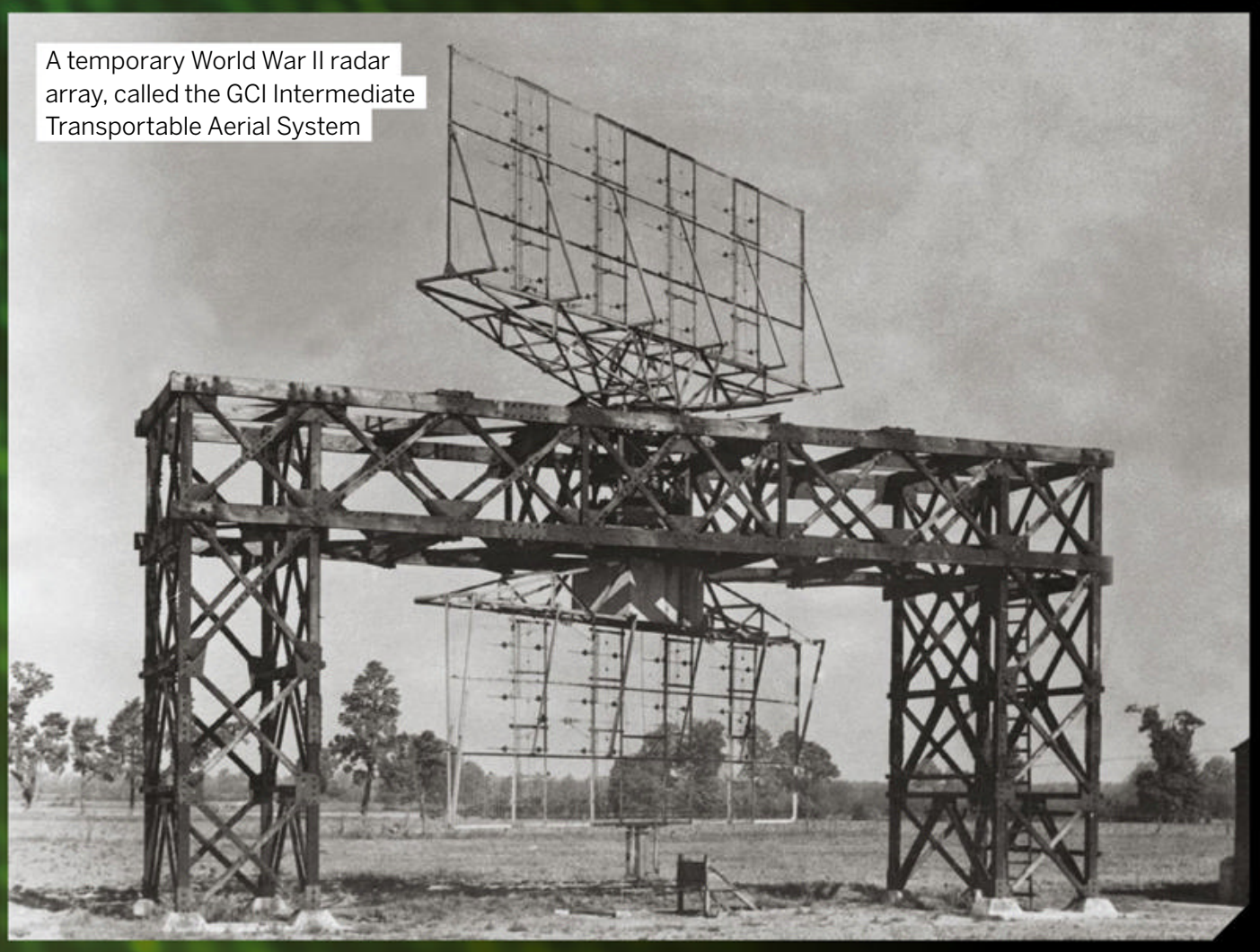
An example of a cavity magnetron at the National Electronics Museum in Maryland

THE FUTURE OF RADAR

WORDS BEN BIGGS

What are the capabilities of modern military radar? We visit a cutting-edge radar production facility to find out

DID YOU KNOW? BAE Systems supplies and maintains radar for every major warship in the Royal Navy



A temporary World War II radar array, called the GCI Intermediate Transportable Aerial System

We're sitting in a conference room in a high-tech facility on the Isle of Wight, as one of Britain's foremost experts in radar technology paints a picture of what BAE Systems does in one of the most advanced radar development and production sites in the world. There's no doubt he knows his craft, but he's got his work cut out for him explaining his way through arrays, TR units and non-cooperative target recognition to a humble journalist who has little more than a few science GCSEs.

Radar architect Martin Widgery slides a large oblong of circuit board set into a wooden frame across the table. It's covered in soldered microchips each as big as a thumb and looks like the motherboard out of a Windows 95-era PC. It's nearly as old as that, too. This 'demonstrator' unit is a proof-of-concept prototype that BAE Systems' enormous Sampson radar system, commonly found atop the Royal Navy's Type 45 Destroyer, is based on. Widgery points at one end of the board, let's call it the 'business end', and tells us that each one of the channels is its own radiating antenna that contributes to thousands of little antennae that can be electronically, rather than mechanically steered. He points to other parts of the test board that are a staple of today's radar systems: individual radio frequency signal generation and reception, a power amplifier, phase and gain control for steering.

We're already more than a little blinded by the science, but it has turned our notion of radar on its head. 80 years ago a series of green blips lighting up a circular display impressed Britain's top brass and changed the course of World War II, though the hardware of these experimental systems amounted to little more than what Widgery describes as an "RF horn and a reflector on a beam that was focused by a bent bit of tin." Not that we're trying to downplay one of the most important inventions of the 20th century, but it's not exactly high-tech next to one of BAE Systems' modern active electronically scanned array (AESA) systems – not to look at and not on paper either. When the Chain Home early warning radar stations were built around the coast of Britain in 1938, it had a range of up to around 100 miles and a precision to within five miles or less.

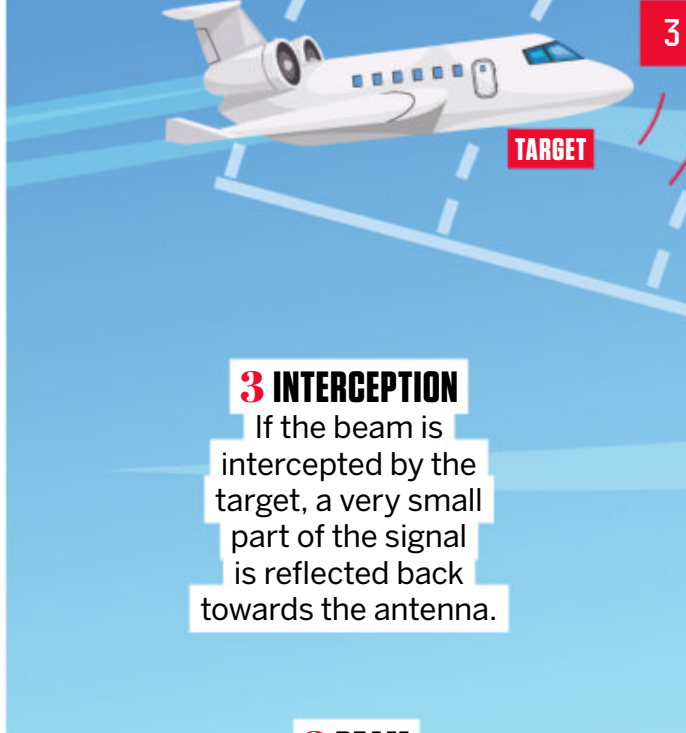
Did you know?

Police use radar to measure the speed of vehicles

Today's radar can pinpoint a cricket ball flying at that range.

That's a really one-dimensional picture of modern radar's capabilities, though. Old-fashioned radar made a rotation every 2 to 15 seconds, depending on its range, and updated everything on the screen in the same way. Modern radar does this in milliseconds, identifying targets with razor precision at much greater ranges, in a much noisier radio airspace and in infinitely more detail than radar technology of generations past. On the workshop floor, the same radar technology is getting cheaper and easier to produce, and the core technology – such as the 30-year-old demonstrator unit we were shown – has already been shrunk down to something that's about the size of a one pence piece, with the benefits of this smaller scale being felt on and off the battlefield.

Aircraft carriers such as HMS Prince of Wales need sophisticated radar systems for air-traffic management, as well as defence



The AN/FPS-85 phased array radar in Eglin, Florida, is part of the Space Force's space surveillance network and has a whopping peak power of 32 megawatts

The latest generation of radar can already do some incredible things with microwaves, rather than radio waves, that Robert Watson-Watt and his pioneering colleagues would have been amazed by. Modern military radar can easily discriminate between fixed and rotary wing aircraft – jets or helicopters – for example. Widgery points to a series of fuzzy peaks and troughs on a screengrab from an auxiliary radar display, traces his finger around a busy area that he says is the central body of the aircraft, then two patches that appear to be going around in circles – the main rotor and tail rotor of a helicopter. But a trained operator in front of a live radar display can be even more precise than that. They can ascertain the telltale shape of a target, pick out the number of engines and blades on an aircraft, count the rotors on a helicopter and see how fast they're spinning around. It's the kind of detail that, in the context of a battlefield scenario, will allow the operator to determine the exact type of aircraft that's popped up on their screen long before the target is within visual range.

Did you know?

Some radar systems can bounce beams around the Earth

One of the coolest advances BAE Systems is making inroads in is in what they call 'non-cooperative target recognition', or 'ballistic missile defence discrimination'. This is when a missile has been fired that has separated into multiple pieces, possibly with decoys and multiple warheads, as well as bits of debris. The radar operator needs to easily distinguish between all the little bits that might appear in a tight bunch on the screen, determine what is and isn't a threat, then relay all the vital details to the decision makers. And this has to

Commander radar systems are huge, but can be moved around the battlefield with relative ease and be maintained by army engineers

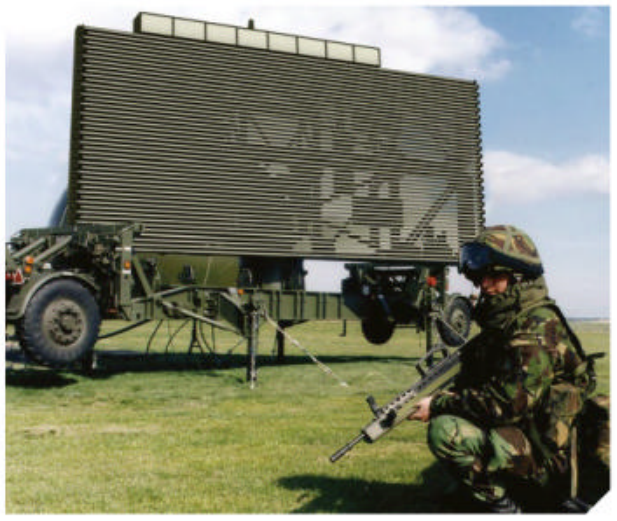
DID YOU KNOW? Routine servicing of the Royal Navy's Sampson radar costs in the region of £500,000 ($633,175) a year

be done fast. Missiles can travel at many times the speed of sound, so they can be on top of you at your position in a matter of seconds. It's only by transmitting with increased power and bandwidth to generate higher resolution radar images that this is possible.

So where do people at the bleeding edge of radar go with the technology next? After the miniaturisation of the hardware, the next logical step isn't to make it even smaller, but to ditch as much of the physical circuitry as possible and digitise it. In other words, turn it into pieces of computer software. Certain parts of radar still need to be a physical component. The power amplifier, for example, might be reduced in size but not digitised. But a lot of the sensitive circuitry could be converted to digital and uploaded to a big computer network. And one major benefit of having large chunks of a modular radar system in a digital format is that if you need to upgrade it, or fix something that isn't working, it's much simpler to change some lines of code in a piece of software, which is then uploaded to wherever it's needed, than it is to change the antenna face on a warship at sea.

"Certain parts of radar still need to be a physical component"

LAND AND SEA DEFENCE



COMMANDER
Land-air defence

This long-range tactical radar system can be deployed and moved quickly around combat zones by a trained army unit. It can also be controlled and monitored remotely. It has been used in Iraq and Afghanistan.

ARTISAN
Naval surveillance

Artisan is used for medium-range target designation on Royal Navy ships, as well as air-traffic management on its big aircraft carriers, like the flagship HMS Queen Elizabeth. It can detect objects as small as a tennis ball travelling at over 2,000 miles per hour from over 15 miles away.

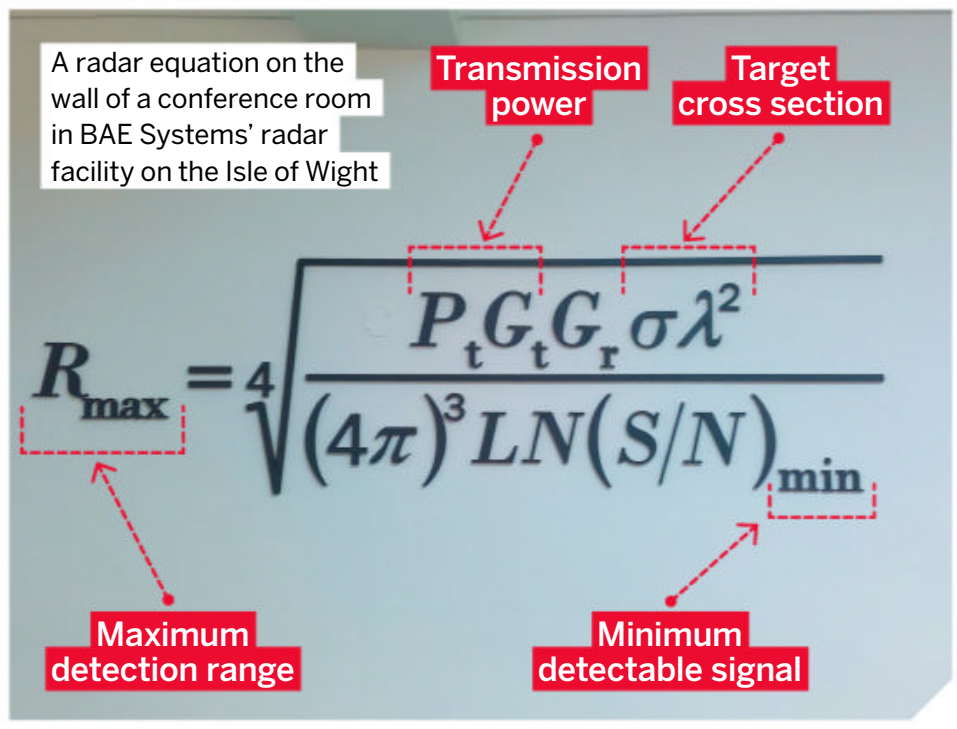
SAMPSON
Multi-function radar

The primary sensor for Type 45 destroyers, this imposing radar system is sometimes referred to as 'the Dalek'. It can track hundreds of targets simultaneously, including objects no bigger than a golf ball as far as the horizon, and provide in-air course correction for homing missiles.

WHY RADAR IS HARD

The word 'radar' is an acronym for 'radio detection and ranging', which makes it sound a lot like the technology used by radio stations to transmit their programmes for reception in home radio systems. But there's one gulf of a difference between these two. Basic radar uses a transmitter to beam microwave signals that are reflected off a target and picked up by a receiver. The energy reflected back to the receiver can be calculated with a radar equation that factors in variables such as transmission wavelength and target cross section – but it all boils down to the same limiting factor: the amount of energy received from the target is a tiny fraction of the energy required for transmission.

If you want to detect a small target at a long range, you'll need to put a huge amount of energy into the transmission. A commercial radio station might use 100 kilowatts of power, whereas a long-range military radar can transmit in pulses that are 20 or 30 times that – easily into the megawatt range.



A radar equation on the wall of a conference room in BAE Systems' radar facility on the Isle of Wight

An engineer calibrates the turning unit of an Artisan radar on the workshop floor

A WHISTLE-STOP TOUR

The building that houses BAE Systems' radar facility isn't exactly labyrinthine, but there must be miles of winding corridors and staircases spanning multiple levels – plenty enough to get lost in. Given the company's military contracts, security is unsurprisingly tight, so we weren't able to go anywhere without an escort, not even to the toilet. There's a strict no unauthorised photography regulation in place over most of the interior, and some places were completely off limits to us. Other parts of the building, such as the Test Room, required everyone to place all their electronic devices into a locker before they could enter. Out of an overabundance of caution, some staff did not want to be identified.

Did you know?

Artisan radar can cost over £4 million ($5 million)

Despite these restrictions, we were still given an incredible level of access to the facility, starting with the shop floor. This is effectively a large warehouse with a high roof to allow BAE Systems' big radar to be assembled and worked upon by dozens of mechanical engineers. An imposing Commander array periodically spun on its turning unit at the far end, next to a freshly painted Sampson. Near the gallery where we stood, a man in a white coat and gloves carefully applied something to a large metal radar mount. He could have just been greasing the steel bolts around its circumference, but this seemingly simple job was much more technical than meets the eye.

A short walk around the perimeter of the workshop took us to one of the most fascinating places in the whole facility: the anechoic test chamber. This room is taller than it is wide to accommodate the biggest radar in BAE Systems' armoury for near-field testing. The walls and ceiling are covered with carbon-fibre foam spikes that prevent any electromagnetic echoes reverberating off flat surfaces. That also stopped the sound of our conversation dead, nearly as soon as it had left our mouths. The small adjoining antechamber wasn't much bigger than a garden shed, yet it had more of an echo than this enormous room, which was a very surreal experience.

DEADLY REMNANTS

Although BAE Systems has only been at the Cowes facility for the last few decades, the site has a defence history that dates back to the early 20th century. A civil aerodrome was established in 1915, which was commandeered by the War Office for testing amphibious aircraft in World War II. Towards the end of the war, the Canadian Navy was stationed at the site in preparation for the D-Day landings, and they had a plan in case the Nazis mounted a successful invasion of the island: they booby-trapped the site with pipe mines. When the Canadians left, they destroyed all their sensitive documents, including a plan that showed the location of all the buried bombs. Over the years since the closure of the airfield in the 1950s, most of the pipe mines have been found, defused and removed.

An amphibious aircraft at Cowes aerodrome in 1930

BLIPS ON THE SCREEN

Martin Widgery, future maritime technical lead at BAE Systems' Maritime Services, tells us where radar technology is going next

What can modern radar do that old generations of radar can't?
Modern radar is able to second by second, millisecond by millisecond, decide where they're going to look next, what they're going to do in order to cover the search space they need to cover, but also maintain more information on anything of particular interest or threat. That can quite often mean deciding to spend more time and energy interrogating a target of high priority in order to identify it in detail, determine whether it's a threat and provide high quality track information to support its interception. That's the business we've been in for 30 years – those radar have been gradually surpassing the previous generation.

Why do we need even better radar?
The primary thing that's driving the need to go from the current generation to the future more than anything is the emergence of faster, smaller threats, including ballistic and hypersonic missiles. Their increased approach speeds demand earlier detection at greater range, which in turn demands increases in radar power. In addition, radar must now also address a broader variety of threats, including drones and surface craft, that they did not previously have to deal with, often in highly cluttered environments where such targets can be far more difficult to separate from natural returns, moving or otherwise.

There is now also far greater need to operate in environments that are

DID YOU KNOW? Artisan can 'see' through noisy radio interference equal to 10,000 mobile phone signals

1 WORKSHOP
Many of the components for a radar system are built off-site, but they are assembled in the Cowes facility. Here, mechanical engineers test the moving parts on stabilised turning units.

2 SAMPSON TEST ROOM
A small room is set up to test the Sampson radar that will eventually be installed on Type 45 destroyers, with computers arranged in similar positions as the stations you'd find in the control room. It's a strict no-photography zone.

3 NEAR-FIELD TEST FACILITY
A large anechoic chamber is used to calibrate big radar, with enormous double-entrance doors to allow access to the six-tonne Sampson. A huge half-circle track allows a probe to run in a 270-degree arc around the radar, which makes the chamber look a lot like the black hole drive from the 1997 sci-fi horror film *Event Horizon*.

4 BUILDING 30
Access to the anechoic chamber is via this building, which is used for building and installing radar array modules, as well as Sampson assembly and maintenance, before they are moved into the near-field test facility on hover pads.

5 RADAR INTEGRATION TEST FACILITY
Prior to mounting on their respective Royal Navy vessels, the radar are lifted onto test towers outside, connected to the computers in the Sampson test room and put through a battery of tests.

ambiguous, with increased potential for confusion with neutral targets demanding increased radar measurement fidelity to assist identification.

What more could radar do in the future?
There is now a lot of drive to take all the platforms we've got in a fleet, and maybe some of the land radar in the area that they happen to be operating in, network all that information and combine it to derive a much improved common picture shared across the wider force. You've got the individual sensors and weapons, you've got the combat system on the ship that joins all that together. And then there's a layer of networking between ships that is shared between nations across NATO generally. It's cross-platform integration, allowing ships in, say, a carrier group to share information at a lower level than they do now. Where we are now is a Typhoon aircraft might detect a threat, pass a warning, the ship will go and look for it, find it and use it.

In the near future, the enhanced networking of sensors and shooters will provide the ability for the aircraft to be able to see something, perhaps even over the horizon from the perspective of the ship, and for the ship to be able to shoot at it based solely on information from the aircraft. That's where we're headed.

TERABIT BROADBAND

A new fibre-optic breakthrough promises to unleash broadband up to 4.5 million times faster than what you might have at home

WORDS JACK PARSONS

DID YOU KNOW? Every person on Earth generates 1.7 megabytes of data – enough to fill an 850-page book – every second

The internet is inundated. There are now 5.35 billion people online – that's 66 per cent of the world's population. On average, they spend seven hours a day surfing the web. And 80 per cent of what they do is watch video – whether that's video calling for work or watching Netflix shows. Both eat up a lot of bandwidth, which is what we call the maximum rate at which data can be transferred. This is measured in bits per second.

It's not just people who are putting the internet under strain. There are more than 15 billion gadgets connected too. Almost two-thirds of these are personal devices like phones and tablets, which get more powerful with each upgrade. But there are also hundreds of millions more 'smart sensors' that connect to the internet all on their own. They monitor everything from the weather to factory machinery. Each one might only send a tiny bit of data, but they're constantly working, and there are so many of them that it all adds up

Did you know?

There are around 198 million websites

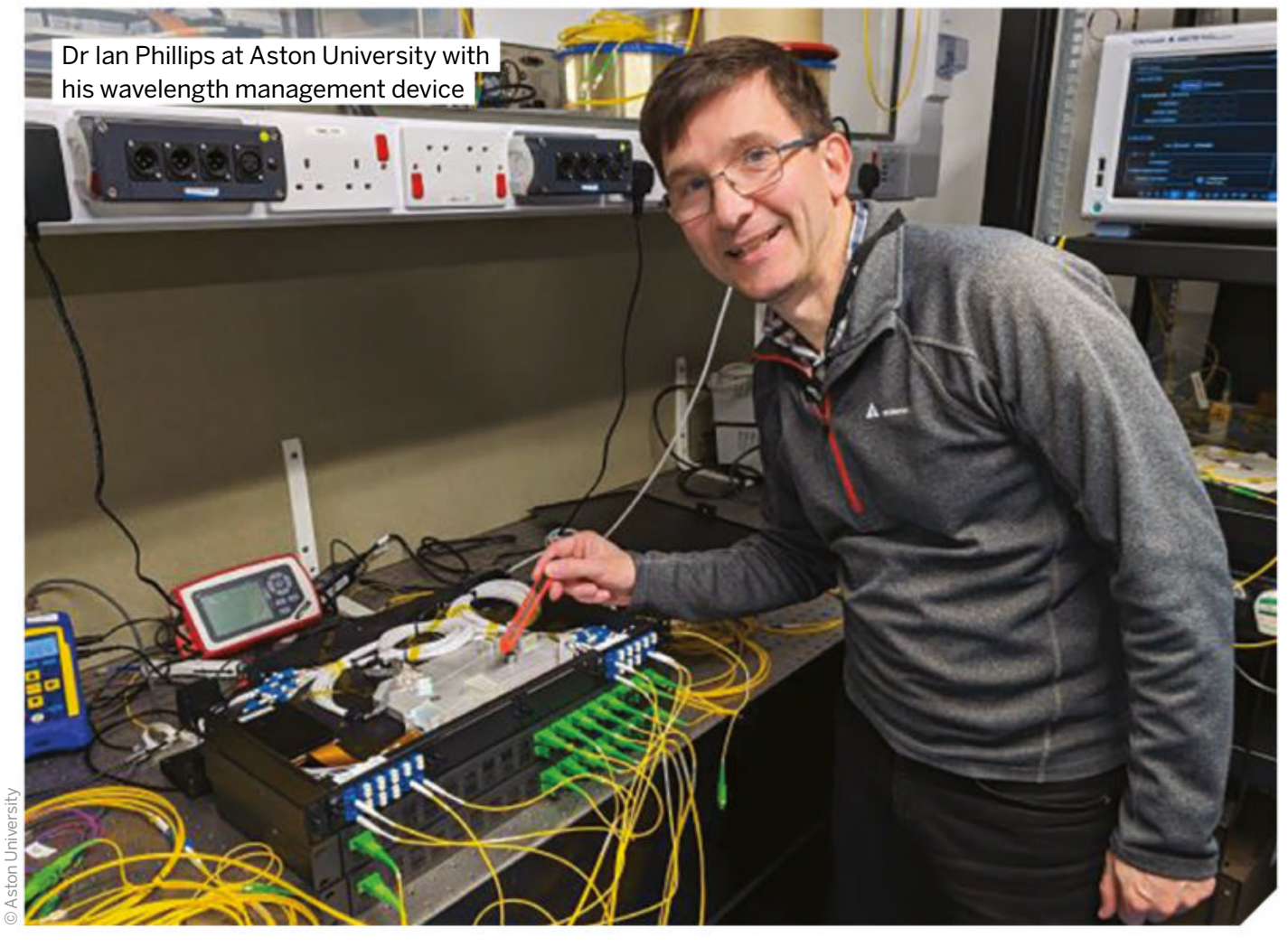
It's easy to think we live in a limitless wireless world. But 5G phone masts are only the tip of the internet iceberg. Around 95 per cent of the world's web traffic is actually carried by fibre-optic cables – most of them hidden underwater. Currently, there are 378 of these telecommunication tentacles crisscrossing the seafloor. With a combined length of around 74,564 miles, they connect every continent except Antarctica.

Once these subsea cables reach land, they link to landing stations on the coast. From here, your internet is carried in a variety of ways – whether that's fibre-optic cables, copper phone lines or some mixture of the two – right to your door. But because all this internet infrastructure is physical, it's also finite. Eventually, it will run out of room to carry all the data we want to send and receive. Downloads will slow to a crawl, streaming will stutter and connections will drop out more frequently.

There are ways to boost capacity. We can add more cables to start with. Pack those cables with more data-carrying optical fibres. Or even shift traffic onto satellite networks like Elon Musk's Starlink constellation. But these steps are expensive, time-consuming and only delay the inevitable. The real solution is to make the infrastructure smarter. One of the ways to do that is to ensure it works more efficiently, freeing up capacity in the existing network.

Aston University may have just done that. Researchers in Birmingham in the UK have transferred data at a rate of 301 terabits. That's 301 million megabits per second – and each megabit is made up of a million bits. That's the equivalent of delivering 1,800 4K movies to your home in a second. It's also 4.5 million times faster than the UK's average broadband speed of just 69.4 megabits per second.

This isn't the world's fastest. The National Institute of Information and Communications Technology (NICT) in Japan achieved 22.9 petabits per second – 75 times faster than Aston University''s rate. But they had to invent an entirely new type of cable to do this. The Aston University approach, developed in partnership with NICT and Nokia Bell Labs in the US, works with our existing fibre-optic network. "By increasing transmission capacity in the backbone network, our experiment could lead to vastly improved connections for end users," said Wladek Forysiak, a professor at the Aston Institute of Photonic Technologies. "This groundbreaking accomplishment highlights the crucial role of advancing optical-fibre technology in revolutionising communication networks for faster and more reliable data transmission."

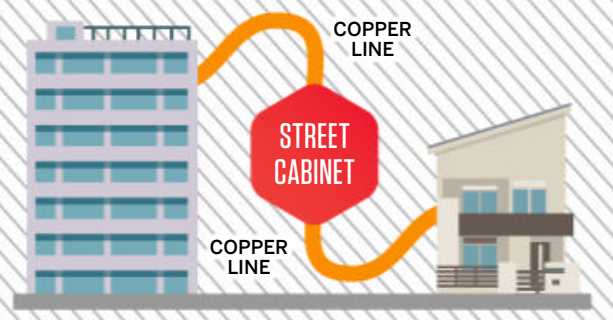


Dr Ian Phillips at Aston University with his wavelength management device

© Aston University

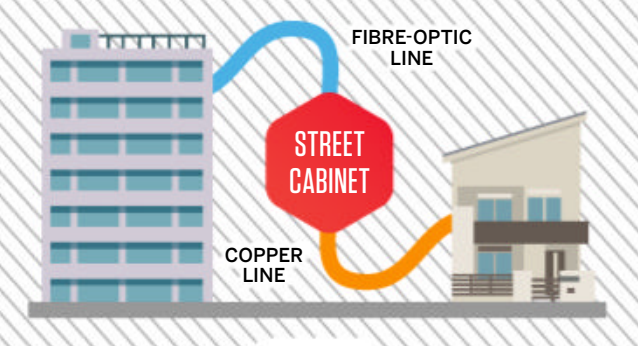
BROADBAND CHOICES

Go from the phone line to the fast lane with these connection options



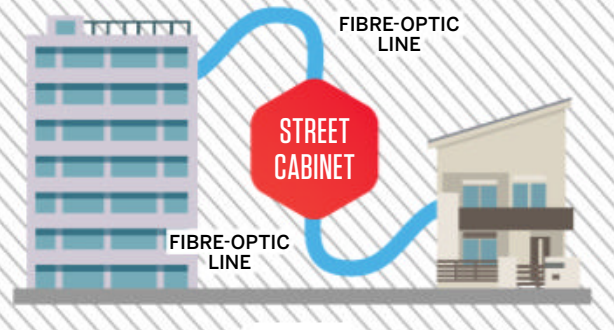
1 ADSL

This method – short for 'asymmetric digital subscriber line' – uses copper cables to carry signals to a street-level cabinet or junction box and on to your house. This old telephone line network is relatively slow.



2 FTTC

'Fibre to the cabinet' broadband uses fibre-optic cable connections to the street-level cabinet, then copper from there to your house. It has an average speed of 67 megabits per second, but can reach 80.



3 FTTP

'Fibre-to-the-premises' broadband runs fibre-optic cables all the way to your house. It's much faster, with average speeds of one gigabit per second. As Aston University has proven, it can reach much higher speeds.

© Getty

HOW DID ASTON UNIVERSITY DO IT?

Computers transmit information through fibre optics by sending light signals. What's more, they use particular light wavelength bands. They are all in the infrared part of the spectrum, so can't be seen. But switching between a wavelength is like transmitting different colours of light down the glass tube. The C-band is the workhorse wavelength range that's most used for fibre optics. This is because it falls in the sweet spot of the spectrum that experiences low attenuation as it travels through glass. This means the signal doesn't lose much energy over long distances. The L-band, which has a slightly different wavelength, has even lower attenuation, so is used to send information over even greater distances.

However, to achieve terabit speeds, Aston's Institute of Photonic Technologies' Wladek Forysiak worked closely with Dr Ian Phillips to harness bands that have never been used for fibre optics before: the E-band and S-band. The E-band in particular is three times wider than the C-band, so can carry a lot more information. But both the E and S-band have shorter wavelengths, meaning they have higher attenuation. Think of the C and L-bands as large trucks, while the E and S-bands are like smaller cars. The trucks can handle the bumpy road of the fibre, while the cars are jostled more. The researchers had to develop all-new amplifiers to boost their particular signals. "Before the development of our device, no one had been able to properly emulate the E-band channels in a controlled way," says Phillips.

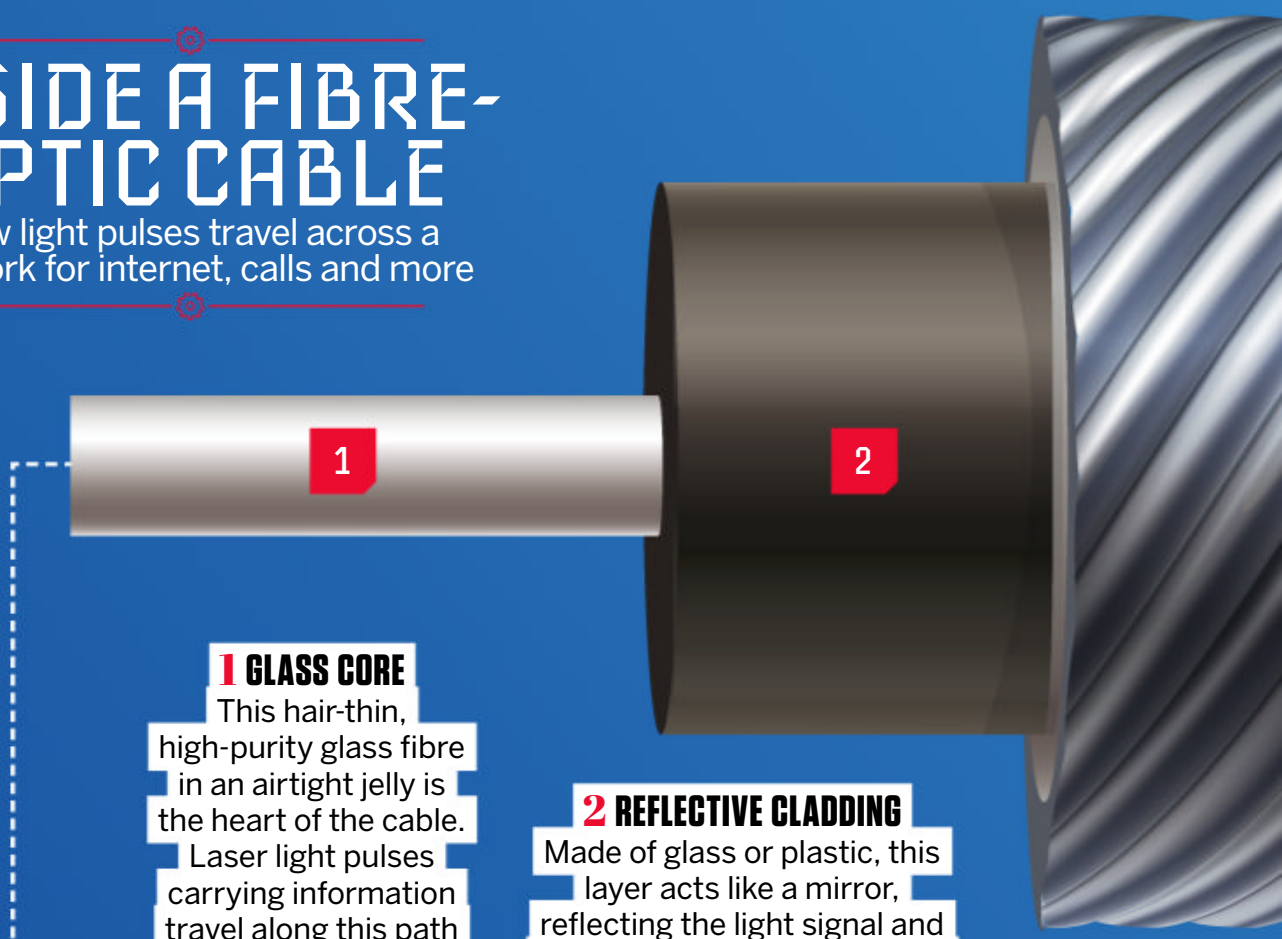
"Growing system capacity by using more of the available spectrum – not just the conventional C-band but also other bands such as the L, S and now E-bands – can help to keep the cost of providing this bandwidth down," adds Forysiak.

Did you know?

Global web traffic grew 95-fold from 2005 to 2020

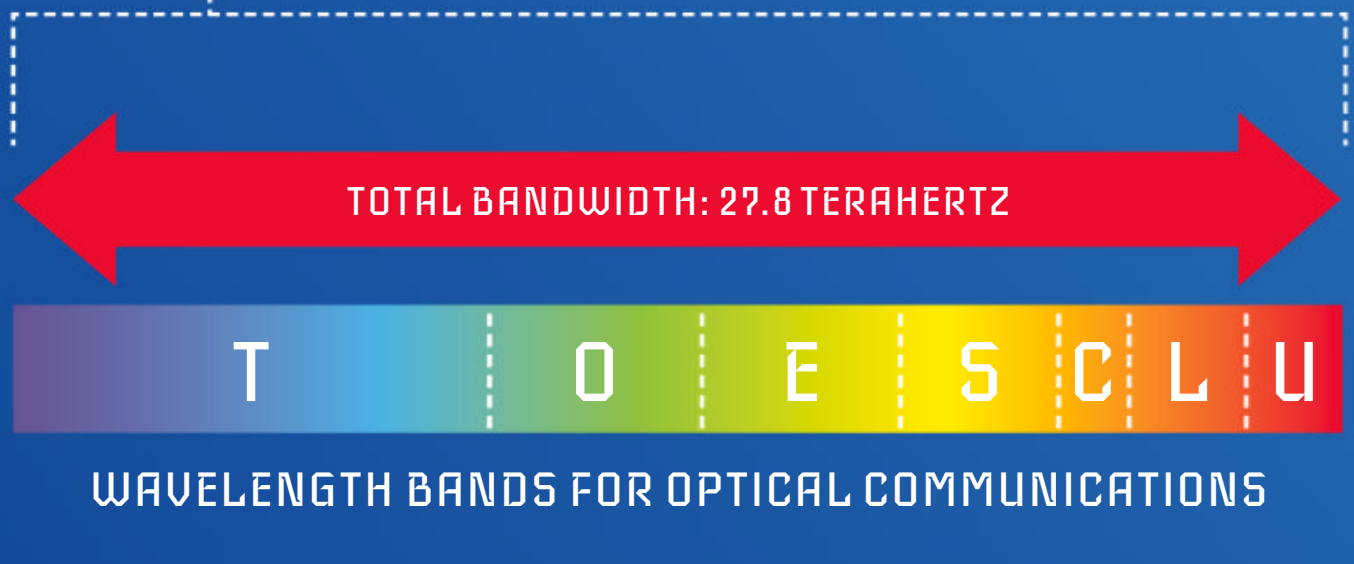
INSIDE A FIBRE-OPTIC CABLE

How light pulses travel across a network for internet, calls and more



1 GLASS CORE
This hair-thin, high-purity glass fibre in an airtight jelly is the heart of the cable. Laser light pulses carrying information travel along this path at incredible speeds.

2 REFLECTIVE CLADDING
Made of glass or plastic, this layer acts like a mirror, reflecting the light signal and keeping it bouncing down the core. This clever trick allows data to travel long distances within the cable.



TERABIT AT A TIME

1969
Computers at US universities were connected using 50 kilobit per second circuits, establishing ARPANET, the precursor to the internet.

© WIKI_FastLizard4

1973
The early internet went international as ARPNET connected to computers in London and Norway via satellite link.

1983
Created to connect computers over long distances, ethernet offered ten megabits per second as standard.

1991
The World Wide Web was invented by Tim Berners-Lee at CERN, revolutionising how we access information online.

1995
Dial-up speeds reached a peak of 56 kilobits per second, allowing for faster downloads – still a far cry from today's standards.

1996
Integrated Services Digital Network (ISDN) became commercially available in some regions, offering up to 128 kilobits per second.

DID YOU KNOW? Fibre optics don't conduct electricity, reducing the risk of fire and making them safer than copper cables

3 SHOCK ABSORBER
This cushioning layer protects the delicate core and cladding from bumps, vibrations and even moisture that could mess with the light signal.

4 HIDDEN STRENGTH
These thin threads, often made of Kevlar, give the cable surprising strength. They prevent it from breaking under tension and ensure it can withstand the push and pull of everyday use.

5 OUTER CASING
To protect against damage or moisture, cables are encased in polyethylene, a hard plastic also used to make water bottles.

6 PENCIL THIN
Fibre-optic cables are eight to ten millimetres wide. They are also lightweight and easier to install than traditional copper cables, even though they carry much more information.

TERABIT SPEEDS: STILL LOADING...

Harnessing the E and S bands produced increased speeds in Aston University's lab. But lab is the key word – this breakthrough is still in the research phase. The technology needs further testing to make sure it's reliable for everyday use. While being able to use existing cables saves costs, challenges remain. The team's unique amplifiers will need to be reproduced in a way that they can be affordably mass-produced, while installing them worldwide will also take time. If and when the technology is rolled out, you won't get 301 terabits per second at home. The truth is you don't even need this much bandwidth at the moment. But you will enjoy the benefits secondhand as these transfer rates transform your internet service provider and the data centres that your favourite apps and games use.

5 FACTS WHAT'S SO GREAT ABOUT TERABIT SPEEDS?

1 LIGHT SPEED UPGRADE
This internet speed is 4.5 million times faster than the average home broadband, so you can download an entire movie in milliseconds.

2 GREEN MACHINE
As the terabit technology uses existing fibre-optic infrastructure, we can enjoy massive data capacity increases without the environmental impact of having to lay new cables.

3 COST-EFFECTIVE CHANGE
As network providers can upgrade by only making minor changes to their existing network, rolling out these breakthrough speeds shouldn't have to break the bank.

4 KEEPING UP WITH DEMAND
With more of the world moving online, global data usage is set to triple by 2027. Technologies like this can help us expand our data capacity.

5 UNLEASHING NEW TECHNOLOGIES
Just as high-speed internet made cloud computing and streaming services possible, terabit bandwidth could accelerate innovations like AI, virtual reality and remote surgery that use lots of data or need real-time responsiveness.

2000
The birth of broadband internet brought significantly faster data transfer speeds, enabling activities like photo-sharing, video streaming and online gaming.

2006
South Korea became a global leader in internet speeds, reaching 100 megabits per second as the standard for everyday users.

2009
The first 4G LTE data networks launched, putting the internet in the palm of the user's hands.

2016
Tech giant Google launched one gigabit per second Google Fiber in select US states, pushing the boundaries of home internet speeds.

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BRAINDUMP

Amazing answers to your curious questions

Why do we use liquid hydrogen propellant?

Liquid hydrogen is used as a rocket propellant because it has the highest efficiency relative to the amount used over any other known propellant. In combination with an oxidiser like liquid oxygen, it's light and extremely powerful, burning at over 3,000 degrees Celsius. However, there were significant challenges and hazards to using liquid hydrogen when it was being developed in the 1960s. Both liquid hydrogen and liquid oxygen are cryogenic gases, meaning they only phase change to liquid at an extremely low temperature. Liquid hydrogen needs to be stored at -252 degrees Celsius and carefully insulated from all sources of heat to prevent it from boiling off and stop it expanding and exploding the propellant tank. Liquid hydrogen can also seep through tiny cracks between welds in the tank, so some very technical engineering must be employed to create a rocket capable of safely using this kind of propellant.

HOW ARE MARBLES MADE?

The oldest marbles were handmade by rolling clay, carving ivory or grinding stone. Glass marbles can also be made by hand in a process that resembles making seaside rock. Molten coloured glass is rolled into rods and stacked together to form a pattern. The glass is then cut with special scissors while still soft and the sections are rolled into balls. Mass-produced marbles use multiple nozzles to combine streams of liquid glass that are cut into even-sized lumps and passed between two parallel rotating screw threads. As the screws rotate, the marbles are moved along the production line, constantly rolling to form spheres as they cool.

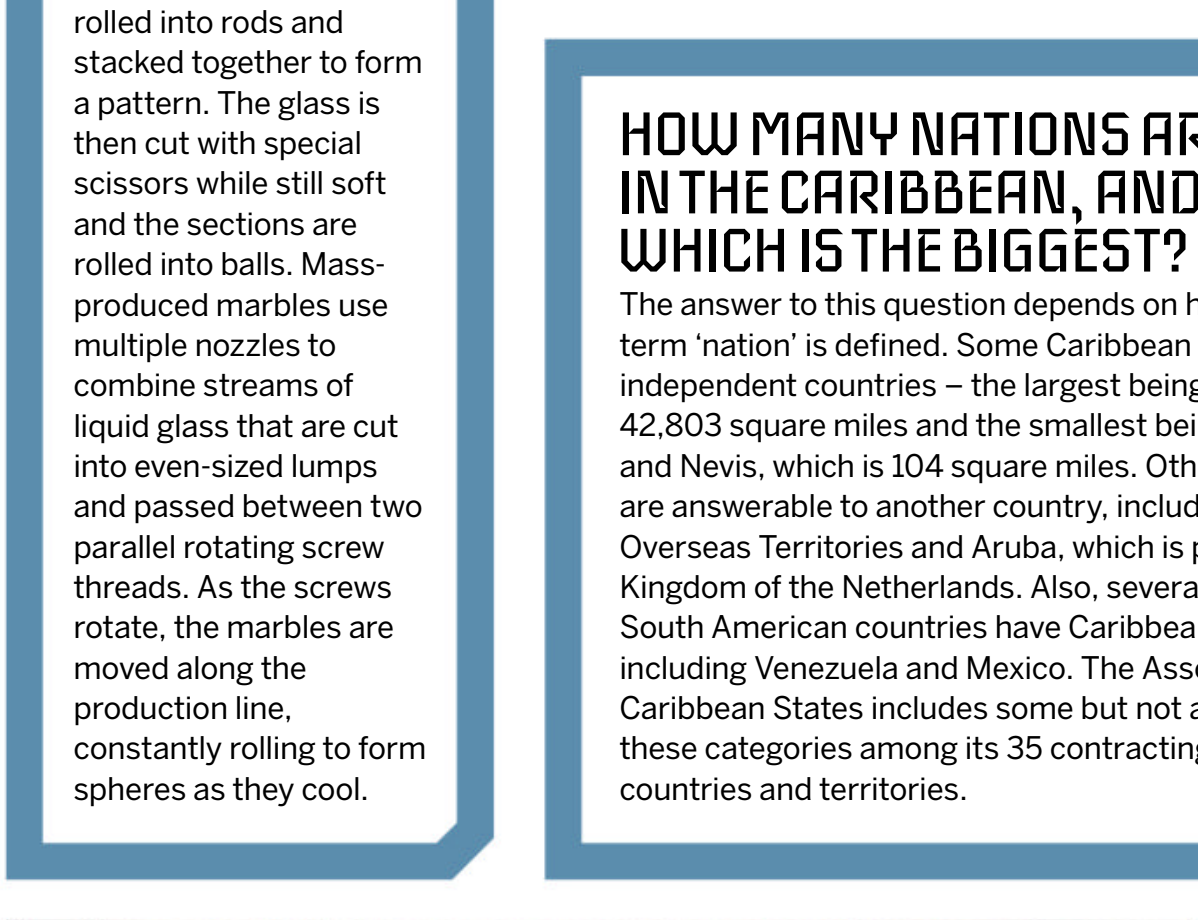
IS IT TRUE THAT HIPPOS ARE INCREDIBLY DANGEROUS?

As they wallow in the waters of a muddy river, hippos look like the layabouts of the African savannah. Yet this suggestion of lethargy disguises their potential for terrifying ferocity. Hippos are territorial animals in water and are not afraid to intimidate rivals and predators invading their space. They are also known to attack humans that get too close.

A hippo's ivory tusks – actually extended canine teeth – make for formidable weapons. Together with a wide gape and powerful jaw muscles, they give the hippopotamus a killer bite. Swimming hippos are particularly dangerous because their buoyancy allows them to move their bulk with surprising speed. An adult could easily capsize a canoe.

HOW MANY NATIONS ARE IN THE CARIBBEAN, AND WHICH IS THE BIGGEST?

The answer to this question depends on how the term 'nation' is defined. Some Caribbean islands are independent countries – the largest being Cuba at 42,803 square miles and the smallest being Saint Kitts and Nevis, which is 104 square miles. Other communities are answerable to another country, including British Overseas Territories and Aruba, which is part of the Kingdom of the Netherlands. Also, several Latin and South American countries have Caribbean coastlines, including Venezuela and Mexico. The Association of Caribbean States includes some but not all places in these categories among its 35 contracting states, countries and territories.

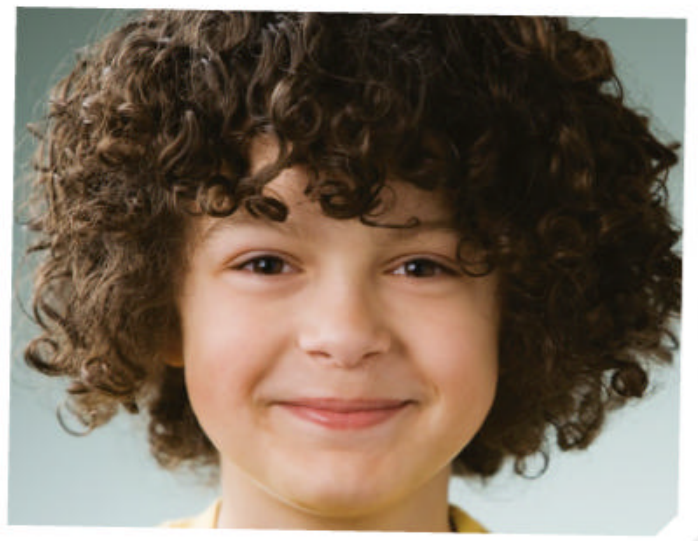


What are freckles and how are they caused?

Freckles are clusters of the pigment melanin. This is produced by melanocytes deep in the skin, with greater concentrations giving rise to darker skin tones, and hence ethnicity. Melanin protects the skin against harmful ultraviolet sunlight, but is also found in other locations around the body, such as the brain. Freckles are mostly genetically inherited, but not always. They become more prominent during sunlight exposure because the melanocytes are triggered to increase production of melanin, leading to a darker complexion. People with freckles generally have pale skin tones, and if they stay in the sunlight for too long they can damage their skin cells, leading to skin cancers like melanoma.

BRAINDUMP

WHAT CAUSES PEOPLE TO HAVE STRAIGHT OR CURLY HAIR?



This is entirely down to your parents – or, more specifically, the genes you inherited from your parents. Curly hair is an autosomal dominant trait. That means if one of your parents gives you a curly haired gene but the other gives you a straight-haired gene, the 'stronger' curly haired gene wins the day and expresses its trait. However, it's not always quite so clear cut, and depending on the type and strength of the genes you can end up with something in between, such as wavy hair. Other examples of autosomal dominance include brown over blue eyes, freckles over no freckles and dark over blonde hair.

With approximately 100,000 hairs on the human head, it's a busy area of growth. Hair starts growing in follicles that are located in the dermal layer of the skin. Flattened hair follicles lead to thinner hair strands that naturally curl. Rounder hair follicles lead to tubular strands of hair that are harder to curl, and so grow straight. Of course, some people with straight hair want curly hair, and vice versa. Straightening or curling hair is a way to overcome genetics, but it won't last very long as the hair will continue to grow in its natural way.

Where did fortune cookies originate?

The majority of food historians suspect that the modern form of this prophesying confection originated not in China but in one of two American cities. Around the start of the 20th century, Makoto Hagiwara, a Japanese-American caretaker of Golden Gate Park's Japanese Tea Garden in San Francisco, reputedly gave out notes of gratitude embedded in cookies after a sympathetic mayor gave him his job back. His inspiration might have been similarly folded cookies that have been made in bakeries in Japan for generations. Around 20 years later in Los Angeles, Chinese immigrant David Jung – founder of the Hong Kong Noodle Company – supposedly handed out cookies containing inspiring messages to the city's poor. But exactly how either of their creations later became associated with westernised Chinese cuisine isn't clear.

IS IT TRUE THAT IF YOU WEAR A COAT INSIDE, YOU WON'T FEEL ITS BENEFIT WHEN YOU GO OUTSIDE?

The answer is found in a combination of biology and survival tactics. Hypothermia sets in when the core body temperature drops by one or two degrees Celsius. Waiting until you're outside before putting your coat on will lead to a short but significant loss of body heat through convection and conduction until you cover up. Leaving your coat on all the time indoors will lead to vasodilatation, which can also increase your heat loss and take time to reverse when you step outside. The answer may be a compromise: putting your coat on shortly before you're due to go outside will allow a warm, protective layer of heated air to be captured around your body without causing excessive vasodilatation.

WHY ARE ASH TREES IN THE UK UNDER THREAT?

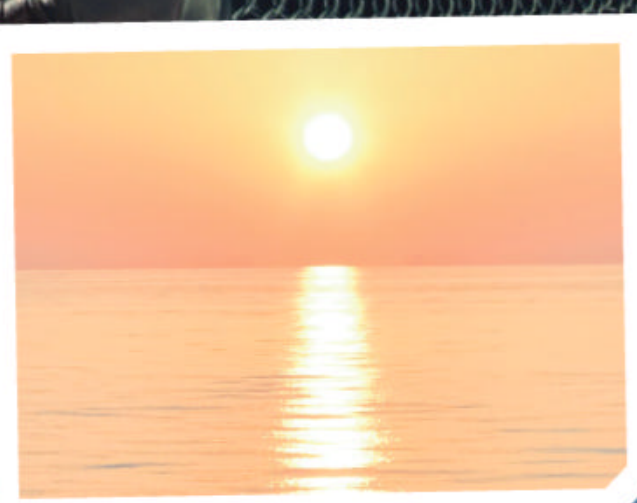
Ash dieback disease is caused by the fungus *Hymenoscyphus fraxineus*. The disease begins with the leaves wilting and turning black and then spreads. As the fungus grows into the tree it blocks the xylem vessels, which transport water in the trunk and branches, and the tree eventually dies. The disease has become entrenched across most of Europe, but it has only recently been confirmed in the UK. There are 80 million ash trees in Britain and over 100,000 saplings have already been destroyed to try and control the disease. In Asia, ash trees are immune to the disease, so it's possible a treatment might be derived from them.

Could anyone become a knight in medieval times?

In general, any medieval soldier could be considered for knighthood after showing exceptional bravery in battle. The sons of nobles had a foot in the door, though, by virtue of their status and connections. At around the age of eight these children were packed off to a castle to be a page. A page would run errands for a lord or knight, receive basic combat training and get beefed up enough to wear armour and wield a heavy sword. In the classroom a page would be introduced to chivalry and learn how to read, write and speak in French and Latin. In their mid-teens, those who had impressed would be promoted to knight's squire. Duties could include dressing and waiting on their employer as well as maintaining the knight's gear and being his shield carrier. Also, a squire's physical training was more intense because he might have to go into battle alongside his master. If the squire fought well, he could arise to knighthood at around the age of 20. He could then lead his own squires into battle hoping that all his noble training wouldn't go to waste at the end of an enemy sword.

WHY DOES THE SUN REFLECT OFF WATER?

When the Sun is high in the sky, seas and lakes appear dark because they are actually very good absorbers of sunlight. It's only if the Sun is low on the horizon or the surface is rippled that water reflects most of the light striking it. This is because when a ray of light passes from air into water, its direction of travel alters slightly as it slows down. When sunlight is coming from overhead, this change in direction makes no difference, but when it touches the water at a shallow angle the change is enough to bounce it straight back off the surface.



How do engineers demolish a skyscraper?

First, the building is stripped as much as possible, removing copper wire and aluminium for recycling, as well as all the windows and insulation to prevent health-and-safety hazards from flying debris. Then explosives are used to shatter the load-bearing structures on some of the floors. The explosives are synchronised using detonating cord – a thin plastic pipe filled with an explosive called pentaerythritol tetranitrate, which burns at four miles per second. The aim is for the upper storeys to fall vertically down so that the whole building collapses onto its own footprint and surrounding buildings aren't damaged.

In France, the technique of vérinage is often used instead of explosives. This employs hydraulic rams to push the load-bearing members of one of the middle floors sideways. At a certain point they all give way at the same time and the top half of the building falls straight down onto the bottom half. The end result is very similar to an explosive demolition. The Japanese Kajima Corporation has developed a system of propping up an entire tower block with hydraulic jacks and demolishing the ground floor using ordinary diggers and bulldozers. The jacks then lower the building down a storey and the process repeats.

WHY ARE HUGE BUBBLES WOBBLY, BUTTINY ONES ARE PERFECT SPHERES?

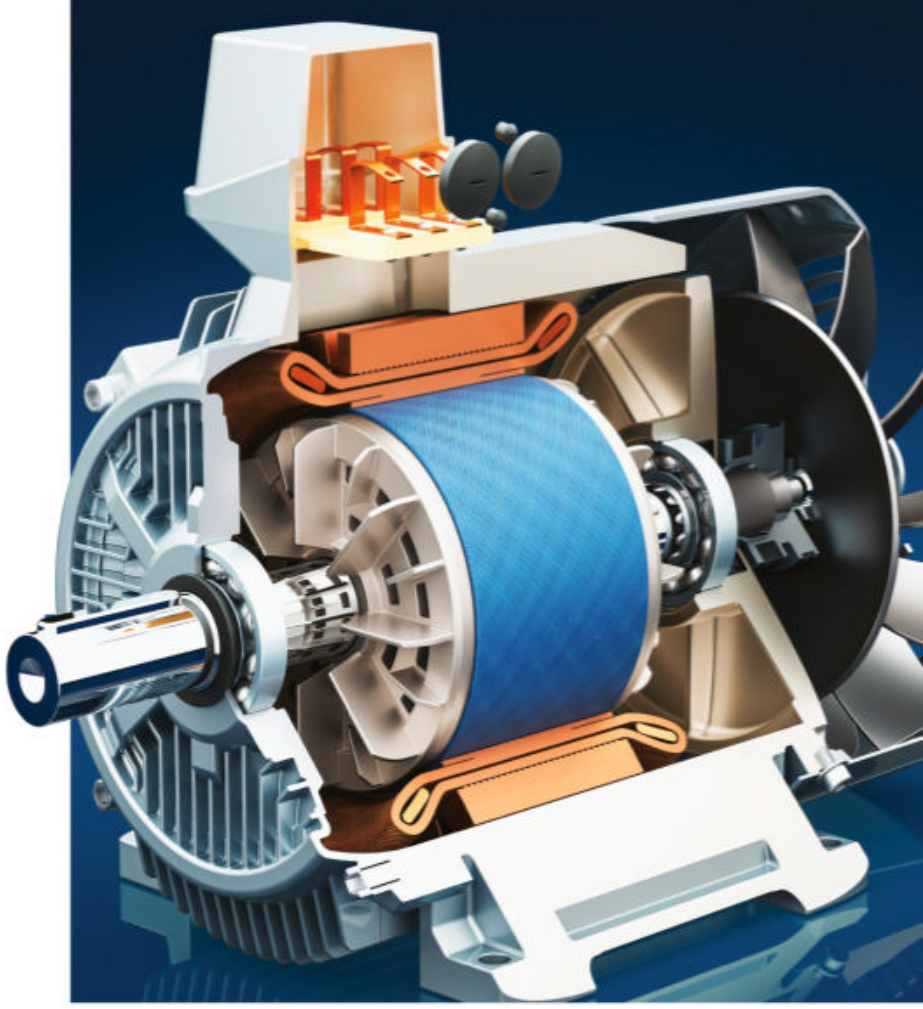
A bubble's shape is essentially a trade-off between the forces acting on it. Surface tension and external pressure squeeze inwards, shrinking the bubble's surface area, while the air trapped inside pushes back. The bubble therefore adopts a shape that has the smallest surface area for a given volume: a sphere. Changes in external pressure – like a gust of wind – disrupt this equilibrium and the bubble 'wobbles' as it adjusts to maintain the balance of forces. For a small bubble, surface tension is relatively strong, and thus it can regain its shape quickly. However, surface tension doesn't grow stronger as a bubble increases in size – quite the opposite, in fact. As a result, the bigger the bubble, the more influential external pressure becomes and the more vulnerable it is to turbulence.

COULD WE EVER MAKE A LIGHTSABER IN REAL LIFE?

Lightsabers certainly look cool – and just think how much time you'd save if you could slice your bread and toast it at the same time – but in reality you just can't get light to behave that way. Once you have let a beam of light go – firing it out of the hilt of a lightsaber, for instance – it will keep on travelling in a straight line forever unless something gets in its way, so you'd need something to trap light within it. Imitation lightsabers work in this way, bouncing light around inside a semi-transparent tube-shaped 'blade'. This also lets you play at fighting with them – in reality, two beams of light would just pass straight through each other rather than clashing. The closest thing we could get to a real-life lightsaber would actually be a beam of plasma – glowing, superhot electrically charged gas trapped in a powerful magnetic field. This is the same stuff that the Sun is largely made of, but producing it on Earth requires huge amounts of energy – a lot more than you could ever store in a lightsaber.

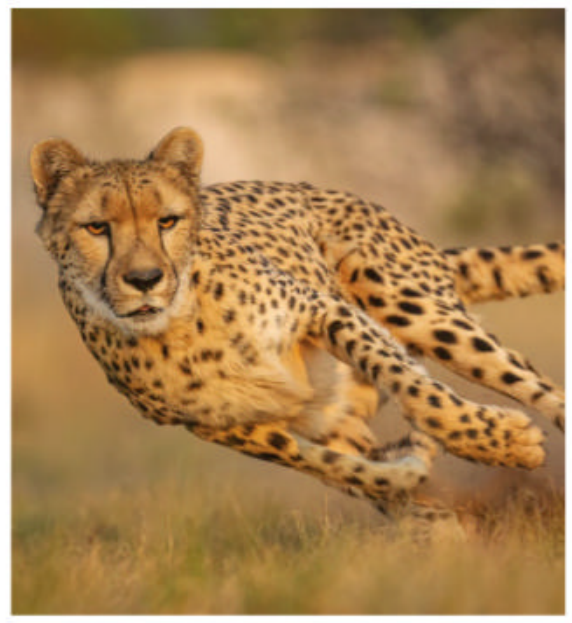
HOW DOES ELECTRICITY MAKE A MOTOR TURN?

Electric motors use magnets to convert electricity into motion. Electrons have weak magnetic properties, but these usually cancel each other out. An electric current, however, forces unpaired electrons inside a metal wire to line up, allowing them to join forces and create a coherent magnetic field. This field is very weak, but by wrapping the wire into a coil its strength is multiplied – this is an electromagnet. Inside an electric motor, permanent magnets are set onto a ring surrounding a coil of wire. When the appliance's switch is flicked on, electrons flow through the wire, turning it into an electromagnet. The attractive and repulsive forces of the permanent magnets around it make the electromagnet spin. This circular motion is then used to power anything from a fan to an electric car.



WHY WOULDN'T USAIN BOLT BEAT A CHEETAH IN 100-METRE SPRINT?

Bolt might be the fastest man on Earth, but a cheetah can run 100 metres over three-and-a-half seconds quicker. A cheetah called Sarah from Cincinnati Zoo holds the record at just 5.95 seconds. Cheetahs are faster than humans because they are smaller, which means they require less force to accelerate. They also have four legs, which gives them more points of contact with the ground to push themselves forwards. But the reason cheetahs are faster than any other four-legged animal is their incredibly flexible spine. As they run, it folds up to the point where the back legs actually overtake the front legs. This gives them an effective stride of about seven metres.



How does global warming affect the Gulf Stream?

Our planet's oceans are in constant motion as dense water sinks, driving a worldwide system of currents. The warm waters of the Gulf Stream increase temperatures in northern Europe by several degrees, but such currents are themselves vulnerable to changes in our climate. Global warming is causing Arctic sea ice to melt, dumping excess freshwater into the North Atlantic. This could in turn affect the currents of dense water sinking in this region and slow down the Gulf Stream in coming years. Recent measurements seem to support this theory, but the complexity of global climate systems makes it very difficult to prove beyond doubt.

THE LIBRARY

The latest book releases for curious minds

THE WORLD'S FIRST ROLLERCOASTER: AND OTHER AMAZING INVENTIONS

LAUGH AND LEARN WITH THESE COMIC-STRIP HISTORIES

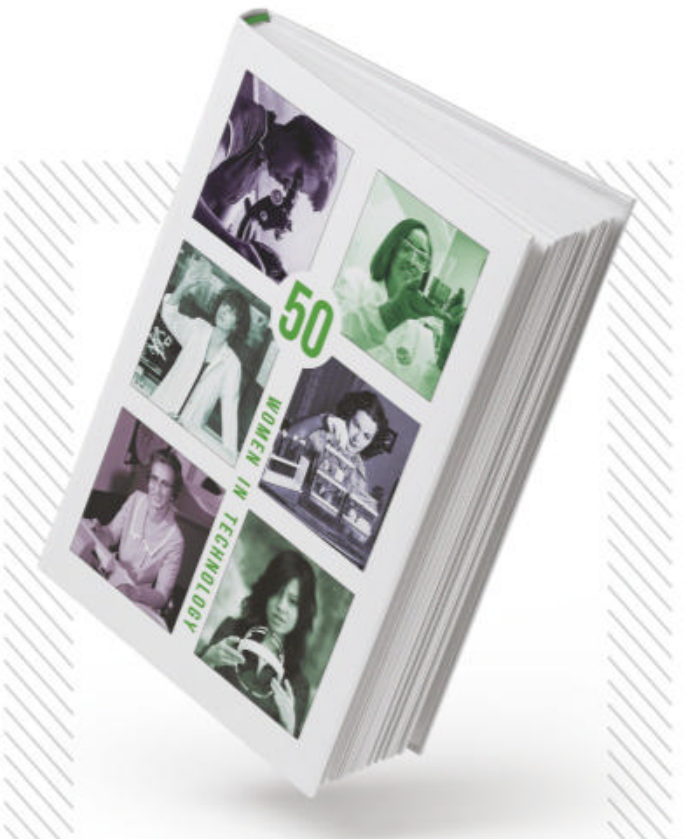
AUTHOR **MIKE BARFIELD**
ILLUSTRATOR **FRANZISKA HÖLLBACHER**
PUBLISHER **TEMPLAR PUBLISHING**
PRICE **£10.99 / $15.78**
RELEASE **OUT NOW**

You can't go wrong with cool facts and funny comic strips, so author and illustrator dream team Mike Barfield and Franziska Höllbacher are off to a pretty good start with *The World's First Rollercoaster: and Other Amazing Inventions*. It charts the greatest inventions from the last century or so – and when we say 'greatest', we don't necessarily mean the inventions that have significantly furthered our species. In fact, fun inventions like the rollercoaster, the hamburger, skateboards and video games take more of a precedent over the likes of electric vehicles and smartphones. This is where Höllbacher and Barfield have the most fun. There's a full-page comic strip for every item on the contents page, giving a history of the people behind the invention and their world-famous ideas.

Some are a little more out there, like the 'invention' of the dog, which was domesticated over the course of the last 10,000 years or so, the history of which has been distilled into a single silly-yet-informative comic strip. But even the more conventional inventions have been injected with good humour and an interesting angle. Instead of telling us how Carl Benz built the world's first petrol-drive automobile in 1885, Barfield has veered slightly off course to talk about Benz's wife, Bertha, who achieved her own firsts with Carl's

"There's a full-page comic strip for every item"

invention and without whom we wouldn't even know the name Benz in the world of motoring. If you want to learn more about that, you'll just have to read the book. We promise you it's well worth it. *The World's First Rollercoaster: and Other Amazing Inventions* is as amusing as it will be interesting to anyone of any age, and by the end you'll be sure to have learned a thing or two you never even considered about some of your favourite inventions in the world.



50 WOMEN IN TECHNOLOGY

MEET THE TRAILBLAZERS THAT CHANGED THE WORLD OF STEM

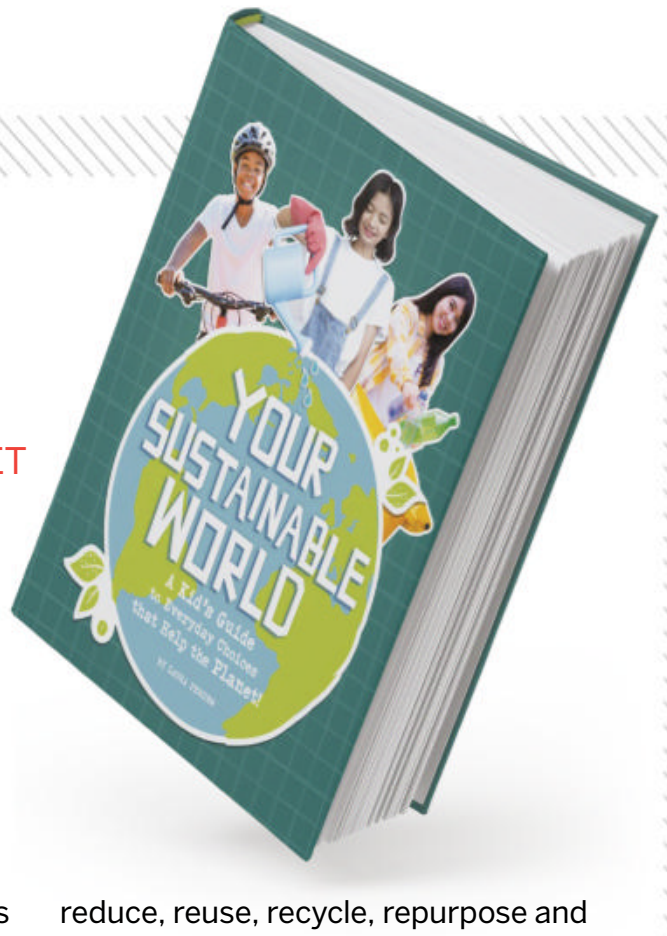
AUTHOR **GEORGINA FERRY, INÊS ALMEIDA AND BRIDGET GREENWOOD**
PUBLISHER **AURORA METRO**
PRICE **£19.99 / $29.99**
RELEASE **OUT NOW**

In celebration of the female pioneers who advanced technology throughout history, this book is sure to inspire the next generation of brilliant scientists. Along with some of the more recognisable names such as Katherine Johnston or Marie Curie, there are many unsung heroes of science to discover, such as Vera Rubin, whose work led to the discovery of dark matter. In part, this reference book acts as a reminder of the work of great women who have paved the way for modern minds. For example, Stephanie Willerth, a professor at the University of Victoria in Canada, oversees research to engineer treatments for central nervous system disorders, and data scientist Rumman Chowdhury is tackling solutions for ethical artificial intelligence. These are the minds you'll meet through a series of interview-based biographies that reveal the motivations and impact on women who are making strides in technology.

YOUR SUSTAINABLE WORLD

A KID'S GUIDE TO EVERYDAY CHOICES THAT HELP THE PLANET

AUTHOR **LAURA PERDEW**
PUBLISHER **CAPSTONE**
PRICE **£8 / $9.99**
RELEASE **1 AUGUST**



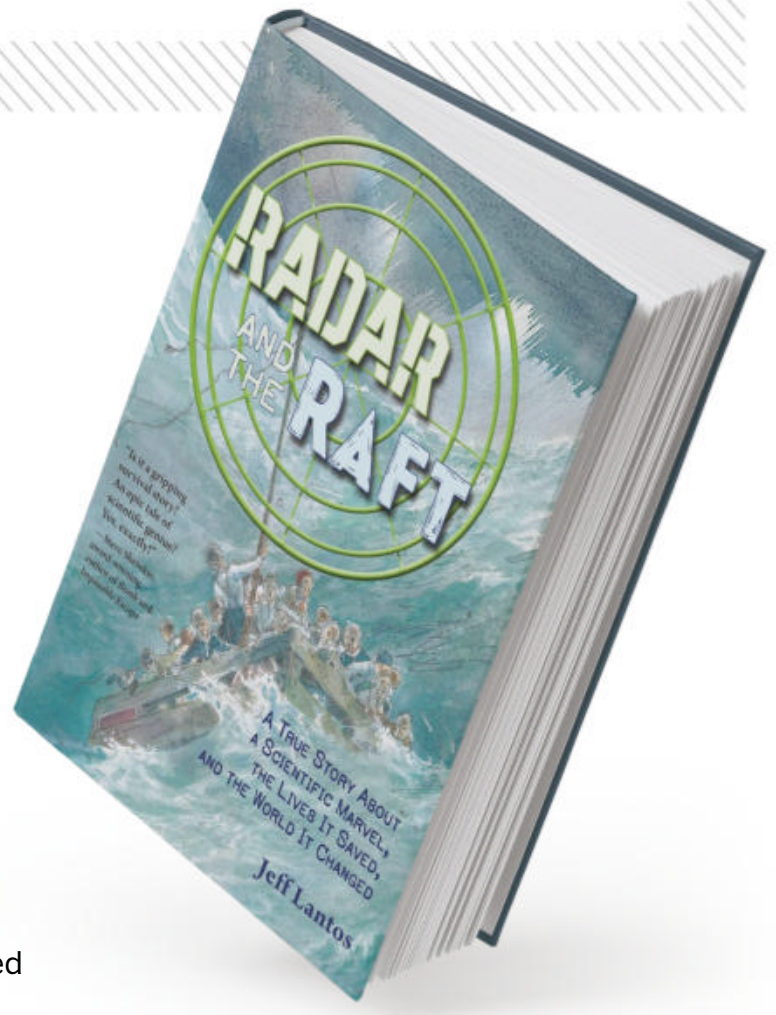
It's safe to say that children have never been more aware of the impact that the climate crisis is having on the world. With that awareness comes countless questions about how families can play their part in protecting the planet. In this simple guide to sustainable living, children will learn about different climate challenges and some of the small ways we can help reduce our negative impact on the environment.

Along with well-known concepts in sustainability such as the five Rs – reduce, reuse, recycle, repurpose and refuse – there are new ways to be greener to explore, such as 'green fashion' and 'smart eating'. Packed with helpful tips and advice, *Your Sustainable World* is sure to inspire young children to make more environmentally friendly choices.

RADAR AND THE RAFT

A TRUE STORY ABOUT A SCIENTIFIC MARVEL, THE LIVES IT SAVED AND THE WORLD IT CHANGED

AUTHOR **JEFF LANTOS**
PUBLISHER **CHARLESBRIDGE**
PRICE **£16.99 / $18.99**
RELEASE **24 SEPTEMBER**



The story of radar, its inventors and contributing scientists are combined in this true story about the technology's emergence and lifesaving uses. Written for readers around the ages of 10 to 13, *Radar and the Raft* is for those with an interest in history and technology. Unlike many technology-based non-fiction books, *Radar and the Raft* largely focuses on the people behind the technology, as well as life during World War II.

The book includes a combination of character stories and multiple scientific discoveries, intriguing the reader as to how they connect together. Towards the end of the book, these stories and inventions meet in a dramatic scene that demonstrates the lifesaving potential of science. *Radar and the Raft* grips readers through both personal stories and the evolution of technology. By connecting the story of the Bell family's near-death experience during World War II with that of radar's discovery, the author has produced an engaging and informative storyline. This is a great read that explores the direct consequences of scientific discoveries.

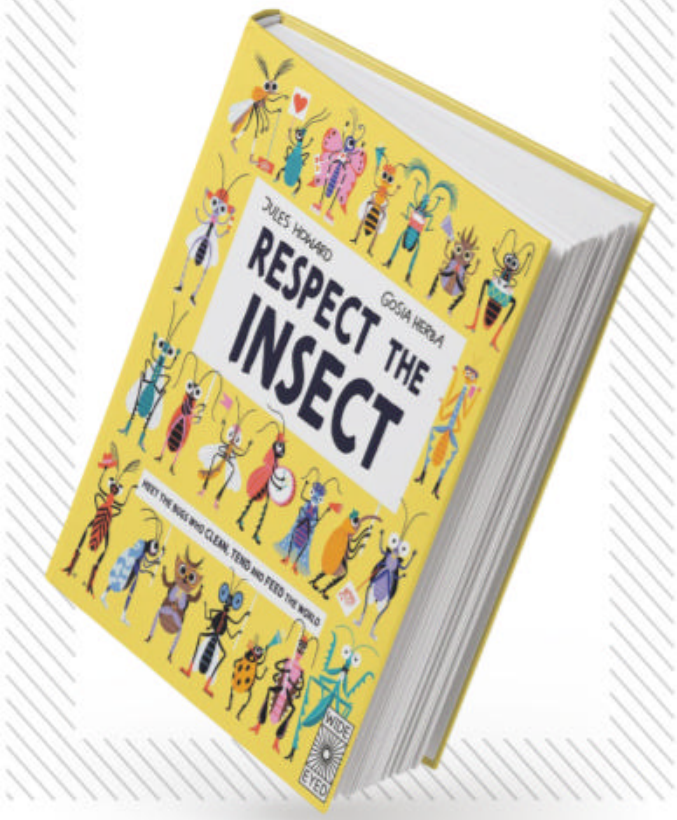
"Grips through both personal stories and the evolution of technology"

RESPECT THE INSECT

MEET THE BUGS WHO CLEAN, TEND AND FEED THE WORLD

AUTHOR **JULES HOWARD**
ILLUSTRATOR **GOSIA HERBA**
PUBLISHER **QUARTO**
PRICE **£14.99 / $22.99**
RELEASE **4 JULY**

In this amusing, factual and engaging book, young readers are introduced to the insect world in a visual way to help understand each creature's importance. Each insect is personified by a cartoon character who will explain their daily role in the environment. Let the critters welcome you into their homes for a grand tour, detailing how they built their homes and some of the ways their actions are misunderstood. From the plastic problem-solving wax moth caterpillar to earth-moving termites and honey-making bees, each page shows a new animal in action. From desert dwellers to insects that need to live in conditions so cold they would die if you touched them, wherever you live in the world, this ensures the next time you come across one of these species, you will hold more respect for the insect.



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

MEDIUM

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

HARD

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

Word search

Find the following words

DRONES
FOOD
RADAR
CARBON
SINK
TERABIT
OWL
BLACK
FLYING
TUNNEL
BROADBAND
HOLE

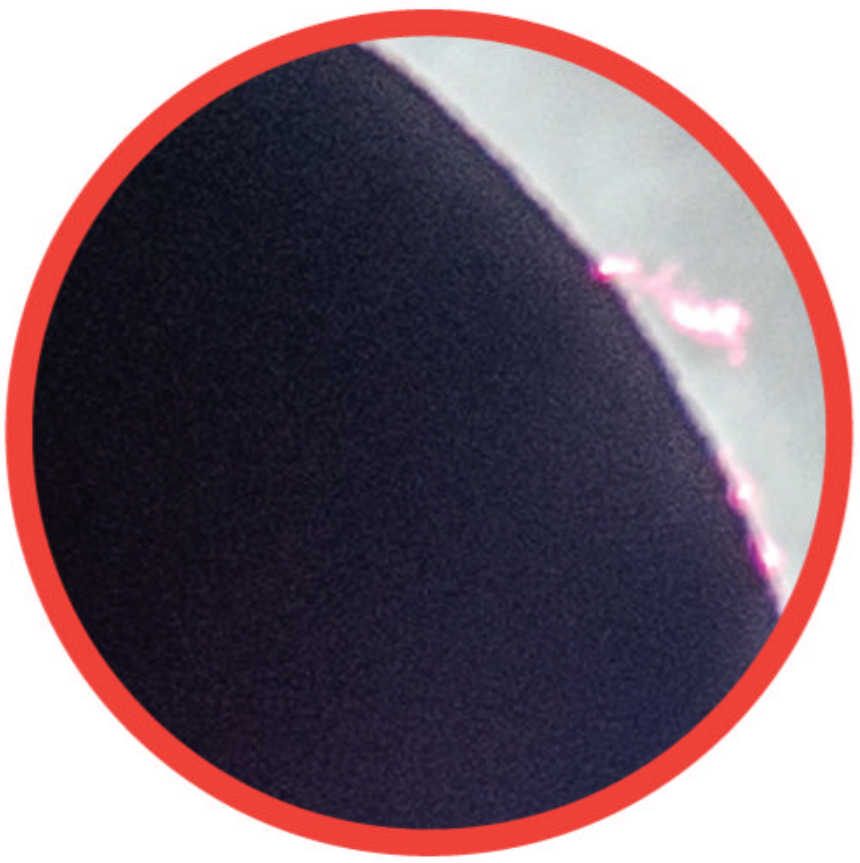
A	L	T	I	M	A	N	C	J	O	L	E	A	U	M
O	D	U	L	Y	W	I	H	D	E	R	B	A	S	D
C	R	N	A	T	E	R	A	B	I	T	B	O	I	N
R	O	N	D	A	R	O	W	Z	L	E	S	E	N	U
A	N	E	Q	I	B	L	A	K	C	A	T	U	K	P
V	E	L	C	Z	R	K	O	M	H	O	L	E	B	A
D	S	N	D	B	C	R	O	A	D	J	H	C	U	N
N	E	L	O	A	P	N	W	Y	N	O	B	R	A	C
A	W	S	L	A	C	K	F	L	Y	I	N	G	O	W
B	A	B	O	N	E	K	O	X	E	B	A	N	B	D
D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

What is it?

Hint:

Use the right eyewear!

A



Spot the difference

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

QUICKFIRE QUESTIONS

Q1 What celestial body does the Parker Solar Probe orbit?

- Proxima Centauri
- Earth
- Jupiter
- The Sun

Q2 Which physical process makes the sky blue?

- Refraction
- Reflection
- Diffraction
- Rayleigh scattering

Q3 What is the World Mosquito Program using to limit the spread of dengue fever?

- A vaccine
- Engineered mosquitos
- Fire
- Ibuprofen

Q4 Which land animal has the biggest ears?

- Basset hound
- Long-eared jerboa
- African elephant
- Hare

Q5 Which of these animals is the most venomous?

- Gila monster
- Inland taipan
- Pufferfish
- Box jellyfish

Q6 What year is the next total solar eclipse?

- 2026
- 2036
- 2046
- 2096

Answers

Find the solutions to last issue's puzzle pages

Q1 6.5 METRES
Q2 191
Q3 METAMORPHOSIS
Q4 ANTICOAGULANT
Q5 33 BILLION
Q6 STICKY RICE

What is it?

HELICOPTER

Spot the difference

MAKE A RAINBOW WATER COLUMN

By stacking different water densities, you can capture a rainbow in a glass

1 GATHER YOUR EQUIPMENT

For this experiment you will need one more glass than the number of layers you wish to create in the column. The extra glass should be tall and thin.

2 POUR IN THE WATER

Fill all but the tall glass with warm water. Make sure you keep the volume of water relatively equal for each glass.

3 DROP IN SOME COLOUR

Add a few drops of a different coloured food colouring to each of the glasses of water. Keep the number of drops consistent.

4 LEVEL UP THE SUGAR

Now it's time to add some sugar. Add no sugar to the first glass of water, one tablespoon to the second and two tablespoons to the third. Continue adding one more spoonful each time as you progress through the colours.

5 MIX THE CONTENTS

Mix each of the sugar-water glasses until the sugar grains have dissolved completely. Using warm water will make this process quicker.

6 ADD LAYER ONE

If you have four colours, fill a quarter of the glass with the solution containing the most sugar. If you have five colours fill one-fifth, one-sixth for six colours and so on.

NEXT ISSUE
MAKE A PH PICTURE WITH COLOUR-CHANGING TURMERIC

KIT LIST

- Sugar
- Water
- Food colouring
- Tablespoon
- Five to six glasses
- Pipette or syringe

DON'T DO IT ALONE!
If you're under 16, make sure you have an adult with you

7 DECREASE THE DENSITY

Use a pipette or syringe to carefully add the next layer on top of the previous one. Make sure you're adding the water with one fewer tablespoon of sugar next, and continue to decrease in order of sugar density.

8 RETURNING TO LAYERS

By using a pipette or syringe, you can add more water to the previous layers by slowly lowering the utensil until the end is in contact with the matching colour. This helps even up the column.

9 CAREFULLY COMPLETE

By the time you've progressed to the final layer with no sugar, you should find that the previous layers haven't mixed. Take a photo of your column and send it to **howitworks@futurenet.com** to have it featured in our letters page.

SUMMARY

The density of an object is its mass compared to its volume – in the case of this experiment, the number of sugar particles in a given volume of water. In the water with the highest sugar content, more of the space between the water particles is filled with dissolved sugar particles. This makes the water more dense. The more dense a substance is, the more likely it is to sink due to its higher mass. By putting the densest layer of water into the glass first, it creates a stable layer as the heaviest in the column. As the next layer is less dense, it won't fight with the layer below and sink in it. Instead it will sit on top. If you were to add the layers in the reverse order, the denser water would sink through the other layers and settle on the bottom, causing the colours to mix and preventing a clear rainbow tower.

Had a go? Let us know!

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

INBOX

Speak your mind

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

FRUIT PRESERVATION

Dear **HIW**,
When I put lemon juice on a cut avocado it stays green longer. What is in lemon juice that prevents browning?
Jess Burns

Avocados have an enzyme called polyphenol oxidase (PPO) underneath the skin. When these enzymes are exposed to oxygen, they alter compounds in the avocado and turn it brown. As soon as the avocado's protective skin is broken, the air makes contact with its flesh and this process begins. PPO is only active when in certain pH conditions, between 6 and 7.5. By adding lemon juice, the pH becomes more acidic and prevents the enzyme from reacting. Covering the exposed surface with this natural preservative soon after cutting the avocado slows browning and can keep the avocado relatively fresh in the fridge for around three days.

Lemon juice has a pH between 2 and 3

BREAKING OLD HABITS

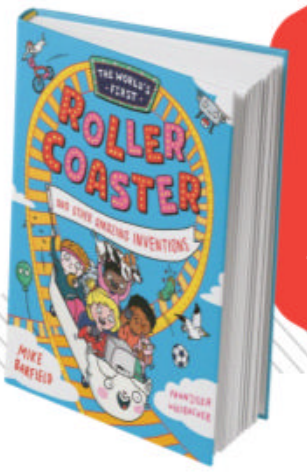
LETTER of the MONTH

Nail biting is often associated with anxiety

Dear **HIW**,
I have been a nail-biter for years and can't seem to break the habit. What are the best ways to break old habits?
Nadia Reynolds

When an action becomes a habit it can be difficult to change your ways because the act of biting your nails becomes subconscious. However, if you want to kick a habit, there are some methods that you can use to increase your chances of changing bad habits and replacing them with healthier ones. Firstly, take note of what you were doing before a habit kicked in, or any common denominators that could be causing you to bite your nails. For example, is it something you do in social situations, when stressed or during a specific activity? By understanding what triggers your habits, you stand a better chance of stopping them. Look for ways in which you can prevent certain scenarios from happening, if possible.

If a habit is caused by something you can't change, you could try to control your response. One proven method is to find a replacement action and make a conscious effort to do this instead. For example, some people choose to use fidget toys for this purpose. Using these whenever you're in a triggering situation can help you retrain your mind to revert to habits that are less damaging to the body. This also works for other habits, such as unhealthy eating. Making the effort to eat fruit every time you crave something sweet can cause lasting healthy eating habits over time. Make sure the replacement habit is a simple one, because the simpler the new habit is, the easier it will be for your brain to incorporate it subconsciously. When you have begun this process, remain persistent. The more you try to incorporate a new habit and the more routinely you stick to it, the more likely it is to become a new, healthy habit.



WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

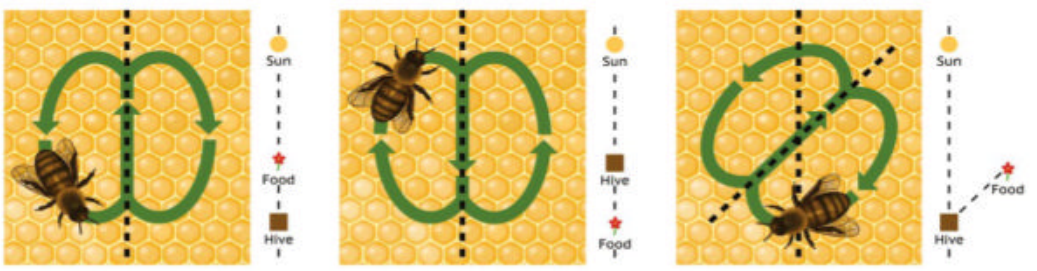
THE WORLD'S FIRST ROLLERCOASTER: AND OTHER AMAZING INVENTIONS

The fascinating true stories behind an amazing range of inventions and innovations – from trainers to teddy bears

ANIMAL TALK

Dear **HIW**,
How do animals talk to each other without using words?
Mason Brown

There are many ways in which animals can do this. Some animals use low-frequency calls to communicate over long distances, such as whales, which make different sounds to relay a threat, mating call or other situation. Despite not using words in the way humans do, animals make many other noises that make sense to their species. In addition, non-verbal communication is common in the animal world. Bees, for example, display elaborate dances to describe the location of food sources, dolphins slap their tails on top of the water's surface to send messages to other dolphins and ants release chemicals to communicate with others in the colony. Each animal has evolved its own method to communicate safely in the wild, and those that can't be translated by humans and other animals mean their form of communication is safer.



Bees' waggle dances communicates the direction of food in relation to the Sun and the beehive

Bears can slow their heart and breathing rates by 75 per cent during hibernation

HUMAN HIBERNATION

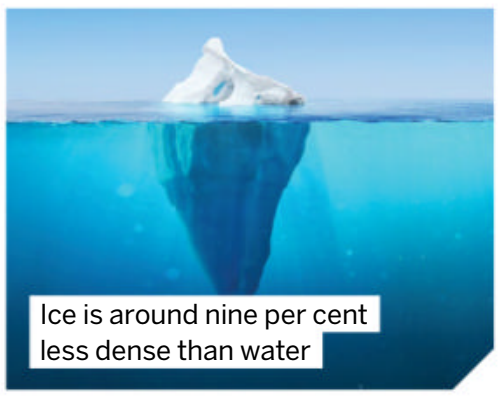
Dear **HIW**,
Could humans hibernate? What makes the biology of hibernating animals different?
Charlotte Hill

Humans don't need to hibernate because we discovered fire, shelter, clothes, hunting and agriculture as ways to stay warm and well fed through winter. Animals that hibernate have evolved metabolic adaptations to survive long periods asleep and without food. Hibernation causes the heart rate and body temperature of the animal to decrease. Summer-loving humans may wish that they could hibernate through the colder and darker months, but because our ancestors evolved in relatively warm regions, we don't have the same biological capabilities as hibernating species.

WATER WONDER

Dear **HIW**,
Ice feels heavier than water, so why does it float on top?
Benjamin C

A given volume of water will weigh the same after freezing into ice because they are made of the same substance (H_2O). When water freezes, its molecules rearrange into a crystalline structure and expand to fill more space. As the same mass of water takes up more space in frozen form, ice is less dense. This is caused by the larger spaces between water molecules. Per unit of volume, water is heavier, and so it falls below the ice. Ice sits buoyant on the water's surface.



Ice is around nine per cent less dense than water

WE ASKED YOU

This month on social media, we asked you:
Where is your favourite place on Earth?

@JEANMCDOUGALL8333
BY THE SEA

DAVID JOHNSON
I LOVE THE SWISS ALPS FOR THE MAJESTIC MOUNTAINS

@DOODLENEWS
THE BEACHES OF CORNWALL

ALEX RODRIGUEZ
IN THE FORESTS. I LOVE BEING SURROUNDED BY NATURE, ESPECIALLY WHEN OUT FOR A RUN

RACHEL P
THE HILLS OF TUSCANY AND UNIQUE MEDIEVAL TOWNS

@????FATEMEH????
UNEXPLORED MADAGASCAR

JESSICA THOMSON
ICELAND IS MY FAVOURITE COUNTRY I'VE VISITED. I LIKE ITS DRAMATIC LANDSCAPES AND SKIES

NEXT ISSUE

ISSUE 192 ON SALE 11 JULY 2024

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Future PLC Quay House, The Ambury, Bath, BA1 1UA

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Editor **Ben Biggs**
Senior Art Editor **Duncan Crook**
Production Editor **Nikole Robinson**
Senior Staff Writer **Scott Dutfield**
Staff Writer **Ailsa Harvey**
Editor-in-Chief **Tim Williamson**

Contributors
Dr. Andrew May, Jack Parsons, Harry Baker, Owen Hughes, Patrick Pester, Joanna Thompson, Robert Lea, Sascha Pare, Skylar Ware, Jennifer Nalewicki, Paul Sutter, Meg Duff, Stephanie Pappas, Emily Cooke, Hayley Birch

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Advertising
Media packs are available on request
Graduate Sales Executive **Sophie Dickinson**
sophie.dickinson@futurenet.com

Advertising Sales Director **Lara Jaggon**
lara.jaggon@futurenet.com
07515 961911

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FAST FACTS

Amazing trivia that will blow your mind

A BITE FROM THE LONE STAR TICK CAN MAKE YOU ALLERGIC TO RED MEAT AND DAIRY

75%

Around three-quarters of the food we eat comes from just 12 plants and five animal species

123456 is still one of the world's most common passwords

5,500 YEARS OLD

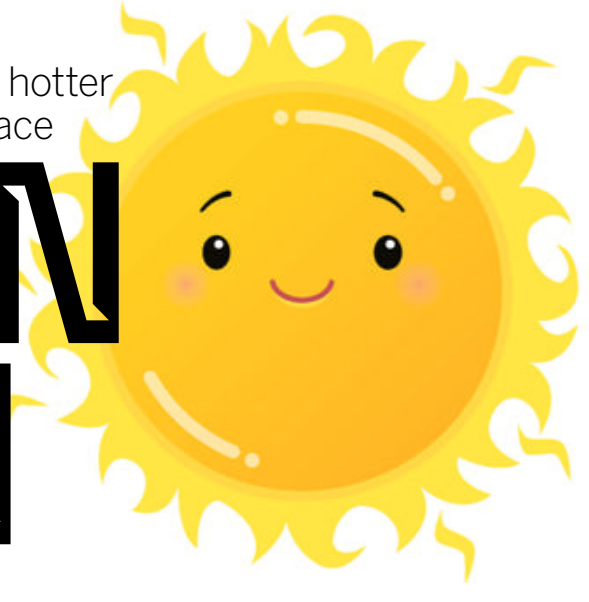
The world's oldest honey was found in Georgia in 2023 – it was still edible

1936

88 years ago, Vladimir Lukyanov built a computer powered by water

100 MILLION KELVIN

Solar flares can be thousands of times hotter than the Sun's surface

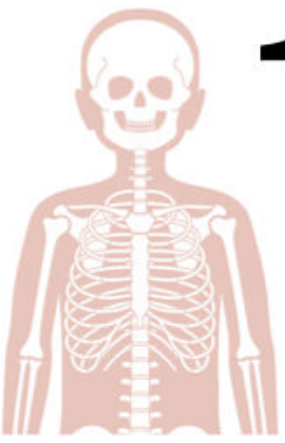


11 metres

Mexico's 'Cave of the Crystals' contains gypsum crystals over six times taller than a human

4.5 BILLION YEARS AGO

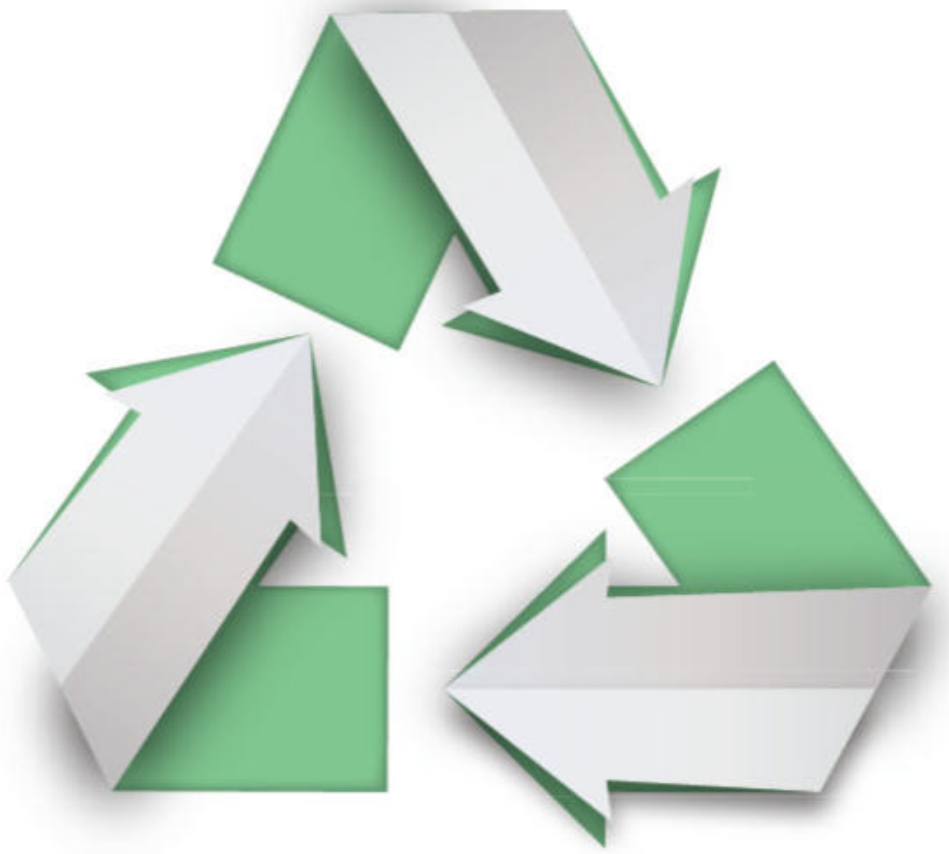
A massive impactor is thought to have hit the ancient Earth, creating the Moon



100

You lose around this many bones as you grow from a baby into an adult

A STING FROM THE IRUKANDJI JELLYFISH CAN ELICIT A SENSE OF IMPENDING DOOM



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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