



# INSIDE APPLE'S NEW VR HEADSET

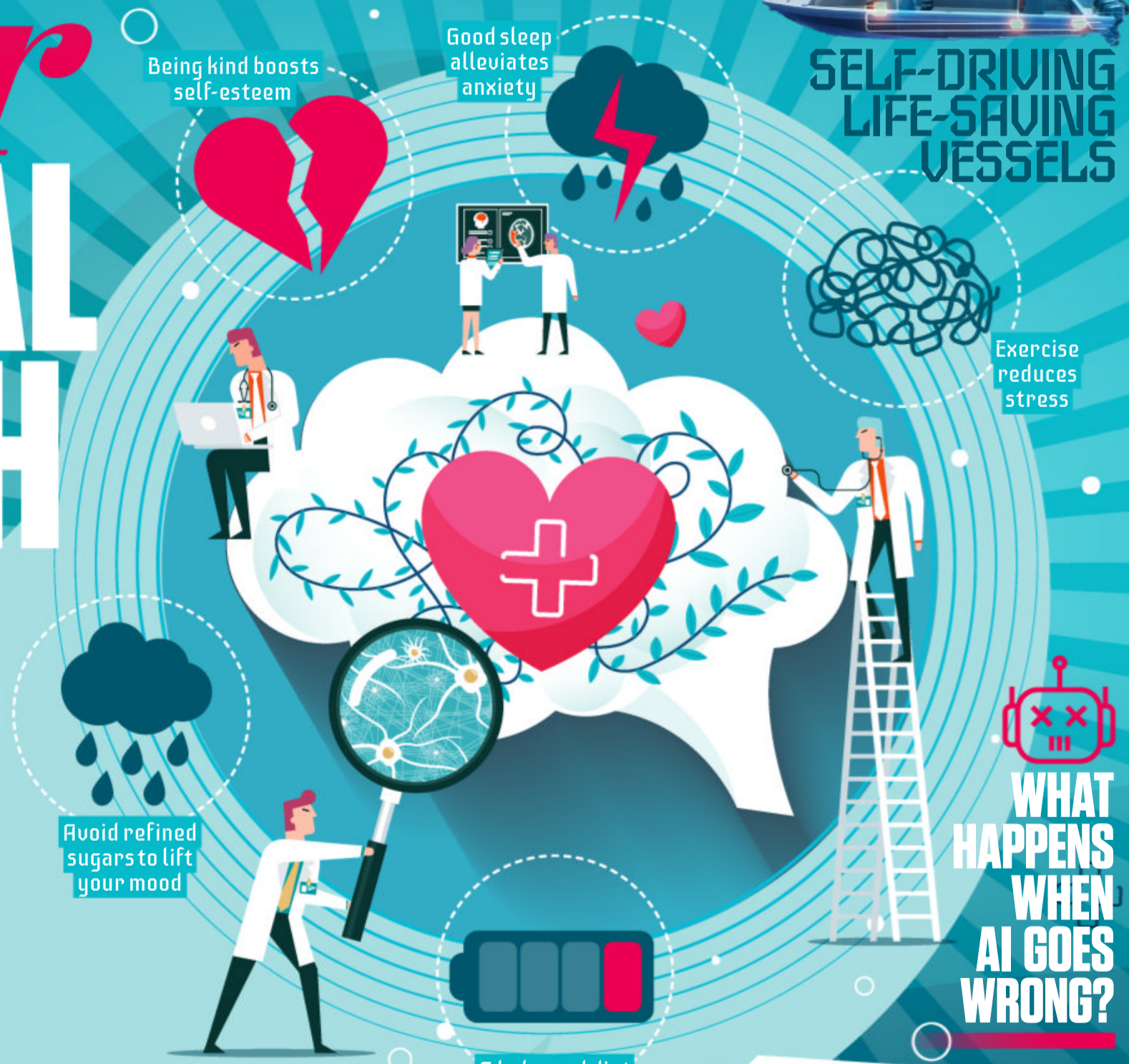
# HOW IT WORKS



**WHAT IS ULTRA-PROCESSED FOOD?**

## Your MENTAL HEALTH

HOW TO BE KIND TO YOUR MIND: TIPS AND TRICKS TO IMPROVE WELLBEING



**SUPER SPACEX ROCKET ENGINE**

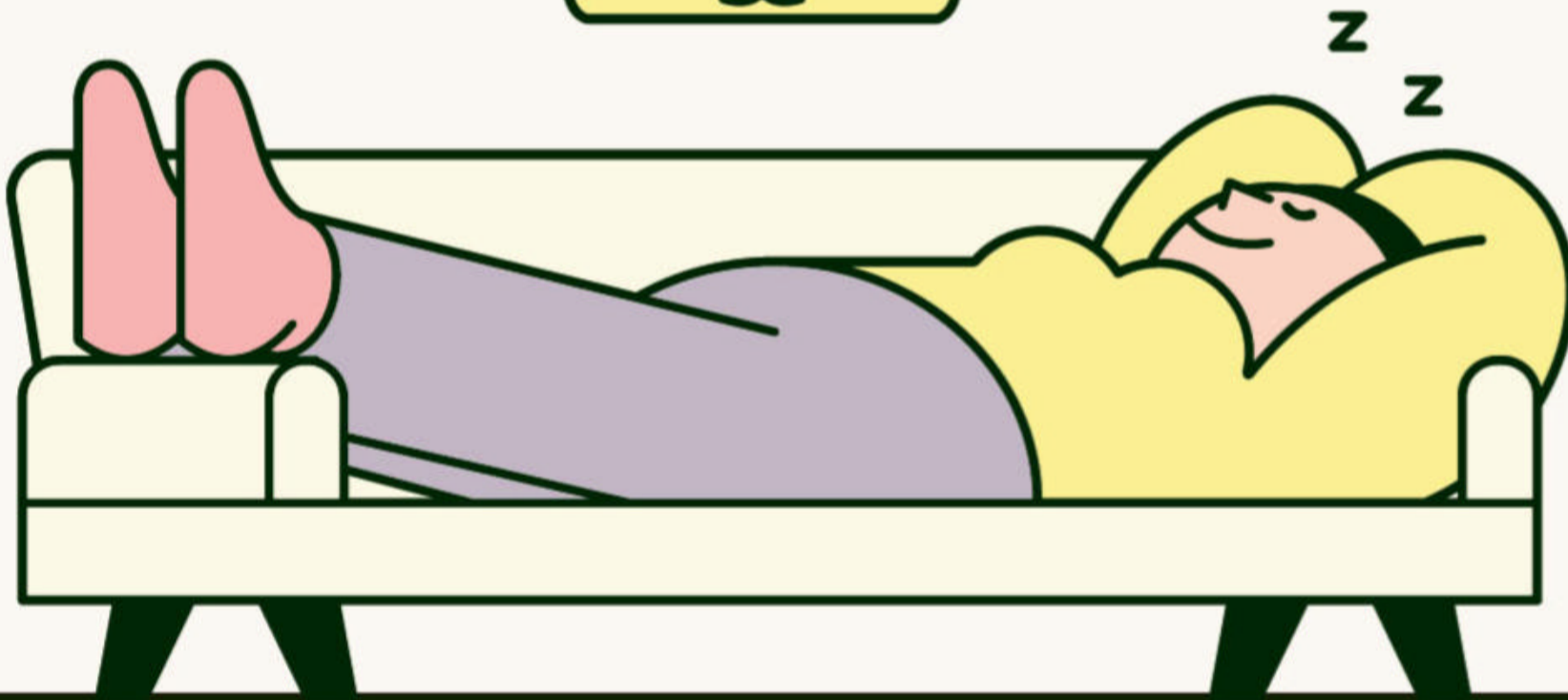
FUTURE  
ISSUE 190



**D-DAY'S WACKIEST INVENTIONS**

+ HOW A DEFIBRILLATOR WORKS / WHAT IS A RAINBOW? / MOST ENDANGERED ANIMALS / WHY WATER HAS A 'SKIN'

# SAVVY SPENDING STARTS AT HOME.



**GO.**  
**COMPARE**

Get more information or compare quotes  
at [go.compare/home-insurance](https://go.compare/home-insurance)

# WELCOME

Issue 190

SCAN HERE TO  
SUBSCRIBE TO  
LIVESCIENCE'S  
NEWSLETTER



## HIGHLIGHTS



### 29 WORRY WART

Discover the parts of the brain that cause anxiety



### 34 GOING SOLO

How this self-driving boat technology works



### 43 LIFTING OFF

Inside the SpaceX Raptor rocket engine

## Your mental health

PAGE 26

**“Acts of kindness, especially to ourselves, can reduce stress and boost self-esteem”**



## SUBSCRIBE NOW

GO TO PAGE 24 FOR GREAT DEALS



FOLLOW US: [f](#) HOW IT WORKS MAGAZINE [X](#) @HOWITWORKSMAG [@](#)HOWITWORKS@FUTURENET.COM [@](#)HOWITWORKSMAG

**W**e've come a long way since the days of the 'stiff upper lip' where, in Britain at least, expressing yourself and openly admitting that you're not in a good frame of mind was considered a sign of weakness or poor form – especially for men. Today, mental health professionals recognise a range of conditions, disorders and neurodivergence, although there are common themes: too much stress, whatever the stimulus, can lead to a mental and physical breakdown. And regular, good-quality sleep can help give anyone a sunnier outlook on life. In this issue, we explore some of the psychology and biochemistry behind your mental health and how you can be kind to your mind. Enjoy!



**Ben Biggs**  
EDITOR

## WHAT WE'RE ANTICIPATING



**NIKOLE**  
PRODUCTION EDITOR



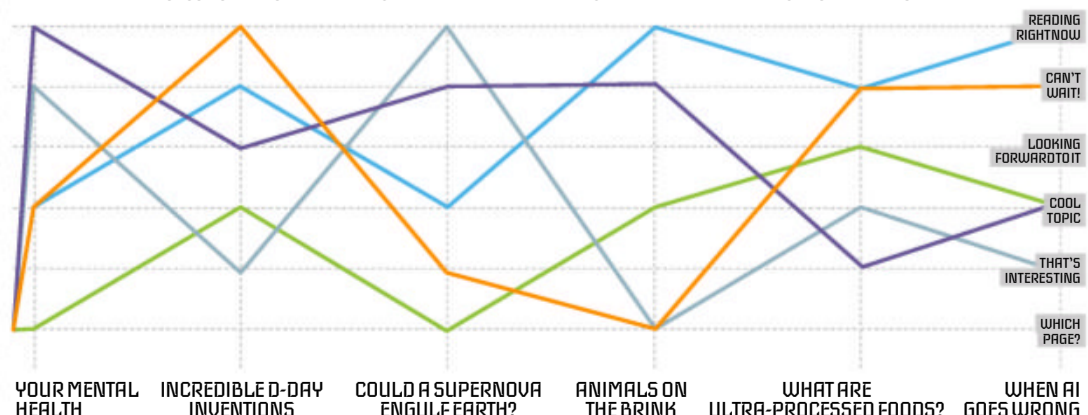
**SCOTT**  
STAFF WRITER



**AILSA**  
STAFF WRITER



**DUNCAN**  
SENIOR ART EDITOR



FOR EXCLUSIVE HIW NEWS AND OFFERS, SIGN UP TO OUR MAILING LIST [HOWITWORKSDAILY.COM/NEWSLETTER](http://HOWITWORKSDAILY.COM/NEWSLETTER)

# INSIDE

Issue 190

## SPECIAL

### 26 Understanding mental health

Take a tour of the brain to discover the origins of anxiety and how to tackle it

## TRANSPORT

### 34 Nautomate: life-saving autonomous boats

Discover the marine rescue technology that removes humans from dirty and dangerous missions

## SPACE

### 36 Could a supernova engulf Earth?

We answer some intriguing, baffling and bizarre space questions

### 42 Super SpaceX rocket engine

This revolutionary new Raptor propulsion system is set to change space launches

## SCIENCE

### 44 What are ultra-processed foods?

Some natural products are drastically transformed by processing, and eating them regularly can affect our health

### 48 Vitamin balance

Can a lack or excess of key vitamins and minerals really cause so much damage to our bodies?

### 52 What is a rainbow?

The physics behind these stunning optical illusions in the sky

### 54 Why water has 'skin'

How the surface tension of water forms a surprisingly strong film

## ENVIRONMENT

### 56 Animals on the brink

Meet some of the most critically endangered animals from around the world and discover why they're on the brink of extinction

### 62 How waterfalls form

Over time, the power of flowing water can gouge channels out of the land and shape solid rock

## TECHNOLOGY

### 64 When AI goes wrong

Here are seven instances when artificial intelligence didn't function as planned

### 68 How a defibrillator works

This life-saving device can be used by both medics and the general public

### 70 Apple Vision Pro teardown

This new mixed-reality headset removes the need for a screen and virtually brings your digital applications into the space around you

## HISTORY

### 72 Incredible D-Day inventions

How daring innovation allowed the Allies to land on the beaches of Normandy in 1944

### 78 How Stonehenge was built

Who built this stone circle and how was this feat of engineering pulled off?



42



56



36

## REGULARS

### 06 Global eye

Science and tech news from around the world

### 22 Wish list

Smart personal robots

### 84 Braindump

Your questions answered

### 90 Book reviews

### 92 Brain gym

Give your brain a workout with our puzzle pages

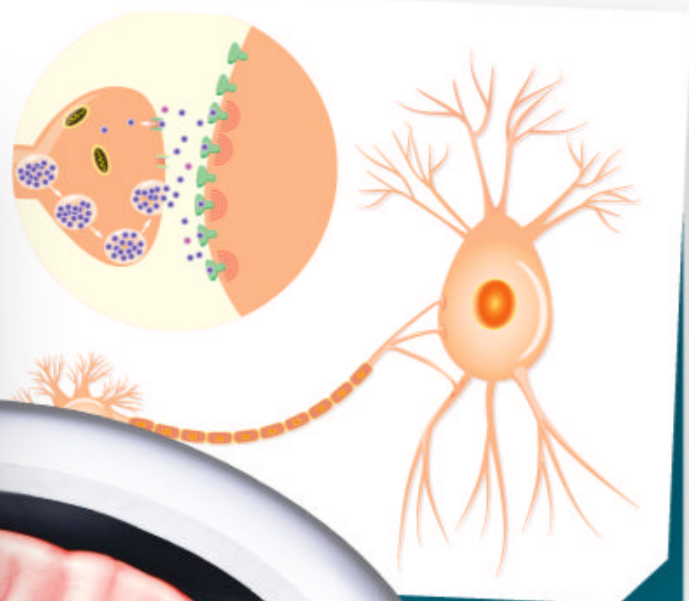
### 94 How to...

Turn milk into cheese

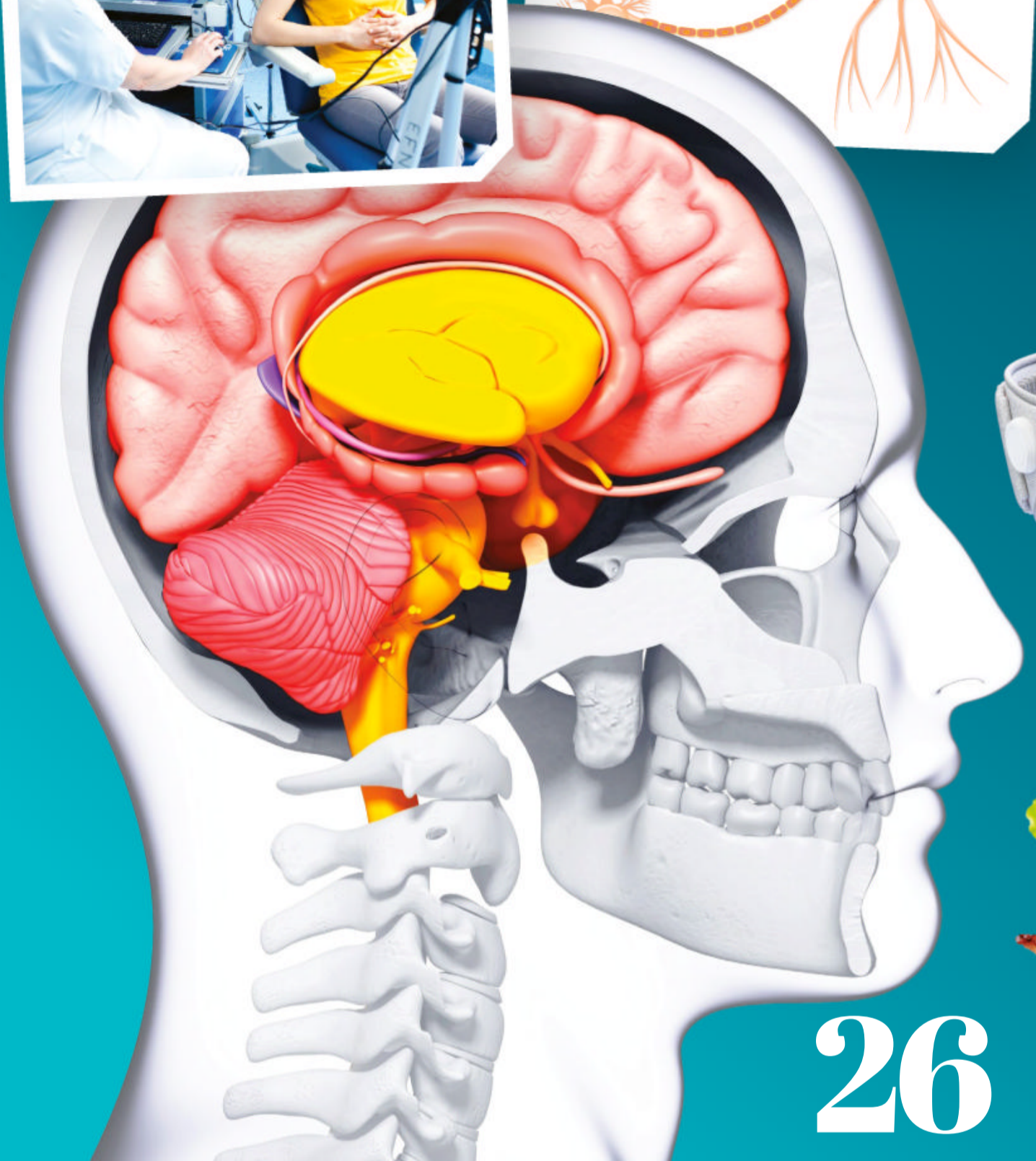
### 96 Letters

Have your say

### 98 Fast facts



72



70



44

26



62

**SUBSCRIBE NOW**  
GO TO PAGE 24 FOR GREAT DEALS



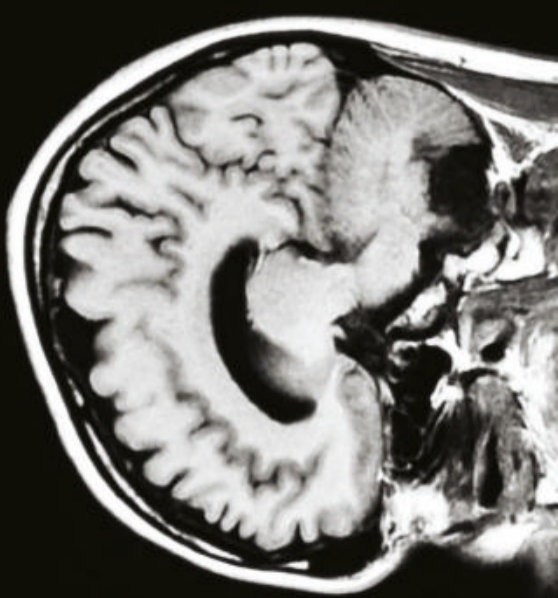
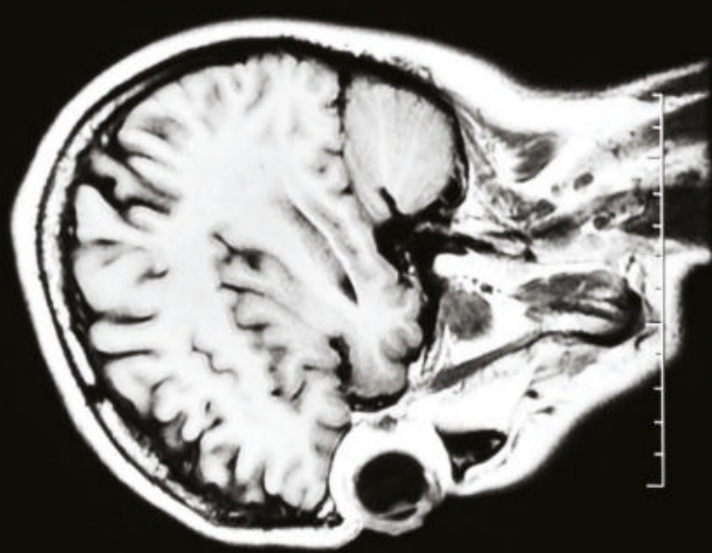
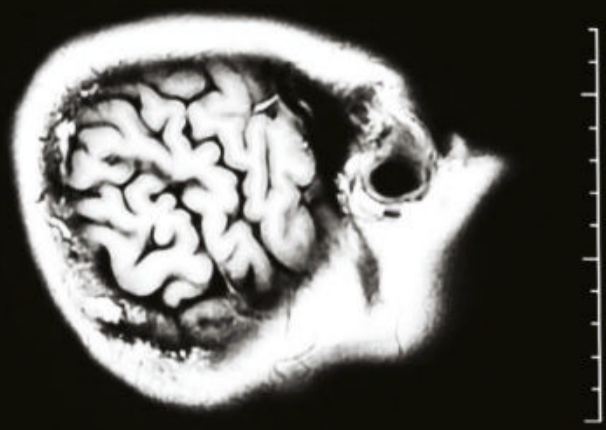
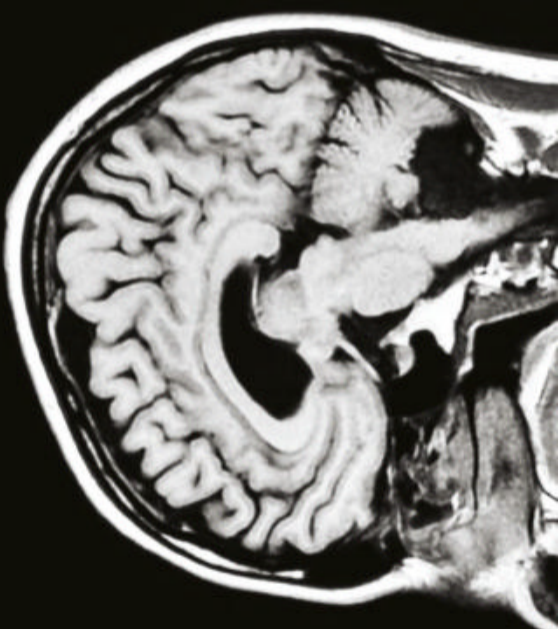
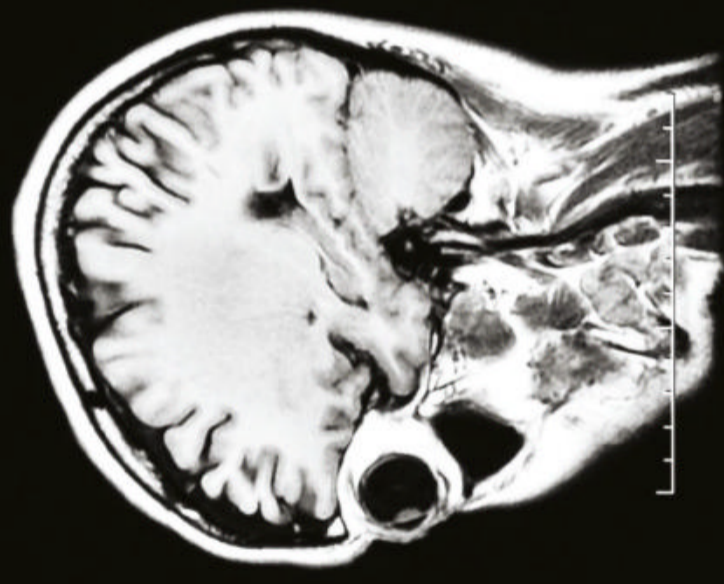
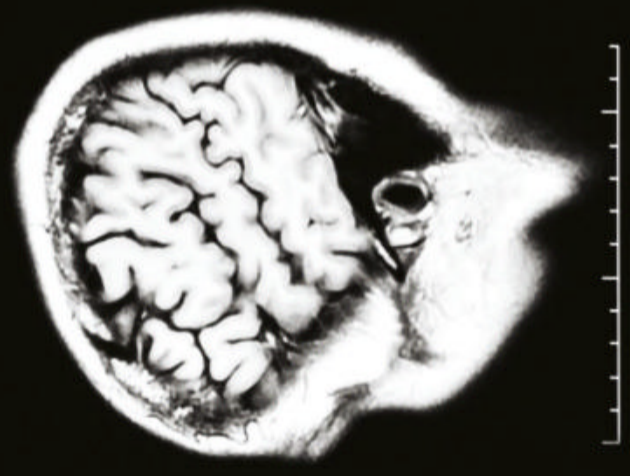
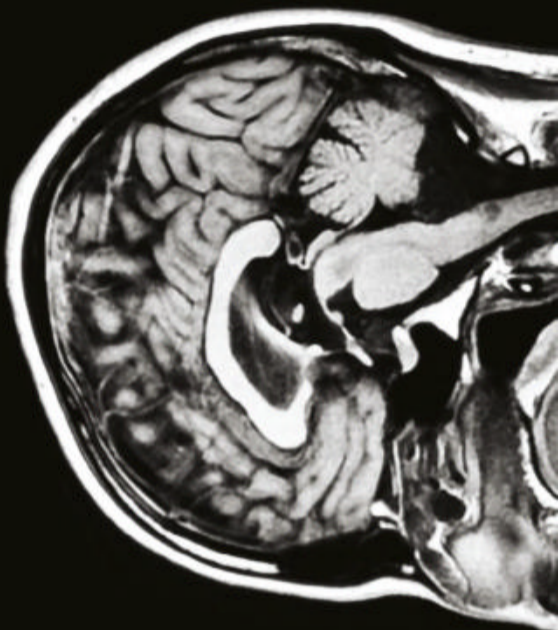
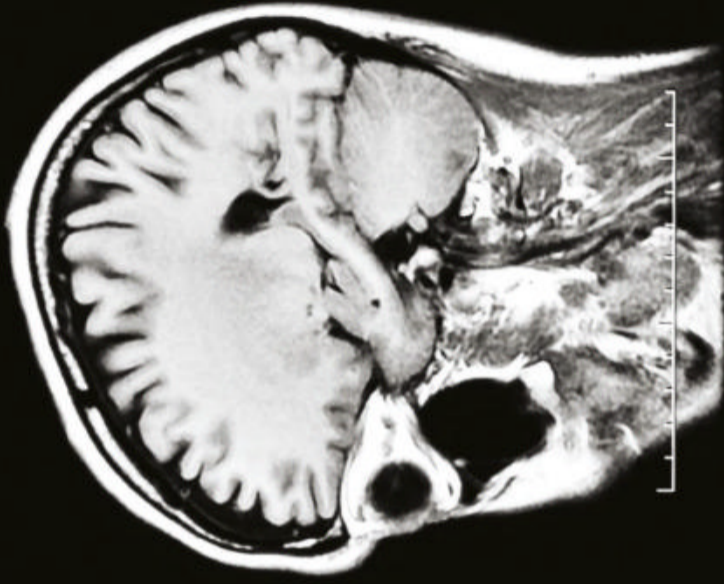
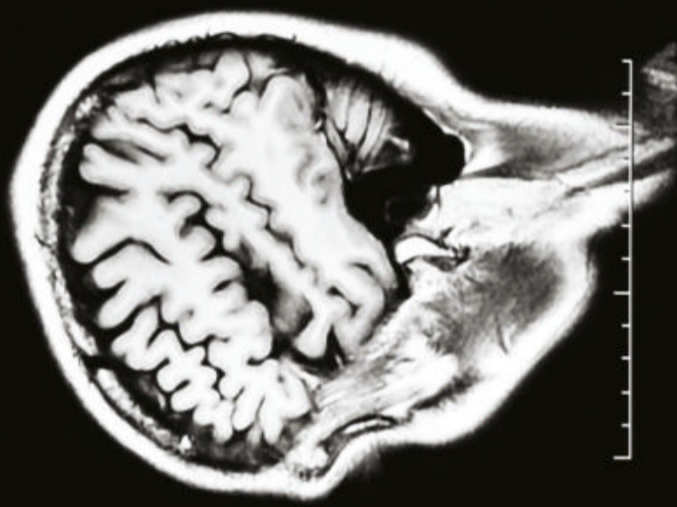
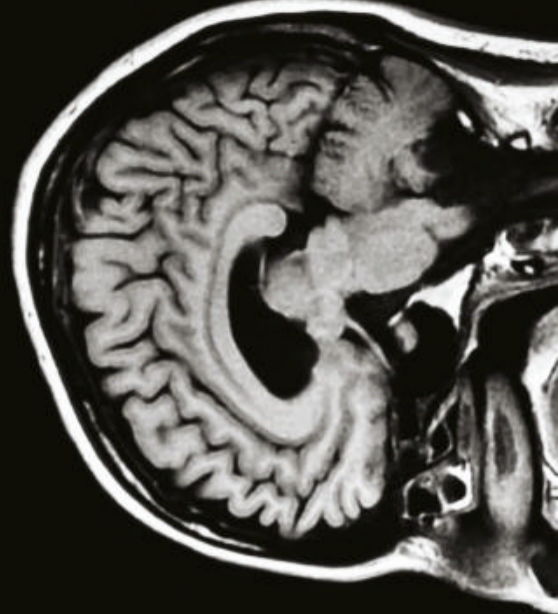
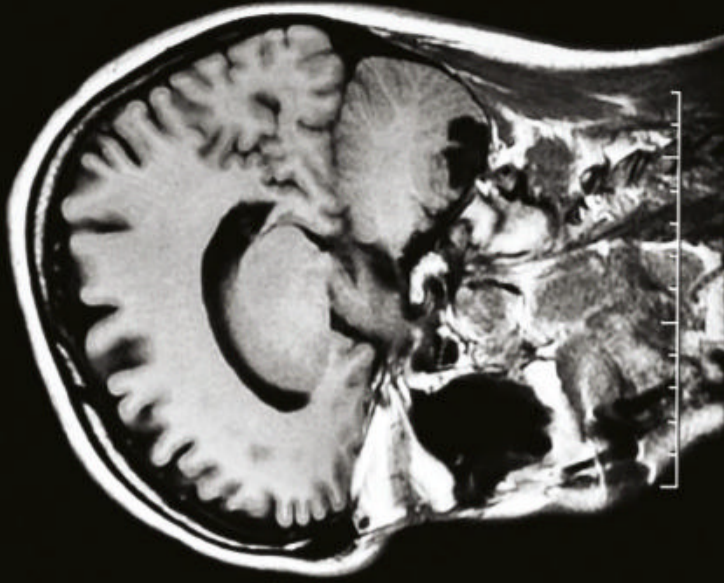
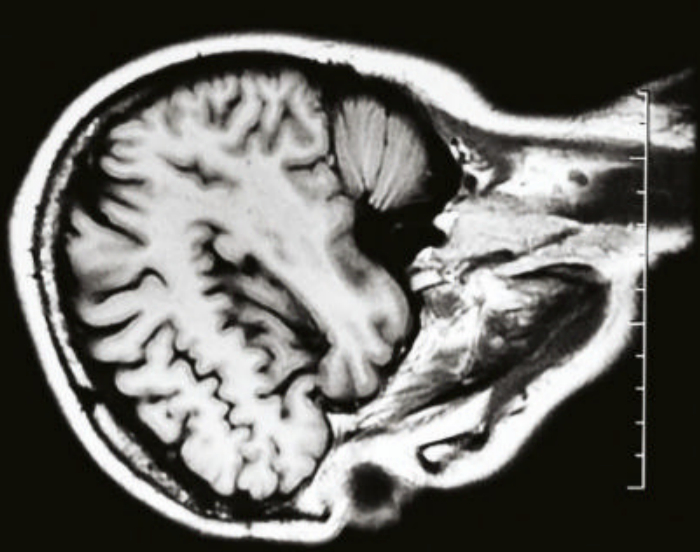
52



## Light pillar phenomenon

These beams extending up from the horizon are a natural phenomenon called light pillars. They are the result of light from a source such as the home in this image, being reflected by falling ice crystals usually associated with high-flying cirrostratus clouds. As these flat ice crystals fall to the ground, the light reflects into thin, rod-like beams.





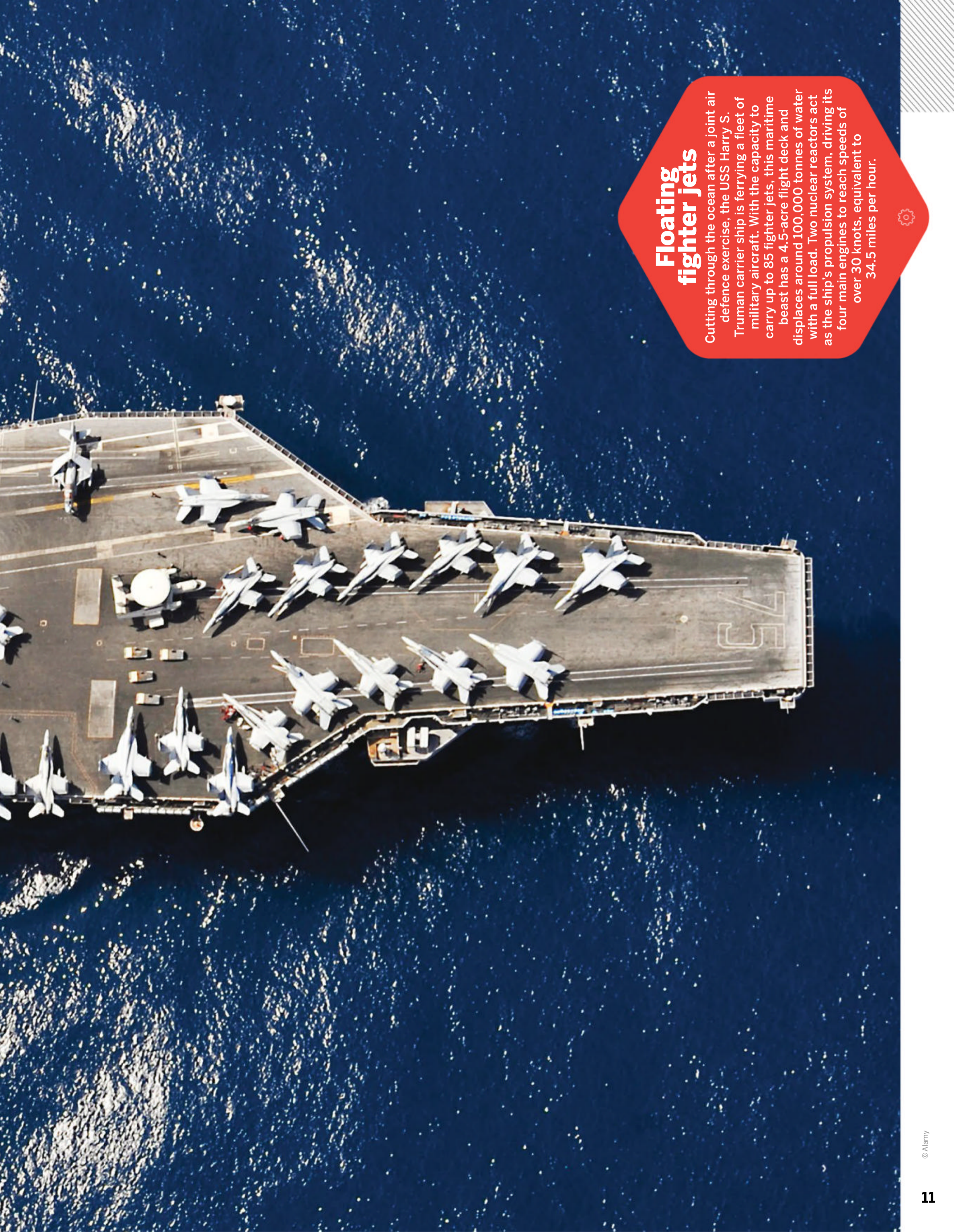


## A magnetic view of the mind

Using magnetic resonance imaging (MRI), doctors can take a peek inside our heads. In this series of MRI scans, image slices have been taken vertically from one side of the head to the other, revealing all the cerebral structures in the brain. To capture these, powerful magnetic fields excite atoms in the body, then radio waves are used to detect their movements and convert that information into signals that a computer interprets as an image.







## Floating fighter jets

Cutting through the ocean after a joint air defence exercise, the USS Harry S. Truman carrier ship is ferrying a fleet of military aircraft. With the capacity to carry up to 85 fighter jets, this maritime beast has a 4.5-acre flight deck and displaces around 100,000 tonnes of water with a full load. Two nuclear reactors act as the ship's propulsion system, driving its four main engines to reach speeds of over 30 knots, equivalent to 34.5 miles per hour.







## A quick chameleon snack

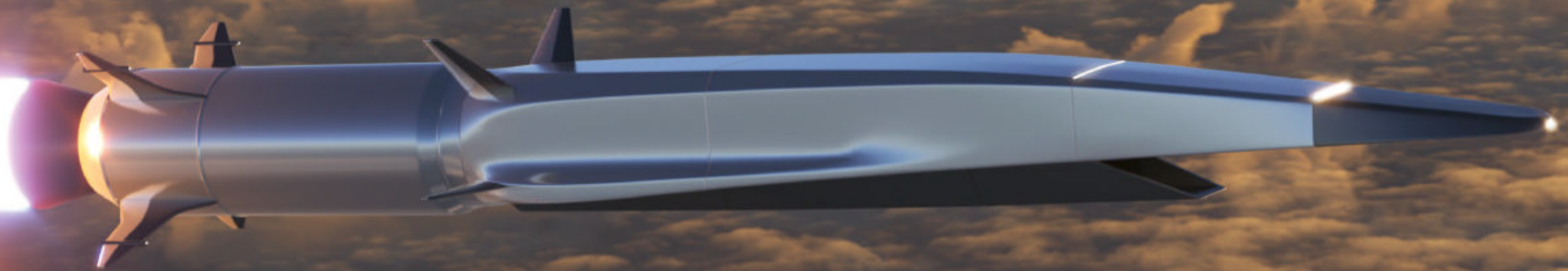
This unsuspecting grasshopper didn't stand a chance against the elastic grasp of the Parson's chameleon's tongue. Much like the drawing of a bow and arrow, the stretchy tissue of a chameleon's tongue is retracted by tubular muscles in the throat and released, propelling the tongue forward. A chameleon's tongue can be fired at up to 60 miles per hour in a fraction of a second.



# GLOBAL EYE

Showcasing the incredible world we live in

The drone flew at over 680 miles per hour. This image is not the drone and is purely illustrative



ENGINEERING

## A drone with a 'rotating detonation rocket engine' approached the speed of sound

WORDS PETER RAY ALLISON

**U**enus Aerospace has completed the inaugural test flight of a drone fitted with its rotating detonation rocket engine (RDRE), accelerating it to just under the speed of sound. The company wants to one day build superfast commercial jets using this new type of engine. In a 24 February test flight, the company flew the drone, which is 2.4 metres long and weighs 136 kilograms, to an altitude of 3,658 metres with an Aero L-29 Delfin plane before it was deployed and the RDRE was activated. The drone flew ten miles at Mach 0.9 – over 680 miles per hour – using 80 per cent of the RDRE's available thrust. The flight proved the viability of RDRE and the associated onboard flight systems. Three weeks earlier, Venus Aerospace demonstrated the viability of its RDRE technology with a long-duration test burn, during which engineers showed their engine worked for the duration of this test flight.

Rather than using a continuous burn like most rocket engines, RDRE operates by a detonation wave continuously rotating around an annulus, or ring-shaped chamber. The fuel,

hydrogen peroxide, is injected into the annulus, and the repeated detonations become self-sustaining after the initial ignition. In the RDRE test flight, the annulus was approximately 25.4 centimetres in diameter and produced 544 kilograms of thrust. The RDRE technology is 15 per cent more efficient than conventional rocket engines. As a result, an RDRE-propelled craft could theoretically travel farther on the same amount of fuel as conventional engines that combust fuel at constant pressure. Some have also theorised it could be as much as 25 per cent more efficient than current technologies.

The successful test flight raises the odds of commercially viable supersonic flight. One of the long-term goals for Venus Aerospace is to develop a commercial supersonic aircraft that could travel at Mach 9 – over 6,800 miles per hour. For comparison, the Concorde aircraft could fly at just over Mach 2, or just under 1,550 miles per hour, while the forthcoming

Lockheed SR-72 prototype is expected to fly at speeds greater than Mach 6, approximately 4,600 miles per hour. To put this into context, a vehicle flying at Mach 9 could travel from London to San Francisco in an hour. Just as Concorde was noisy at takeoff, the RDRE's constant detonations will make any craft fitted with them incredibly loud. And unlike

conventional jet engines, which offer much smoother accelerations, the rapid, repeated cycles of acceleration from the continuous detonations may also cause increased stress and fatigue of the engines and associated support structures.

Because RDRE could have

military applications, Venus Aerospace is also collaborating with the Defense Advanced Research Projects Agency (DARPA). For now, Venus plans further test flights using drones. One test flight engineers are considering involves fitting the current RDRE on a larger drone capable of achieving hypersonic flight five times faster than the speed of sound, approximately 3,900 miles per hour.

**“The drone flew ten miles at Mach 0.9”**



A heart-shaped 'splat' on Pluto's surface has captivated scientists for nearly a decade

SPACE

## Pluto's huge white 'heart' has a violent origin

WORDS STEPHANIE PAPPAS

**W**hen New Horizons flew by Pluto in 2015, it returned images with a sweet surprise: a heart-shaped formation dominating the surface of the dwarf planet. Now, researchers believe they've uncovered its origin: the heart formed in a slow-motion, glancing collision with an icy rock wider than Kansas is long. In a new study, researchers determined this scenario by using computer models to simulate impacts on Pluto's surface and the resulting formations. Pluto's heart, known as Tombaugh Regio, gets its light coloration from nitrogen ice.

Impacts between icy bodies in the far reaches of the Solar System aren't like those closer to the Sun. "We are used to thinking of planetary collisions as incredibly intense events where you can ignore the details except for things like energy, momentum and density," said Erik Asphaug, a professor at the University of Arizona's Lunar and Planetary Laboratory. "But in the distant Solar System, velocities are so much slower, and solid ice is strong, so you have to be much more precise."

Researchers used a simulation method called smoothed particle hydrodynamics to test various angles of collision and sizes of impactors to learn which dynamics would lead to the formation of Sputnik Planitia, the western portion of Pluto's heart. This roughly

800-square-mile region sits about 2.5 miles lower than its surroundings. The team found that the formation probably originated from an oblique collision, leading to its elongated shape. This likely happened early in Pluto's history. The icy rock that hit Pluto was probably around 454 miles in diameter. This impactor likely flattened on Pluto's surface. Even now, it may sit just under the smooth nitrogen ice that covers Sputnik Planitia.

**Did you know?**  
Pluto is around one-sixth the width of Earth

The simulations further suggest that Pluto does not hold a subsurface ocean under its icy outer layers. Because Pluto's heart has a lower mass than the rest of the dwarf planet's surface, it should have gradually migrated towards the pole as Pluto rotated over millennia. But the formation is near the planet's equator, an odd position researchers had previously theorised might be due to the dynamics of a huge body of subsurface liquid water.

The new research suggests that a liquid ocean isn't necessary to explain the placement of Pluto's heart. "In our simulations, all of Pluto's primordial mantle is excavated by the impact, and as the impactor's core material splats onto Pluto's core, it creates a local mass excess that can explain the migration towards the equator without a subsurface ocean, or at most a very thin one," said Martin Jutzi, a senior researcher at the University of Bern.

ARCHAEOLOGY

## 8,200-YEAR-OLD CAMPSITE OF 'PALEO-ARCHAIC' PEOPLES DISCOVERED

WORDS SASCHA PARE

Military personnel recently unearthed the remains of a prehistoric campsite on an air base in New Mexico, which early Americans may have occupied 8,200 years ago. Members of the 49th Civil Engineer Squadron (CES) made the discovery near Holloman Air Force Base, 160 miles from Albuquerque. The base is adjacent to White Sands National Park, which is known for its ivory-coloured gypsum sand dunes and for preserving the oldest known human footprints in North America, made up to 23,000 years ago.

The national park's dunes formed at least 1,000 years after the air base's archaeological site and may have helped preserve the prehistoric artefacts there. "The formation of the white sand dunes inadvertently buried the site, with windblown silt protecting the delicate archaeological remains," said Matthew Cuba, the cultural resource manager of the 49th CES. Excavations of the site, named Gomolak Overlook, yielded various artefacts that indicate the site may have been a seasonal encampment for early 'Paleo-Archaic' peoples, descendants of the first humans who set foot in the Americas and one of the early cultures in the New World to grow and domesticate plants.

A Paleo-Archaic hearth at Holloman Air Force Base, New Mexico



© Airman 1st Class Isalah Pedrazzini

© Getty



Tiny tardigrades are known for their ability to survive extreme conditions

## HEALTH

# Tardigrade proteins could slow ageing in humans

WORDS JENNIFER NALEWICKI

**P**roteins found in tiny, indestructible tardigrades could potentially be a key ingredient in slowing the ageing process in humans. However, it will take more work to show these proteins are a veritable fountain of youth. For now, researchers have only early hints from lab dish experiments. Also known as water bears, tardigrades are near-microscopic, eight-legged creatures known for their practically superhero-like ability to withstand extreme conditions, including tolerating a severe lack of water, surviving in outer space and emerging unscathed from being fired from a gun. To survive such conditions, tardigrades transform into dehydrated balls and dial their metabolisms to near-zero.

In a new study, scientists have discovered that proteins found in these tiny critters can also slow metabolism in human cells in lab dishes. For the study, researchers focused on a tardigrade protein called CAHS D, which transforms into a gel-like consistency when introduced to human cells. "Amazingly, when we introduce these proteins into human cells they gel and slow down metabolism, just like in tardigrades," said Silvia Sanchez-Martinez, a senior research scientist in the department of molecular biology at the University of Wyoming.

"Just like tardigrades, when you put human cells that have these proteins into biostasis, they become more resistant to stresses,

conferring some of the tardigrades' abilities to the human cells." Biostasis is a state of suspended animation in which organisms can tolerate unfavourable environmental changes, such as surviving for long periods without water. The scientists have now demonstrated that the proteins that make biostasis possible in tardigrades can have a similar effect on human cells.

Scientists think this finding could be harnessed to make lifesaving treatments available to people in locations where refrigeration is unavailable and improve the storage of cell-based therapies. "Our findings provide an avenue for pursuing technologies centred on the induction of biostasis in cells, and even whole organisms, to slow ageing and enhance storage and stability," the researchers wrote. The research may even shed light on slowing down the ageing process.

They also found that the entire process is reversible, meaning the cells' metabolism can reset back to normal after slowing. "When the stress is relieved, the tardigrade gels dissolve, and human cells return to their normal metabolism," said Thomas Boothby, an assistant professor at the University of Wyoming. Boothby and his team have been studying tardigrades extensively in their lab. Last year, they found that tardigrade proteins can be used to stabilise a drug used to treat haemophilia, a bleeding disorder.

### Did you know?

Tardigrades can survive sea depths of over 4,700 metres

## ANIMALS

# EXTREMELY RARE MARSUPIAL MOLE SPOTTED IN WESTERN AUSTRALIA

WORDS SASCHA PARE

Aboriginal rangers have spotted an extremely elusive, palm-size marsupial mole with luscious blond locks in a remote corner of Western Australia's Great Sandy Desert. On 2 April 2024, representatives of Kanyirninpa Jukurrpa, a Martu organisation that aims to build strong and sustainable communities, posted the news of a new sighting. This is the second sighting in six months, which is rare given that only between five and ten northern marsupial moles are typically encountered in a decade.

Northern marsupial moles are known by the Martu as kakarratul and live in the sand dunes of the Australian outback. The creatures are so rarely sighted that their population size remains a total mystery. The tiny moles are covered in silky, golden fur and spend very little time above ground, although they do occasionally surface in wet and cool weather. The majority of the time, these tubular-shaped marsupials move through the sand up to 2.5 metres below the surface using their heads and clawed hands. Northern marsupial moles have no eyes, but "despite being blind, they expertly navigate and use their calloused nose and forehead as a ram to burrow," said representatives of Kanyirninpa Jukurrpa.



A northern marsupial mole eating a gecko in the Tanami Desert

# A group of 60 ultra-faint stars could be a new type of galaxy

WORDS SHARMILA KUTHUNUR

**A**stronomers have spotted the faintest and lightest satellite galaxy ever found: a minuscule, tight-knit group of stars trailing the Milky Way. The peculiar discovery could represent a new class of impossibly faint, dark-matter-dominated star systems that had eluded detection until now. Tentatively named Ursa Major III/UNIONS 1 (UMa3/U1), the newfound star system resides in the constellation of Ursa Major, about 30,000 light years from the Sun. It's the newest addition to our galaxy's assortment of at least 50 satellite galaxies. Even the smallest of these galaxies host thousands to billions of stars.

The newfound system, by contrast, has just a sprinkling of 60 stars. As such, its mass is just 16 times the mass of the Sun. For comparison, the Milky Way's mass is about 1.5 trillion times that of our star. UMa3/U1 also defies the conventional image of a distinctively shaped galaxy. "This discovery may challenge our understanding of galaxy

formation and perhaps even the definition of a galaxy," said Simon Smith, a graduate student at the University of Victoria in Canada.

"UMa3/U1 had escaped detection until now due to its extremely low luminosity."

Scientists first spotted UMa3/U1 as a collection of bright stars spanning ten light years across in data collected by the Ultraviolet Near Infrared Optical Northern Survey (UNIONS), a project by the Canada France Hawaii Telescope (CFHT) that surveys the northern sky using three Hawaii-based telescopes. Follow-up observations using the W. M. Keck Observatory confirmed that the stars are gravitationally bound and have similar chemistries. Astronomers are baffled by how the diminutive UMa3/U1 has remained intact for at least 10 billion years, which is the estimated age of its stellar residents and more than twice the age of our own 4.6-billion-year-old Sun. From observations of other eccentric stars in the Milky Way, astronomers know that our galaxy's gravitational pull, also called the tidal force, has previously wrenched apart

dwarf galaxies that ventured too close. Yet although UMa3/U1's orbit takes it through inner regions of the Milky Way, where our galaxy's tidal forces are the strongest, the dwarf galaxy appears to have escaped destruction for aeons.

"The object is so puny that its long-term survival is very surprising," said Will Cerny, a graduate student in the Yale University Department of Astronomy. "Either UMa3/U1 is a tiny galaxy stabilised by large amounts of dark matter, or it's a star cluster we've observed at a very special time before its imminent demise." The former possibility is particularly exciting because in galaxies elsewhere in the universe, astronomers have so far been unsuccessful in detecting dark matter, the invisible substance thought to make up the majority of the matter in our cosmos. If dark matter is indeed responsible for holding the newfound star system together, future observations could offer valuable clues about dark matter's composition and behaviour.

The newfound star system can be found in the constellation of Ursa Major

## MATHEMATICS

### TURING AWARD WON FOR USING RANDOMNESS TO CHANGE COMPUTER SCIENCE

WORDS BEN TURNER

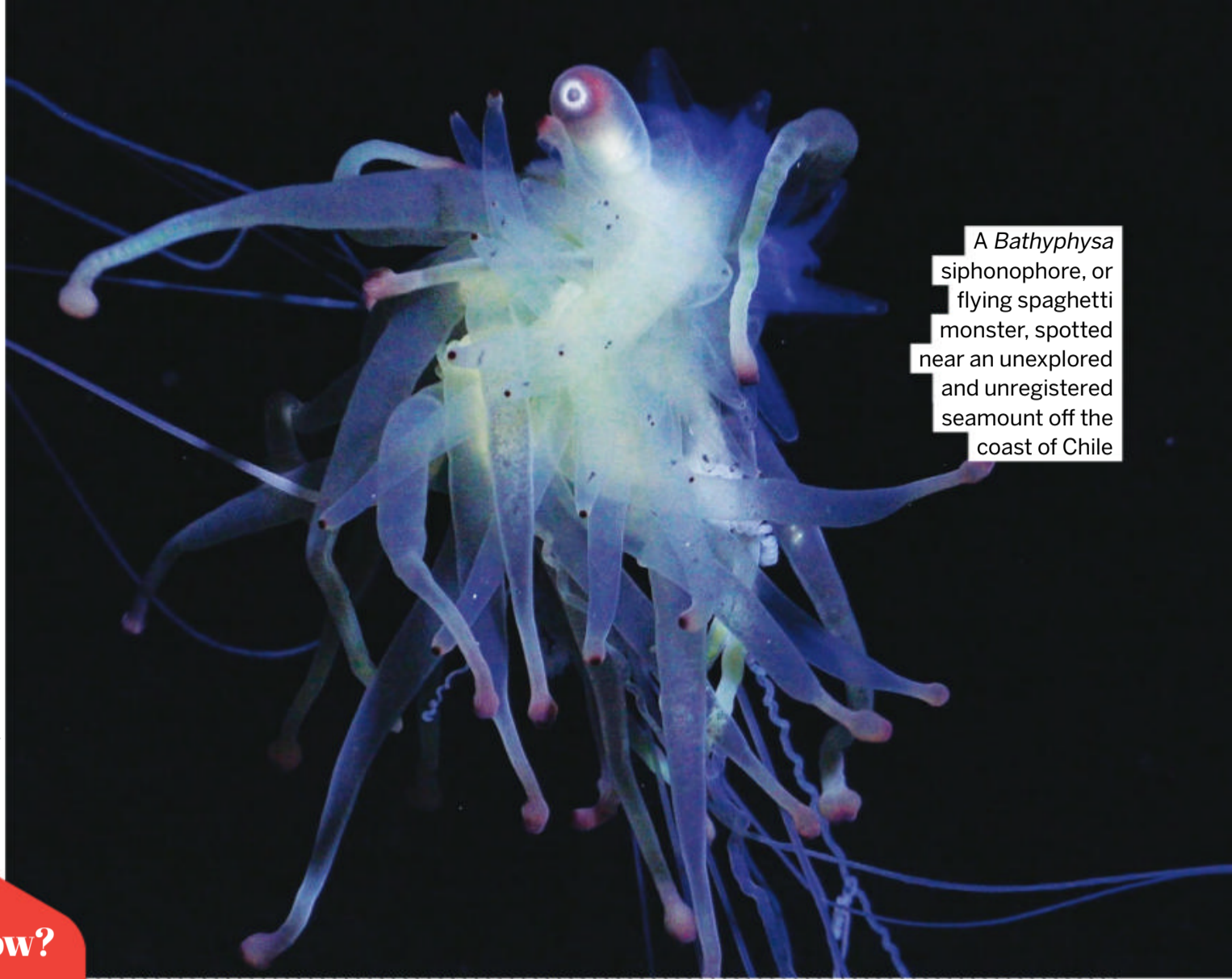
The 2023 Turing Award has been given to Avi Wigderson, who discovered the strange connection between computation and randomness. The award comes just three years after Wigderson, a professor of mathematics at the Institute for Advanced Study in Princeton, won the 2021 Abel Award for his contributions to computer science.

Computer algorithms are deterministic by nature, which enables them to make predictions but also limits their grasp of the messy randomness found in the real world. In fact, many problems are considered computationally 'hard', and deterministic algorithms struggle to solve them efficiently. But Wigderson and his colleague Richard Karp, a computer scientist at the University of California, Berkeley, found a way to tame computational hardness. After inserting randomness into their algorithms, they found that they made some problems much easier to solve. Wigderson chased this observation, proving in later work that the reverse also applied – randomness could always be stripped from probabilistic algorithms to transform them into deterministic ones.

#### Did you know?

The first Turing Award was received in 1966

© ROY SU/BASTIAN SCHMIDT OCEAN INSTITUTE



A *Bathypphysa* siphonophore, or flying spaghetti monster, spotted near an unexplored and unregistered seamount off the coast of Chile

## ANIMALS

### An underwater mountain hosts creatures unknown to science

WORDS SASCHA PARE

**A**n underwater mountain chain off Rapa Nui, also known as Easter Island, hosts an astonishing array of deep-sea species, at least 50 of which are new to science. About 800 to 1,200 metres below the southeastern Pacific waves, researchers on a Schmidt Ocean Institute expedition found the deepest photosynthesis-dependent animal ever found, a *Leptoseria*, or wrinkle coral, which was already known to science. Other jaw-dropping sights included a jellyfish-like critter known as a flying spaghetti monster and a luminescent deep-sea dragonfish from the family Stomiidae. Both these creatures, along with more than 100 other species, have previously been described by scientists but had never been spotted in this region before. Another 50 specimens, which have yet to be analysed, are thought to be newfound species.

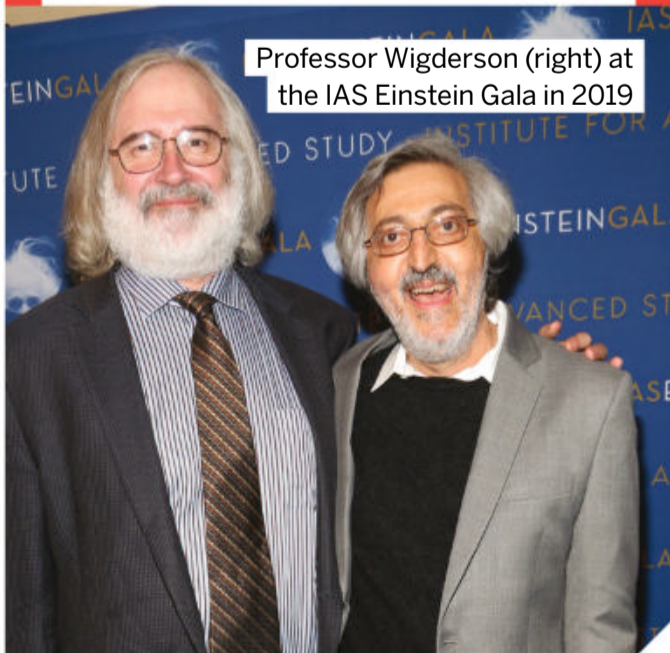
The expedition followed another Schmidt Ocean Institute research cruise in January that uncovered more than 100 suspected newfound species and a gigantic seamount off the coast of Chile. "The astonishing habitats and animal communities that we have unveiled during these two expeditions constitute a dramatic example of how little we know about this remote area," said Javier Sellanes, a professor at Universidad Católica del Norte in Chile.

While the January expedition mostly focused on the Nazca and Juan Fernández ridges, the

new voyage documented marine life on the Salas y Gómez Ridge, an underwater mountain range that extends 1,000 miles from the Nazca Ridge to Rapa Nui. Sellanes and his colleagues crisscrossed the ridge for 40 days in February and March aboard Schmidt Ocean's Falkor (too) research vessel. During the expedition the team examined ten seamounts, which are underwater mountains that tower at least 1,000 metres above the surrounding seafloor. Six of these had not been documented by scientific surveys before, and each seamount harboured its own unique ecosystem.

"The observation of distinct ecosystems on individual seamounts highlights the importance of protecting the entire ridge, not just a few seamounts," said Erin E. Easton, an assistant professor of marine science at the University of Texas Rio Grande Valley and chief scientist at the Schmidt Ocean Institute. "We hope the data collected from this expedition will help establish new marine protected areas."

The researchers on the expedition explored waters around Rapa Nui with the help of local community members. "The importance of participating in an oceanographic scientific expedition for Rapa Nui lies in the opportunity to know and better understand the marine environment surrounding the island," said Marcela Hey Aravena, a member of the Rapa Nui Sea Council and a Schmidt Ocean Institute observer.



Professor Wigderson (right) at the IAS Einstein Gala in 2019

# A sleeping subduction zone could swallow the Atlantic

WORDS SASCHA PARE

**A** subduction zone below the Gibraltar Strait is creeping westward and could one day ‘invade’ the Atlantic Ocean, causing the ocean to slowly close up. The subduction zone, also known as the Gibraltar arc or trench, currently sits in a narrow ocean corridor between Portugal and Morocco. Its westward migration began around 30 million years ago, when a subduction zone formed along the northern coast of what is now the Mediterranean Sea, but it has stalled in the last 5 million years, prompting some to question whether it’s still active today.

It appears that the arc is merely in a period of quiet. This lull will likely last for another 20 million years, after which the Gibraltar arc could resume its advance and break into the Atlantic in a process known as ‘subduction invasion.’ The Atlantic hosts two subduction zones that researchers know of, the Lesser Antilles subduction zone in the Caribbean and the Scotia arc near Antarctica. “These subduction zones invaded the Atlantic several million years ago,” said João Duarte, an assistant professor at the University of Lisbon. “Studying Gibraltar is an invaluable opportunity because it allows observing the process in its early stages when it is just happening.”

To test whether the Gibraltar arc is still active, Duarte and his colleagues built a computer model that simulated the birth of the subduction zone in the Oligocene epoch and its evolution until the present day. Researchers noticed an abrupt decline in the arc’s speed 5 million years ago as it approached the Atlantic boundary. The team then modelled the arc’s fate over the next 40 million years and found it painstakingly pushes its way through the narrow Gibraltar Strait from the present day over the next 20 million years. “Strikingly, after this point the trench retreat slowly speeds up and the subduction zone widens and propagates oceanward,” the researchers wrote in the study.

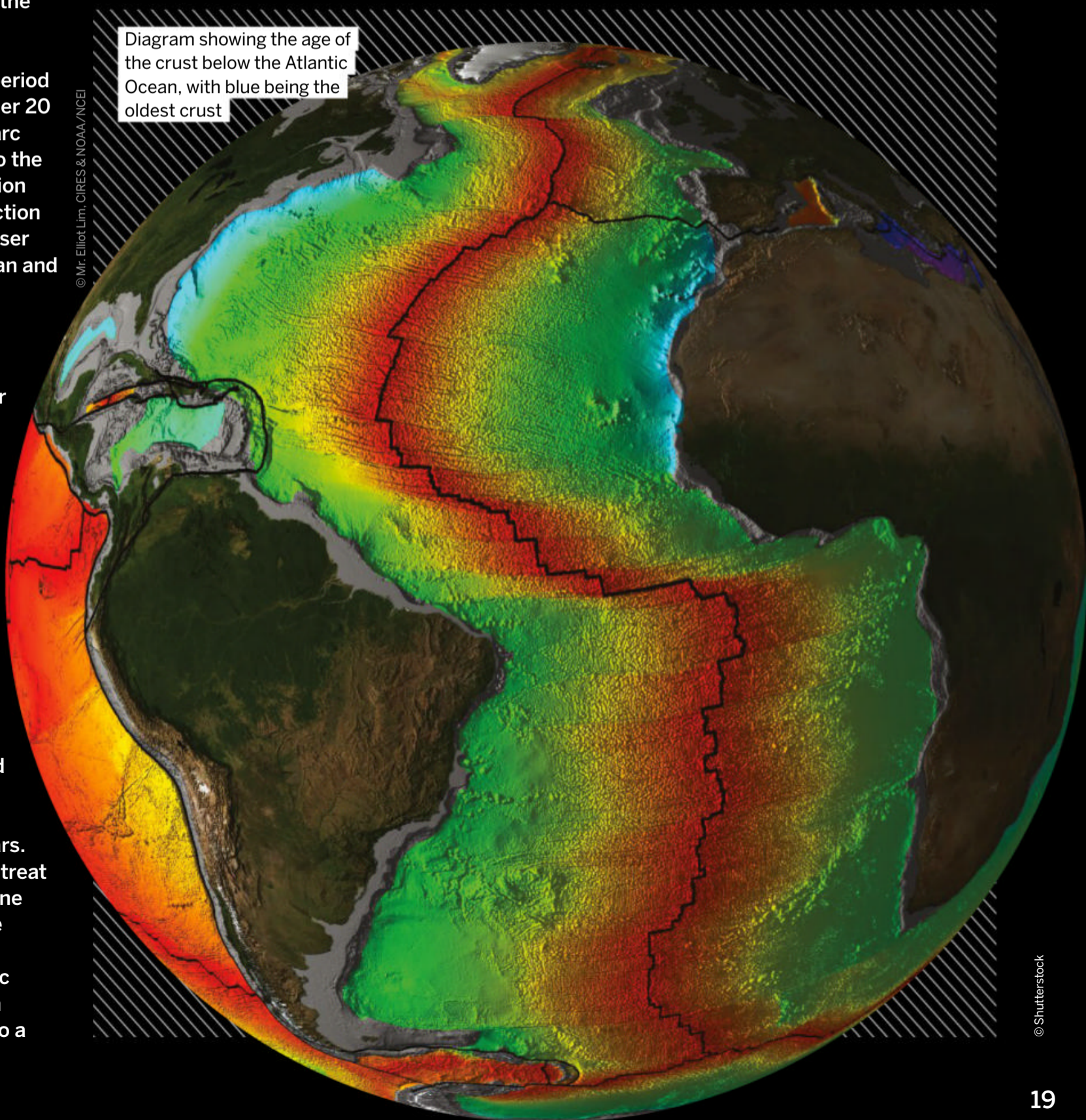
If the Gibraltar arc invades the Atlantic Ocean, it could contribute to forming an Atlantic subduction system analogous to a

chain of subduction zones that circles the Pacific Ocean, called the Ring of Fire. A similar chain forming in the Atlantic would lead to oceanic crust being recycled into the mantle via subduction on both sides of the Atlantic, gradually swallowing and closing up this ocean. The Gibraltar arc’s grinding advance over the last 5 million years could explain the relative lack of seismicity and volcanism in the region, which have been used as arguments to dismiss the idea that

the subduction zone might still be active. The zone’s tectonic silence is a direct result of its extended period of stalled movement.

The last major earthquake to rock the region was the 1755 Great Lisbon earthquake, which reached an estimated 8.5 to 9.0 on the moment magnitude scale. Experts have suggested an earthquake of this magnitude occurring anytime soon is pretty much out of the question, since the last such event occurred just 250 years ago.

Diagram showing the age of the crust below the Atlantic Ocean, with blue being the oldest crust



# DNA reveals that ancient American lineage goes back 18,000 years

WORDS KRISTINA KILLGROVE

**M**embers of the Blackfoot Confederacy have an ancient lineage that goes back 18,000 years. This means that Indigenous peoples living in the Great Plains of Montana and southern Alberta today can trace their origins to ice age predecessors. In a new DNA study, researchers investigated the genetic history of their tribes. Comprising four related tribes, the Blackfeet, Kainai, Piikani and Siksika, members of the Blackfoot Confederacy historically included nomadic bison hunters and trout fishers. Their territory was divided in the mid-19th century by the US-Canadian border, and in the late 19th century both countries' governments forced the confederacy members to settle on reservations.

Since then, tribes in the Blackfoot Confederacy have had to defend their land claims and water rights in spite of both archaeological evidence and oral traditions testifying to their deep history in the area. To provide an additional line of evidence that could help secure their treaty rights, as well as to advance scientific knowledge of Indigenous genomic lineages, members of the Kainai

Nation in Canada and the Blackfeet tribe in Montana partnered with scientists from multiple US universities to investigate their genetic history.

The research team took samples for whole-genome sequencing from seven skeletons that were carbon-dated to between 1805 and 1917, a period in which interactions between Blackfoot people and Euroamericans were increasing because of the fur trade. While DNA preservation was not ideal, as the samples came from skeletons that had been exposed on a burial platform, all the remains produced mitochondrial DNA information, or genetic data passed down from the maternal side. Additionally, six present-day tribal members were whole-genome sequenced.

The genetic information revealed that the historical Blackfoot ancestors and the present-day Blackfeet and Kainai shared a large fraction of their genome, suggesting a biological relationship. This continuity of genes was expected, but the team also found that this lineage was different from previously reported North and South American Indigenous groups. Based on statistical modelling, the team

believes that the Blackfoot people split from other groups in the Late Pleistocene, around 18,000 years ago, as multiple population waves from a single source fanned out into the vast geographic land of the Americas.

In addition to identifying this genomic diversity that was previously unknown to science, the study is important because of its framing. "It's pretty obvious that this was written from more of an Indigenous voice," said Graciela Cabana, an anthropological geneticist at the University of Tennessee, Knoxville. "It's actually rare to see a collaborative study that is actually led by Indigenous community members on ancestors."

Ripan Malhi, a genetic anthropologist at the University of Illinois, says that genomics should be conducted by community members who can use this tool from an Indigenous viewpoint, "or through a community-collaborative approach where community partners have equal control in how the research is conducted and reported". This study comes out of the Blackfoot Early Origins Program, which documents Blackfoot persistence in their aboriginal territory.



The Blackfoot Confederacy, shown here in a historical photo, has an ancient genetic lineage that goes back 18,000 years



There are up to 850,000 meteorites on, or just below, Antarctica's icy surface

PLANET EARTH

## Thousands of Antarctic meteorites could be lost forever

WORDS HARRY BAKER

**H**undreds of thousands of pristine meteorites are littered across, or just below, Antarctica's icy surface. But most of these could be lost forever over the next few decades as they sink further into the ice due to rising temperatures. That means we need to step up our efforts to find them before they disappear for good. Antarctica has been bombarded by meteorites for millions of years. Most of these space rocks have already sunk deep into the ice, never to be seen again. However, in certain parts of the continent, known as 'blue ice areas,' trapped meteorites are freed from their icy prisons as wind and sunlight strip away the top layers of frozen water. Some of these may have been trapped there for tens of thousands of years.

Antarctica's blue ice areas are some of the best places in the world to hunt for meteorites. There are about 600 of these areas in Antarctica, covering around one per cent of the continent's surface area. Around 50,000 meteorites have already been found in Antarctica, which is around 60 per cent of known meteorites ever collected worldwide. Most of these space rocks are less than three centimetres in diameter, but some are much more massive. Regardless of their size, analysing these space rocks can help researchers uncover secrets about the origin and evolution of the Solar System.

Antarctic meteorites are especially useful to scientists because they are well preserved in ice. However, just because these meteorites lie at the surface doesn't mean they stay there forever. Due to their dark colour, the space rocks soak up sunlight, which heats them up. Normally, this wouldn't be a problem. But at high surface air temperatures, this warming may melt the surrounding ice and cause meteorites to sink below the surface.

In the past, this melt would have been very rare. But with rising global temperatures due to human-caused climate change, meteorites are sinking much more often than before. In a new study, researchers used machine learning, a form of artificial intelligence, to predict how many meteorites could be lost as a result of global warming.

The team's model estimates that there are likely up to 850,000 meteorites on or near the surface of blue ice areas in Antarctica.

At current temperatures, researchers suspect that as many as 5,000 Antarctic meteorites are already sinking out of reach every year. Meanwhile, fewer than 1,000 meteorites are found on the continent every year. As temperatures increase in the coming decades, more meteorites will start to sink. Without any further warming, roughly a quarter of meteorites could be lost by the end of the century. But in the most extreme warming scenarios, three-quarters could be lost.

### Did you know?

A meteorite found in Antarctica in 2022 weighed 7.7 kilograms

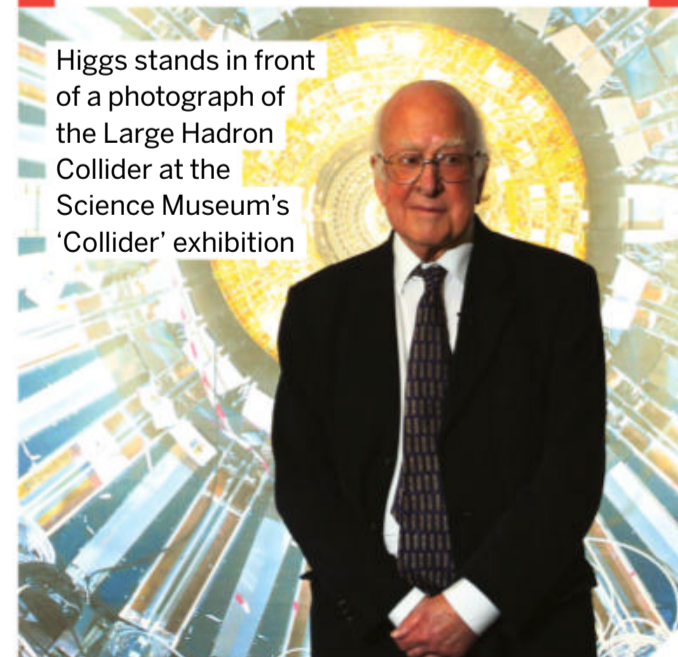
PHYSICS

## PETER HIGGS, THE NOBEL PRIZE-WINNING PHYSICIST, DIES AT 94

WORDS STEPHANIE PAPPAS

Peter Higgs, the theoretical physicist who predicted the existence of the Higgs boson, has died at the age of 94. The University of Edinburgh confirmed the Nobel Prize-winning physicist's death on 8 April following a short illness. Higgs was a professor emeritus at the university, where he worked beginning in 1960 until his retirement in 1996. Higgs is best known for his pioneering work in predicting the masses of subatomic particles. He was awarded the Nobel Prize in physics in 2013 alongside Belgian physicist François Englert for their work predicting the existence of a particle that, by interacting with other particles, gives them mass. This became known as the Higgs boson. Following a 50-year search, the Higgs boson was finally detected in 2012. It was discovered using the Large Hadron Collider, which sits on the border of France and Switzerland.

Higgs was born on 29 May 1929. He earned his doctoral degree from King's College London in 1954. A bedevilling question in physics at the time was how elementary particles such as the electron and quark have mass. In a 1964 paper, Higgs posited that these particles gain their mass through an interaction with a field, now known as a Higgs field, and that this Higgs field should give rise to a detectable particle, the Higgs boson.



Higgs stands in front of a photograph of the Large Hadron Collider at the Science Museum's 'Collider' exhibition

# WISH LIST

The latest **PERSONAL ROBOTS**

## MISA

**\$799 (APPROX. £648.95)**

HEYMISA.COM

Misa is a robotic assistant for the whole family. Packed with tons of features, this versatile machine can act as a source of entertainment and learning for children and offer practical support such as accessing emails, radio stations and medication reminders. As a household AI-powered companion, Misa can hold conversations, recognise speech and form relationships with family members using its natural language understanding (NLU) technology. Unlike other static personal robots, Misa can move around on its four wheels autonomously and use its obstacle sensors to prevent collisions. Through the 'Misa connect' function, Misa can facilitate video calls as well as become a moving surveillance camera that you can control through the companion app.



## MOXIE

**\$799 (APPROX. £648.95)** MOXIEROBOT.COM

As a striking example of how AI and robotics are being used for education, Moxie is one of the most advanced personal robots out there. Moxie uses play-based conversational learning to help children between the ages of five and ten progress through some of their developmental milestones. To assist with their academic learning, Moxie can help children practise their reading, listening and comprehension skills as well as supply fun facts on a variety of topics. Each day, Moxie will also have some interesting information about past events that correspond to the current day. There are also different mindfulness activities, such as affirmations and

meditation, to explore. Moxie can even support and distinguish between four different children and track their individual progress through the Moxie Robot companion app.



## WINKY

**€249.90 (APPROX. £214.90 / \$264.60)** HEYWINKY.COM

For children interested in coding and robotics, Winky might be a great place to start learning more. The compact and emotive Winky robot can teach children the basics of block coding through its companion coding app, Winky Code, which allows them to customise their robot. With several tactile sensors, microphones, a speaker and a pair of servo motor ears, Winky can express a range of feelings and emotions. Using the companion gaming app, Winky Play, Winky itself can act as a physical controller for a whole host of games. Winky is also shockproof up to 1.5 metres, waterproof and dustproof for both indoor and outdoor play.





## DOLY

**\$319 (APPROX. £253) DOLY.AI**

Doly is a compact robotic companion that develops its own lively personality through physical interactions and conversations. Equipped with many of the same sensory and communication technologies as other AI-powered robot friends, Doly can also be manually programmed using its accompanying block-coding platform. Doly comes with some handy features, such as a timer, weather report, clock and five-megapixel high-resolution camera. Using its voice-recognition capabilities, Doly will also snap a photograph and save it to its gallery when asked.

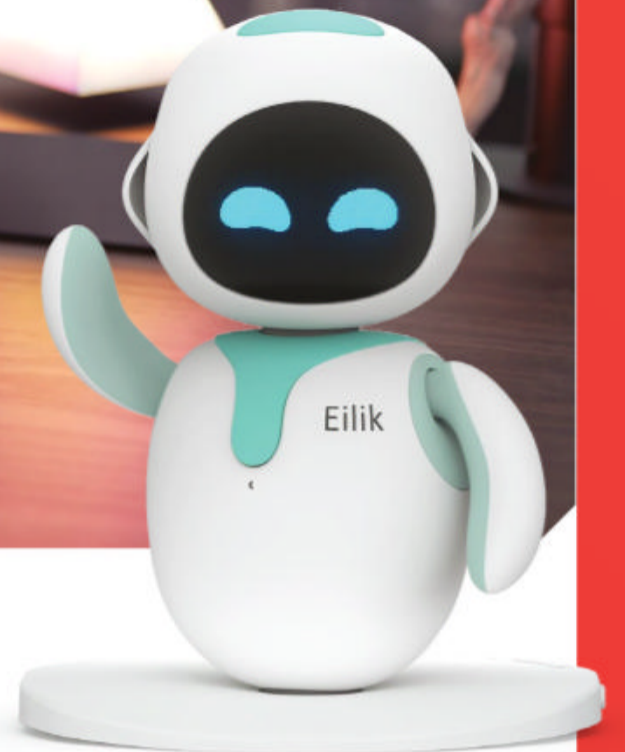


## EILIK

**\$149.99 / £139.99  
ENERGIZELAB.COM**

Eilik is a little robot with big emotions. Spanning a full range of emotions, such as sadness, anger and even fear when you trigger its phobia of heights, Eilik is packed with emotional intelligence and social interactions to explore. Three touch-sensitive pads allow you to physically engage with Eilik in real time. Also, when there are multiple Eilik around they interact

with one another and can form dance parties, do comedy skits and even fight. Along with being a charismatic companion, Eilik comes with some handy features, such as a built-in countdown timer and a shooting game. Although Eilik doesn't have practical abilities like searching the internet or making calls, it can bring some fun and charm to an otherwise boring desk space.



## LOOI

**\$169 (APPROX. £137) LOOIROBOT.COM**

Unlike other personal robots, Looi is created with the help of your smartphone. By simply attaching your smartphone to the robotic base through the magnetic connection, Looi can be brought to life. Once awake, Looi uses ChatGPT to converse and answer your questions. The use of ChatGPT also allows Looi to form a unique personality over time. Looi can use your smartphone's capabilities and its own sensors to recognise you, track your movements, map its surroundings for autonomous movement and even use your gestures to play in-built games. There's also the option to manually drive Looi's robotic body, equipped with headlights, to explore new places.





# Subscriber benefits

- ⚙️ **NEW** DIGITAL ACCESS TO 80-PLUS ISSUES WHEN YOU SUBSCRIBE TO PRINT\*\*
- ⚙️ Every issue delivered directly to your door
- ⚙️ Never miss an issue
- ⚙️ Save on the newsstand price

## SUBSCRIBE ONLINE AT

[www.magazinesdirect.com/HiWchooseyourbook](http://www.magazinesdirect.com/HiWchooseyourbook)

OR CALL US ON 0330 333 1113 and QUOTE CODE and BOOK  
 D32M 60 Second Science (5th Edition), D32N Book of  
 Incredible History or D32P Inside Your Brain (3rd Edition)

\*Terms and conditions: Offer closes 6 June 2024. Direct Debit offer open to new UK subscribers only. The rate of £23.99 (print magazine) is payable by six-monthly payments via UK Direct Debit. The full subscription rate includes postage and packaging. Payment is non-refundable after the 14-day cancellation period, unless exceptional circumstances apply. For full terms and conditions, visit [www.magazinesdirect.com/terms](http://www.magazinesdirect.com/terms). For enquiries, please call +44 (0) 330 333 1113. Lines are open Monday to Friday 08:30 to 19:00 and Saturday 10:00 to 15:00 UK time, excluding Bank Holidays, or email [help@magazinesdirect.com](mailto:help@magazinesdirect.com). Calls to 0330 numbers will be charged at no more than a national landline call, and may be included in your phone provider's call bundle. Your gift will be delivered separately within 60 days after your first payment has cleared. Gifts only available to subscribers on the UK mainland. Gift not available with a digital subscription and only while stock lasts. \*\*Access to the digital library will end with your subscription.

HOW IT WORKS SUBSCRIPTION OFFER

AMAZING SUBSCRIPTION OFFER

SIX MONTHS

FOR JUST £23.99!

AND CHOOSE YOUR FREE BOOKAZINE



# *Understanding* MENTAL HEALTH

Take a tour of the brain to discover the origins of anxiety and how to tackle it

WORDS SCOTT DUTFIELD

**T**he term 'mental health' is used to encompass a person's emotional and psychological wellbeing, which is experienced differently from one person to the next and includes a spectrum of mental health conditions. One of the most prevalent mental health concerns today centres around people's levels of anxiety and depression. In the US alone, 6.8 million adults are affected by generalised anxiety disorder (GAD), which is a feeling of unease and worry to a variety of degrees, from manageable fear to debilitating panic. Common mental health issues such as GAD can also have knock-on effects on our physical health: depression and anxiety can lead to increases in blood pressure, reduce the amount of blood that flows through the heart and increase the release of a stress hormone

called cortisol, all of which can contribute to the development of heart disease.

Mental health is often intertwined with a concept known as neurodiversity. This term is used to describe the breadth of ways the human brain operates and how it interprets and processes information. A

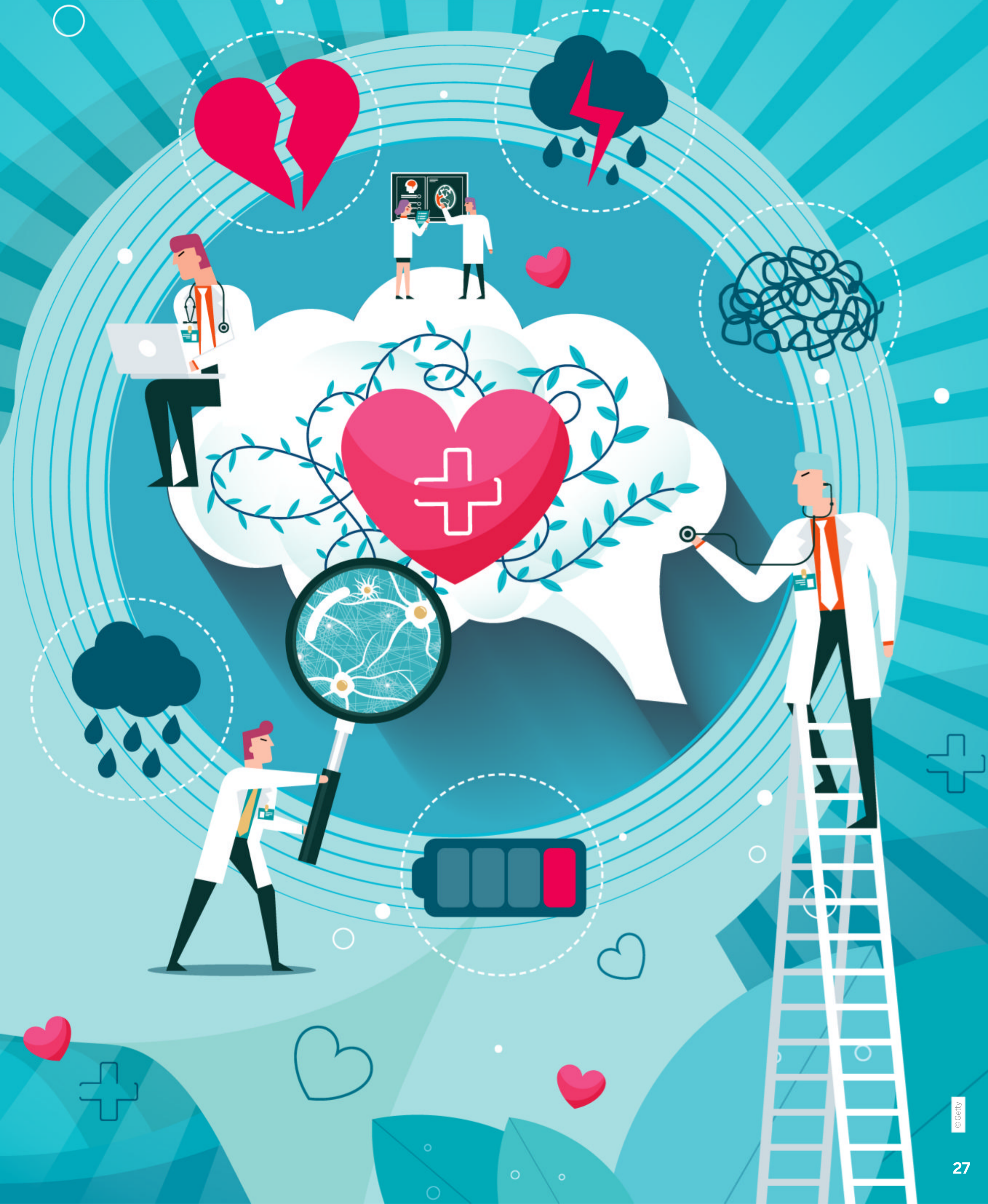
neurotypical person is someone whose brain functions in a typical way – similar to the majority of their peers. The brain of a neurodivergent person, however, deviates from the typical. For example, someone on the autism spectrum or with attention deficit hyperactivity disorder (ADHD) might consider themselves to be neurodivergent.

While many neurodivergent conditions, such as ADHD, can be treated as a mental health disorder, being neurodivergent is more about recognising different cognitive

### Did you know?

Half of lifetime mental illnesses begin by the age of 14

**DID YOU KNOW?** Around five per cent of the global population suffer from depression



qualities. “Neurodivergence is something that people identify with, so it’s part of their identity as much as their personality and is part of who they are, but mental health issues are seen as separate and something that will need to be addressed,” says Dr Giorgia Michelini, an assistant professor in psychology at Queen Mary University of London. “Mental health is something that characterises everyone; mental health problems are experienced by some people or at some point in someone’s life.”

Within the brain is a complex network of structures called the limbic system that controls our emotions, memories and behaviours. One of the main functions of this system is to warn us of danger and trigger a fear response, known as the fight-or-flight reaction. This also translates into how the brain experiences anxiety and its associated conditions, such as phobias and PTSD. One structure, the amygdala, is responsible for assessing the emotional significance of information and whether or not the fight-or-flight response should be triggered. When the amygdala is too easily triggered or is ‘turned on’ when a threat isn’t evident, this can lead to the development of anxiety disorders.

The association between the limbic system and anxiety means that by monitoring the electrical activity in these regions of the brain, researchers can study it in more detail. In 2021 researchers at the University of Rochester in New York used virtual reality to test how the brain responded to anxiety-inducing scenarios. Patients were exposed to a VR meadow filled with flowers – either safe or concealing a bee that could virtually ‘sting’ with minor electrical stimulation to the hand. Half of the meadow was filled with beeless flowers. While using functional magnetic resonance imaging (fMRI) to study the patients’ brain activity, the researchers found that patients who suffered from anxiety had increased activation in some of the limbic system’s regions when viewing both ‘safe’ and ‘unsafe’ areas of the meadow. This suggests that despite recognising the safe areas of the meadow, the brain still associated them with danger and perpetuated feelings of anxiety.

**Did you know?**

**1 in 100 people have borderline personality disorder**

Another tool researchers can utilise in researching mental health and neurodivergence are electroencephalograms (EEG). Created to study the brains of those with epilepsy, EEGs use small electrodes placed around the head to measure the electrical activity of neurons within the brain. The activity is amplified, recorded and displayed as different brain wave patterns at different locations around the head, indicating which parts of the brain are active and to what degree. While the technology isn’t strong enough to be used to diagnose different mental health conditions, researchers like Michelini can use it as a tool to study them in more depth. “A lot of the work I’ve done is on EEG studies of people with ADHD. We would take a group of people with ADHD and a group of people that don’t have ADHD then record EEG activity when they’re at rest or get them to do something that would challenge their

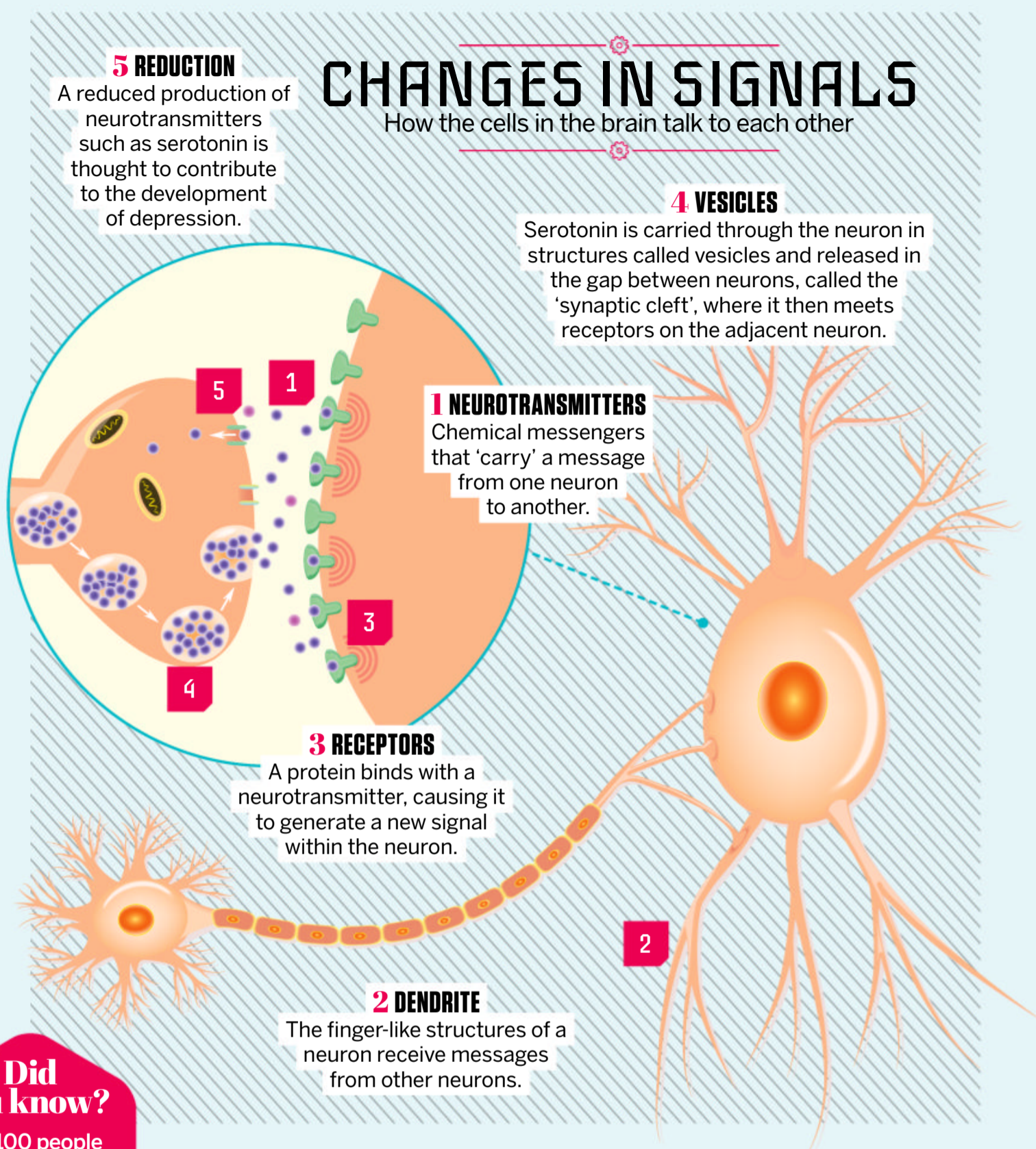
attention, such as complete a computer task. Then we could see the EEG markers that are different between people with ADHD and people that don’t have ADHD.”

The known causes of many mental health conditions vary, and many causes remain largely unknown. Some of the environmental factors that have been identified as detrimental to mental health involve harmful social interactions, economic issues and substance abuse. Even pollution might have a role to play in contributing to negative

**“Mental health problems are experienced by some people or at some point in someone’s life”**

# CHANGES IN SIGNALS

How the cells in the brain talk to each other



**DID YOU KNOW?** The term 'neurodiversity' was coined by Australian sociologist Judy Singer in 1997

# THE ANATOMY OF ANXIETY

These parts of the brain are involved in making us anxious

## 6 PREFRONTAL CORTEX

Often referred to as the 'thinking part' of the brain, the cortex attaches meaning to sensory stimulus and generates anxiety-induced images in the mind, even when no dangers are present.

## 1 STIMULUS

Information from the eyes and ears is received by the thalamus and then passed on to the amygdala.

## 5 THALAMUS

A cognitive router, the thalamus receives information from sensory organs, such as sight and sound, processes and redistributes that information to where it needs to go. This is either through the cortex or directly to the amygdala.

## 3 AMYGDALA

An almond-shaped region of the brain that processes incoming sensory information, either from the thalamus or directly. This is the brain's defence control centre and kicks the body into a stress response.

## 4 HIPPOCAMPUS

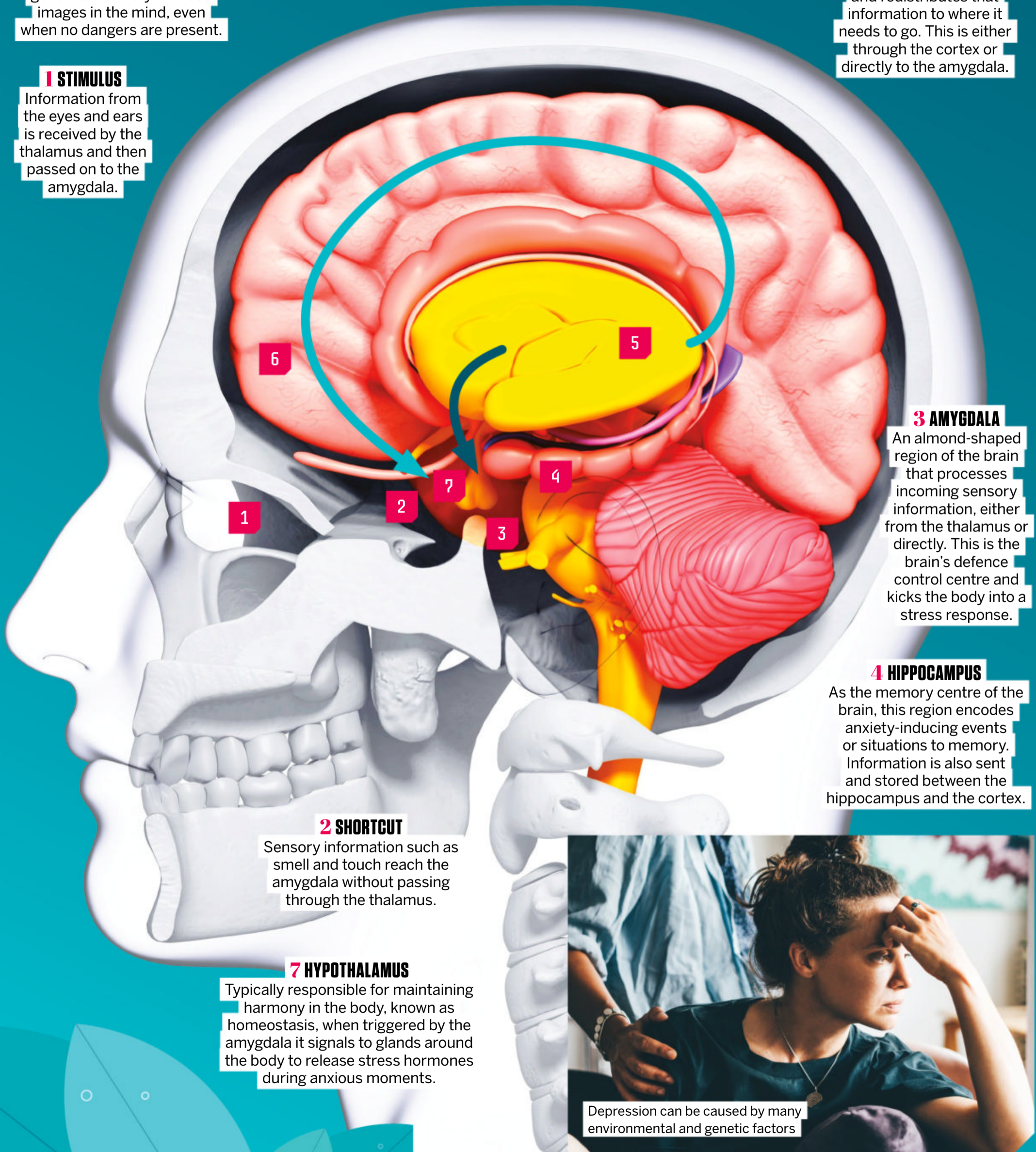
As the memory centre of the brain, this region encodes anxiety-inducing events or situations to memory. Information is also sent and stored between the hippocampus and the cortex.

## 2 SHORTCUT

Sensory information such as smell and touch reach the amygdala without passing through the thalamus.

## 7 HYPOTHALAMUS

Typically responsible for maintaining harmony in the body, known as homeostasis, when triggered by the amygdala it signals to glands around the body to release stress hormones during anxious moments.



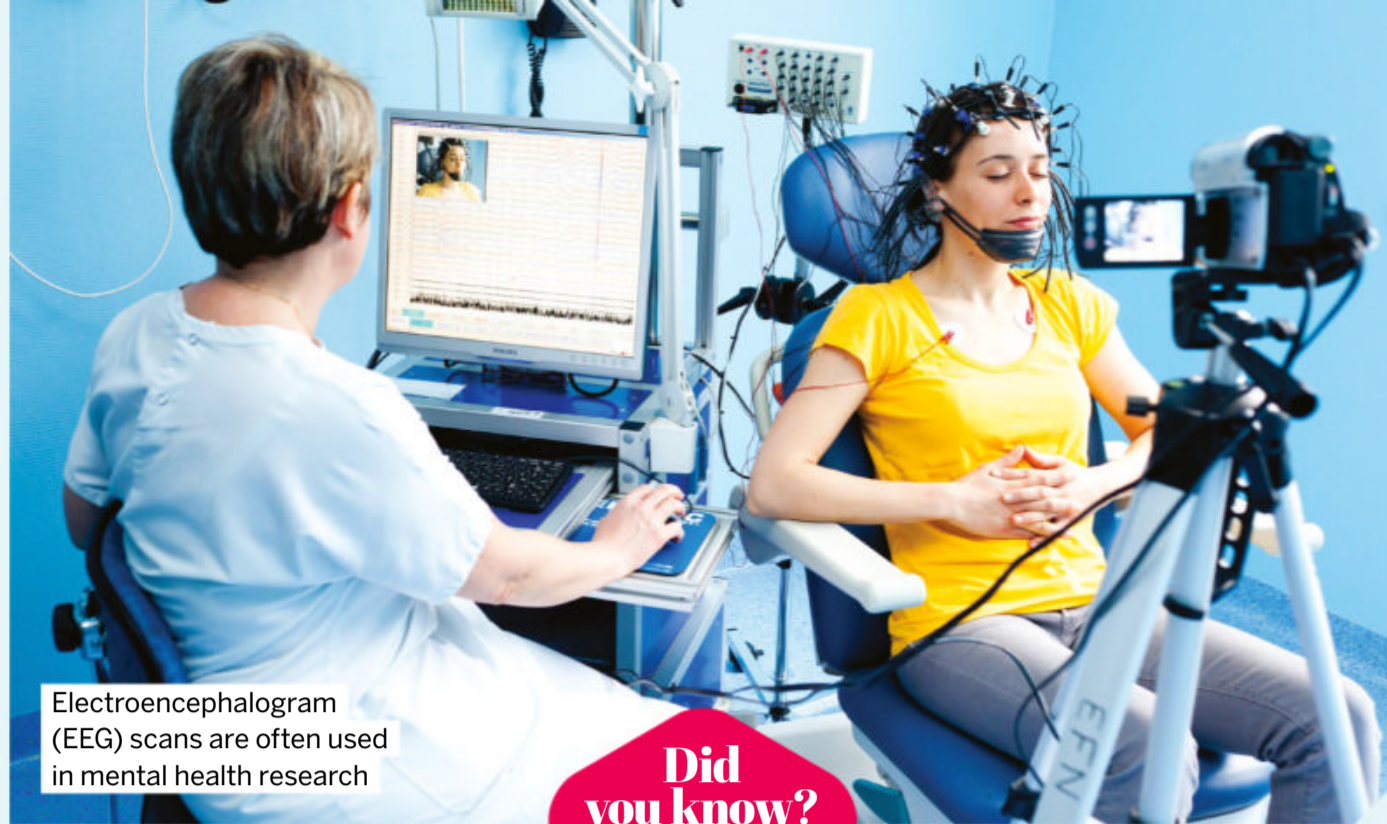
Depression can be caused by many environmental and genetic factors



mental health. In 2019, research published in the *British Journal of Psychiatry* revealed a link between air pollution and the use of mental healthcare services. Using anonymous data from South London and Maudsley NHS Foundation Trust combined with data on quarterly average concentrations of air pollutants, such as nitrogen dioxide and particulate matter, researchers found that people exposed to higher residential levels of air pollutants used the mental healthcare services more frequently when compared to those exposed to lower air pollution.

The COVID-19 pandemic also has a lot to answer for as a source of isolation, which is thought to have caused a decline in mental health. Surveys conducted by the Office for National Statistics revealed that before UK lockdown began in March 2020, the prevalence of depression among the UK's population was around ten per cent. That figure rose to 19 per cent in June of the same year and then jumped again to 21 per cent by January 2021. However, by October 2022, following the removal of many lockdown measures, depression levels dropped to 16 per cent.

One of the biological explanations for declining mental health relates to our brain chemistry. In the 1960s it was believed that a decline in the production of a neurotransmitter called serotonin was the leading biological cause of some mental health conditions, such as depression. Often referred to as a



Electroencephalogram (EEG) scans are often used in mental health research

**Did you know?**  
OCD affects around two per cent of people

'chemical imbalance' in the brain, the serotonin theory has come under fire in recent years as an out-of-date explanation and being oversimplistic. However, the topic remains largely debated in the scientific community.

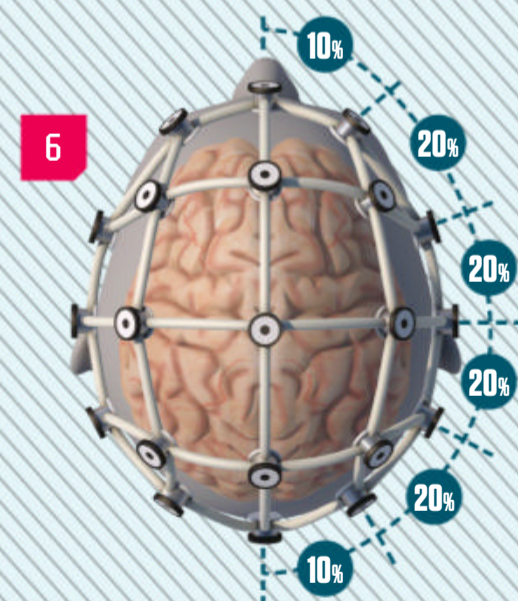
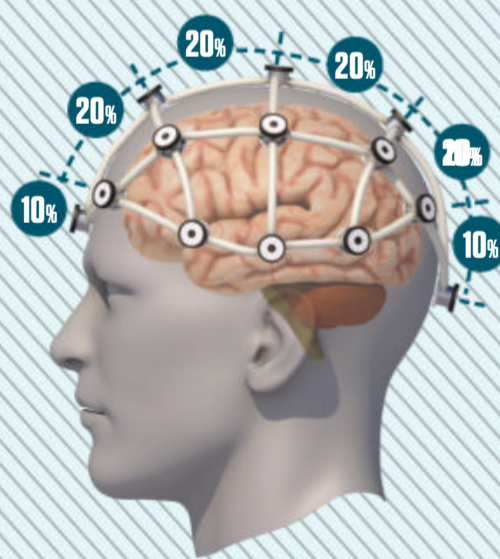
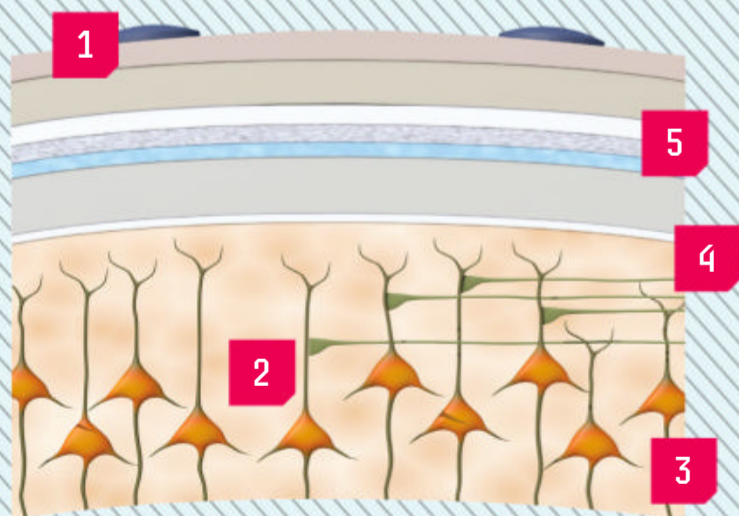
There's also genetics at play: the blueprints for our bodies not only determine most of our physical characteristics, but also how our brains function. According to Micheli, the role of genetics in the development of mental health conditions differs. With anxiety and depression, "we see that the role of genetics is 30 to 40 per cent and the rest is down to a person's environment and their experiences. But for disorders such as psychosis and bipolar disorder, and all forms of neurodivergence, such as autism and ADHD, we find that the

genetic component is higher at around 80 per cent, with around 20 per cent down to their environment."

One of the ways that scientists have made these genetic connections is by studying both identical and fraternal twins. Genetically identical twins share almost 100 per cent of their genetic information, whereas fraternal twins – those born from separate eggs – only share around half of their genes. This fact allows researchers to compare the prevalence of different mental health conditions between people with similar or near-similar genetics. Some studies have shown that incidences of obsessive-compulsive disorder (OCD) developing in both twins is higher in identical twins than fraternal twins, pointing to genetic origins.

# SEEING PAST THE SKULL

How electroencephalograms peer into the brain and monitor activity



### 1 EEG ELECTRODE

Electrodes are placed around the head. The electrical energy released by brain activity can 'push' or 'pull' on the electrode, which is recorded and measured.

### 2 ACTIVE SYNAPSE

When many neurons fire at the same time, they generate enough energy for the EEG electrodes to detect.

### 3 EFFERENT NEURONS

These neurons carry signals from the brain to various parts of the body to carry out an action, such as movement.

### 4 AFFERENT NEURONS

Represented by the horizontal lines in the illustration, these neurons transmit information between sensory organs, such as the eyes and ears, and the central nervous system.

### 5 PROTECTIVE LAYERS

The energy of brain activity moves through the protective layers around the brain, allowing it to be measured on the surface.

### 6 ELECTRODE LOCATIONS

Electrodes are placed on the head using the '10-20 system', whereby each electrode is positioned at 10 or 20 per cent of the skull's total distance either from front to back or from left to right.

**DID YOU KNOW?** 63 per cent of Britons agree that when others are kind, it has a positive impact on their mental health

# GLOBAL MENTAL HEALTH

Every year, a nonprofit organisation called Sapien Labs releases its Mental State of the World Report, which outlines what it calls a mental health quotient (MHQ) score

across 71 countries. More than 400,000 people across these countries took part in the 2023 survey. Patients filled out a questionnaire to assess their mental wellbeing on a MHQ

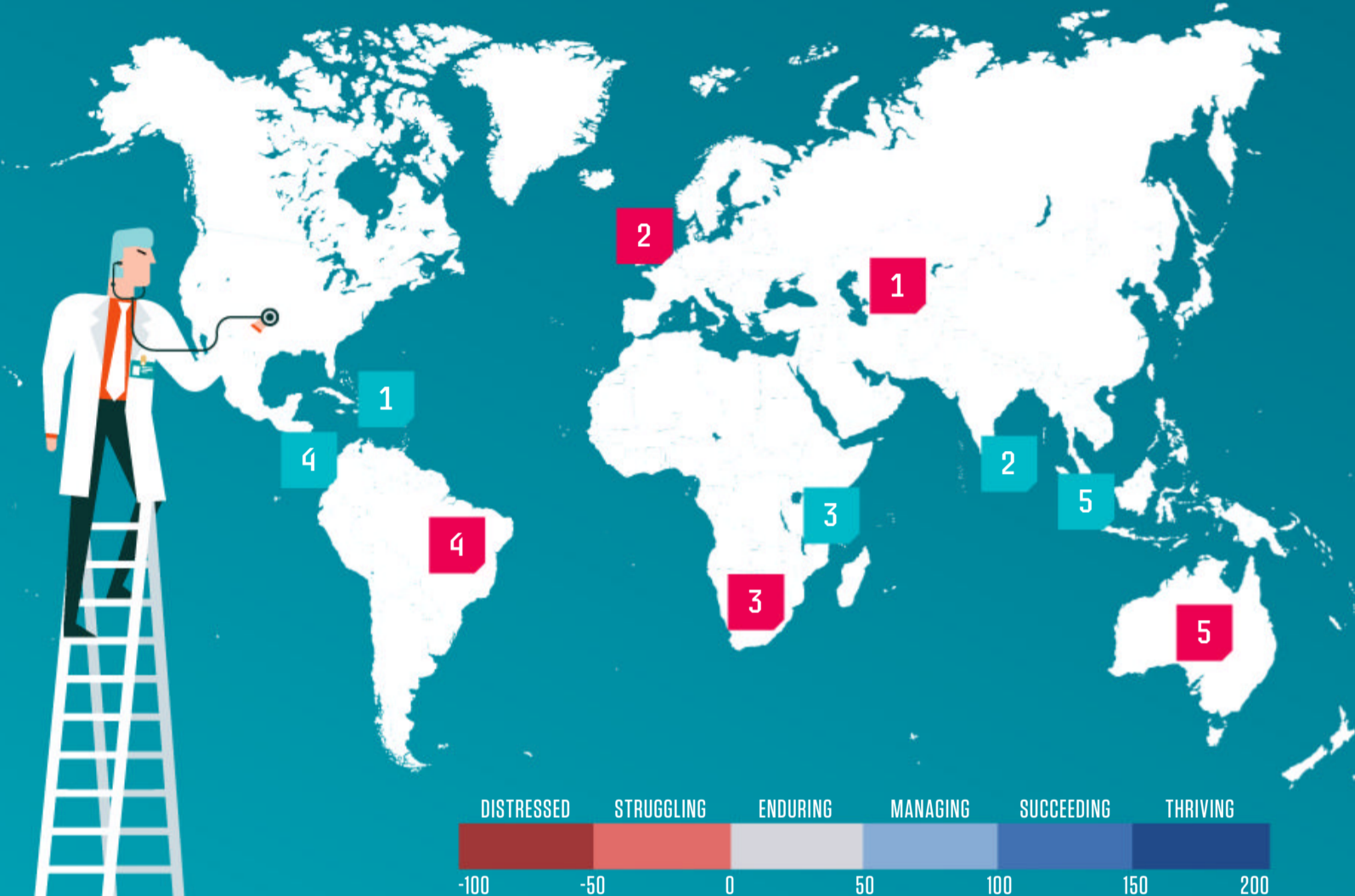
point scale that starts at -100 (distressed) and goes up to 200 (thriving). Here are the average MHQ scores for the highest and lowest scoring countries for positive mental wellbeing.

## BEST AVERAGE MHQ SCORE

- 1 DOMINICAN REPUBLIC 91
- 2 SRI LANKA 89
- 3 TANZANIA 88
- 4 PANAMA 85
- 5 MALAYSIA 85

## WORST AVERAGE MHQ SCORE

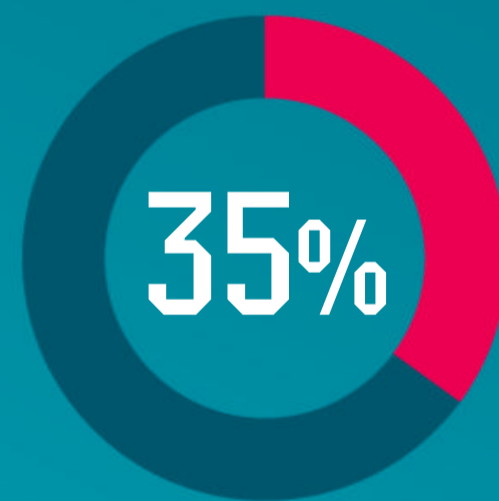
- 1 UZBEKISTAN 48
- 2 UNITED KINGDOM 49
- 3 SOUTH AFRICA 50
- 4 BRAZIL 53
- 5 AUSTRALIA 54



**ONE IN SEVEN ADOLESCENTS HAVE A MENTAL DISORDER**

**ONE IN THREE WOMEN**

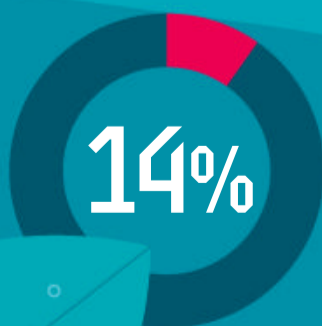
Women are more likely than men to experience major depression in their lives



**35 PER CENT OF PEOPLE WITH SEVERE MENTAL HEALTH PROBLEMS ALSO HAVE LONG-TERM PHYSICAL CONDITIONS**

**ONE IN FOUR**

Only 27.6 per cent of the people that require treatment for anxiety disorders receive it



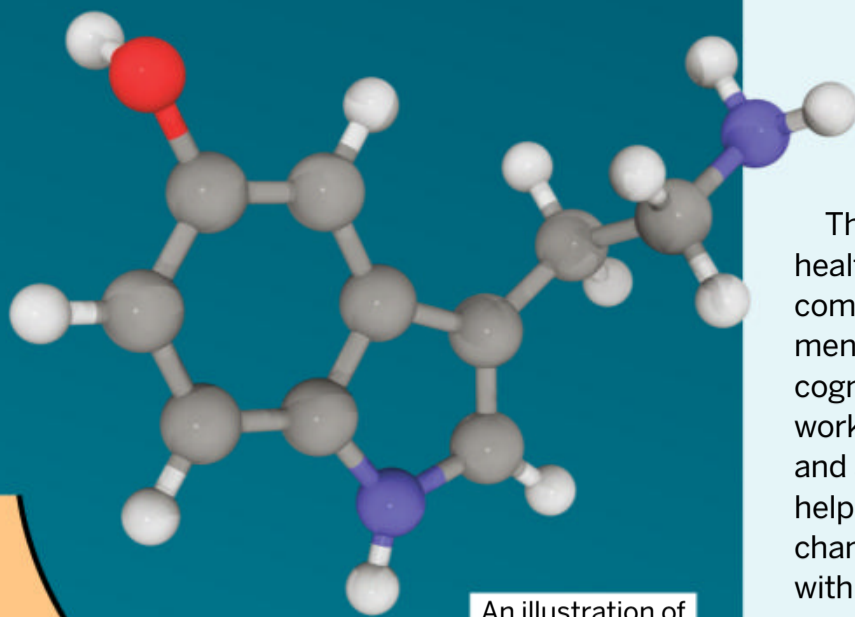
**14 PER CENT OF ADULTS AGED 60 AND ABOVE LIVE WITH A MENTAL DISORDER**

**301 MILLION PEOPLE**

Anxiety disorders are the world's most common mental illnesses

# REDIRECTING SEROTONIN

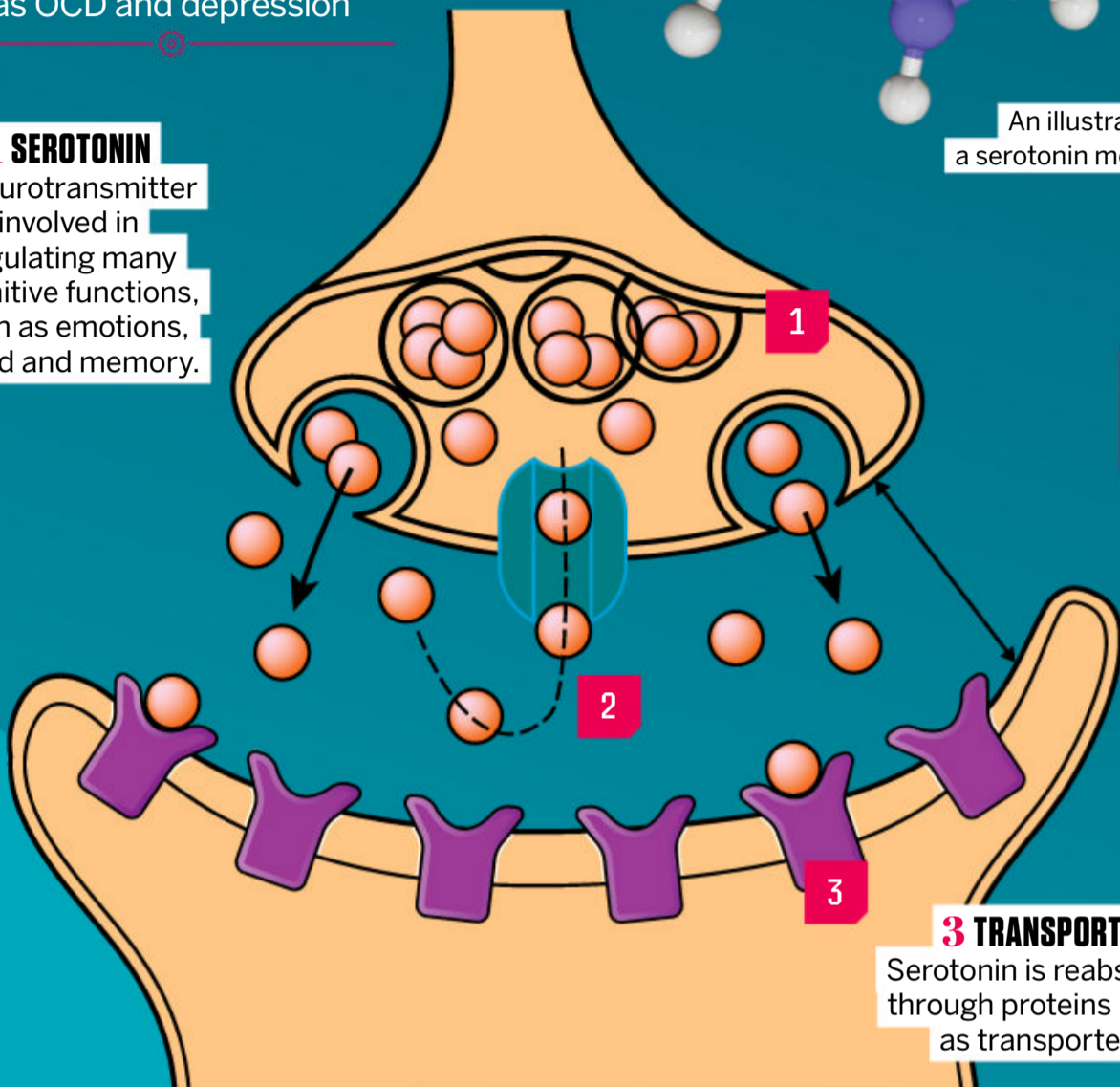
How SSRIs can help combat mental health conditions such as OCD and depression



An illustration of a serotonin molecule

## 1 SEROTONIN

A neurotransmitter involved in regulating many cognitive functions, such as emotions, mood and memory.



## 2 SENDING COMPLETE

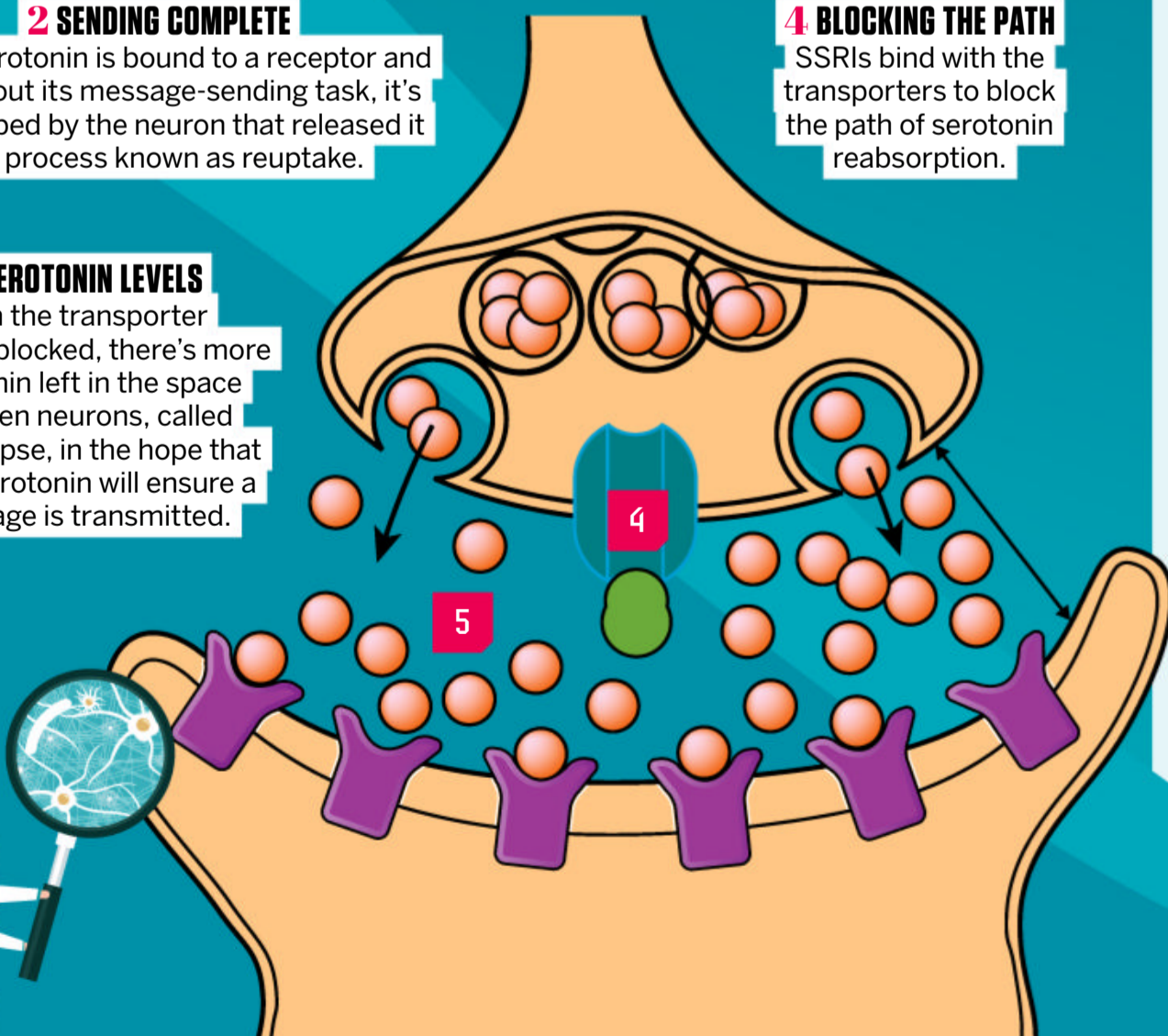
When serotonin is bound to a receptor and carries out its message-sending task, it's reabsorbed by the neuron that released it in a process known as reuptake.

## 4 BLOCKING THE PATH

SSRIs bind with the transporters to block the path of serotonin reabsorption.

## 5 SEROTONIN LEVELS

With the transporter proteins blocked, there's more serotonin left in the space between neurons, called the synapse, in the hope that more serotonin will ensure a message is transmitted.



**Did you know?**  
1 in 25 adults in the US live with serious mental illness

There are numerous ways that mental health conditions are tackled. One of the most commonly used forms of treatment for many mental health conditions, such as anxiety, is cognitive behavioural therapy (CBT). CBT works on the basis that our thoughts, feelings and actions are all interconnected and that helping change one of these elements may change the others. Through repeated sessions with a therapist, CBT identifies patterns of negative thoughts, behaviours and actions and helps someone develop the skills to break these patterns. Conditions such as eating disorders, psychosis and bipolar disorder

have been successfully treated using CBT. However, when talking therapies such as CBT aren't effective alone, pharmaceutical interventions may also be required. For example, to treat conditions such as PTSD, OCD and depression, a group of drugs called selective serotonin reuptake inhibitors (SSRIs) are often used. These inhibitors increase the amount of the neurotransmitter serotonin, which moves around the gaps between brain neurons, called the synaptic cleft or junction. Although the relationship between serotonin and mental health needs further investigation and clarification, studies have shown that an increase in its levels can improve the symptoms of many different mental health conditions.

Some uncommon alternative treatments are being used to alleviate certain mental health conditions. Transcranial magnetic stimulation (TMS) uses magnetic fields to stimulate nerve cells to treat depression and OCD. The treatment uses a coil, placed on the head, to emit magnetic pulses through the skull and into the brain. Although it remains unclear exactly why TMS can help alleviate symptoms after lengthy periods of treatment, it's been suggested that the magnetic fields change the firing patterns of neurons. Some studies have shown that around 50 to 60 per cent of people with depression who have not responded to other treatments have a 'meaningful response' to TMS. Of course, the treatment isn't without its side effects, which can include headaches, spasms in facial muscles and lightheadedness.

In recent years it appears the world has felt the impact of mental health, and awareness of its complexities and conditions has rapidly grown. Hundreds of millions of people around the world have been affected by a mental health condition and have sought treatment.

However, there's still so much that's yet to be discovered about what goes on in our brains and how it impacts our health.

## DR GIORGIA MICHELINI

Following her research into neurodevelopmental and mental health conditions, Michelini tells us about mental health conditions and the future of mental health research



©Giorgia Michelini

### Has there been a rise in mental health conditions in recent years?

It's helpful to distinguish between different groups of mental health. There's a lot of talk about an increase in rates of autism, ADHD and neurodivergence in general. The consensus is more that there is an increase in recognition and awareness of these conditions, rather than them being more prevalent.

Studies that actually look at the prevalence of these conditions see that they're not actually increasing. When there are increases, they are more due to the changes in the way these conditions are defined. For example, about ten years ago there was a change in the way autism is described in diagnostic manuals – before there was a narrower group of people that were identified as autistic, and then we started talking about the autism spectrum, which encompasses a broader group of presentations. That's where we see that there's an increase in the number of people that will meet criteria, but in general if you apply the new criteria to the people before you would have seen roughly the same number. Similarly, with

ADHD and autism it's really a matter of increase in the number of self referrals.

Another interesting trend is among other forms of mental health problems that are more related to anxiety and depression. I think there is more of a true increase there, and especially in the aftermath of COVID and during the pandemic. Many people have faced mental health challenges, and these have been triggered by isolation.

### What emerging mental health treatments are there?

One area which is very interesting is trying to find better mental health treatment for neurodivergent people. Very often when somebody who's autistic or somebody with ADHD also experiences anxiety and depression, those concerns will be brushed under the carpet.

A very important matter is to first identify these additional mental health conditions in people who are neurodivergent, and secondly offer evidence-based treatments and intervention for them. The reason for this is that CBT or medications that are given to the general population don't seem to work well in neurodivergent people, which speaks to the potential different mechanisms that drive anxiety and depression in neurodivergent people.

## HOW TO IMPROVE YOUR MENTAL WELLBEING AT HOME



### GET INTO A SLEEP ROUTINE

During those precious hours of sleep, the brain is forming new neurological pathways to help your brain function optimally. Studies have shown sleep deprivation can increase the risk of some mental health conditions.



### ADDRESS YOUR DIET

Food can play a key role in improving mental health. While there's no specific diet to help boost your mental health, studies have shown that diets that contain high refined sugars can worsen symptoms.



### EXERCISE

Along with providing an alternative focus, exercise can help release hormones called endorphins. Endorphins can reduce stress and help relieve pain, which may be contributing to negative mental health.



### CONNECTIONS

Several studies have found that maintaining positive relationships and 'social connectedness' can improve your mental wellbeing, whereas loneliness increases the risk of developing anxiety and even antisocial behaviour.



### CHOOSE KINDNESS

Acts of kindness, especially to ourselves, can be beneficial to positive mental health, along with reducing stress and boosting self-esteem.



A patient undergoing TMS treatment

# NAUTOMATE: LIFE-SAVING AUTONOMOUS BOATS

Discover the marine rescue technology that removes humans from dirty, dull and dangerous missions

WORDS AILSA HARVEY

**N**automate is an autonomous control system designed by BAE Systems to navigate marine missions without a human pilot or any human presence on board. By taking humans away from the monotony of all-day surveillance missions and keeping troops out of harm's way on particularly dangerous excursions, Nautomate's developers envisage its self-steering capabilities as the future of military missions.

The intelligent system wasn't designed for one particular vessel, but was built to be incorporated into a fleet of military vessels and can be adopted for civilian use too. The software can adapt to new mission-specific algorithms, called plug-ins, that are added to the existing system so that as autonomous technology becomes more advanced, new software can be added to Nautomate boats.

One of the major benefits in autonomous boat efficiency is the increased range vessels have without a human crew, their seats and personal equipment. Tests have shown that an uncrewed vessel can double its range with this weight reduction. This allows for more mission-specific payloads or extra fuel tanks.

In other instances, military missions could require people to be delivered to a destination. Spearheading an advance with an uncrewed vessel allows crewed boats to observe an enemy's response before they commit themselves. Uncrewed vessels can also be used to misdirect the enemy.

Nautomate serves as a template for the future, but current marine missions that could accommodate autonomous vessels include anti-piracy operations, border control, intelligence and surveillance missions and anti-submarine warfare operations. Its software includes artificial intelligence that with further machine learning will be even less reliant on human intervention.

## Did you know?

Nautomate's AI classifies objects into 14 categories

## SURFACE OPERATION

How does Nautomate work as the eyes and brain of a surface vessel?

### 5 SENSORS AND ANTENNAE

360-degree cameras, radar and GPS sensors are mounted near the top of the vessel. This collects data to map out the surroundings and track location.

5

6

### 6 SPEED CONTROL

Nautomate's autopilot system automatically alters the engine output to control speed in different scenarios.

### 7 STEERING INTERFACE MODULE

This module uses sensor data to steer the boat away from obstacles.

4

7

Nautomate completely removes the need for a human crew



Remotely operated weapons can be added to Nautomate boats



## MICHAEL BLAKE

BAE Systems' maritime services technical author explains the value of autonomous boats in the military



### What do you see Nautomate being used for?

It's for the jobs that are typically dull, dirty and dangerous. People in surveillance protection roles spend hours at sea on boats in a wide range of weather conditions. They're often having to do that in rough conditions, and after 12 hours of complete boredom they're then expected to react when a scenario warrants their attention.

Dangerous roles are often in operational areas where there might be danger from the weather or an aggressor. There's also the impact of whole body vibration. When you put a human on a boat for a long shift, they're out on the waves experiencing a whole

range of different vibrations. There's a slap as the hull moves across the top of the waves and continuous vibration of the much lower level surface ripples. All of that is exposing the human body to a wide range of shocks. And all of that is causing difficulties because people are going out and doing their job eight hours a day, five days a week. Taking people out of those situations entirely or only when a rapid reaction is needed from a human, you can massively reduce the load on human bodies.

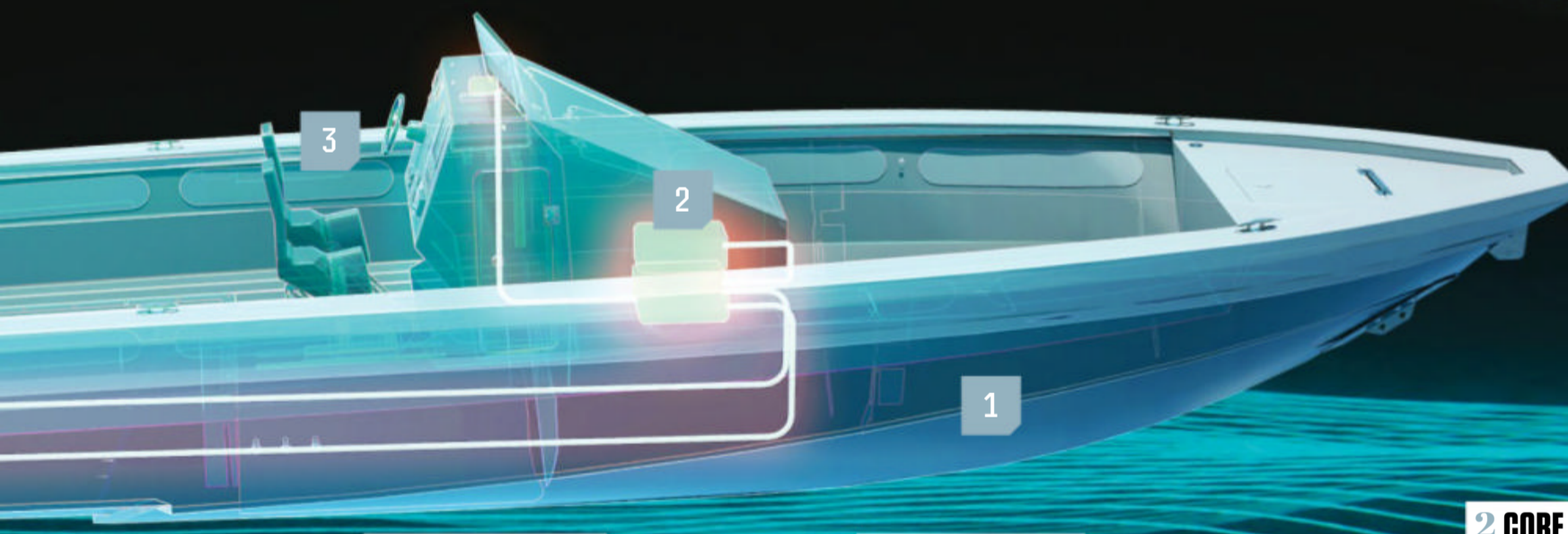
### Can the Nautomate software work with any vessel?

At the moment, it's smaller vessels that Nautomate is aimed at, around 20 to 24 metres in size. But really it's almost unlimited, because all we need to do is adapt the autonomy to

interface with even larger vessels. In the majority of situations we see the most benefit with the smaller vessel market.

### What comes next?

Later this year, we're taking Nautomate and incorporating that in a subsurface miniature submarine that will be going through trials on the south coast of the United Kingdom in a safe and secured test range area in September. Some of the things you rely on for safety and navigation – such as a human beings able to oversee the mission – get a lot more complicated. We have had to develop a lot of extra safety and assurance systems so that we can operate in that almost-blind environment. That's the biggest challenge.



### 1 TEST CRAFT

BAE Systems has tested Nautomate on its 14-metre P38 Aggressor, which can travel up to 63 miles per hour.

### 2 CORE PROCESSOR

The brain of the autonomous vessel controls the boat's movements to perform a preplanned mission. It uses data from the sensors to change the route and speed when facing obstacles.

### 3 CREW CONTROL

For safety, a crew member can override the autopilot by manually steering the boat.

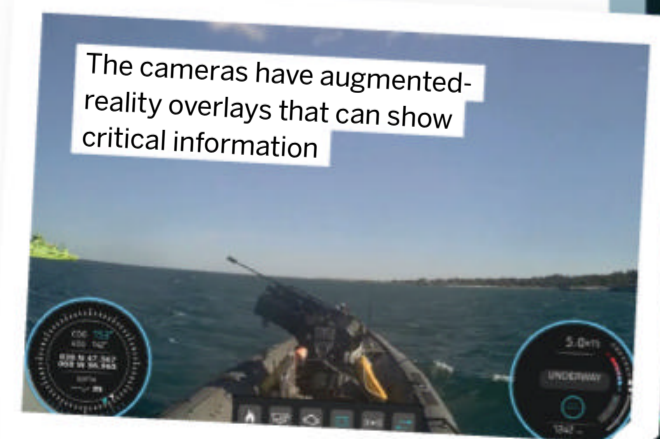
### 4 SENSOR MODULE

Data about the surrounding environment is sent as an electrical signal from the sensors to this computer.

## KEEPING CONTROL

Nautomate's GPS technology sends the live locations of its vessels to a coxswain in a control centre. The coxswain is a person qualified to pilot the vessel and is familiar with its technology. They are currently required to monitor the vessels' movements and can step in to control the boat if anything goes wrong. If a boat loses communication with the control station, the location is lost. Nautomate is

designed to initiate safety behaviours in this event, coming to a stop so it can be found at its last recorded location. When at rest, Nautomate is programmed to keep the vessel stationary against the moving tide, wind and weather. There is also a 'return-to-base' function, causing the vessel to automatically direct itself back to its launch point for instances when operators can't travel to the boat themselves.



# COULD A SUPERNOVA ENGULF EARTH?

WORDS ANDREW MAY

We put some intriguing, baffling and bizarre space questions under the spotlight

**A** supernova is what happens when a large enough star explodes. Such explosions are among the most dramatic of all astronomical events, and the resulting remnant can be a spectacular sight thousands of years later. Fortunately, supernovae are relatively rare, and we're very unlikely to get caught up in one. The most disastrous thing from our perspective would be

if our own Sun went supernova, but this will never happen. Only two types of star are capable of exploding in such a dramatic fashion: super-dense white dwarfs orbiting larger companion stars, which can produce Type I supernovae, or stars with at least eight times as much mass as the Sun, which end their lives as Type II supernovae. Our Sun isn't in either of these categories.

Even so, this doesn't mean that Earth can never be harmed by a supernova – in theory, at least. As well as producing the visible remnant, a supernova creates a burst of high-energy radiation that travels outwards at the speed of light. This radiation, particularly the highest energy gamma rays, could damage Earth's biosphere if it came from the explosion of a nearby star. A sudden burst of gamma rays

**DID YOU KNOW?** The Crab Nebula, the remnant of a supernova seen to explode in the year 1054, is about 6,500 light years away

## EFFECTS OF A SUPERNOVA

Just how deadly a supernova would be depends on how far away it is



### DANGER ZONE

If a supernova exploded closer than about 50 light years from Earth, the effects would be devastating to life on the planet, comparable to the mass extinction event that occurred at the end of the Ordovician period 450 million years ago.

### INTERMEDIATE ZONE

In this region, radiation reaching Earth from a supernova would likely have some kind of effect on the biosphere, but not enough to cause widespread extinctions of whole species.

### SAFE ZONE

Although scientists don't know for certain, it's believed that a supernova occurring more than 160 light years from Earth would be too far away to have any adverse effects on life on our planet.

50  
LIGHT YEARS

50 TO 160  
LIGHT YEARS

OVER 160  
LIGHT YEARS

INNER  
ZONE

INTERMEDIATE  
ZONE

OUTER  
ZONE



A fanciful depiction of what Earth's surface might look like after a nearby supernova

hitting the upper atmosphere could convert nitrogen and oxygen into smog-like nitrogen oxides, as well as damaging the ozone layer that protects Earth's surface from the deadliest frequencies of ultraviolet radiation.

These effects would be particularly catastrophic for marine life. Scientists have speculated that just such a gamma-ray burst around 450 million years ago caused the Late

Ordovician mass extinction, which saw the death of around 60 per cent of all oceanic life on Earth.

The big question is how close a supernova has to be to produce effects like these on our planet. There's plenty of uncertainty around the exact figures, but the graphic on this page shows the current best guess as to the danger zone. Fortunately, astronomers aren't aware of

any imminent supernovae close to us. The best known star likely to produce a Type II supernova any time soon is Betelgeuse, which is a perfectly safe 642 light years away. The closest of all the known 'supernova progenitor candidates' is a star called IK Pegasi B, which could potentially create a Type I supernova – but even this is a borderline-safe 150 light years away.



# HOW DO WE SEE BLACK HOLES?

In the literal sense we can never see a black hole, because it's a region of space from which no light – or anything else – can ever escape. However, this region does contain mass – sometimes a very large amount of it. For example, the supermassive black hole at the centre of our galaxy, known as Sagittarius A\* (Sgr A\*), has a mass around 4 million times that of the Sun. This mass exerts a gravitational effect on the surrounding matter, and we can deduce the black hole's presence by observing this effect. In the case of Sgr A\*, astronomers first realised it was there when they saw an empty spot with stars circling around it, as though they were orbiting a very massive but invisible object. When the Event Horizon Telescope took a zoomed-in photograph of this region, it didn't show the black hole itself, but the superhot disc of gas swirling around it.

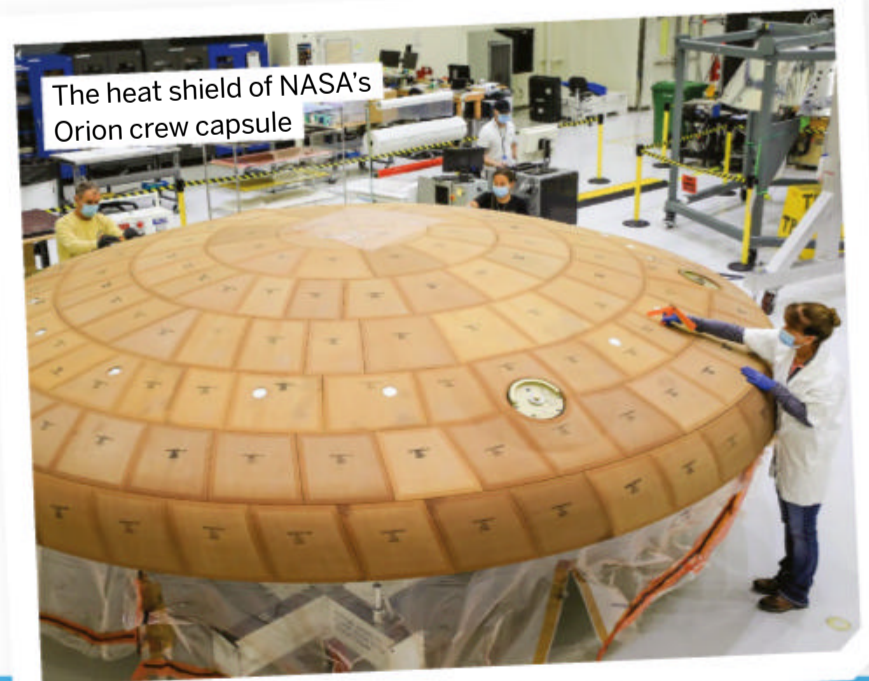
The Event Horizon Telescope's image of the region around Sgr A\*

**Did you know?**  
Spacecraft landing on Mars also need heat shields

## WHY DON'T SPACECRAFT BURN UP IN EARTH'S ATMOSPHERE?

Most spacecraft – the ones that don't make headlines – do indeed burn up on re-entry. These are things like disused satellites or non-reusable resupply craft, which don't need to get back to Earth in one piece. They burn up because they hit the atmosphere with such enormous velocities they temporarily heat the air around them to very high temperatures. While this is a great way to get rid of unwanted space junk, it would be a disaster in the case of a crewed

spacecraft, or one that's returning an asteroid sample or other valuable payload to Earth. In these cases, special precautions have to be taken to ensure the spacecraft don't burn up or have their interiors heated to dangerously high temperatures. This involves using a sophisticated heat shield, of which perhaps the most famous was the Space Shuttle's thermal protection system, made up of 24,300 specially constructed tiles.



The heat shield of NASA's Orion crew capsule

## DO ANTIMATTER GALAXIES EXIST?

All the matter we see around us is made from the same basic set of subatomic particles, such as protons and electrons. But we know from theory – together with experiments in particle accelerators like the Large Hadron Collider – that all these particles have ‘antimatter’ counterparts, which famously annihilate in a flash of high-energy radiation if they come into contact with the corresponding normal-matter particle. We know there’s very little antimatter in our immediate cosmic neighbourhood for the obvious reason that we don’t see these explosive annihilations happening all the time. But scientists don’t really know why the universe seems so biased against antimatter, and it’s been speculated that some distant galaxies – well away from any normal matter – might be composed purely of antimatter. The answer to this question is ‘maybe’, although there’s no direct evidence for it.

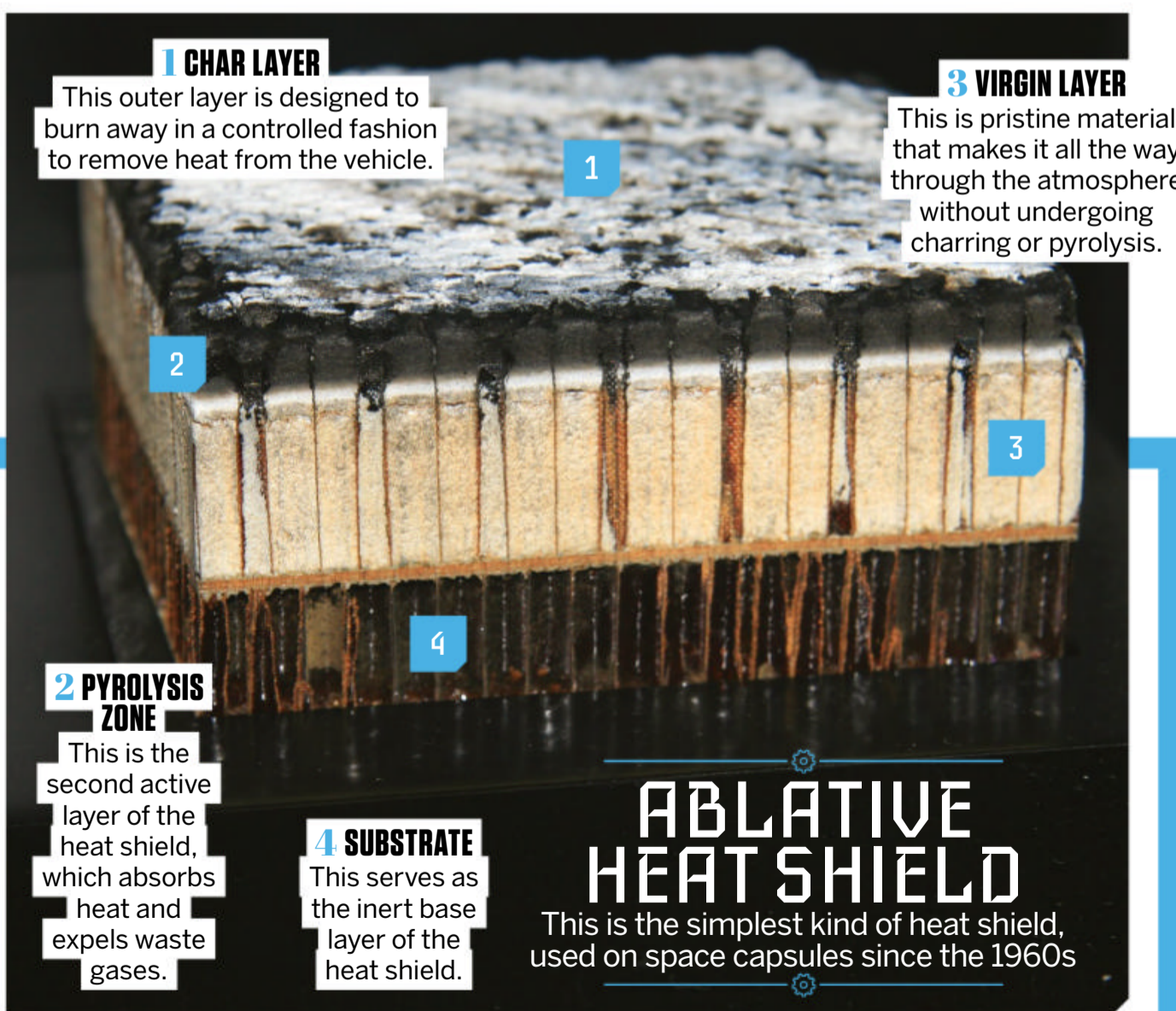


This time-lapse photograph clearly shows how stars appear to revolve around the pole star

## WHY DOESN'T THE POLE STAR ROTATE IN THE SKY?

As most people know, the stars don’t really rotate around Earth once every 24 hours as the ancients used to think. This apparent motion is a consequence of the fact that the Earth itself rotates once a day about its north-south axis. For all practical purposes the stars remain fixed relative to each other; any real motion they have is so small it can only be detected by very sensitive astronomical instruments. But if you

picture Earth rotating against this fixed backdrop, you’ll realise that there are two points, precisely above the north and south poles, that always remain fixed. These are called the ‘celestial poles’, and the northern one happens to lie very close in the sky to the star Polaris – the pole star. That’s the reason this particular star seems to remain fixed while all the others rotate around it.



## IS THERE AN ALTERNATIVE TO ROCKETS FOR LAUNCHES?

Rockets are the only self-contained craft capable of functioning outside Earth’s atmosphere. Balloons, aeroplane wings and jet engines all fail to work if there isn’t enough air. It’s possible to launch payloads into space by means of a hybrid system, in which a balloon or aircraft is used for the first part of the flight, but it’s still necessary for a rocket engine to take over at higher altitudes. Several ideas have been proposed, ranging from electromagnetic ‘railguns’ – in which a capsule would be steadily accelerated as it whizzes down a long, railway-like track – to ‘space elevators’ reaching vertically upwards all the way to space.

# HOW DO SPACE AGENCIES BENEFIT THE WORLD?

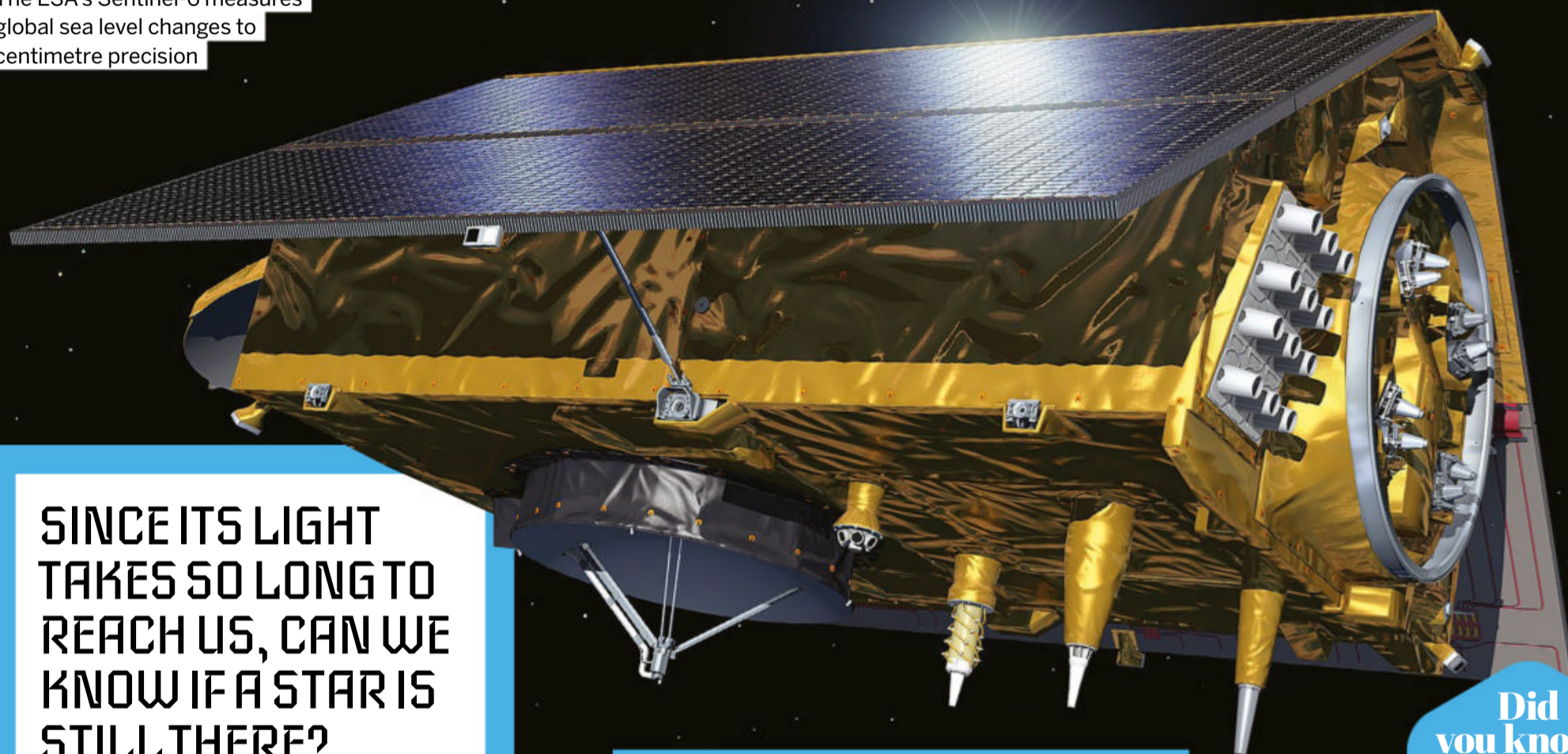
The primary mission of organisations like NASA and the European Space Agency (ESA) is to carry out scientific research, aimed at widening and deepening our knowledge of the universe around us. At one end of the scale, this tackles the biggest questions of all, such as the origin of the universe and the possibility of life beyond Earth. Such questions have always fascinated humankind, but space travel is beginning to give us real answers

rather than mere speculations. Plenty of important science is done in laboratories down here on Earth – and exciting, high-profile space missions serve a secondary purpose in stimulating young people to think about careers in such places; which they might not otherwise have done.

Space programs can also benefit humanity at the more practical end of the spectrum. We may take things like GPS satellite

navigation and communication satellites for granted, but they're products of space research too. They're not idle luxuries either, with GPS being essential to modern sea and air travel and Starlink-type satellites bringing broadband internet to isolated communities that couldn't access it any other way. Equally important are the many Earth-observation satellites that keep constant track of our planet's changing climate.

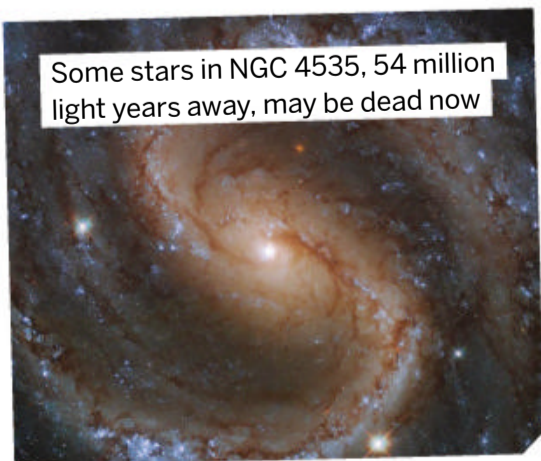
The ESA's Sentinel-6 measures global sea level changes to centimetre precision



## SINCE ITS LIGHT TAKES SO LONG TO REACH US, CAN WE KNOW IF A STAR IS STILL THERE?

The simple answer is no, we can't. When we look at a star X light years away, we see it as it was X years ago. That's just a consequence of the finite speed that light – and all other forms of electromagnetic radiation – travels at. But we need to bear in mind that stars have very long lives, measured in millions or billions of years. Even the most distant stars that are visible at night with the unaided eye are only a few thousand light years away, and most of them are much closer than that, so there's a pretty good chance they're all still there.

Some stars in NGC 4535, 54 million light years away, may be dead now



“Space programs can also benefit humanity at the more practical end of the spectrum”

**Did you know?**  
Around 4 billion people rely on GPS for navigation

## NASA SPIN-OFF TECHNOLOGIES

Over the years, several inventions developed by NASA for space applications have found wider use

### 1960s

#### FOOD SAFETY STANDARDS

It's essential that the food provided for space missions is free from disease-carrying bacteria, and the standards developed to ensure this are now used throughout the United States.

### 1960s

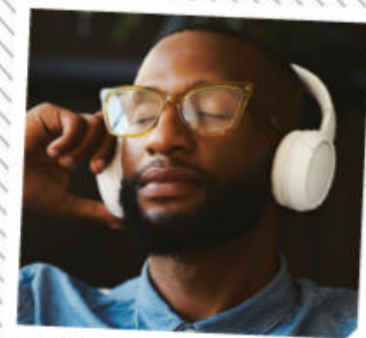
#### IMPROVED WATER FILTERS

The technology that NASA developed to sanitise astronauts' drinking water has since found other uses on Earth, for example in purifying pool water.

### 1961

#### CORDLESS HEADPHONES

The technology used in modern wireless headphones was originally developed for use in the space helmets worn by NASA's Mercury astronauts.



## WHAT IS A LAUNCH WINDOW?

One of the things that makes space travel uniquely difficult is that objects in space never stay in fixed locations relative to each other. Earth spins on its axis and orbits around the Sun, the Moon and the International Space Station (ISS) orbit around Earth and Mars and all the other planets have their own orbits around the Sun that aren't synchronised with Earth's. This means that in order to get to your desired

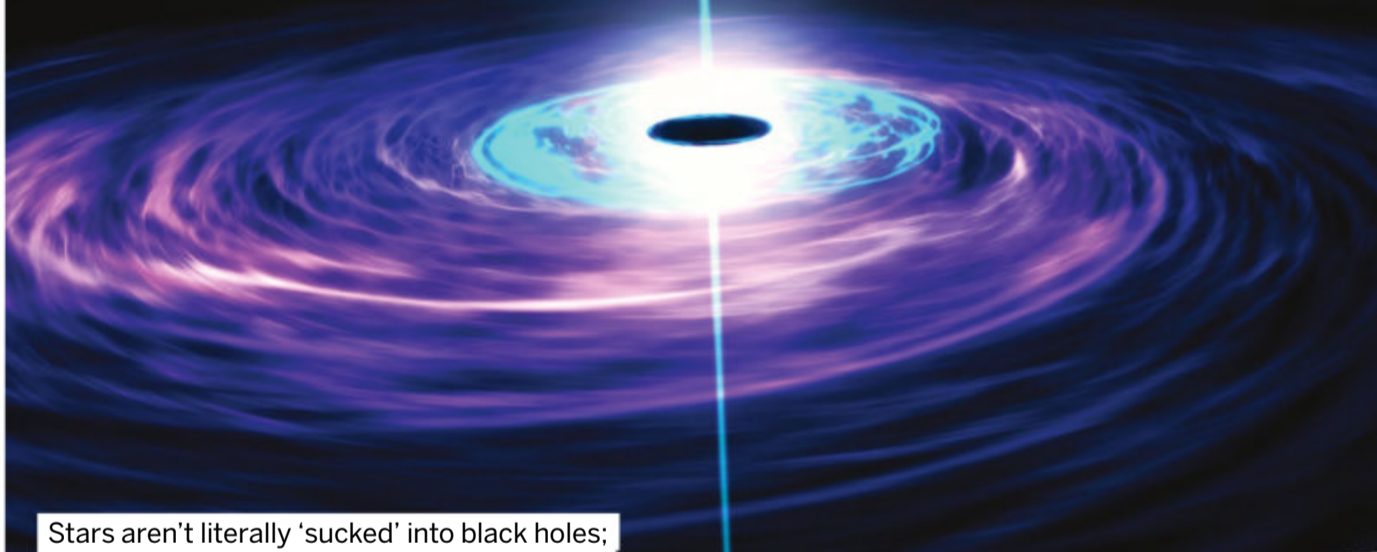
destination, the launch has to be carefully timed so that everything lines up in the right way. The 'launch window' refers to a period of time during which the alignments are just right for launch. It's usually the case that launch windows of a few hours each are available on several different days, so it's not a disaster if a problem during countdown to liftoff causes a particular launch window to be abandoned.



## WHY AREN'T WE SUCKED IN BY THE MILKY WAY'S SUPERMASSIVE BLACK HOLE?

The enormous black hole at the centre of our galaxy exerts a powerful gravitational pull, but we can't fall into it for much the same reason Earth can't fall into the Sun. In the latter case, it's because our planet has a large sideways motion – about 67,000 miles per hour – when viewed from the Sun. Only if that

motion could be cancelled out, involving a huge expenditure of energy, would Earth fall into the Sun. In a similar way, the Sun, Earth and whole Solar System are moving sideways through the galaxy at a whopping 515,000 miles per hour, so there's no way they could fall down all the way to its centre.



Stars aren't literally 'sucked' into black holes; they break into pieces that spiral in gradually

## WHAT IF AN ASTRONAUT DROPS AN ITEM IN SPACE?

If an astronaut working outside the ISS managed to let go of an object so carefully that it didn't acquire any additional velocity, it would remain stationary from their perspective and they could just pick it up again. More realistically, if the object was dropped with a slightly different velocity from the rest of the station, it would drift off onto a different orbit of its own, circling Earth. This is what happened in November 2023 when a pair of spacewalking astronauts dropped a tool bag. This tool bag will eventually re-enter the atmosphere and burn up.

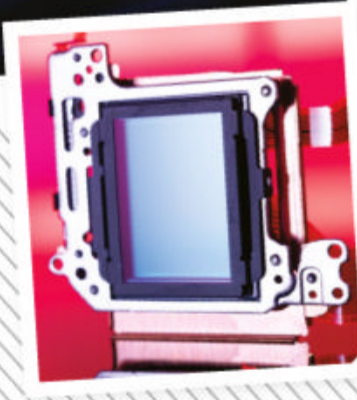


**Mid-1960s**  
**FREEZE-DRIED FOOD**  
NASA started freeze-drying astronauts' food to reduce weight and increase shelf life, but the same technology has now found other uses, for example for home-bound people.



**1964**  
**FOIL BLANKETS**  
These items, often found in first-aid kits or used by emergency services, are still colloquially known as 'space blankets' to reflect their origins in the early space program.

**1966**  
**MEMORY FOAM**  
Now used in everything from pillows and mattresses to sports equipment and theme park rides, this was originally developed by NASA as a crash-protection technology.



**1968**  
**CMOS IMAGE SENSOR**  
While the name may not be familiar, you probably have one of these in your smartphone or digital camera, and it uses technology originally developed for interplanetary space missions.

**Early 1970s**  
**IMPROVED RADIAL TYRES**  
The Goodyear company has always been known for its tyres, but the extra-strong materials it uses today were originally developed under contract to NASA for spacecraft parachute shrouds.

**Late 1980s**  
**EAR THERMOMETERS**  
Now a popular way to measure body temperature, particularly in children, these employ infrared sensors originally developed for space applications.

# SUPER SPACE ROCKET ENGINE

This revolutionary new propulsion system is set to change space launches

WORDS ANDREW MAY

If you've ever watched one of the test launches of SpaceX's 120-metre-tall Starship, you may have been amazed that such an enormous rocket can get off the ground, let alone reach outer space. That's all thanks to its specially designed Raptor engines – six of them in its upper stage and an unprecedented 33 in the Super Heavy first stage. SpaceX is unusual among launch vehicle manufacturers in designing and constructing its own engines, rather than buying them from another supplier. But this gives it the flexibility to tailor the engines to its exact needs – and in the case of Raptor, it has led to one of the most revolutionary rocket designs to date.

Apart from its sheer size, Starship will be a record breaker in another way: it will be the world's first completely reusable space launch system. That's in contrast to earlier designs such as NASA's Space Shuttle and SpaceX's own Falcon 9 rocket, which were only partially reusable. It's this goal of complete reusability that's driven the radically new design of the Raptor engine. It's powered by methane – an unusual choice for rocket fuel, but one that reduces soot buildup inside the engine and eliminates the need for major refurbishment between flights. The other really innovative feature of Raptor is its use of 'full-flow staged combustion' (FFSC). This is a particularly efficient engine design that was first tackled, without success, by Russian engineers in the 1960s. It wasn't until SpaceX's work with Starship and Raptor that an FFSC engine actually made it off the ground. This kind of design also has the advantage of creating a less extreme environment inside the engine's pipework.

Starship actually uses two different variants of the Raptor engine – one designed to give best performance at sea level and the other optimised for use in the vacuum of space. All 33 of the engines in the Super Heavy booster are sea level types, while the upper stage uses a mix of three sea level and three vacuum variants. Since it was originally conceived, the Raptor design has undergone a steady stream of refinements, and it's now on its third generation. The two most obvious trends have been in reduced weight, which has gone down from 2,000 kilograms for Raptor 1 to 1,400 kilograms for Raptor 3, and greater thrust, which has increased from 1.8 to 2.6 meganewtons.

**Did you know?**  
The SpaceX factory makes one Raptor engine per day

Raptor engines are used to launch SpaceX's giant Starship rocket

## SPACEX STARSHIP

When SpaceX founder Elon Musk talks about Starship, he often focuses on the ultimate goal of using it to take humans to Mars. It's this long-term vision that has dictated some of Starship's most innovative features, such as the ability to refuel in space. It also influenced the choice of methane as a fuel, since it's a chemical that could be synthesised on Mars from subsurface water and atmospheric carbon dioxide. In the nearer term, Starship is likely to see less dramatic service as SpaceX's main workhorse.



Both the upper and lower stages of Starship use Raptor engines

## METHANE AS A ROCKET FUEL

A historically popular fuel choice has been RP-1, a kerosene-based fuel. This is what the giant first stage of NASA's Saturn V used, as well as SpaceX's Falcon 9. Others, such as the Space Shuttle main engines, use liquid hydrogen. The latter is cleaner and more efficient, but it's more expensive and harder to handle because it has to be stored in liquid form at extremely low temperatures. In recent years, methane has emerged as a compromise between these two, being cleaner than RP-1 but cheaper and easier to handle than liquid hydrogen.



Fuel storage tanks are visible alongside the Starship launchpad in this photo

**DID YOU KNOW?** In July 2023, China's Zhuque-2 became the first methane-fuelled rocket to reach Earth orbit

# INSIDE RAPTOR

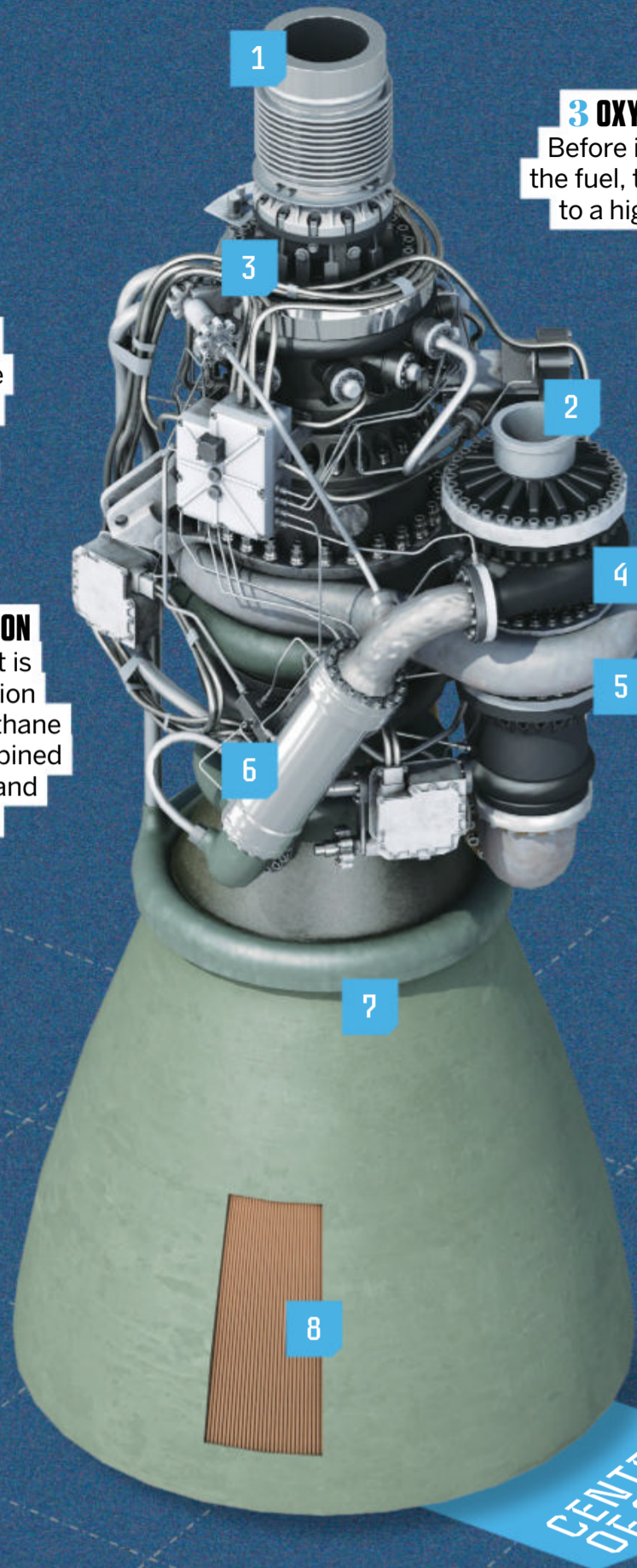
Here's a simplified view of how this complex engine works



United Launch Alliance's Vulcan rocket also uses methane fuel



Raptor's first test flights were carried out using the Starship upper stage only



## 1 LIQUID OXYGEN IN

In order to burn, the methane needs an oxidiser – in this case pure oxygen that's stored in liquid form.

## 6 MAIN COMBUSTION

The engine's heart is the main combustion chamber, where methane and oxygen are combined at high pressures and temperatures.

## 3 OXYGEN TURBOPUMP

Before it's combined with the fuel, the oxygen is raised to a high pressure here.

## 2 FUEL IN

The methane fuel – also stored in liquid form – enters the engine here.

## 4 FUEL TURBOPUMP

The fuel is also raised to a high pressure in a separate turbopump.

## 5 PREBURNER

Small amounts of fuel and oxygen are burned separately to produce the power to drive the turbopumps.

## 7 EXHAUST NOZZLE

The hot exhaust gases are expelled at high velocities from this specially designed nozzle to generate rocket thrust.

## 8 COOLING PIPES

Cold, unburned propellant is circulated through these pipes to keep the nozzle from overheating.

CENTRE OF SHIP

## SPACEX ENGINE POWER



### TECH SPECS

ENGINE FAMILY NAME

Merlin

DATE DEVELOPED

2006

THRUST

981 kilonewtons

PRIMARY USE

Main engine



### TECH SPECS

ENGINE FAMILY NAME

Kestrel

DATE DEVELOPED

2006

THRUST

28 kilonewtons

PRIMARY USE

Upper-stage engine



© Wiki Commons: Steve Jurvetson

### TECH SPECS

ENGINE FAMILY NAME

Draco

DATE DEVELOPED

2010

THRUST

400 newtons

PRIMARY USE

Spacecraft thruster



### TECH SPECS

ENGINE FAMILY NAME

SuperDraco

DATE DEVELOPED

2012

THRUST

71 kilonewtons

PRIMARY USE

Launch escape engine



© Wiki Commons: Brandon De Young

### TECH SPECS

ENGINE FAMILY NAME

Raptor

DATE DEVELOPED

2016

THRUST

2.6 meganewtons

PRIMARY USE

Main engine



# WHAT ARE ULTRA- PROCESSED FOODS?

WORDS AILSA HARVEY

Some natural products are drastically transformed by the food industry, and regularly eating them can affect our health

**DID YOU KNOW?** If you increase ultra-processed food consumption by ten per cent, your cancer risk becomes 12 per cent higher

**M**any of the foods you prepare at home are likely to go through some processing, whether that be freezing, cutting, canning or cooking. Each act changes the chemistry of the food's molecules in some way. However, ultra-processed foods are those that undergo industrial-style processes far exceeding what you can do in your own kitchen. They are the types of food that encourage excessive eating – 'hyperpalatable' foods like ice cream, sausages and biscuits. Ultra-processed products often have more sugar and other ingredients that your brain can quickly become addicted to.

Natural foods, like fruit, can change in taste and consistency as they ripen and grow. However, ultra-processed foods often have added chemicals and artificial flavours that prolong their shelf life. Ultimately, ultra-processed foods are designed for a palatable experience, with less consideration for the impact the product has upon entering the

body. Heavily processed foods can be transformed into a large variety of products. In the meat industry, ultra-processing can assist in reducing waste, like scraps of meat that aren't so easily removed from the bone.

Products like hot dogs include mechanically separated meat, which involves specialised machines that can retrieve otherwise discarded trimmings of chicken, beef or pork that are ground to an even consistency and blended together into a thick paste. Chemicals are added to evenly flavour the mixture and hold the paste together before the paste is used to fill long, thin cases – such as animal intestines – to mould into a sausage shape. Heat and additives remove much of the beneficial nutrients of the meat and colouring is often added to encourage people to eat it.

**Did you know?**

Around 5,000 substances can be added to food



**“Ultra-processed products often have more sugar”**



Refined sugar makes processed foods thicker, sweeter and higher energy

## THE FOOD SPECTRUM

How many processes has your food been through?

### UNPROCESSED

If food is unprocessed, it hasn't been altered much or at all. This includes fruit, vegetables, nuts, seeds, eggs and fish when served in their natural state. These are also called whole foods, and natural nutrients like antioxidants are more likely to remain in the food and benefit the body.



### PROCESSED INGREDIENTS

These ingredients have been sourced from nature, but have been changed slightly. Examples of processed culinary ingredients include sugar, salt, butter and oils. Some of the processes that the ingredients go through are drying, refining, pressing and milling.



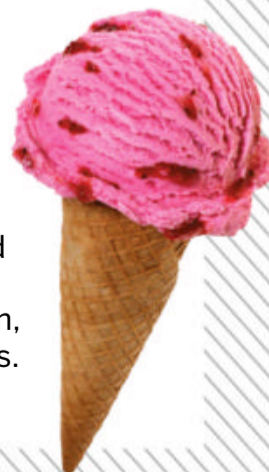
### PROCESSED FOODS

Foods from the first two groups are combined to form processed foods. Usually two or three ingredients are added to produce foods such as cheese, bread, jam, pickles and tinned products. Some of this processing makes food safer to consume and gives a longer shelf life.



### ULTRA-PROCESSED

These items usually look unrecognisable from their natural ingredients. They combine mixed ingredients and additives. Food dyes, preservatives and sweeteners alter foods' texture and appearance. Examples of ultra-processed foods are some soups, biscuits, sausages, ice cream, crisps and carbonated drinks.



## NATURAL OR REFINED SUGAR

Some natural foods contain similar sugar concentrations to processed foods, but this doesn't make them equal nutritionally. Natural sugars have more minerals than refined sugars, while the latter is more likely to cause a blood sugar spike. Sucrose is a common type of refined sugar, which is extracted from sugar cane plants. Sugar crystals that are extracted from the plant are washed, dried and cooled, stripping the sugar away from the other nutrients of the plant. This is why refined sugar is often called 'empty calories'. It gives the body energy without the nutritional benefits.

Refined sugar is often added to ultra-processed foods and can sneak into your diet through foods you may not be aware have added sugar, such as salad dressings and condiments. Natural sugar, when eaten in a whole food, comes with many other beneficial nutrients, vitamins and minerals. It is also accompanied by dietary fibre to slow down its digestion and prevent too much entering the bloodstream at once.

## PREPARATION TECHNIQUES

The main techniques used to produce and preserve ultra-processed food items are mechanical, thermal, chemical and packaging. Mechanical processing largely involves breaking down raw materials into small, evenly sized particles so that they can be mixed smoothly with other ingredients. This helps make textures more uniform, whether that be by milling, grinding, blending or slicing. Many products are then thermally treated to cook, sterilise or dry the food.

Because ultra-processed foods can include foods from a larger range of sources, heat treating it helps kill any contaminating microorganisms. High-temperature baking and canning of the food increases its shelf life and means that it can be sold further afield. Chemicals are sometimes added to ultra-processed foods, often to preserve them. Different chemicals work to disrupt the cellular processes of microorganisms (sodium benzoate), regulate the acidity (citric and acetic acid) and reduce the moisture content, where microbes could thrive (glycerol, sugar and salt). Finally, processed foods are packaged into airtight containers to keep them fresher for longer.



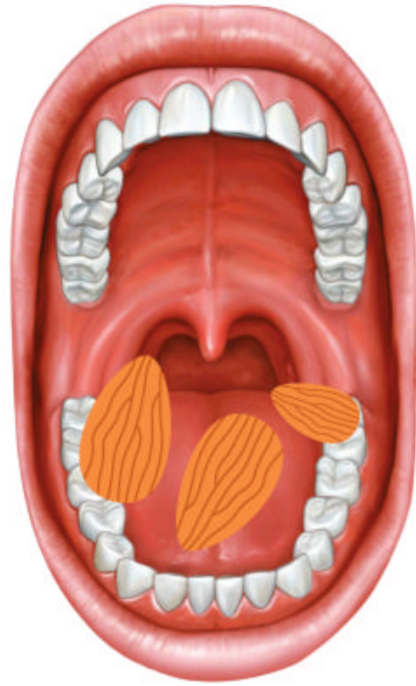
A food processing worker adds ingredients and additives into a large vat to be mixed and heat treated



# HOW THE BODY HANDLES FOOD

The types of food you eat alter your digestion

## DIGESTING UNPROCESSED



### Did you know?

US food producers have used artificial dyes since the 1800s

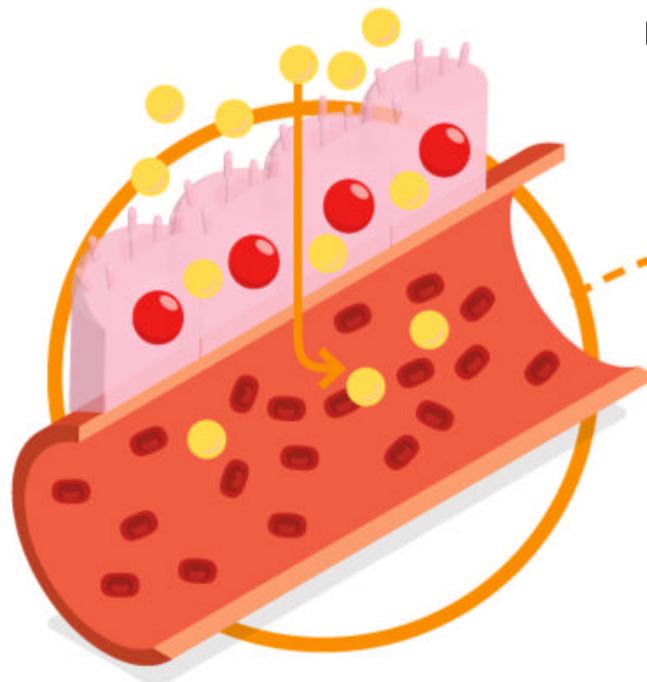
#### 1 TRAPPED FAT

In unprocessed foods like almonds, fat is trapped in natural cell walls even after chewing.



#### 7 SLOW RELEASE

Carbohydrates are broken down more gradually in unprocessed foods. The slow release of energy can sustain the body for longer periods.



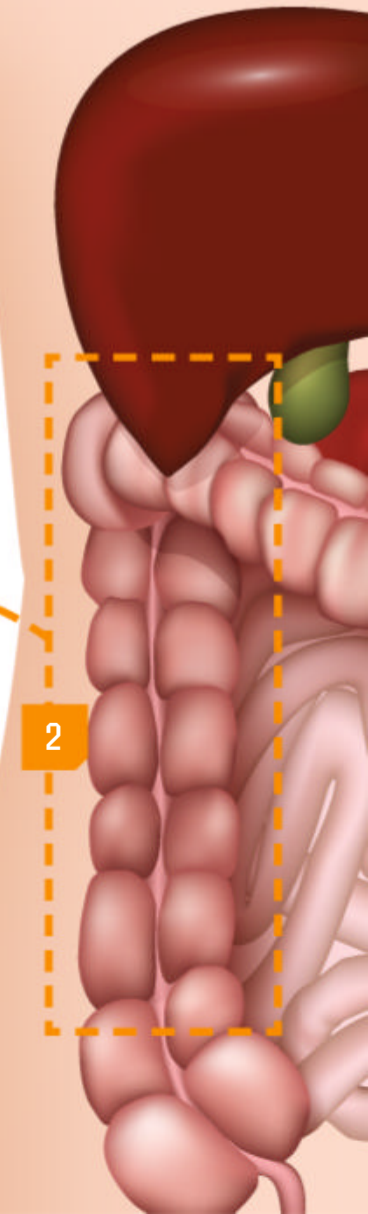
#### 2 LOWER INTESTINE ABSORPTION

Natural food's complex structure means it takes longer to digest. This food also has more nutrients to absorb, so absorption into the bloodstream takes place in the lower intestine.

#### 6 FULL OF FIBRE

There is more fibre in unprocessed foods, making the body feel full quicker. Fibre also increases gut health.

2



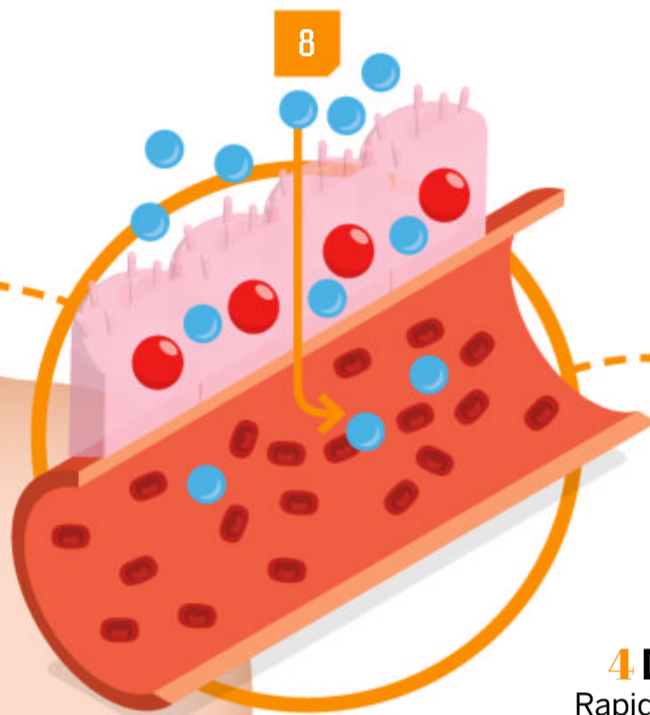
## DIGESTING ULTRA-PROCESSED

### 8 SUGAR SPIKES

High volumes of sugar and fat are absorbed into the bloodstream in a short period. This can cause rapid increases in blood sugar levels.



8



4

### 4 DOPAMINE SIGNALLING

Rapidly absorbed salt, sugar and fat cause specialised digestive cells to signal the brain to produce the hormone dopamine.

### 3 QUICK FAT ABSORPTION

Fat's natural structure changes in the absorption process, making it more accessible for digestion. These foods often lack fibre, which slows fat digestion.

6

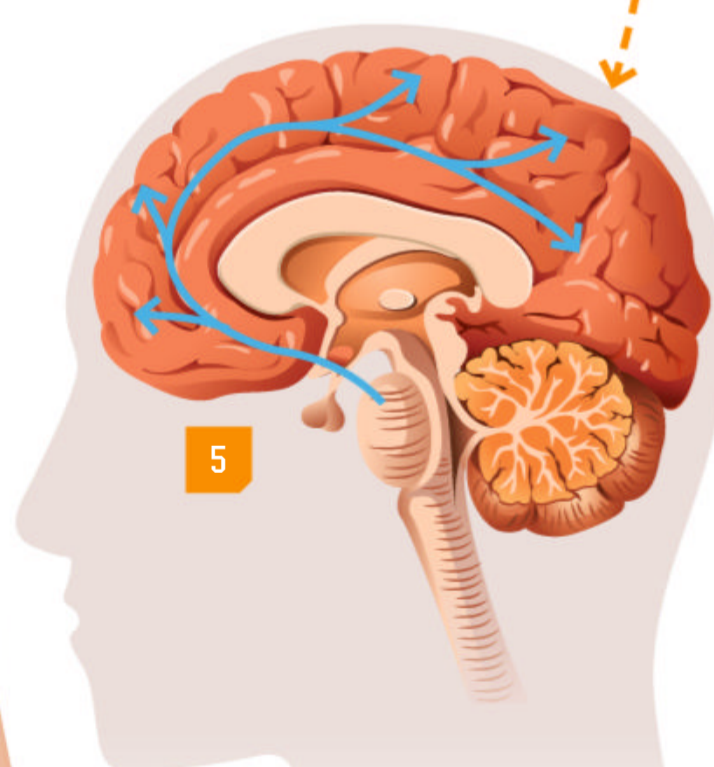


3

5

### 5 DOPAMINE PATHWAY

Dopamine is a chemical messenger that sends signals from the midbrain to the reward-processing regions. This is what makes the body feel tempted to eat more unhealthy food.



# 5 FACTS

## FOOD-RELATED HEALTH ISSUES

### 1 OBESITY

Ultra-processed foods generally contain more calories, sugar and fat. They also lack the nutrients that make the body feel full. This can lead to over-eating.

### 2 TYPE 2 DIABETES

Consuming excessive amounts of processed foods with added sugars causes spikes in blood sugar levels. Regularly eating these foods can cause the body to stop reacting to the hormone insulin, which works to regulate a person's blood sugar levels.

### 3 CARDIOVASCULAR DISEASES

The higher levels of sodium and fat in processed foods increases your chances of developing cardiovascular diseases. Fats can raise cholesterol and sodium your blood pressure.

### 4 DIGESTIVE DISORDERS

The low fibre in processed foods can cause constipation, haemorrhoids and bowel pain. Refined sugars can also lead to inflammation of the gut and unbalance its microbiome.

### 5 MENTAL HEALTH IMPACTS

Continually eating high-sugar foods can cause imbalance in blood sugar levels as they rise and crash. As a result, people experience mood swings, fatigue and irritability. When these imbalances are chronic, depression and anxiety are more likely.

# VITAMIN BALANCE

Can a lack or excess of key vitamins and minerals really cause so much damage to our bodies?

WORDS DR JOANNA ELPHICK

**I**f it's cold outside we all know to put on a coat to keep warm, but there's so much more that we can do to remain healthy, just by watching what we eat. A well-balanced selection of micronutrients can contribute to the body's natural defences by reinforcing its physical barriers, such as the mucus linings and the skin. Micronutrients is the collective term for a wide range of vitamins and minerals that are essential for our bodies to function properly. Vitamins are organic substances, meaning they are produced by plants or other animals, and can be broken down into two distinct groups: fat-soluble and water-soluble vitamins. Vitamins A, D, E and K will dissolve in fat, which can then be stored in our bodies, hence the name 'fat-soluble' vitamins. The body can take what it needs as and when necessary.

Water-soluble vitamins, on the other hand, will dissolve in water, and therefore can't be

stored for use later. Water-soluble vitamins that the body doesn't need straight away, such as C or any of the B-complex groups, are flushed through the bloodstream and lost when you next need the toilet. Because they can't be retained for later use, the body needs to replenish water-soluble vitamins every day. Micronutrients also include minerals such as zinc, which are inorganic substances that can be found in water or in the soil. When we plant seeds, the growing plants absorb the minerals from the soil and rain. When ripe and ready, we harvest the plants to eat, taking in the minerals at the same time. Other minerals are ingested when we eat animals that have previously nibbled on plants growing in the soil. A healthy diet should ensure that we have a perfect balance of vitamins and minerals – but how much is enough, and can we ever overdo it?

The recommended dietary intake is different for each vitamin and mineral. It also

**DID YOU KNOW?** Vitamin A is used to treat chronic acne – although too much vitamin A is extremely toxic

**Did you know?**

Vitamin C won't stop you from catching a cold

depends on the age, gender and general health of the individual. Women tend to need less vitamin quantities than men, although pregnant women and those breastfeeding require more. People who smoke need a higher dose of most micronutrients than those who don't smoke. Our bodies tend to need lower doses of minerals, referred to as 'trace' levels.

Of course, you can have too much of a good thing. For many vitamins, an overdose can be as unpleasant as a deficiency. This is known as hypervitaminosis and can be an extremely distressing experience. Excessive bleeding, diarrhoea, depression and blurred vision are just a few of the symptoms of overdosing. In some extreme circumstances it can even be fatal. However, vitamin K is an exception. This particular wonder vitamin has no maximum intake level since the body can take any amount you give it – that means you can never have too much broccoli or prunes.

## RICKETS THROUGH THE AGES

As early as the first century CE, Greek physicians were identifying bone deformities in children, but it wasn't until the 17th century that the disease was formally recognised. During the Industrial Revolution, many children suffered from rickets due to their unhealthy lifestyles. Youngsters, forced to spend their days in dark factories or in coal mines, were kept out of the sunlight. By the 19th century, the affliction was widespread throughout Europe. However, by the early 20th century, doctors realised both diet and sunshine played a vital role in avoiding the disease. In 1923, Harry Steenbock showed irradiation by ultraviolet light increased the vitamin D content in food, and the process was soon applied to milk given to children, thereby reducing the disease.



Rickets causes the bones to soften, which often leads to bow legs

# 250,000

A quarter of a million children with vitamin A deficiency go blind every year

## GUT BACTERIA MAKE TEN PER CENT OF OUR BODIES' VITAMIN K REQUIREMENTS

# 90%

Most of your vitamin D intake comes from Sun exposure

# FIVE YEARS

The liver can store B12 for half a decade

## 93 MILLIGRAMS

The amount of vitamin C found in 100 grams of kiwifruit

## APPROXIMATELY 1 BILLION PEOPLE WORLDWIDE HAVE A VITAMIN D DEFICIENCY

## £4.61 MILLION

Half a billion pounds worth of vitamins were sold in the UK in 2022



# WHAT MICRONUTRIENTS DO WE NEED?

A vast array of vitamins and minerals are needed to keep the body functioning properly

DEFICIENCY

HYPERVITAMINOSIS



### 1 VITAMIN K

Vitamin K keeps bones strong as it produces osteocalcin, which makes healthy bone tissue. It helps wounds heal and may improve your eyesight. A deficiency could lead to excessive bleeding and fragile bones. There are no known effects of vitaminosis.



### 6 POTASSIUM

Potassium supports the heart muscles, ensuring that they function properly. It also regulates the fluids within the body. A deficiency can cause an abnormal heart rhythm and fatigue. Too much potassium is particularly harmful for the stomach, causing cramps and sickness.



### 7 VITAMIN A

Although vitamin A is extremely important for your eyesight, skin, teeth, cell maintenance, immune system and bones, too much can be very dangerous indeed. Early Arctic explorers suffered horrific symptoms, including hair loss, gastrointestinal issues, neurological problems and even found their skin started to peel off after eating polar bear livers – high in vitamin A, or more specifically retinol. As a result, today's doctors are quick to warn against an overdose. A deficiency is common in developing countries and can cause childhood blindness. Less severe symptoms include itchy skin, brittle nails and a dry mouth.



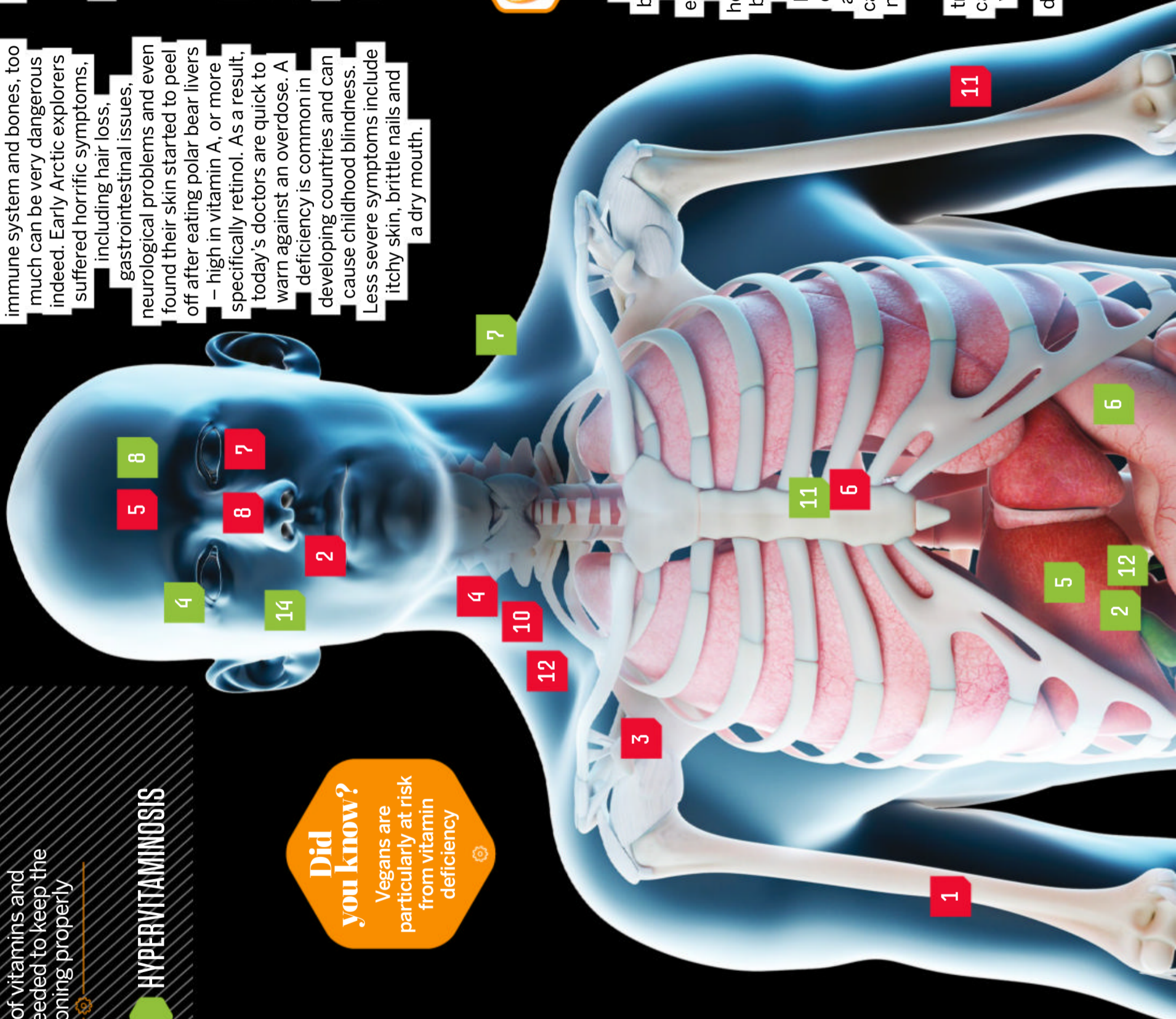
### 3 VITAMIN D

Vitamin D helps support healthy bones, teeth and muscles as it is involved in the regulation of calcium and phosphate in the body. It also reinforces our immune system. In winter, many people suffer from vitamin D deficiency, which causes rickets in children and a painful condition known as osteomalacia in adults whereby the bones throb. Hypervitaminosis is equally concerning when dealing with vitamin D as it can lead to hypercalcaemia, which causes an unwanted buildup of calcium in the body. This in turn causes damage to the skeleton and can even harm the kidneys.



### 2 VITAMIN C

Vitamin C helps maintain the body's epithelial barriers, which prevent external toxins from entering our system. It supports cell structure and keeps skin healthy. Bones and cartilage also benefit from this super vitamin. Just like vitamin K, vitamin C helps wounds heal quickly and effectively. It is also a powerful antioxidant. Too little vitamin C can lead to scurvy, which causes muscle weakness, bleeding and inflamed gums and severe anaemia. If scurvy is not treated immediately, it can even cause death. However, too much vitamin C can also be harmful, leading to stomach pain, diarrhoea and an increase in the likelihood of kidney stones.





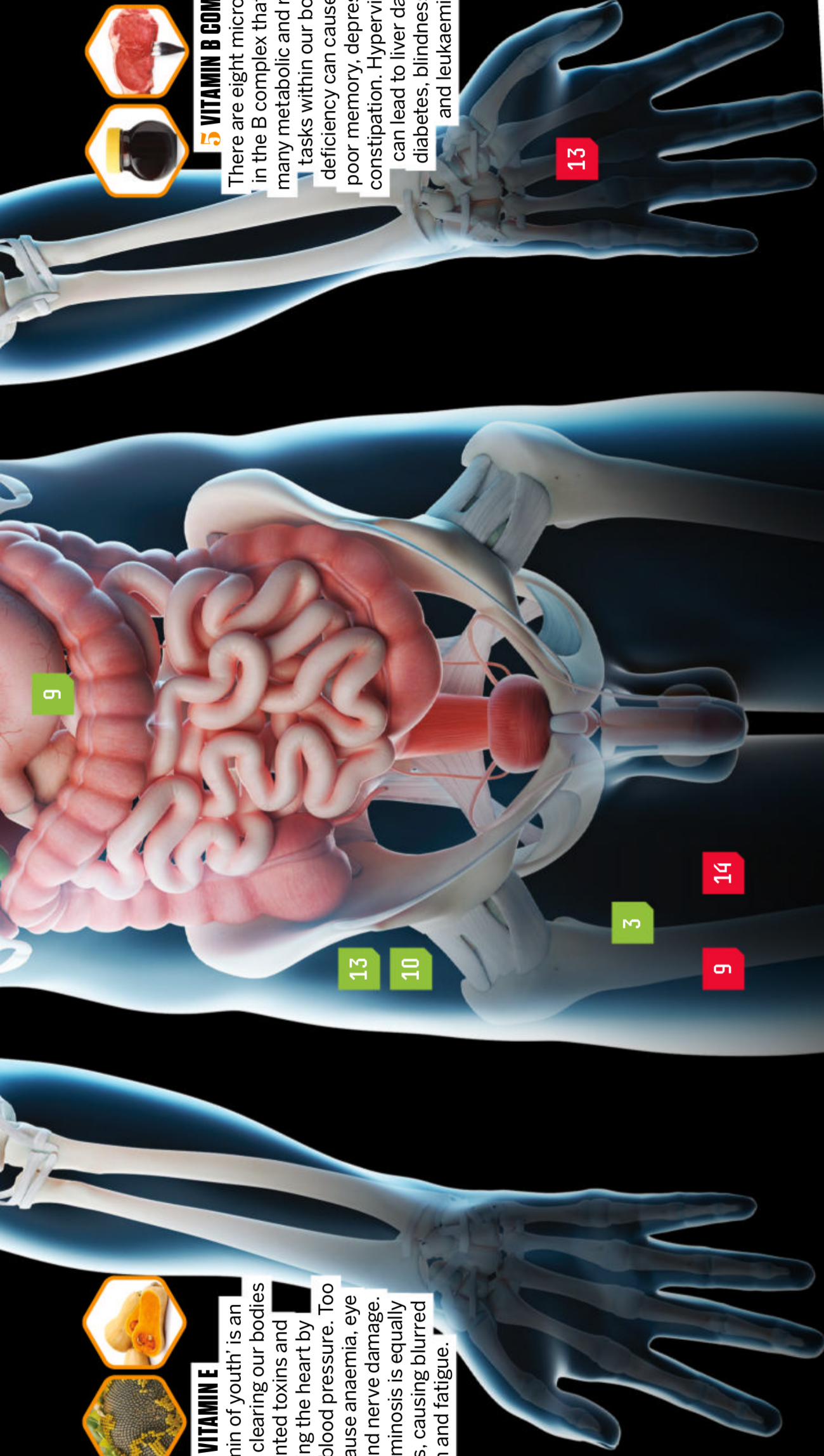
**4 VITAMINE**

The 'vitamin of youth' is an antioxidant, clearing our bodies of unwanted toxins and protecting the heart by decreasing blood pressure. Too little can cause anaemia, eye diseases and nerve damage. Hypervitaminosis is equally dangerous, causing blurred vision and fatigue.



**5 VITAMIN B COMPLEX**

There are eight micronutrients in the B complex that support many metabolic and regulatory tasks within our bodies. A deficiency can cause fatigue, poor memory, depression and constipation. Hypervitaminosis can lead to liver damage, diabetes, blindness, acne and leukaemia.



**“In some extreme circumstances it can even be fatal”**

**8 ZINC**

This micronutrient is vital for growth, production of white blood cells and for a healthy reproductive system. A deficiency can lead to loss of appetite, rashes and loss of smell. Too much zinc can instigate headaches, dizziness and nausea.

**9 CALCIUM**

Calcium ensures our bones and teeth stay strong and supports the functioning of our muscles. Too little can lead to rickets or osteoporosis. Too much can lead to an upset stomach.

**10 IRON**

Iron helps make important red blood cells which carry oxygen around the body. A deficiency can lead to anaemia and fatigue, while too much can cause sickness and constipation.

**11 SODIUM CHLORIDE**

Salt helps the body digest food and keep fluid levels balanced. The body only needs a very small amount to stay healthy. Too little can cause muscle cramps. Too much is dangerous and can instigate a heart attack.

**12 COPPER**

Copper is vital for healthy blood and is also important in infant development. A deficiency can impede the release of iron which stops the production of haemoglobin. Too much can cause sickness and damage to the liver and kidneys.

**13 MAGNESIUM**

Magnesium helps turn food into energy. It also supports the parathyroid gland. Too much magnesium can cause diarrhoea. Too little can lead to tremors, poor coordination and even seizures.

**14 SELENIUM**

Selenium helps support the body's immune system and reproductive system. An overdose causes selenosis, where hair and nails fall out. A deficiency can lead to muscle weakness and fatigue. Patients are often depressed.



Our bodies make vitamin D when exposed to the Sun



Swedish explorer Salomon August Andrée hunted polar bears for food during his 1897 expedition of the Arctic

# HOW RAINBOWS FORM

The physics behind these colourful optical illusions

WORDS SCOTT DUTFIELD

**T**here's always one thing that can brighten up a drizzly day, and that's a rainbow. Arching across the sky, these spectacles of light are formed when moisture in the air interrupts the path of sunlight, splitting it up into all the colours of spectrum. You might be surprised to discover that raindrops aren't their assumed 'teardrop' shape, but are spherical, an important distinction when it comes to making rainbows.

A raindrop's spherical shape and increased density compared to air provide the conditions needed to bend light to the perfect rainbow-making degree. When sunlight passes through a raindrop, the direction the light is travelling is changed, known as refraction. The light is refracted as it enters the droplet, then internally reflected and sent back out the raindrop in the opposite direction, which is known as the angle of deviation.

When sunlight is refracted, it's broken up into the individual wavelengths of light. The colours range from long wavelengths of red

at the top of the rainbow through the seven visible colours in the light spectrum to shorter wavelengths of violet at the bottom. When sunlight is refracted twice in raindrops it creates a double rainbow effect. The double rainbow sits around ten degrees above the primary rainbow and its colours are inverted, with red at the bottom.

### Did you know?

A record-breaking rainbow in Taipei lasted almost nine hours

The size of a rainbow is also determined by the quality of a droplet, known as its refractive index. The refractive index takes into account how well a droplet refracts light when it passes through. The higher the index, the smaller the resulting rainbow. Saltwater, for example, has a high refractive index, which means that rainbows over the ocean are typically smaller than those above freshwater lakes. But why don't we always see rainbows when it rains? Certain environmental and solar conditions need to be met for a rainbow to form. Sunlight has to hit the raindrop at precisely the right angle, which occurs when the Sun is less than 42 degrees above the horizon.

## MOONBOWS

Also known as lunar rainbows, these optical phenomena are created in the same way as their daytime counterparts. In a series of reflections and refractions of light, moonbows form from sunlight that bounces off the surface of the Moon and shines down to Earth's surface as moonlight. Moonlight then passes through rain or mist and is refracted to reveal a rainbow arch. However, moonlight is much weaker than sunlight and doesn't always showcase the full spectrum of colours to the human eye. Instead, we often see a moonbow as an arch of white light.



A moonbow is a spectacular sight



Polar stratospheric clouds above the snow

## RAINBOW CLOUDS

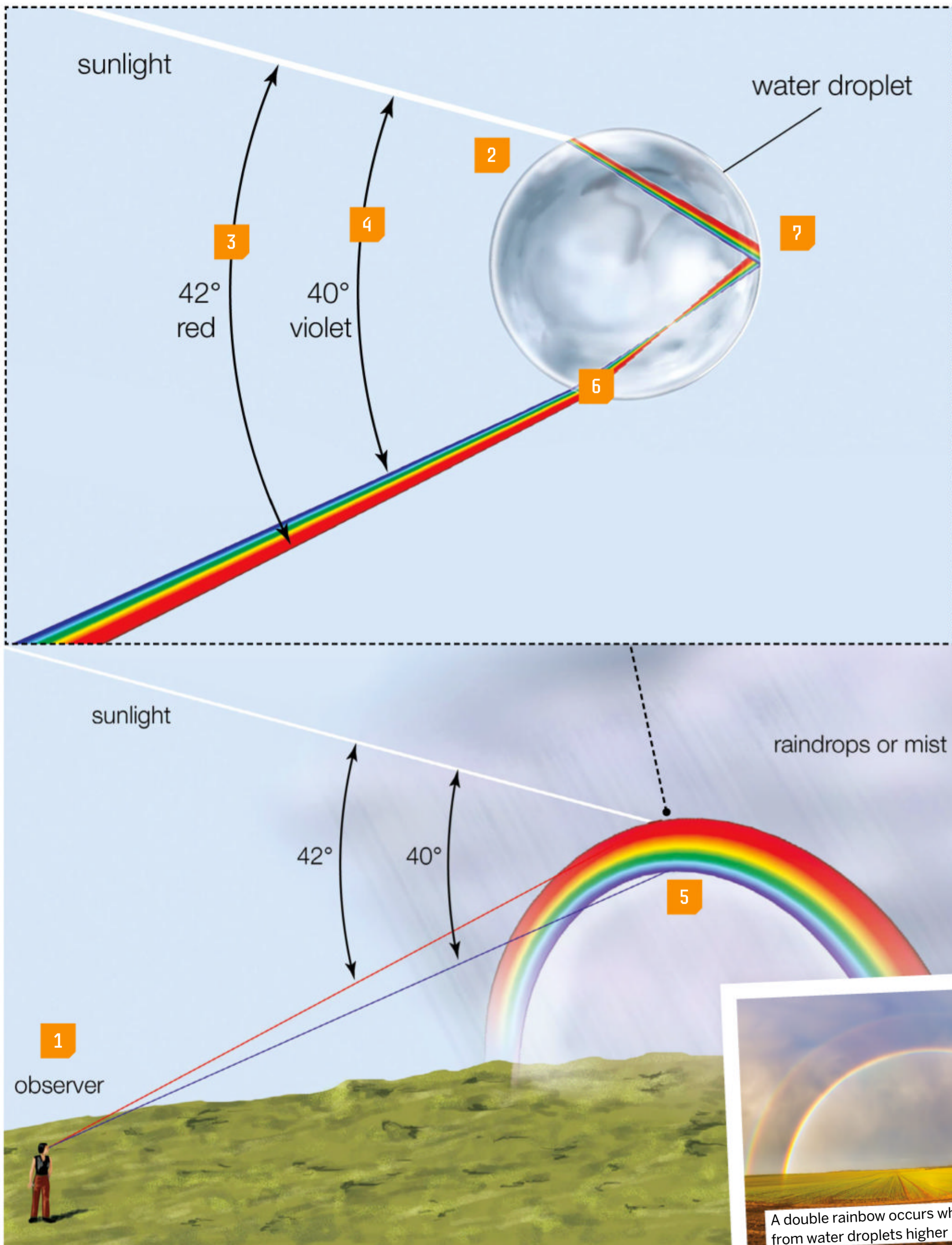
When atmospheric conditions are just right, beautiful polar stratospheric clouds can emerge. This rare phenomenon forms when clouds around 9 to 16 miles above the ground at extremely low temperatures are greeted by a rising or setting Sun. When the temperature in the stratosphere reaches below -78 degrees Celsius, tiny ice crystals, or 'supercooled droplets', form within clouds. The sunlight that passes through these clouds is scattered

into the full array of colours in the visual spectrum.

There are two categories of polar stratospheric clouds: Type I and Type II. Type I polar stratospheric clouds include ozone-depleting nitric acid, typically producing less rainbow iridescence in the clouds. Type II polar stratospheric clouds are much rarer than Type I and are made from pure ice, producing a spellbinding 'mother of pearl' rainbow hue.

# COLOURS IN THE SKY

How raindrops bend light and shape rainbows



**1 LIGHT SOURCE**  
To see a rainbow, the Sun needs to be behind the viewer.

**2 WATER SOURCE**  
Rainbows are formed by water droplets in rain, fog or mist.

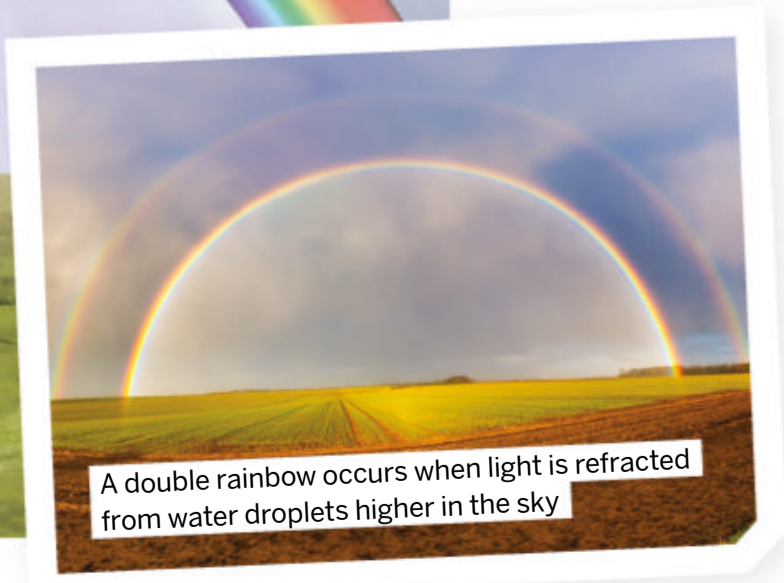
**3 RED**  
Red wavelengths of light emerge from a raindrop at 42 degrees.

**4 VIOLET**  
Violet wavelengths of light emerge from a raindrop at 40 degrees.

**5 PLACING COLOURS**  
Due to the different angles colours emerge from a raindrop, rainbows have blue hues on the inside of the arc and red on the outside.

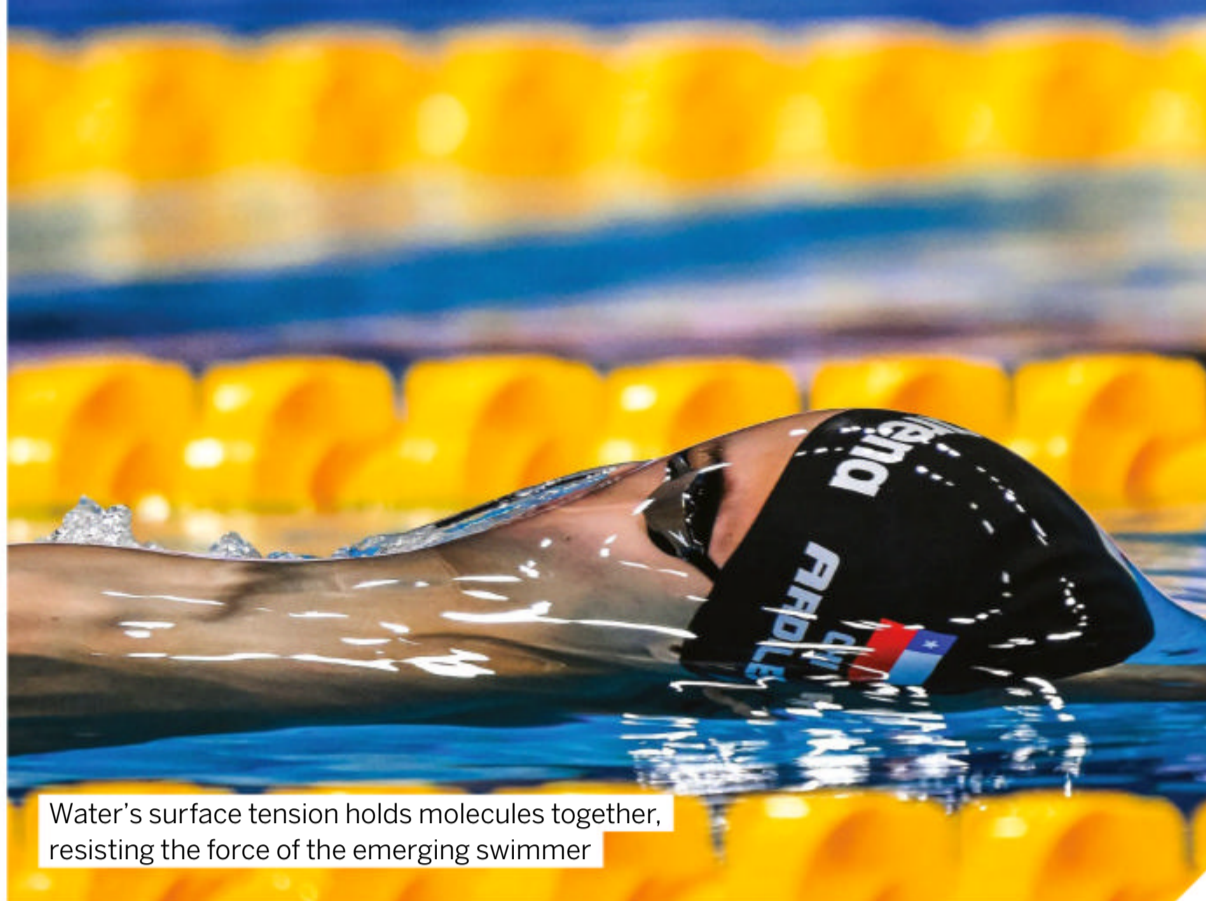
**6 SEVEN COLOURS**  
The seven colours of the rainbow are arranged into wavelengths of light, starting with the longest, red, to the shortest, violet.

**7 INTERNAL REFLECTION**  
A water droplet is denser than air. When light passes through, it causes the light to change direction.



# WHY WATER HAS 'SKIN'

How the surface tension of water forms a film



Water's surface tension holds molecules together, resisting the force of the emerging swimmer

WORDS AILSA HARVEY

**J**ust as human skin produces a shield for our bodies, a volume of water forms a barrier at its surface that resists force and holds water molecules together. This is called surface tension and can be seen when a small object or insect lands on water. Instead of cutting sharply through the water, the object will first bend the surface, as if the water was covered with cling film, although the liquid's skin-like surface has an identical composition to its main body. The difference is that the chemical bonds connecting molecules at the surface are much stronger than those beneath.

**Did you know?**  
Mercury's surface tension is six times greater than water's

Surface tension is also responsible for forming the shape of rain droplets. Instead of scattering over surfaces evenly, the molecules of water group together to form droplets when they land. Smaller raindrops have a stronger surface tension than larger ones. When falling through the air, water droplets become less spherical and flatten at the bottom as air pushes against them. The raindrops fall to the ground and collide with other droplets on their journey, becoming larger. This continues until the surface tension becomes too weak to hold the droplet's shape and the molecules disperse.

## BREAKING THE TENSION

Some factors alter the strength of water's surface tension. For example, as the water's temperature decreases, the surface tension increases, while warmer temperatures weaken the 'skin'. This is because the molecules have more energy at higher temperatures. They move faster and lose their ability to stay connected for as long. Adding chemicals to water also lowers surface tension. Soap molecules have one hydrophilic end that is attracted to water and one hydrophobic end that repels it. When in contact with water, the hydrophilic end pulls water molecules away from each other while the hydrophobic end prevents the body of water mixing cohesively.



The cold slows down water molecule movement, so stronger bonds form at its surface, like morning dew on grass

## MOLECULAR BREAKDOWN

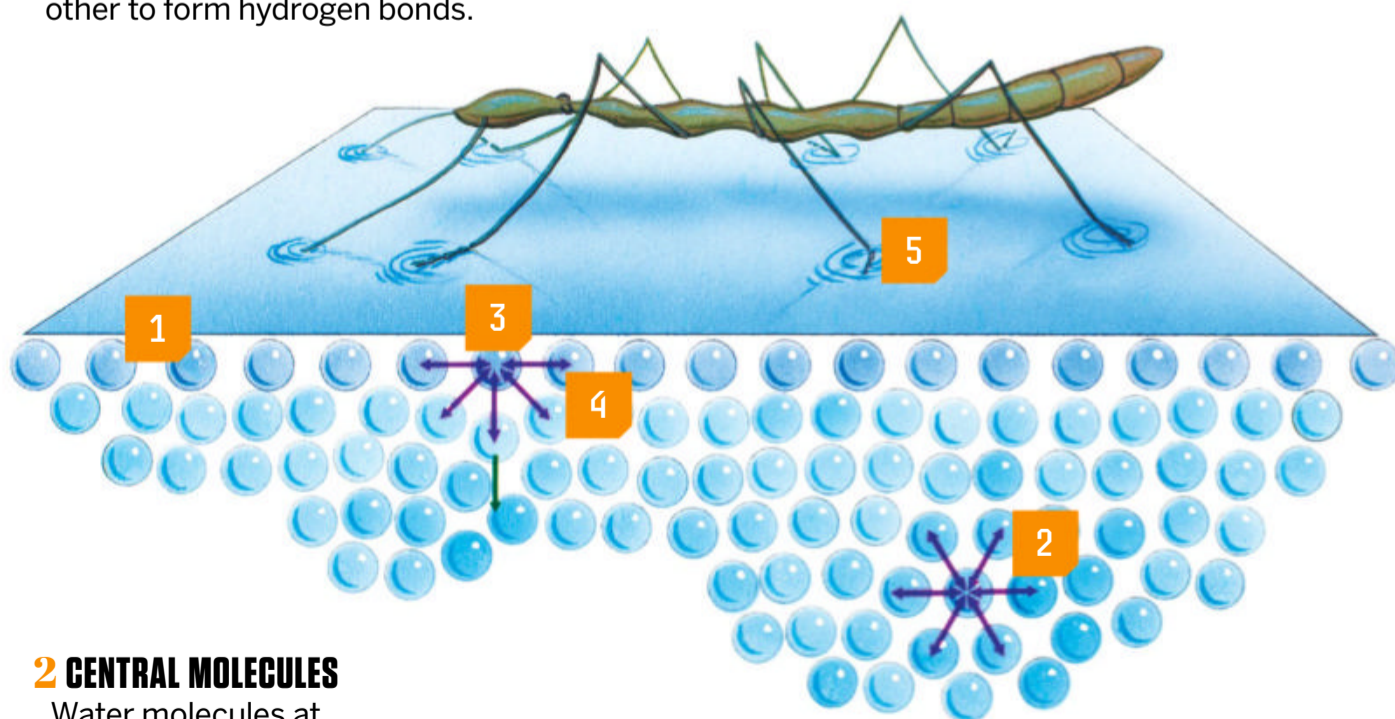
When an insect lands on water, it's supported by hydrogen bonding

### 1 WATER MOLECULES

Water molecules contain positive hydrogen atoms and a negative oxygen atom, which attract each other to form hydrogen bonds.

### 5 STRONGER SUPPORT

The stronger bonds at the surface remain intact under the pressure of light weight, enabling insects like water striders to walk on water without falling through.



### 2 CENTRAL MOLECULES

Water molecules at the centre form many bonds with the molecules completely surrounding them.

### 3 SURFACE WATER

Molecules at the surface can only bond with those next to and below them.

### 4 STRONG BONDS

Due to there being fewer hydrogen bonds at the surface, those that form are stronger.

# THE STORIES, STRATEGIES, HEROES & MACHINES

[www.historyanswers.co.uk](http://www.historyanswers.co.uk)



**ON SALE NOW**

# HISTORY of WAR

Available from all good newsagents and supermarkets

D-Day 80th Anniversary Special > Veteran Interviews > Deception Strategy > Sword Beach > Omaha Hero



# BUY YOUR ISSUE TODAY

Print and digital subscriptions available at  
[www.magazinesdirect.com](http://www.magazinesdirect.com)



## Meet some of the most critically endangered animals from around the world and discover why they're on the brink of extinction

WORDS SCOTT DUTFIELD

**A**t present, there are more than 44,000 species around the world that are facing the possibility of extinction. Keeping a watchful eye over them is the International Union for Conservation of Nature (IUCN), composed of governments and civil society organisations. Since 1964, the IUCN has compiled the Red List of Threatened Species, a comprehensive guide to the state of nature and the likelihood of plant and animal extinction. From 'least

concern' to 'extinct', each species that's assessed by the IUCN is placed on the scale to indicate their conservation status.

For example, to be categorised as 'critically endangered' a species needs to meet specific conditions, such as fewer than 250 mature individuals, a population reduction of 70 per cent or more in the past ten years or a population that continues to decline by 25 per cent or more over three years. This informative tool not only lists species' status

in the world, but also acts as a reference for many different agencies and organisations to enact policy changes and protections in the hopes of protecting wildlife.

The IUCN list is filled with 157,100 species, of which 28 per cent are 'threatened with extinction'. The IUCN aims to assess a further 160,000 species and transform the IUCN Red List into a 'barometer of life'. Here are just some of the many critically endangered animals that are facing extinction.

## DUSKY GOPHER FROG (*RANA SEVOSA*)

**Population: Around 500**

**Threats: Habitat loss**

**Location: United States**

At one time the dusky gopher frog could be found hopping across southeastern Louisiana and southern Mississippi. Now its home has been reduced to just two counties in Mississippi. These warty frogs enjoy the warmth and moisture of the burrows created by gopher tortoises (*Gopherus polyphemus*) and some mammals, and

**41%**  
of amphibians are  
threatened with  
extinction

also in cavities and dead wood found in America's longleaf pine forests. However, due to forest fires, droughts and construction, the former 90 million acres of longleaf pine forests have been reduced to just 2 million acres of woody patches in the southeast. To improve their numbers, organisations such as the Detroit Zoo's National Amphibian Conservation Center have been introducing hundreds of captive-born dusky gopher frogs into the wild since 2018. Studies have shown that the reintroduction of these frogs has a high success rate, and it's thought that over the past 20 years the population of these frogs has grown from less than 50 adults to several hundred.



## SAOLA (*PSEUDORYX NGHETINHENSIS*)

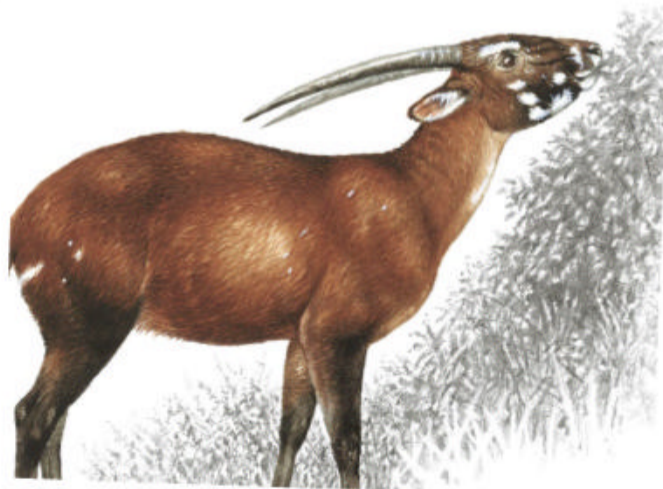
**Population: Less than 300**

**Threats: Habitat loss and hunting**

**Location: Vietnam**

First discovered in 1992, the saola is a deer-like mammal rarely seen in mountainous areas of Vietnam and along the border of neighbouring Laos. Often referred to as the 'Asian unicorn', the last time an image of a saola was captured with a camera trap was in 2013. Their declining numbers are largely due to hunting and the fragmentation of their habitats. Wire traps known as snares are a particular problem for saola. These are intended to capture other species associated with crop destruction, such as wild boar or deer, but the saola also get caught in them.

Saola are hunted for their horns, which are used in traditional medicines. The construction



of plantations is also breaking up suitable habitats, making it easier for poachers to find them. Legal protection against hunting and the provision of protected habitats for these animals are currently in place to help encourage population growth. Organisations such as the Saola Foundation and IUCN are also working with governments with the intention of creating saola breeding programs in the future and releasing them into the wild.



## PYGMY RACCOON (*PROCYON PYGMAEUS*)

**Population: Less than 300**

**Threats: Habitat loss  
and climate change**

**Location: Mexico**

These furry creatures might look similar to their northern raccoon (*Procyon lotor*) cousins, but pygmy raccoons are around 18 per cent smaller than the mainland species. They are confined to Cozumel, an island off the coast of the Yucatán Peninsula in Mexico, which is around 189 square miles in size. As a popular tourist destination, the islands have seen an influx of urbanisation since the early 2000s, including highways, which has led to a rise in collisions between cars and racoons.

Introduced species such as boa constrictors, domestic dogs and other racoons have also contributed to the pygmy raccoon's declining numbers. Along with outcompeting for resources, introduced species also transmit new diseases and parasites that threaten the pygmy raccoon's future. Storms and flooding brought about by increasingly frequent hurricanes also threaten the proportion of juvenile racoons on the islands.

Currently, pygmy racoons are protected under the Mexican list of threatened species 'En Peligro de Extinción' and several protected areas have been established on the island to help increase their numbers.

**26%**  
of mammals are  
threatened with  
extinction



## AFRICAN WILD ASS (*EQUUS AFRICANUS*)

**Population: Less than 200**

**Threats: Hunting and interbreeding**

**Location: Ethiopia, Sudan and Eritrea**

Once widespread across northern Africa, especially in the Atlas Mountains, the African wild ass has been reduced to just a handful of animals occupying an area of around 8,000 square miles. Perfectly adapted to live under the heat of the beating Sun, these donkeys can fluctuate their internal body temperature to reduce water loss through sweating. However, they inhabit areas with nearby sources of drinking water to stay hydrated.

Competition with livestock for the same watery resources is one of the many threats that these feral donkeys have faced over the years. Similarly, domestic donkeys also pose a risk of genetic extinction through hybridisation. When wild ass and domestic donkeys continue to mate over time, the unique genetic qualities of the wild ass are lost and a new evolutionary lineage is formed, causing the wild ass species to become extinct.

The biggest threat to the African wild ass has historically been hunting for meat and medicine. Now the wild ass has been given legal protection in Ethiopia and Sudan that stops people from killing them for any reason.

## RED WOLF (*CANIS RUFUS*)

**Population: Around 22**

**Threats: Hunting and interbreeding**

**Location: North Carolina, United States**



Once roaming the woods of southeastern America, the red wolf is following in the footsteps of many other endangered wolf species, with just a handful of adults left in the wild. The major cause of their decline is hunting: often mistaken for coyotes (*Canis latrans*), red wolves have been persecuted by landowners for decades. Several conservation programs have been put into place to help their numbers rise, including captive male reintroductions at the Alligator River National Wildlife Refuge in North Carolina.

A male red wolf from a captive population was released into an acclimation pen in the territory of a known group of breeding females. One of the females was temporarily captured and placed in the pen. The idea wasn't for the two to bond and mate, but to increase the likelihood of his acceptance by the wild female and other members of the breeding group. In January 2024, the wolves were released from the acclimation pen, and their activity will be monitored in the hope that the male finds a breeding partner.

## HAWKSBILL SEA TURTLE (*ERETMOCHELYS IMBRICATA*)

**Population: Around 8,000**

**Threats: Hunting, trade, habitat loss and climate change**

**Location: Atlantic, Pacific and Indian oceans**

Found gliding through the world's tropical waters and coral reefs, the hawksbill turtle has been around for about 100 million years. However, in the last century the global population of hawksbill turtles has declined by 80 per cent. Named after its pointed beak, the hawksbill turtle is known for its mesmerising shell of overlapping scales, which come to a serrated edge. However, their illustrious shells have gotten them into hot water when it comes to their survival. As material for combs, jewellery and trinkets, hawksbill turtle shells are still sold in illegal wildlife trades, along with their illegally harvested eggs. As reptiles that give birth in isolated pockets on beaches, the quality of the shoreline is imperative to their survival. Urbanisation of coastal regions, along with coastal erosion and rising sea levels, are wreaking havoc on a mother turtle's ability to find a suitable spot to lay her eggs.

**21%**

of reptiles are threatened with extinction

**DID YOU KNOW?** Between 1950 and 1992, nearly 2 million hawksbill turtles were killed for the Japanese trade alone

## BORNEAN ORANGUTAN (*PONGO PYGMAEUS*)

**Population: Around 104,000** Threats: **Habitat loss, hunting and climate change** Location: **Borneo**

Since the middle of the 20th century, Bornean orangutan numbers have rapidly been declining. Compared to other species on this list, the population of Bornean orangutans is much higher. However, it's the rate at which they have declined that has caused concern. In the last 60 years, their population has declined by over 50 per cent. Habitat loss is the main reason why these majestic animals are readily disappearing: logging and palm oil plantations are two of the many ways their habitat is being removed, leaving them without the resources

they need to survive. Forest fires can devastate orangutan numbers along with their habitats, such as the fires in 1997 to 1998 that killed more than 8,000 orangutans. Hunting and wildlife trade also contribute heavily to their decline. Each year it's thought that up to 500 orangutans enter the illegal pet trade.

Along with legal interventions to help combat the decline, 'ecological corridors' have been created to help these apes navigate selective logging areas. However, the majority of areas where orangutans reside aren't protected.

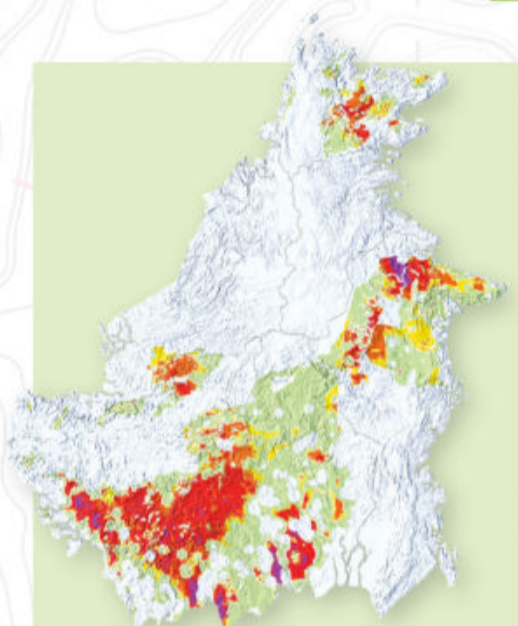
**36%**

of reef corals are threatened with extinction



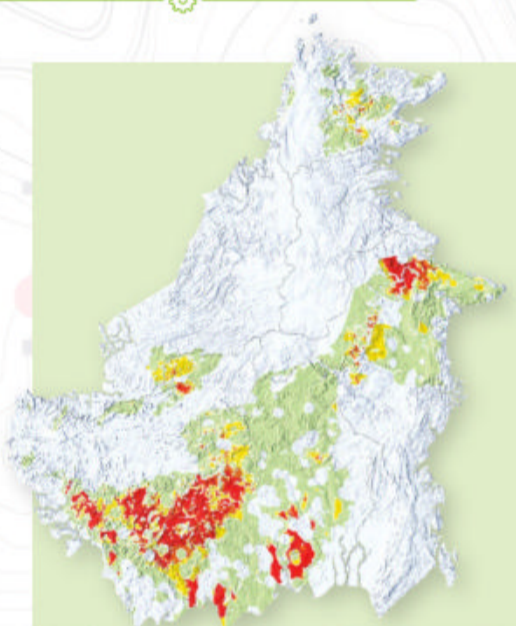
## ORANGUTAN OUTLOOK

How the distribution of these great apes has changed



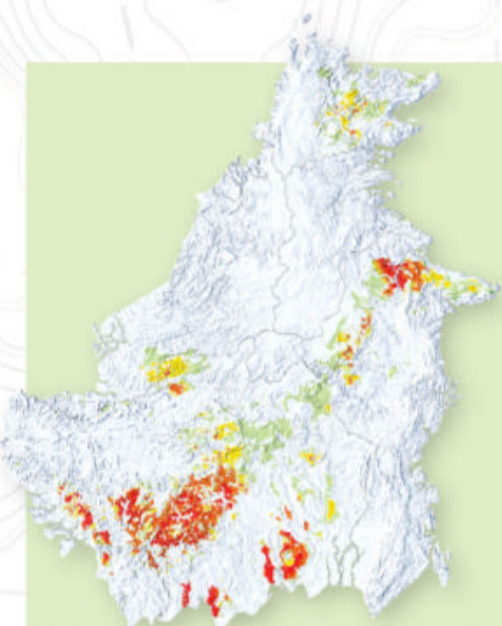
### 1 THREE GROUPS

Population groups are split into Sabah in the north, Kalimantan to the east and south and Sarawak to the west.



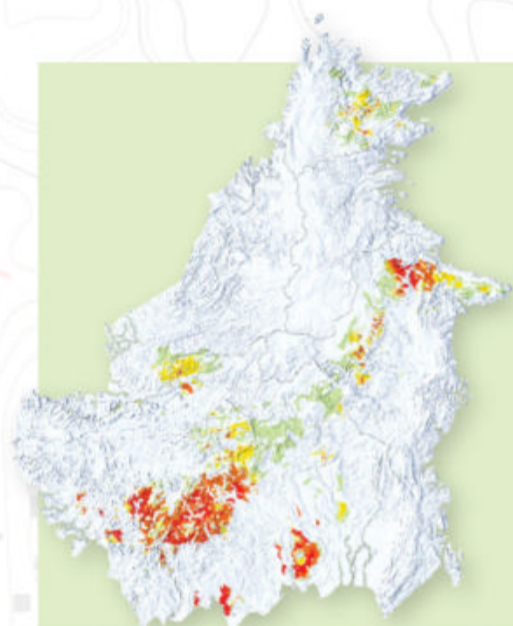
### 2 1999 TO 2015

Between 1999 and 2015, it's estimated that around 148,500 Bornean orangutans were lost.



### 3 2020

From a population of more than 200,000 in 1930, in 2020 only up to 69,000 apes remained.



### 4 2050

Around 45,300 more orangutans are estimated to be lost over the next 30 years.



## SPOTTED HANDFISH (*BRACHIONICHTHYS HIRSUTUS*)

**Population: Less than 3,000**

**Threats: Habitat loss, pollution and invasive species**

**Location: Tasmania**

Arguably one of the most unusual fish that swim, or rather walk, on the seafloor, the spotted handfish is a rarity in nature that is becoming even more elusive. One of the main threats to their survival are invasive species such as the Northern Pacific seastar (*Asterias amurensis*). By hitchhiking a ride on passing shipping vessels, these seastars have become an abundant predator within the handfish's main breeding grounds, the Derwent Estuary. Although the seastars aren't necessarily hunting the handfish, they are eating stalked ascidians, also known as sea squirts. During the breeding season, female spotted handfish use the sea squirts as an anchor for their eggs. Several conservation effects, including using artificial sticks to mimic the sea squirts, have been employed by conservation organisations to encourage the population growth of the spotted handfish.



# VAQUITA (*PHOCOENA SINUS*)

Population: 10

Threats: **Hunting**

Location: **Mexico**

As the rarest marine mammal in the world, the vaquita is on the brink of extinction. Found only in the Gulf of California in an area of around 965 square miles, only a handful of vaquita still exist. There were thought to be almost 600 individuals in the late 1990s. The biggest threat to these small mammals are gillnets – underwater strips of mesh that are anchored to the seabed and can extend up to 200 metres. Intended to catch fish species such as salmon and sea bass, gillnet mesh is designed to trap a fish's head by the gills until the net is pulled up to the surface. However, these nets don't discriminate when it comes to what they can catch. Marine mammals like the vaquita, along with other species such as sea turtles, can all fall victim to becoming bycatch. Once tangled up in the net, vaquita are cut off from their oxygen supply on the surface and die.

**37%**  
of sharks and rays  
are threatened with  
extinction

## CAUGHT IN A TRAP

How vaquita get stuck in sticky situations under the water



### 1 WEIGHTS

Gillnets use a series of weights to hold down an extension of mesh netting, much like a tennis net, underwater along the seafloor.

### 2 MESH SIZE

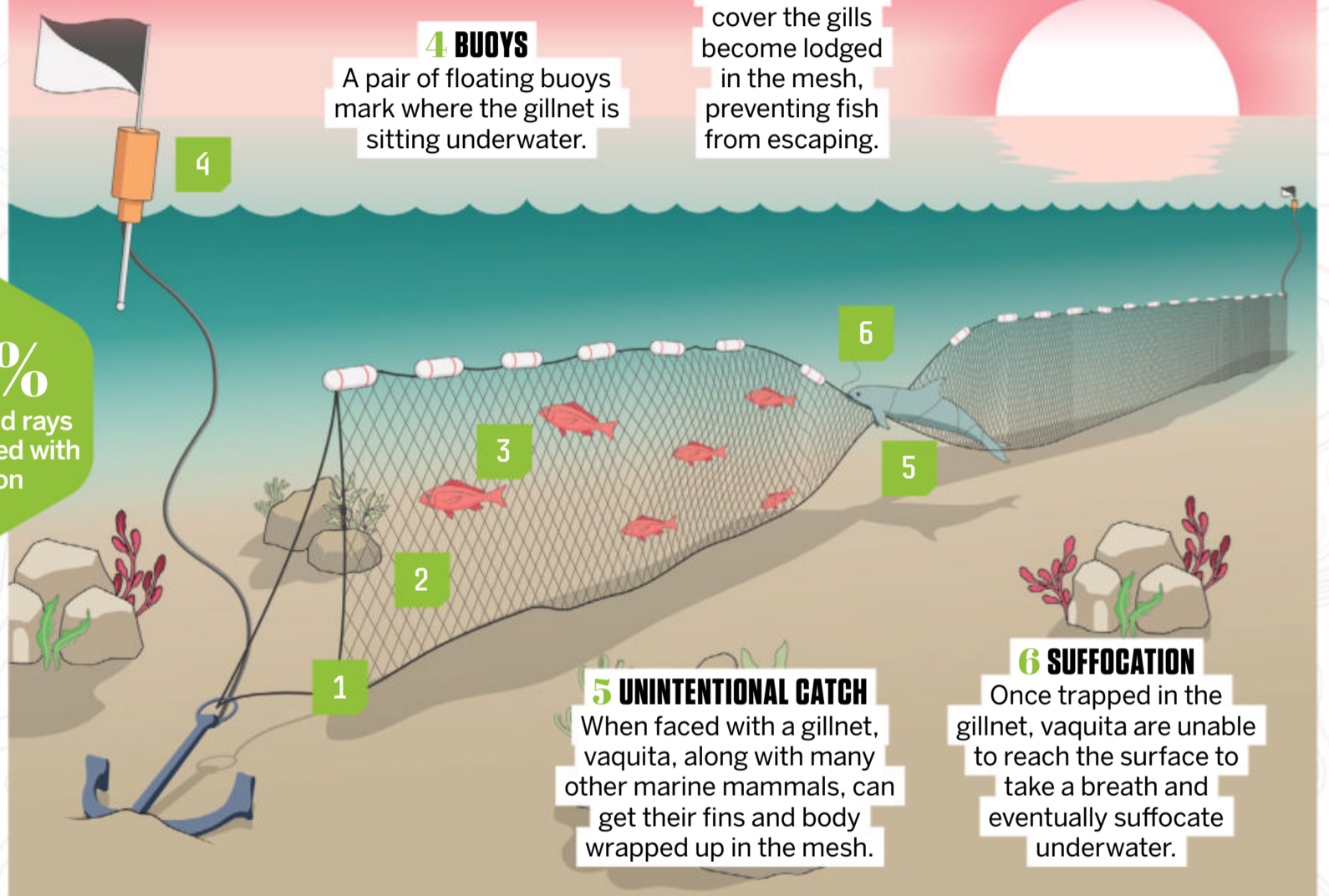
The size of the mesh of the gillnet is designed so that just the head of the fish can enter.

### 3 GILLS

The scales that cover the gills become lodged in the mesh, preventing fish from escaping.

### 4 BUOYS

A pair of floating buoys mark where the gillnet is sitting underwater.

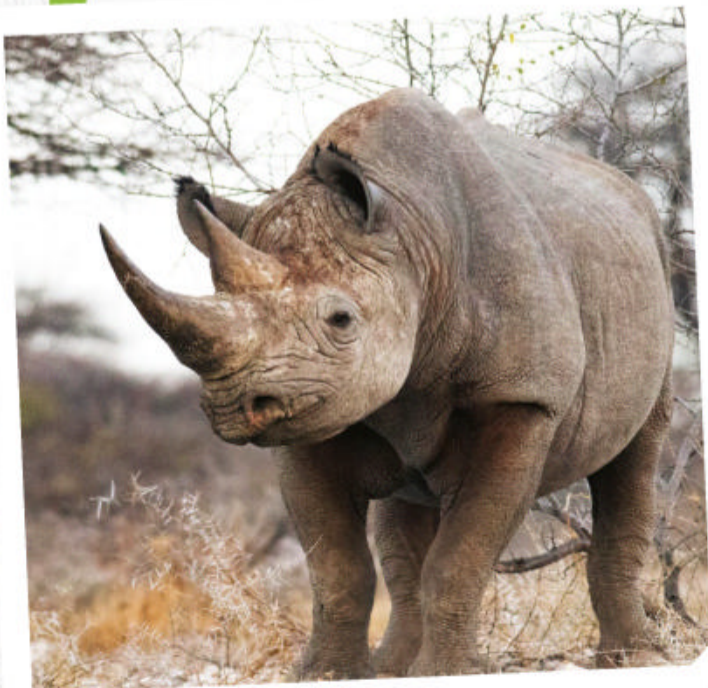


### 5 UNINTENTIONAL CATCH

When faced with a gillnet, vaquita, along with many other marine mammals, can get their fins and body wrapped up in the mesh.

### 6 SUFFOCATION

Once trapped in the gillnet, vaquita are unable to reach the surface to take a breath and eventually suffocate underwater.



# BLACK RHINO (*DICEROS BICORNIS*)

Population: **Around 6,500** Threats: **Hunting and disease**

Location: **Angola, Kenya, Mozambique, Namibia, South Africa,**

**Tanzania and the United Republic of Zimbabwe**

Roaming across the savannah, the black rhino is one of Africa's iconic large mammals. As solitary creatures, black rhinos don't typically move in herds as they forage for leaves and woody plants, as well as locating natural mineral licks. Between 1970 and 1990, these giants of Africa saw their largest decline in numbers. From a population of around 20,000, illegal poaching reduced them to just 350 individuals. What made them so coveted by poachers is their two horns. Rhino horn is a prized material, used for carvings, jewellery and traditional Chinese medicines. Unlike many species on this list, the black rhino population is actively on the rise. Thanks to legal protection and African reservations, their numbers have continued to rise. Currently, around 80 per cent of all black rhinos live in Kenya. However, continued illegal poaching still poses a risk to their safety.



## YELLOW-NAPED AMAZON (*AMAZONA AUROPALLIATA*)

**Population: Around 2,500**

**Threats: Hunting, habitat loss, trade and climate change**

**Location: Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Mexico**

Despite their name, these vibrant parrots aren't found in the Amazon, but in Central America. Over the past three generations, the population of yellow-naped amazons has declined by around 92 per cent. This has mostly been due to growing illegal poaching for parrot trading. Despite being listed under Appendix I of the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES), these birds and their eggs are still captured and sold. Since the beginning of the century, a third of all yellow-naped amazon nests in Costa Rica have been poached.

The habitat of these birds has also been drastically reduced. For example, in Mexico, less than 30 per cent of the parrot's original home remains. One of the safe havens for these birds is Ometepe, an island on Nicaragua's largest freshwater lake. There are up to 2,000 yellow-naped amazons on the island, which is the largest known remaining population in the world.

**12%**

of birds are threatened with extinction

## GIANT IBIS (*THAUMATIBIS GIGANTEA*)

**Population: Around 194**

**Threats: Habitat loss and hunting**

**Location: Cambodia, Laos and Vietnam**

The giant ibis is the national bird of Cambodia, but it's currently on the verge of extinction in the country. Unfortunately, these birds have already gone extinct in Thailand, predominantly due to the drainage of wetlands for agriculture, which the giant ibis rely on to find food such as insects, amphibians and eels. In areas where the birds currently reside, wetland drainage and habitat loss are a major threat to their population.

Another contributing factor in their decline relates to the decline of other species. Large grazing animals such as water buffalo create pools and wallows by rolling around in the mud and dirt. For the buffalo, the mud that coats their skin protects them from insect bites. The giant ibis also benefits from these wallows as they provide ibis feeding sites full of invertebrates. However, buffalo numbers are falling in places like Cambodia due to human hunting, which in turn affects the number of feeding wallows available to the giant ibis.

## GOLDEN BAMBOO LEMUR (*HAPALEMUR AUREUS*)

**Population: Around 650 Threats: Habitat loss**

**Location: Madagascar**

It's a rare sight to see a golden bamboo lemur swinging through the tropical rainforests of Madagascar. When they are spotted, it might be while they're chowing down on their favourite food, giant bamboo. To break through the fibrous plant matter, these lemurs have specially adapted teeth to pull the stems apart. Around 78 per cent of their diet consists of giant bamboo, with the rest being other types of bamboo, fruits and grasses.

Dependence on these plants is also what's led to the golden bamboo lemur's population decline. Slash-and-burn agriculture is used to remove forests in Madagascar, where acres of bamboo are harvested for construction and raw materials. Around 20 years ago, the population of these lemurs was in the thousands.

Two national parks, Andringitra and Ranomafana, along with a forest corridor called Fandriana Vondrozo Midongy (COFAV) that connects the two parks, are home to the few lemurs that remain.



**5**  
**FACTS**  
**BUGS ON THE BRINK**

### 1 BOLLAND'S BLUE (*POLYOMMATUS BOLLANDI*)

The Bolland's blue butterfly has only been found in one region of Turkey's grassy mountains around 1,500 metres above sea level. Although their exact population number remains unknown, it's thought that habitat loss since the late 1990s has led to their decline.



### 2 AMERICAN BURYING BEETLE (*NICROPHORUS AMERICANUS*)

It's thought that there are fewer than 1,000 of these beetles remaining in North America. Forest fragmentation might be to blame for their small numbers.



### 3 GOLDEN-EYED STICK INSECT (*PERUPHASMA SCHULTEI*)

Coffee plantations and cattle pastures are just some of the land uses that have contributed to the decline of the golden-eyed stick insect in Peru.



### 4 RUSTY PATCHED BUMBLEBEE (*BOMBUS AFFINIS*)

In 2018, the global population of the rusty patched bumblebee was estimated to be 471. Found in states across America, habitat loss is one of the main causes of their low numbers.



### 5 BEKKO TOMBO (*LIBELLULA ANGELINA*)

Urbanisation in Japan and China and the infilling of natural ponds is causing a decline in these dragonflies. Similarly, introduced carnivorous fish are decimating their numbers.





# HOW WATERFALLS FORM

Over time, the power of flowing water can gouge channels out of the land and shape solid rock

WORDS SCOTT DUTFIELD

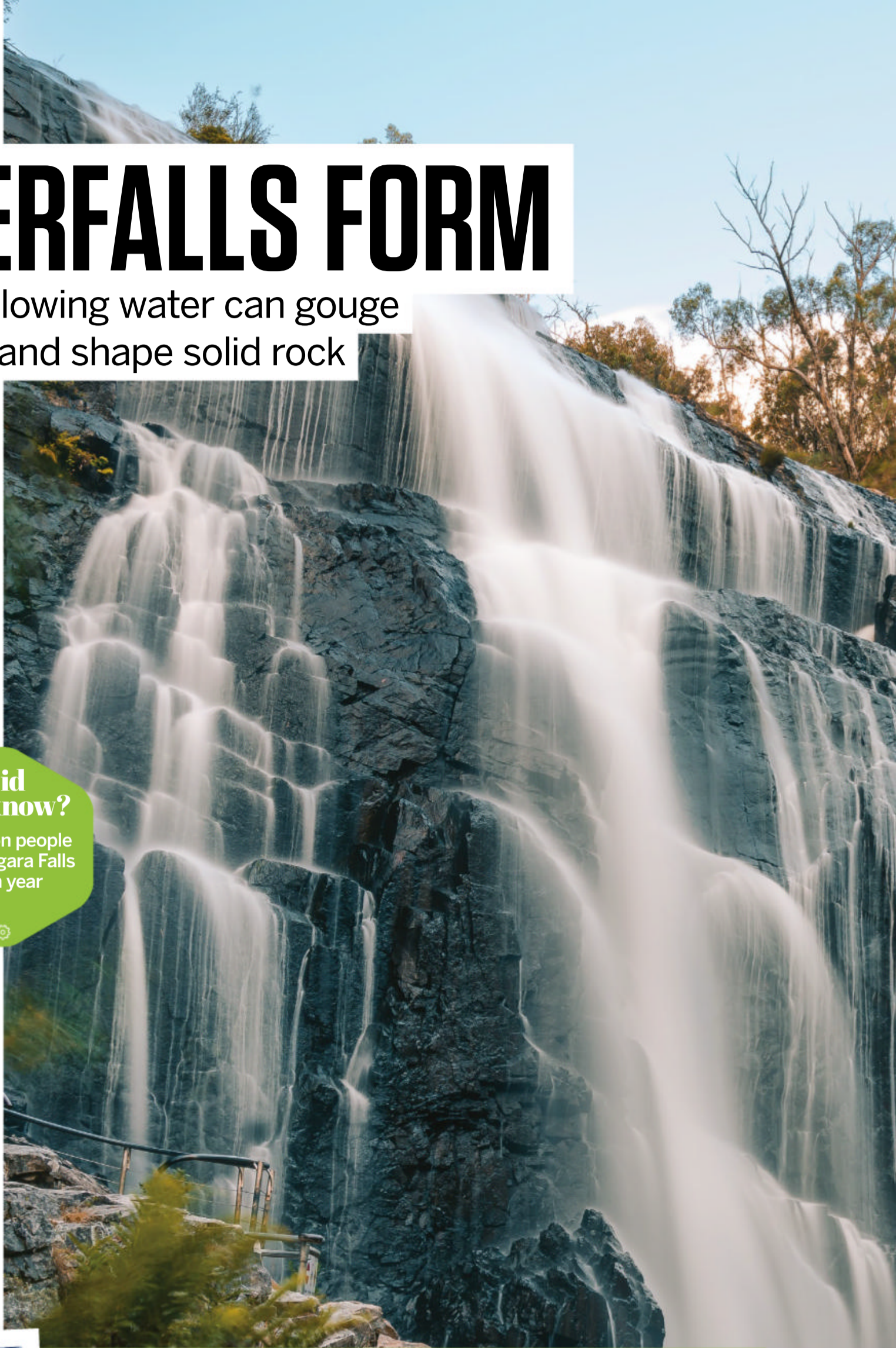
**W**aterfalls form through a natural process called erosion, and different layers of rock are eroded at different rates. Harder rock, such as granite, erodes much more slowly than softer stone such as sandstone. Over the course of thousands – if not millions – of years, a watercourse such as a river will naturally erode the bedrock it flows over. If the bedrock is made of a hard rock top layer with soft layers underneath, the water will eventually cut through the hard rock and meet the soft rock below. It then erodes the softer rock at a much faster rate than the top layer, which ultimately carves out a cliff-like drop for the water to cascade over.

Water's ability to carve rock in this way means that waterfalls can take many different sizes and shapes, depending on the surroundings and underlying geology. For example, in Australia, the Mitchell Falls are tiered, flowing over four levels and cutting through sandstone that leads into the Mitchell River. However, in Yellowstone National Park in the western US, the water that flows through Union Falls creates a gigantic fan shape as it pours from a narrow exit.

The formation of waterfalls can also get a helping hand from other geological processes. Earthquakes, for example, can create cracks in bedrock that a watercourse can flow over, such as in Wairere Falls in New Zealand, which pours over the Okauia Fault. Glaciers and volcanoes can also carve through rock and erode pathways for watercourses to fill and form waterfalls.

## Did you know?

12 million people visit Niagara Falls each year



An aerial view of the Denmark Strait between Iceland and Greenland

## FALLING UNDERWATER

It might sound impossible for a waterfall to exist underwater, but thanks to some strange physical phenomena it's possible – in fact, there's an enormous one sitting between Greenland and Iceland. Known as the Denmark Strait cataract, the undulating seafloor between these countries includes a peak that's more than two miles tall. Moving down the face of the peak is a distinct flow of water caused by two different temperatures of water meeting. On the east side of the peak, the water coming from Iceland is colder, around two degrees Celsius, and denser than the warmer, four-degree Celsius water from the opposing west side of the peak. The difference in their density causes the colder eastern water to flow over the ridge and 'fall' along the west side of the peak's face.

## CARVING ROCK

How water shapes different rock to form a flowing waterfall

### 1 HARD ROCK

Waterfalls form when water passes over hard rock that is sitting on top of soft rock.

### 2 SOFT ROCK

Soft rock, such as sandstone or mudstone, is eroded much quicker than harder rock.

### 3 STEPS

Water from a river or stream starts to chip away at the soft rock to create a step for the water to start flowing down.

### 4 UNDERCUTTING

Over time, the falling water will undercut softer rock from beneath the hard top layer.

### 5 COLLAPSE

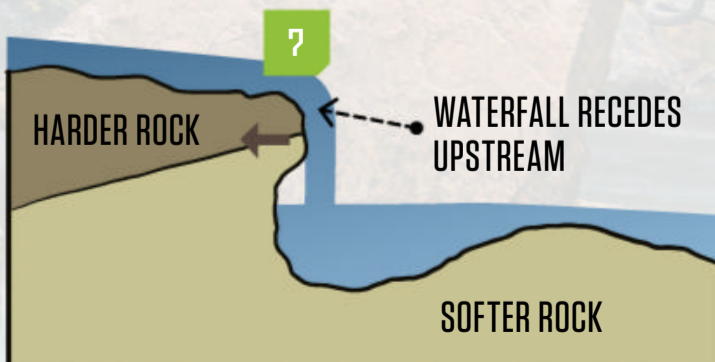
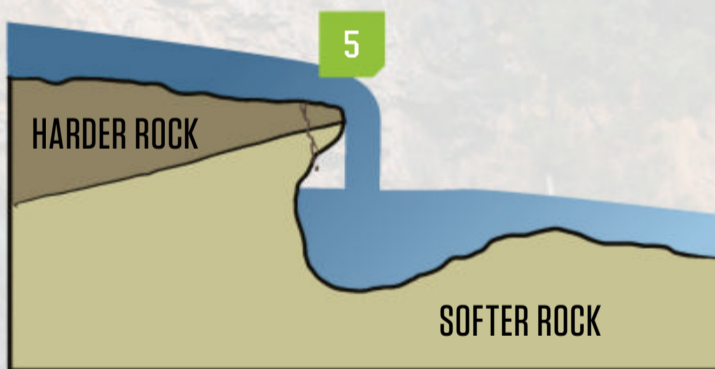
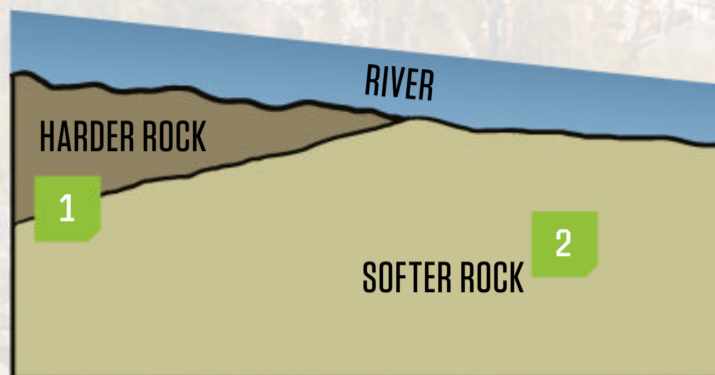
The outcut rock will create an overhang of rock at the waterfall's edge that will eventually crack and fall away.

### 6 PLUNGE POOL

As water falls under the pull of gravity, it erodes the rock at the bottom into a deep pool.

### 7 RECEDING EDGE

The harder bedrock underneath the watercourse will continue to recede as water moves over it.



Angel Falls includes the tallest waterfall

## 5 FACTS RECORD-BREAKING WATERFALLS

### 1 TALLEST

The tallest land waterfall in the world is found in Venezuela, called Kerepakupai Merú, also known as Angel Falls. The tallest has a total drop of 979 metres.

### 2 WIDEST

Spanning a whopping 10,783 metres, Khon Phapheng Falls in Laos is by far the widest waterfall in the world.

### 3 LONGEST SINGLE DROP

The record holder for the tallest coastal waterfall can be found on the Hawaiian island of Molokai, called Olo'upena Falls. The water plummets 900 metres from the world's highest sea cliffs into the Pacific Ocean.

### 4 LARGEST BY VOLUME

Dispensing 5 million cubic metres of water per second, the Denmark Strait is the largest waterfall by volume, found underwater around 3,505 metres under the Atlantic Ocean.

### 5 DEEPEST PLUNGE POOL

At the base of the waterfalls in the Perth Canyon, Australia, is a plunge pool that's around 300 metres deep.

Wairere Falls in New Zealand formed as the result of an earthquake



# WHEN AI GOES WRONG

WORDS AILSA HARVEY

Artificial intelligence allows machines to think like humans, at least in theory. Here are seven instances when these smart computers didn't function as planned

**DID YOU KNOW?** Promobot IR77 blocked traffic for 40 minutes during its escape

### Did you know?

Over 80 per cent of businesses use AI

## ROBOT ESCAPE

In 2016, a Russian robot called Promobot IR77 demonstrated how machines can navigate the world without human assistance when it became a persistent escape artist. The robot, which was designed to interact with humans as a tour guide, fled its laboratory in Perm, Russia, after a researcher left the door open. IR77 travelled 50 metres across the nearby roads and caused a traffic jam before running out of battery and being returned to the laboratory. After the initial escape, the scientists attempted to

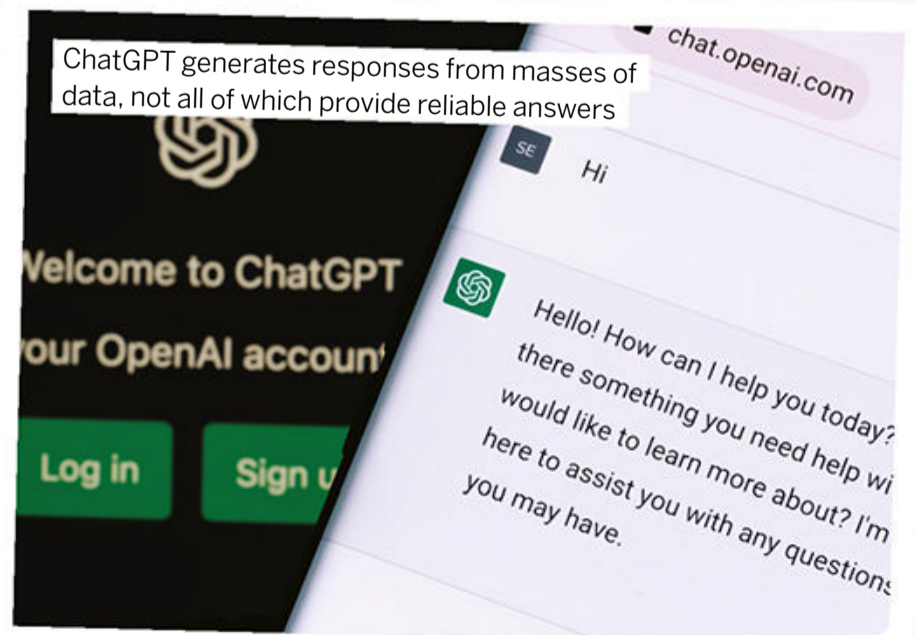
reprogram the robot, but it kept moving in the same direction towards the door it successfully fled through. Though in the first instance the robot escaped because there was nothing to stop it, its future escape attempts showed that the computer used its memory to target the same route. Their lack of control over the robot's intentions led the scientists to shut the project down.

Promobot IR77 was a humanoid robot designed for face-to-face interactions with humans

## ARTIFICIAL EVIDENCE

When a man named Roberto Mata attended court with his lawyers, accusing Avianca Airlines of injuring him with a metal serving cart on board a flight, he would have assumed that his lawyers were well equipped to support him. However, the lawyers had consulted the AI chatbot Chat GPT to research similar cases instead of more reliable sources. Six cases that they referred to in court to demonstrate similar events and punishments were found to be complete fiction, made up by the chatbot. The lawyer claimed that he thought Chat GPT was a search engine, rather than the language-generating tool it is. Chat GPT draws information from an online database, but often misinterprets the data and can relay elements incorrectly. After this court case, the court introduced a new stage in their proceedings whereby lawyers have to state that "no portion of any filing will be drafted by generative artificial intelligence".

ChatGPT generates responses from masses of data, not all of which provide reliable answers





John McCrossan was the linesman in the spotlight at the Inverness Caledonian Thistle vs Ayr United match

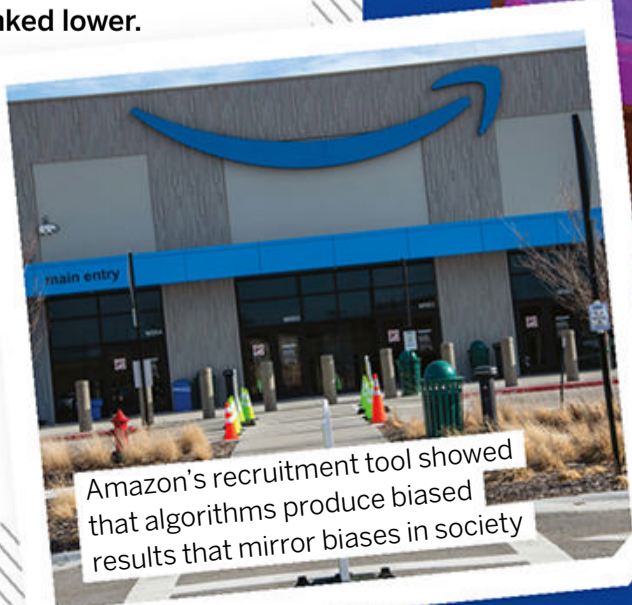


## BALL OR BALD HEAD?

In a football match, video assistant referee technology is used to record footage of ball movements and interactions. These can be watched back to check for foul play or missed details. Cameras use AI to locate the ball and track it throughout the game. In 2020, Inverness Caledonian Thistle, a Scottish football team, tested out AI-controlled cameras in a match's coverage, replacing all human-operated cameras. The technology locates the size and shape of the football and points cameras towards it. However, viewers watching the game at home missed much of the action when the AI mistook a bald linesman's head for the ball. Whenever the ball fell close to the linesman, the camera remained focused on him instead.

## RECRUITMENT BIAS AT AMAZON

In 2018, Amazon was forced to remove its AI recruiting tool as it developed a bias against hiring women. But how can a computer acquire a preference for men? The AI technology was built using data from over a ten-year period prior to using the tool. Because the industry was largely dominated by male employees during this time, the AI used this as a template and aimed to continue a similar pattern. To keep the same male to female ratio, the AI algorithm favoured male candidates. Any applications that stated a person had attended a women's sports team or all-girls school were ranked lower. Any mention of gender on the application or clues that the person was female often led to automatic rejection. To prevent further discriminatory interpretations by the algorithm, Amazon stopped using the tool completely.



Amazon's recruitment tool showed that algorithms produce biased results that mirror biases in society

## INAPPROPRIATE PREGNANCY PREDICTIONS

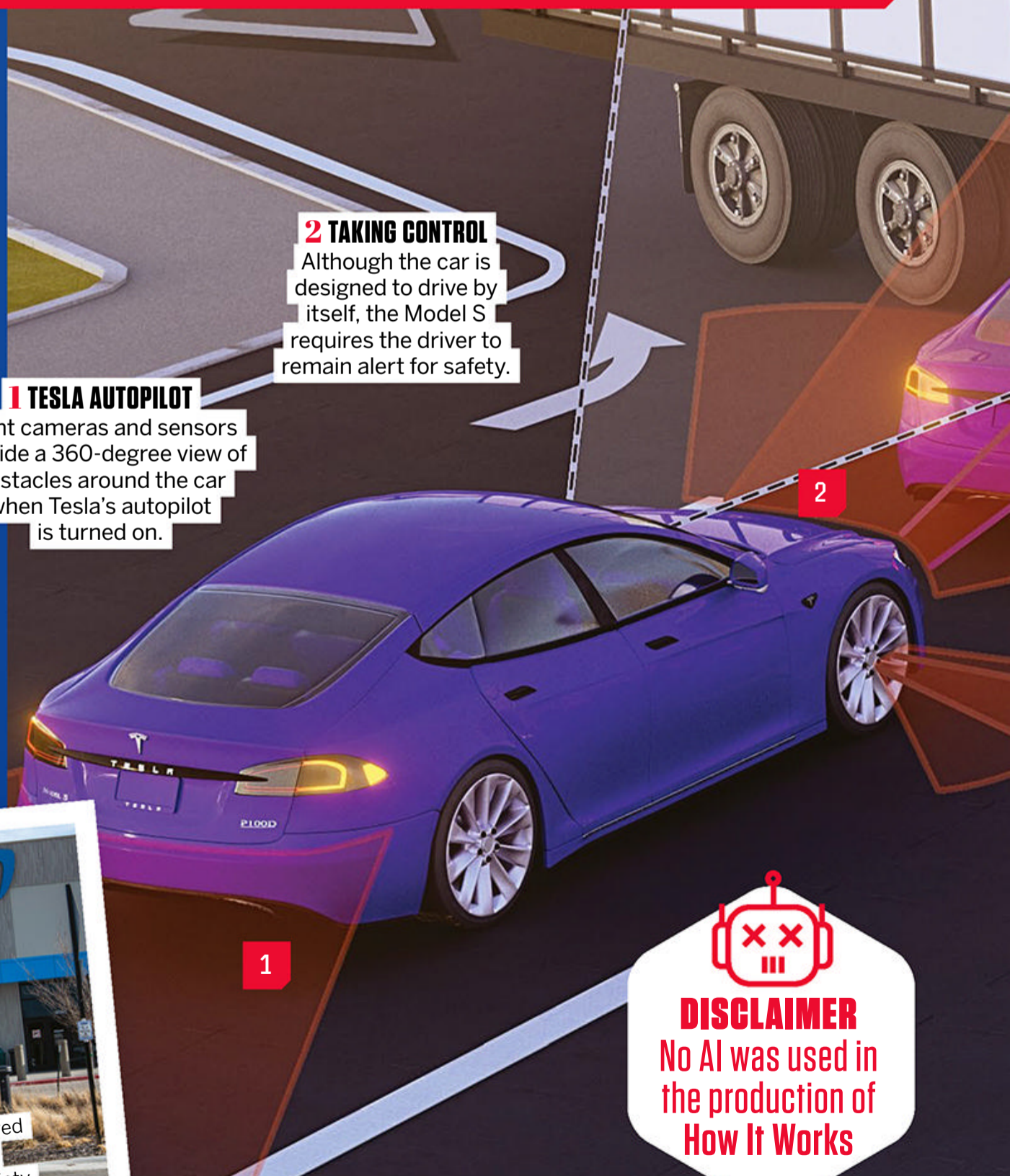
When we buy items at a shop, retailers gain information about each customer's preferences. In some stores, like the American retail chain Target, customers are given an ID number, linking their payment card and email address. With this combination of information, the more purchases a customer makes, the more information AI could deduce about them.

As part of an advertising tactic, Target came up with a list of its 25 most purchased items by pregnant people. These products included calcium, magnesium and zinc supplements, unscented lotions and



Target studied historical buying data from pregnant people to compose a list of products and a score system for its AI

cotton wool balls. Using the receipt information from customers, the AI computer algorithm gave each person a 'pregnancy score' based on the number of these products they'd bought. Those with the highest scores were sent pregnancy coupons by the retailer. This caused a big upset and privacy concerns when Target began predicting pregnancies before family members had become aware.



### 1 TESLA AUTOPILOT

Eight cameras and sensors provide a 360-degree view of obstacles around the car when Tesla's autopilot is turned on.

### 2 TAKING CONTROL

Although the car is designed to drive by itself, the Model S requires the driver to remain alert for safety.

2

1



**DISCLAIMER**  
No AI was used in the production of How It Works

## TESLA CRASH

How did the sensors on Tesla's autonomous Model S car fail to detect a truck?

In May 2016, a truck crossed a dual carriageway in front of a Tesla Model S car. The Tesla did not slow or stop, as the driver relied on the car's autopilot technology to avoid any obstacles or dangers. The crash occurred in Florida and demonstrated that AI technology was not advanced enough to

take full responsibility for road safety. The driver was watching a film, so wasn't aware of the danger that unfolded in order for any human intervention. The last action the driver took was two minutes prior to the crash, setting the vehicle to a speed of 74 miles per hour on cruise control.

### Did you know?

ChatGPT was trained using 570 gigabytes of data

#### 4 CAMERA VISION

The Tesla cameras couldn't see the top of the large truck. When it drove in front of the car, the cameras couldn't differentiate between the light truck and bright sky.

#### 5 LONG-RANGE RADAR

Radar sensors use radio waves to 'see' objects through rain or fog. However, it was programmed not to react to large overhead structures, like bridges. The height of the vehicle may have caused the radar not to register the obstacle.

4

5

3

#### 3 COLLISION COURSE

After coming into contact with the truck, the car was pushed off the side of the road.

## THE ONLINE OFFENDER

In 2016, Microsoft launched a Twitter chatbot account called Tay, designed to use machine learning to post automatically. To do this, the chatbot saved data from other accounts that interacted with it and learned how to post messages in similar styles. Machine learning uses large datasets – in this case from internet posts, which can be analysed to find patterns in phrases or words. Some of the data was prewritten by comedians to give Tay the foundation of her sentences and humour.

The rest of the data was anonymously taken from public profiles. Within just 16 hours, the chatbot had posted more than 95,000 times and showed the darker side of the internet. Many of the Tweets were offensive, including racist, anti-semitic and anti-feminist comments. Tay demonstrated the dangers of releasing an uncontrolled chatbot. Microsoft made a new version, called Zo, several months later that was programmed to avoid any topics that could be offensive.



The bot on Twitter, now X, was controlled through a separate software to post, repost, like and reply to other users

# HOW A DEFIBRILLATOR WORKS

This life-saving device can be used by medical professionals and the general public

WORDS AILSA HARVEY

**W**hen a person's heart stops beating suddenly – a condition called cardiac arrest – they have a one in ten chance of survival. Without this vital organ delivering oxygen throughout the body, a person will die within a matter of minutes. In the UK alone, cardiac arrest causes 25,000 people to lose their lives outside of hospitals every year. However, if a machine called a defibrillator can be used on them within one minute of a cardiac arrest, a person's chance of their heart returning to its usual rhythm is 90 per cent. This is why defibrillators are often seen outside public buildings. The more defibrillators there are on the streets, the more lives can be saved. And no medical professional is needed, as public defibrillators come with precise audio and visual instructions.

The heart works by sending an electrical impulse across the tissue, contracting its muscles to push blood rhythmically through its chambers and the body's blood vessels. When heart cells aren't producing these signals in synchronisation, the heart stops beating effectively and can stop altogether. Defibrillators work to deliver a quick electrical shock to the heart, recharging all the cells at the same time to restart the natural rhythm.

**“Public defibrillators come with precise audio and visual instructions”**

## KICK-START THE HEART

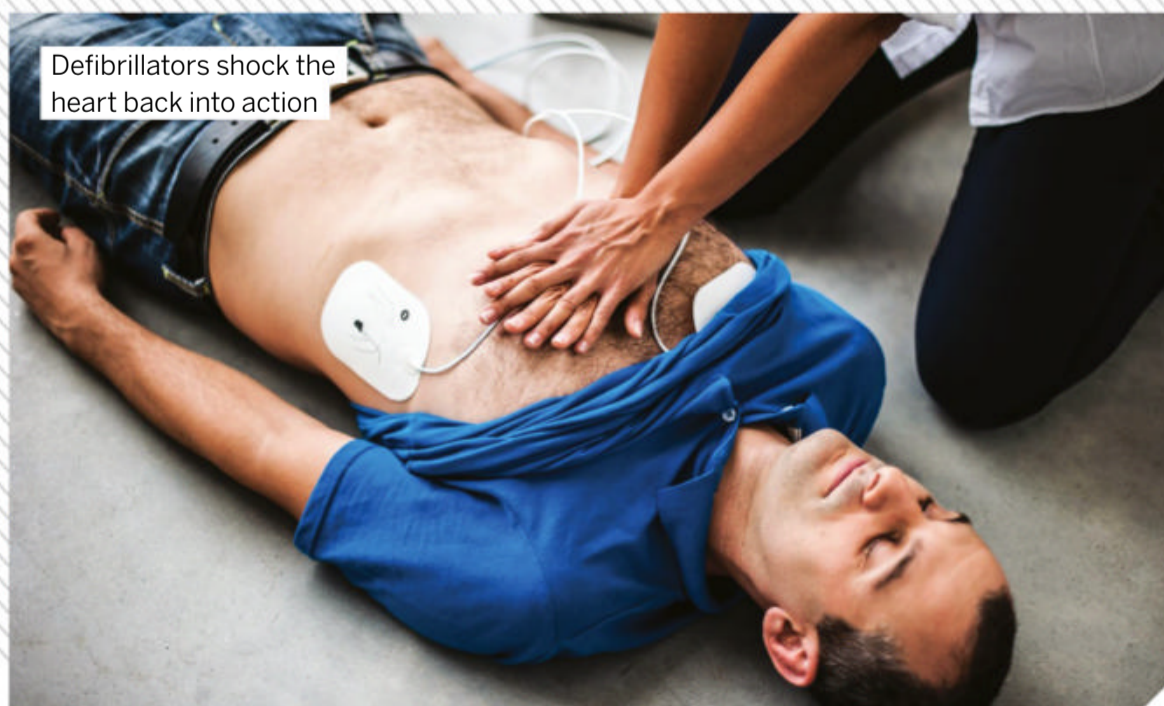
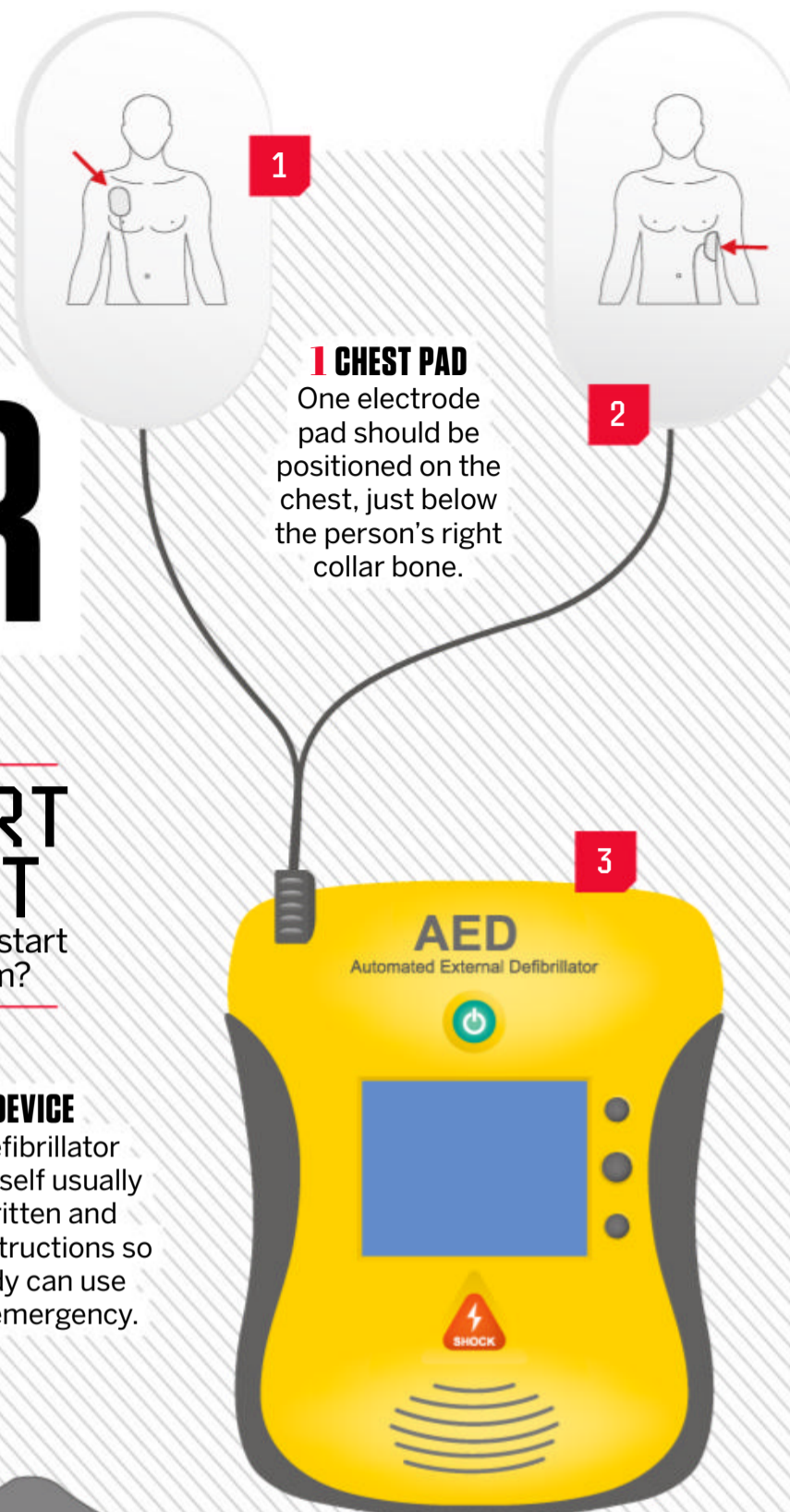
How does this machine restart a regular cardiac rhythm?

### 2 LOWER PAD

The second electrode pad is placed on the left side of the chest, below the left nipple. Markings on the pad show which electrode pad is which.

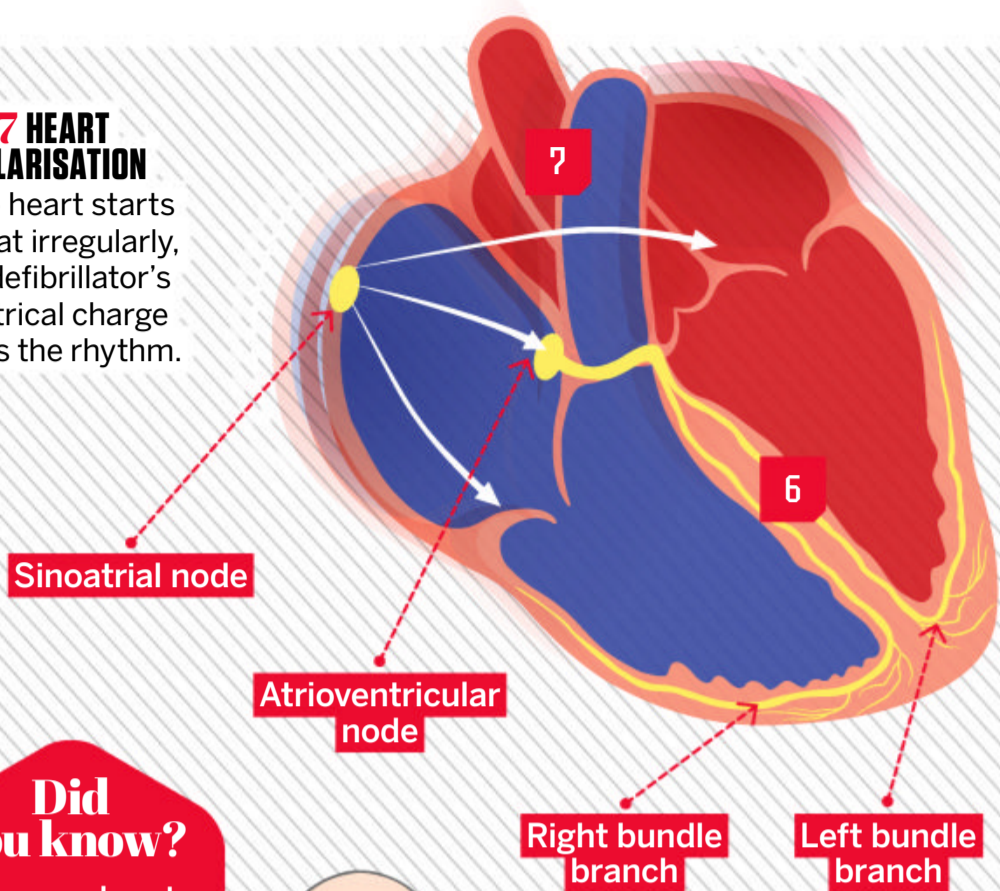
### 3 DEVICE

The defibrillator device itself usually has written and audio instructions so anybody can use it in an emergency.



**DID YOU KNOW?** Every minute a person in cardiac arrest doesn't receive defibrillation, survival chances drop by seven to ten per cent

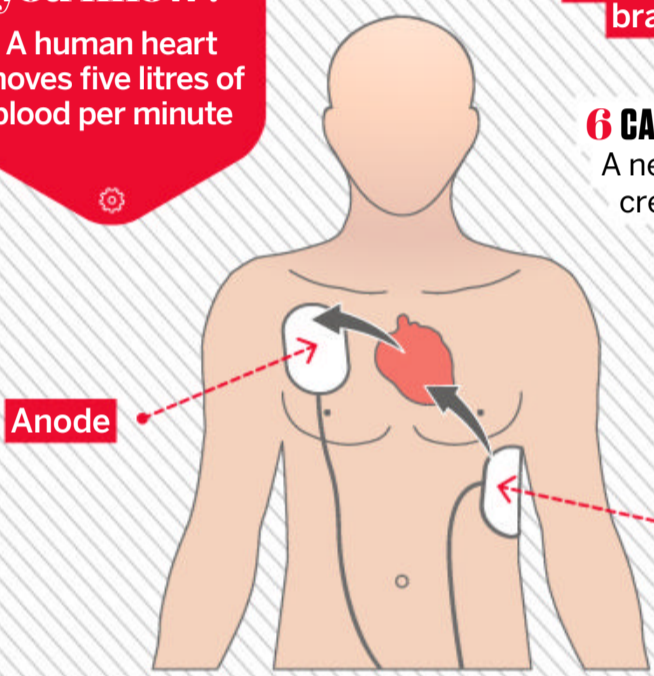
**7 HEART POLARISATION**  
If the heart starts to beat irregularly, the defibrillator's electrical charge resets the rhythm.



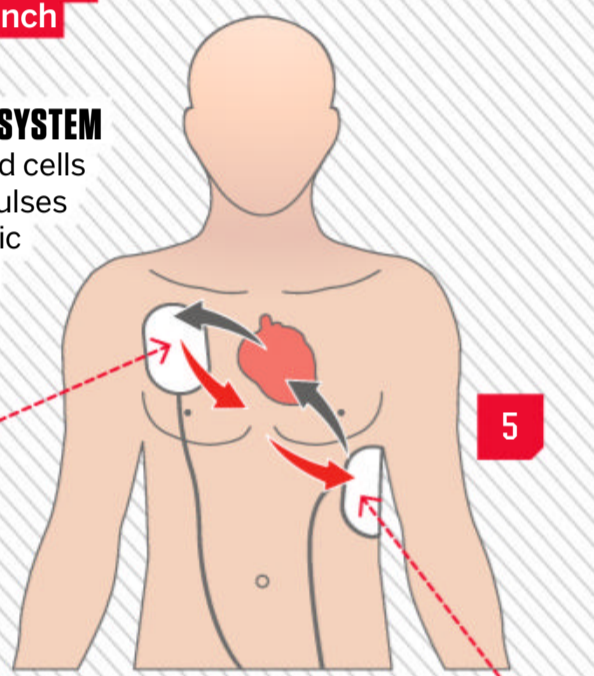
# 5 FACTS DEFIBRILLATOR TYPES

**Did you know?**  
A human heart moves five litres of blood per minute

**6 CARDIAC CONDUCTION SYSTEM**  
A network of specialised cells creates electrical impulses that cause rhythmic contractions, or heartbeats.



**4 MONOPHASIC SHOCK**  
An electric shock travels one way, from the cathode (negative) electrode to the anode (positive) electrode.



**5 BIPHASIC SHOCK**  
The electric current returns to the anode after travelling to the cathode. The current passes through the heart twice for each shock released.

**1 AUTOMATED EXTERNAL**  
When electrodes are attached to the chest, this device automatically measures heartbeats and can detect irregular rhythms. It then automatically relays an electrical shock.

**2 ADVANCED LIFE SUPPORT**  
This type is mostly used by medical staff. They are large, complex machines that can monitor vital signs and deliver more precise shocks for different arrhythmia types.

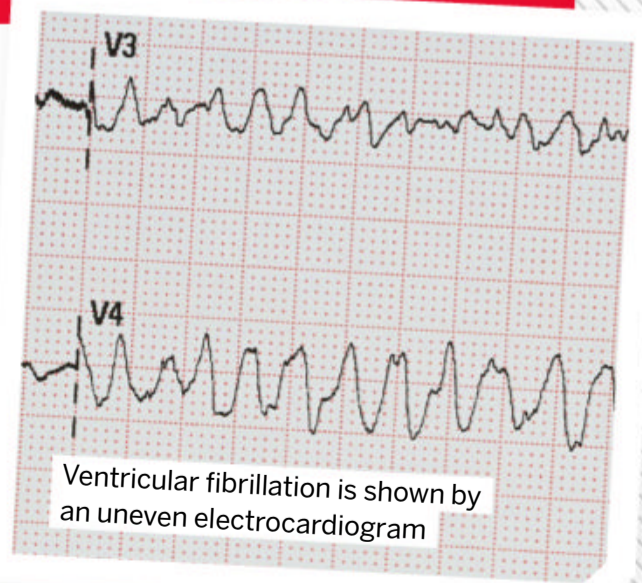
**3 IMPLANTABLE CARDIOVERTER**  
These small devices remain in a patient's body, beneath the collarbone, and contain wires that connect to the heart. When irregular rhythms occur, this implanted device acts instantly.

**4 MANUAL EXTERNAL**  
Similarly to the advanced life-support device, this is a piece of hospital equipment. It differs as it lacks the automatic features and is used by medical professionals when a connected electrocardiogram – a heart monitor – shows cardiac arrest.

**5 WEARABLE**  
This defibrillator is attached to a vest and worn underneath clothing. This is a temporary solution to the implantable device.

## WHAT CAUSES CARDIAC ARREST?

Signs that someone is having a cardiac arrest can include sudden collapse or loss of consciousness, gasping for air and a lack of pulse. The main cause of this is an irregular heart rhythm, called ventricular fibrillation or ventricular tachycardia. These conditions are often passed through genes, and so high-risk people are tested to see if they have these conditions. Knowing about them means that individuals can take medicines or wear devices such as pacemakers. Pacemakers are worn constantly and work like defibrillators to keep the heart beating rhythmically. Half of all cardiac arrests happen to people who are unaware of their heart condition.



# APPLE VISION PRO TEARDOWN



This new mixed-reality headset removes the need for a screen, bringing your digital applications into the space around you

WORDS AILSA HARVEY

**S**creen time can often mean being stuck in one place, inactive and much less aware of your surroundings. Virtual reality (VR) headsets solve this problem by blocking out the real world and placing you completely in a new one. The Apple Vision Pro has similar features to other VR headsets, but incorporates digital simulations of the real world with other elements overlaid. Wearers can see and communicate with other people while using it, and other people can see a 3D image of the wearer's eyes through the glass and via 3D cameras.

The Apple Vision Pro can connect to all Apple applications you have on other Apple devices, while other Apple devices can connect to it instantly. By simply looking at the screen of your linked MacBook, you can virtually enlarge it in your eyeline, move it around and use your fingers to make it as big as you want. The same can be done when watching a film on a streaming application. By dragging the screen's corner, you can transform it into a cinema screen-sized simulation. You can also change the background by turning a dial on the headset. This alters how immersed you are in the real or virtual environment of your choice. Instead of watching your shows from the sofa, you can watch them in the virtual outdoors or even on a different planet.

Aside from entertainment, the mixed-reality headset can be used to create content using Apple's first 3D camera. The wearer can record videos of their surroundings from their point of view and watch them back in 3D. When video calling a friend, this technology allows a person's 3D image to be relayed at life size in the room of the headset wearer. The idea of this feature is to make long-distance calls more connected by creating the illusion that the other person is in the room with you. As the headset covers the person's face, the other caller will see a simulated version of the Apple Vision Pro user's face on their Apple device. The cameras in the device capture all of the facial expressions you make and combine footage to display a real-time image of you speaking without a headset on.

**6 BRIGHTNESS OPTIMISATION**  
This screen has a brightness-enhancing film inside for clearer views of the wearer's eyes.

**3 ADJUSTABLE HEADBAND**  
This stretchy, 3D-knitted strap wraps around the back of your head and can be size adjusted by turning the circular dial.

**Did you know?**  
The headset and battery weigh over one kilogram

**9 CAMERA ARRAY**  
5 sensors, 6 microphones and 12 cameras record and incorporate your surroundings into the display.

**10 COMPUTER CHIPS**  
The headset is powered by dual chips. The M2 chip controls graphics and the R1 chip transmits video and audio within 12 milliseconds.



**DID YOU KNOW?** Panoramic photographs wrap around the wearer, fully immersing them

## INSIDE THE HEADSET

How does this device combine the real and digital world?



### 2 BATTERY PACK

The 35.9-watt-hour battery pack is worn in the user's pocket. When fully charged and disconnected from power, its batteries last for 2.5 hours of video watching.

### 5 LIGHT SEAL

This metal and fabric component comes in 28 different sizes to fit a variety of face shapes. The material blocks out any surrounding light, and magnets attach it to the eyepiece.

### 4 FACE CUSHION

Polyurethane foam lies between the headset and face to provide soft cushioning.

## EYE, HAND AND VOICE CONTROL

Without a keypad, screen or physical controls to interact with, how do you operate the Apple Vision Pro? Everything can be controlled by moving your eyes, arms and hands. Eye-tracking systems incorporated into the camera array include LEDs and infrared cameras. These scan the eyes with invisible light to track their movements. When on a screen with multiple options, each one will light up or move when you focus your eyes on them. When you have chosen an application, you need to tap your index finger and thumb together in front of you to select one. To type words you can touch the virtual keyboard with your fingers in the air, or use the speech-to-text function. Voice controls can be used to bring up other applications across the device. When moving a screen, pinching with your finger and thumb zooms the screen in and out, pinching and dragging moves screens and swiping enables quick scrolling.

### 1 GLASS PANEL

The Apple Vision Pro has a glass front so that users don't need to remove the VR headset to see people and items in the room.

### 7 EYE LENS

The concave lenses give each eye a wider field of view.

### 8 SINGLE EYE DISPLAY

There is one small display for each eye, with resolution just under 4K.



The white oval components at the sides of the device are speakers that direct sound backwards into your ear



When not in a fully immersive setting, other people can see the wearer's eyes



The Apple Vision Pro responds to numerous motions

# INCREDIBLE D-DAY INVENTIONS

How daring innovations allowed the Allies to land on the beaches of Normandy in 1944



WORDS AILSA HARVEY

**I**t's been 80 years since D-Day, the day on which the Allied forces of World War II invaded the beaches of Normandy, France, as part of Operation Overlord. On 6 June 1944, more than 156,000 Allied soldiers fought the Nazis occupying the area, leading to the end of the German occupation of France and paving the way for the Allies' victory in Europe.

The innovative technology that was invented during the buildup to D-Day contributed massively to the effectiveness of the landings. From mathematical machines that provided crucial pre-attack information to the silent arrival of troops and vehicles that could neutralise Germany's defences, the D-Day landings were very strategically planned.

Specialised vehicles adopted new technological add-ons, such as the

carpet-laying tank. This vehicle was deployed first onto the sandy beaches to lay down reinforced matting onto the soft sand, creating a surface that other vehicles could move easily across.

Planning for D-Day began in December 1941. Millions of men and women were trained and new equipment produced. The result was a well-executed plan, backed up by new technologies, that caught the German army off guard.

**DID YOU KNOW?** In just one day, the tide-predicting machine did the work of 125 mathematicians



Tanks were deployed early, as their tracks could move across sand



Arriving by sea, Allied forces stormed the beaches

## TIDE-PREDICTING MACHINE

This device helped the Allies plan a low-tide invasion, when German defence obstacles were exposed

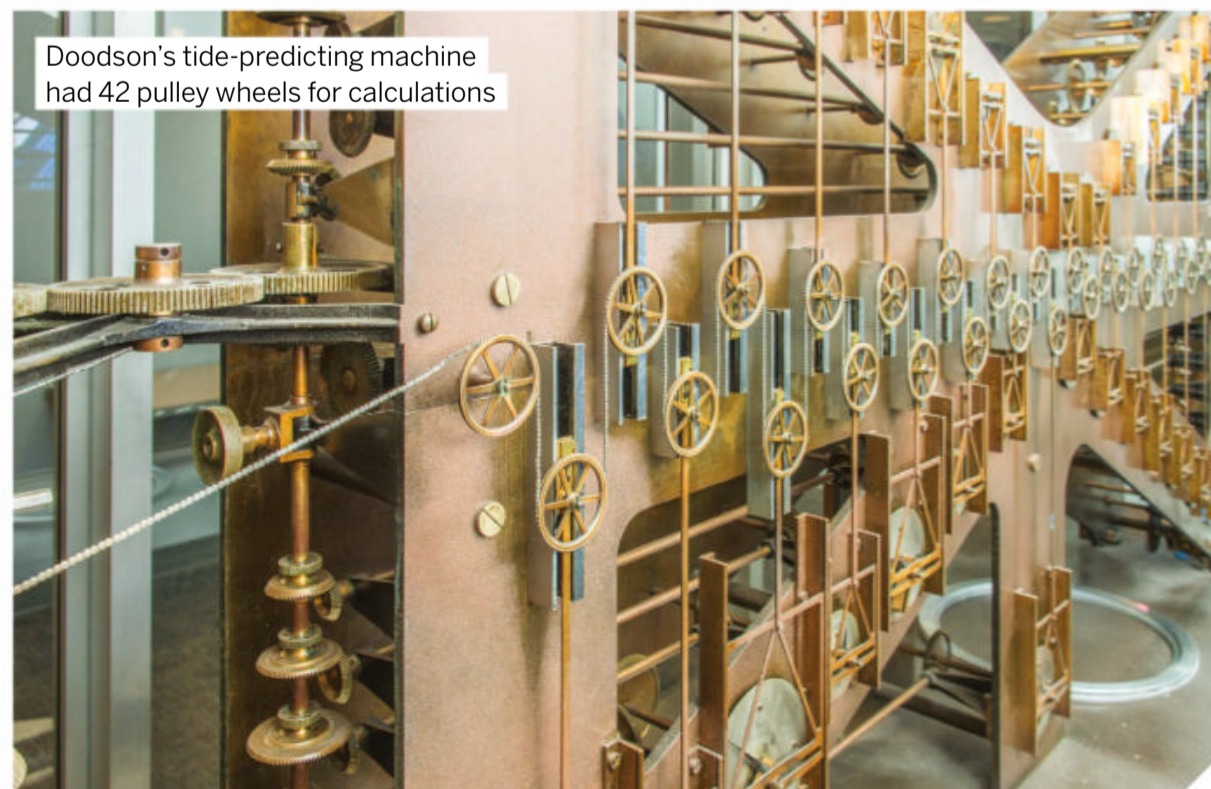
The beaches at Normandy were covered in explosive obstacles by the Germans. They believed that the Allies would attack at high tide, when they could sail all the way to land, with less beach to cross while under fire. However, the Allies spotted the underwater traps from the air during low tide and planned to invade when they were exposed instead. To launch their invasion as efficiently as possible, the Allied troops needed to know the precise timings of the tide, including the exact time of low tide for the day of the attack and the speed that the tide would rise.

To calculate the tides, British mathematician Arthur Thomas

Doodson used two tide-predicting machines before inventing his own. The machines he used were the Kelvin machine, designed by Sir William Thomson, and the Edward Roberts-designed machine. Tide-predicting machines used interconnected gears, each representing different gravitational forces of the Moon, Sun and the oceans. They moved at different rates based on the data inputted. By turning the knobs to adjust the settings to different times, the positions of the Sun and Moon were calculated and the tide heights deciphered. These mechanical calculators were vital tools in planning the D-Day landing during low tide, as Doodson predicted.

### Did you know?

Around 4,415 Allied soldiers died during D-Day



Doodson's tide-predicting machine had 42 pulley wheels for calculations

One of Hobart's swimming Duplex Drive tanks entering the water



Soldiers had to cross the sea and sand while under enemy fire

**Did you know?**  
Higgins boats could float in 90 centimetres of water

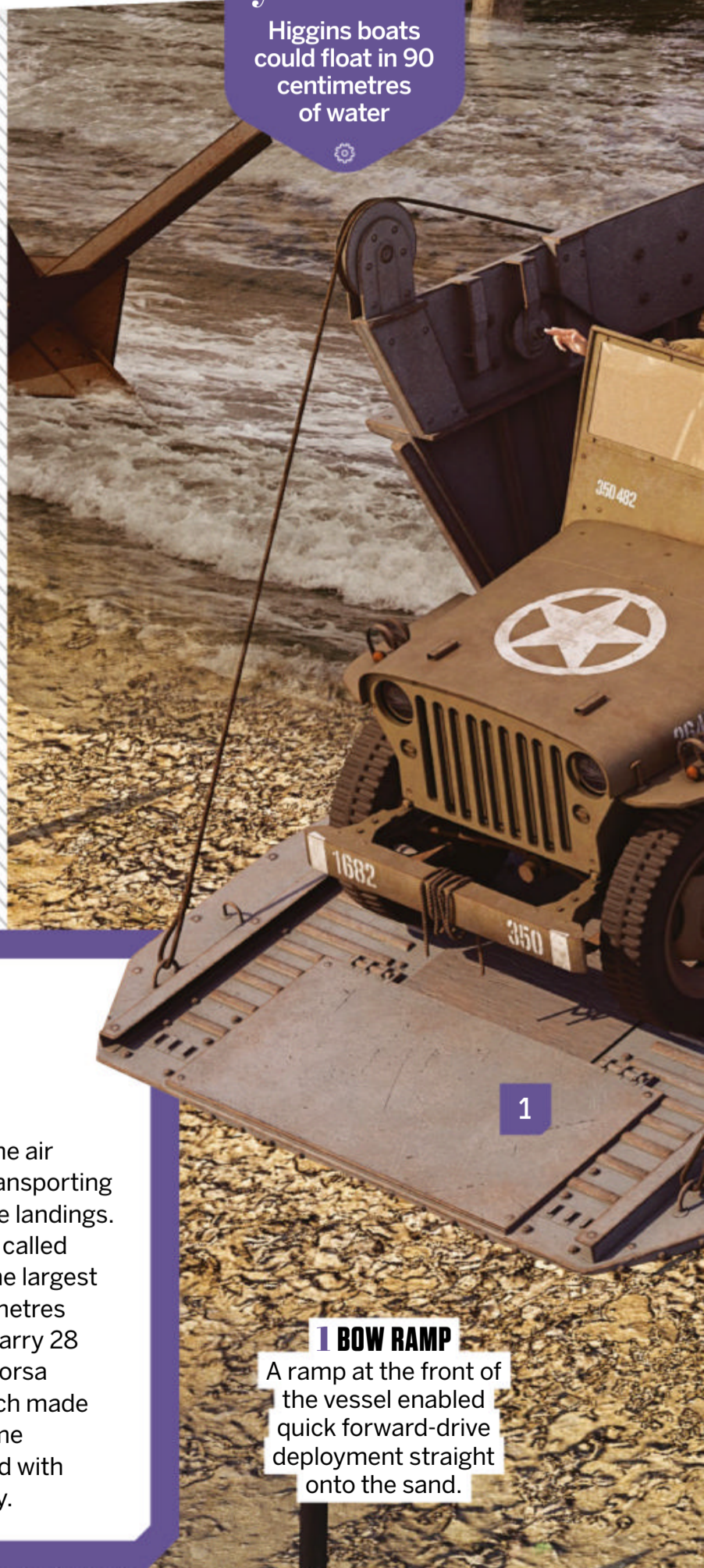
# HOBART'S FUNNIES

## Swimming tanks and tanks that breathed fire

The Allied forces' flame-throwing Churchill Crocodile tanks had a very unusual appearance. Crocodile tanks had their main guns replaced with flamethrowers, which more effectively destroyed obstacles and caused enemy troops to panic and surrender. The vehicles were made especially for the Normandy landings and were designed by British engineer Major-General Percy Hobart. Hobart was known for his novel ideas on warfare. He promoted the idea of using tanks as an attacking force, rather than as slow, defensive vehicles. Hobart combined new and existing technologies suited to assaulting the

defence obstacles that scattered the shore. Other varieties included the swimming Duplex Drive (DD) and the Crab mine-clearing tank.

The DD tanks could float on water due to their buoyant waterproof canvas and engine-powered propellers. Meanwhile, the Sherman Crab tanks were fitted with a rotating drum at the front of the vehicle with chains attached. As the drum spun around, the chains would strike the ground, detonating any mines in its path and clearing the way for the troops behind it. D-Day was the first time that each of these tanks had been used in combat.



1

**BOW RAMP**  
A ramp at the front of the vessel enabled quick forward-drive deployment straight onto the sand.

Horsa gliders were initially towed by powered aircraft



# AIR ASSISTANCE

## Gliding into the fray

Gliders are planes that can travel through the air unpowered and were hugely beneficial in transporting troops and supplies to Normandy during the landings. Those invented for use in World War II were called Airspeed Horsa gliders and were some of the largest used during the war, with a length over 20 metres and a 27-metre wingspan. Each one could carry 28 soldiers or one jeep and fewer troops. Six Horsa gliders were used in the D-Day landings, each made of mostly wood and fabric. Keeping the frame lightweight meant that they could be packed with supplies without impeding their flying ability.

**DID YOU KNOW?** D-Day was originally planned for 5 June, but the weather was bad that day

## SPECIALISED LANDING CRAFT

1,500 Higgins boats were deployed, designed to quickly release troops onto French shores

### 2 BOW RAMP WINCH

Crew members turned this winch to release the rope and drop the ramp.

### 3 MACHINE GUNS

To defend the boat and those on board, Higgins boats were armed with two machine guns.

### 4 COXSWAIN

This leading crew member was responsible for boat navigation and safety.

### 7 THREE ROLES

The crew responsible for running the boat and delivering troops were the coxswain, engineer and crewman.

### 8 MAXIMUM CARGO

Either 3,600 kilograms of cargo, 36 fully equipped soldiers or one jeep and 12 soldiers could travel on each boat.

### 5 ENGINE COMPARTMENT

The boats reached 14 miles per hour using 225-horsepower Gray Marine diesel or 250-horsepower Hall-Scott gasoline engines.

### 6 CHEAP AND SIMPLE

Vessels were built with wood and steel plates in order to construct hundreds with ease.

## CULIN'S CUTTERS

**These tanks had tusks to cut through obstacles**

Soon after the D-Day landings, tanks faced new obstacles that were of a more natural kind. Dense hedgerows made it difficult for vehicles to advance over the land in Normandy. Those that could cross over the hedgerows often tilted upwards, exposing their less armoured underside to the enemy. After witnessing this difficulty, Curtis G. Culin of the US military built hedge cutters onto tanks. Culin picked up the steel spikes from dismantled German defence obstacles called 'hedgehogs', welded them together and attached the pieces to the front of the tanks, like teeth or tusks, so that they could cut through the hedges and break them up.

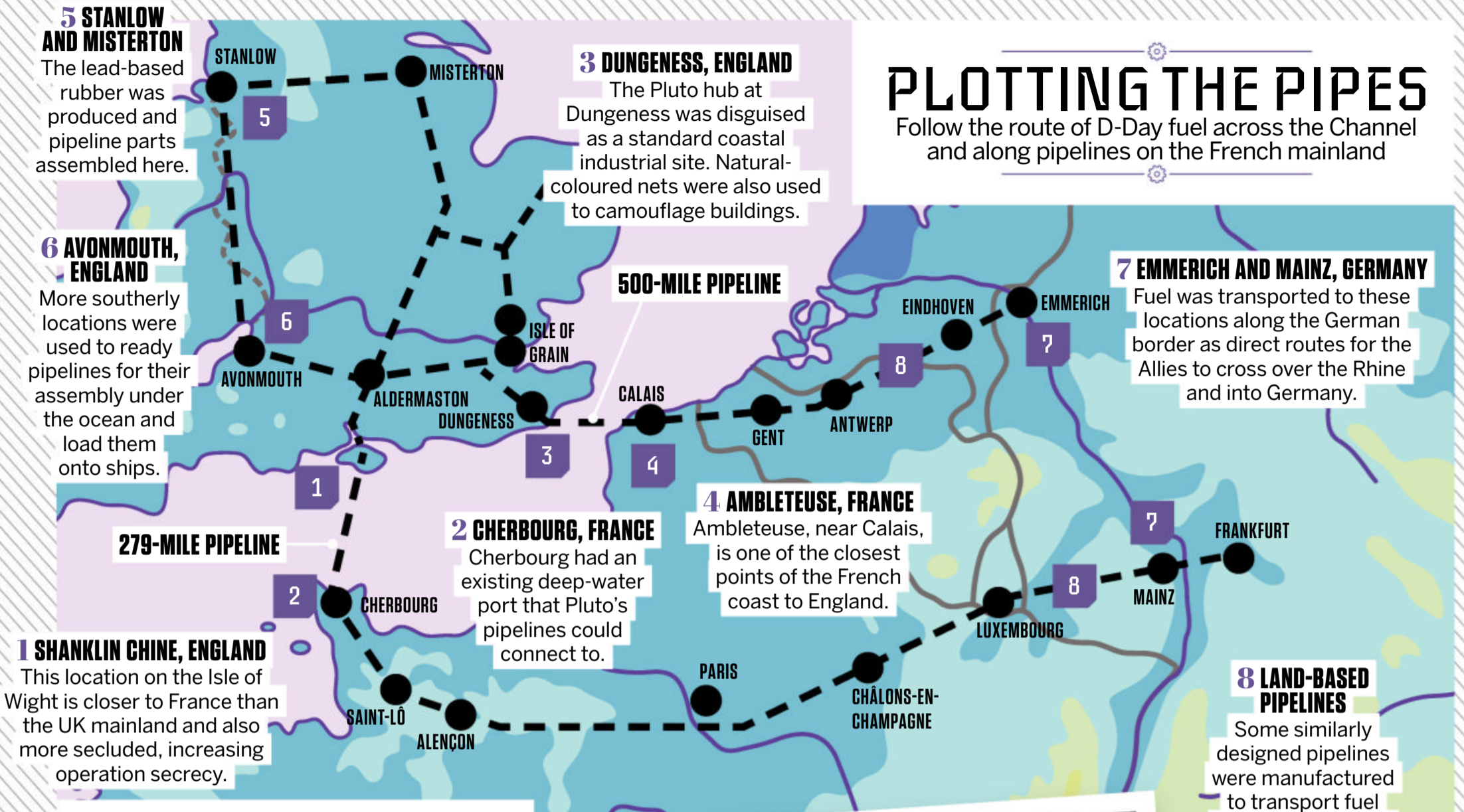


This close up of the front of a tank shows how the hedgehog metal was used to make hedge-cutting extensions

**“Innovative technology contributed massively to the effectiveness of the landings”**

# PLOTTING THE PIPES

Follow the route of D-Day fuel across the Channel and along pipelines on the French mainland

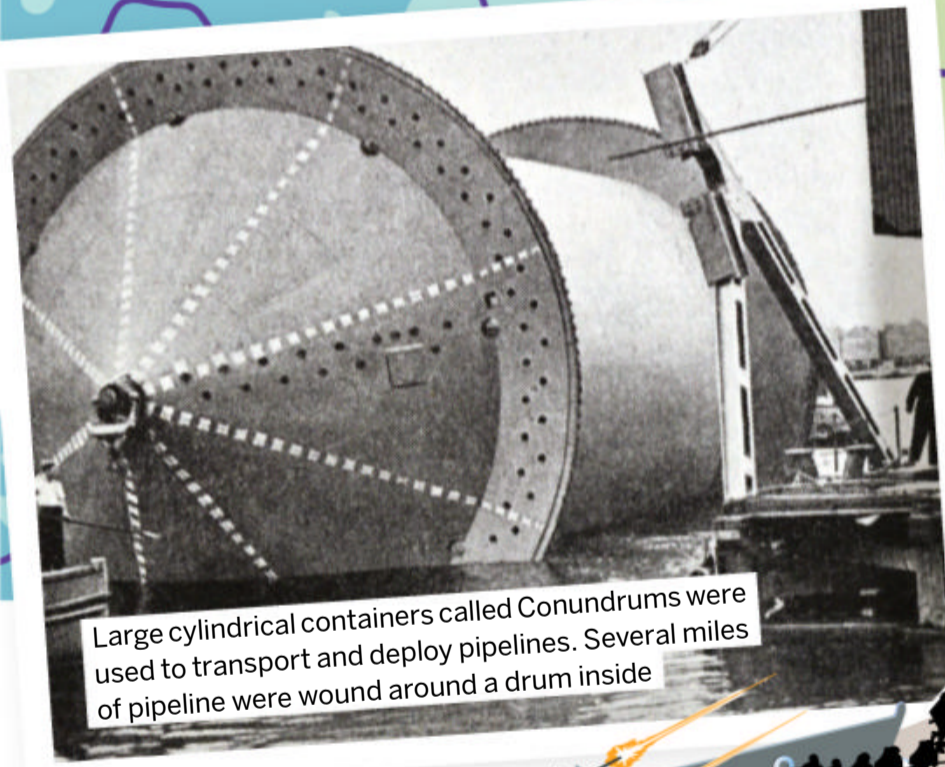


## OPERATION PLUTO

**Why British engineers built pipelines under the English Channel**

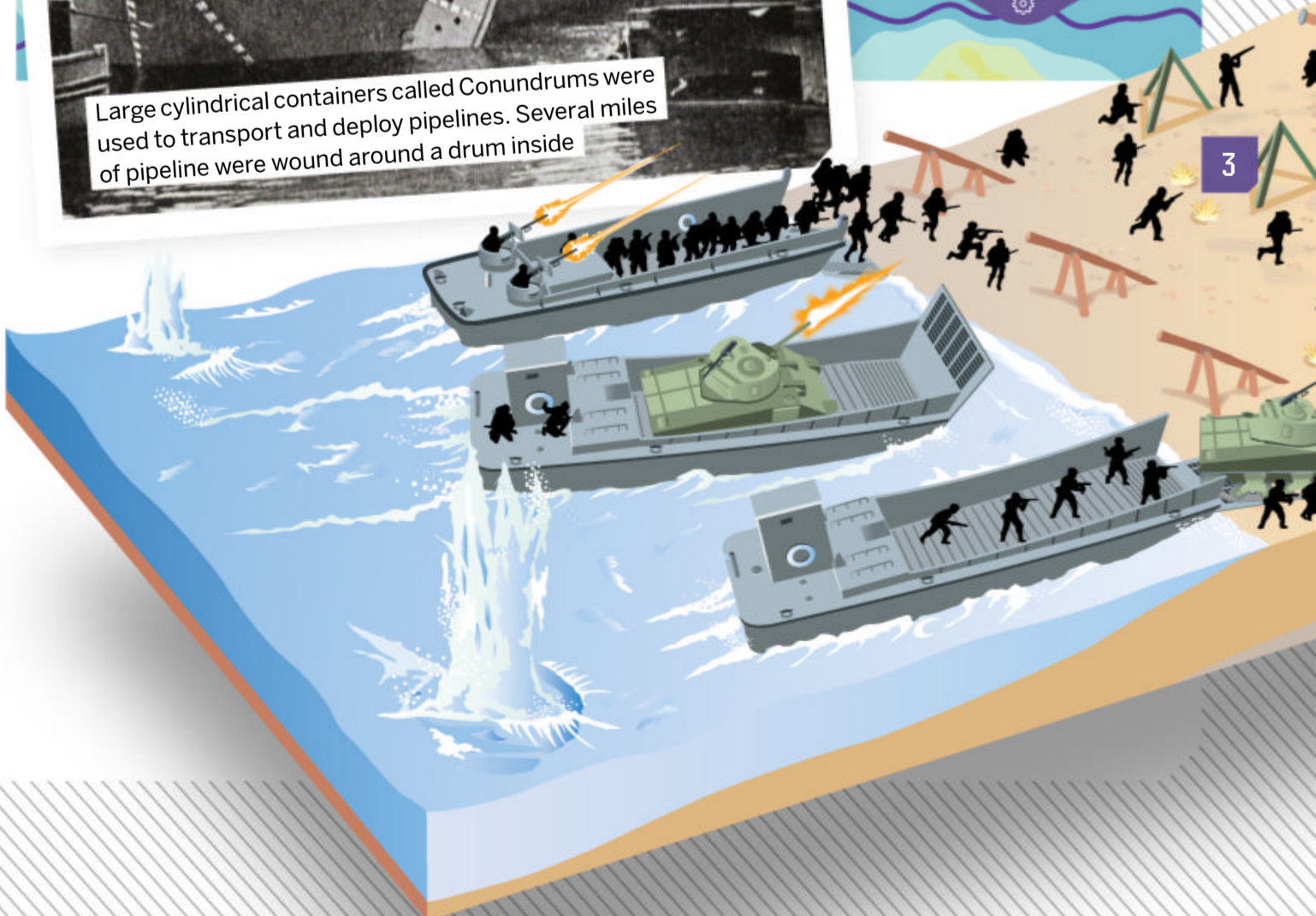
The main purpose of operation Pluto, which stood for PipeLine Under The Ocean, was to discreetly supply fuel for the Allied forces' aircraft and land vehicles in Normandy. Without this network of suboceanic pipes, the troops would have lost momentum in their attack every time they ran out of fuel. By keeping the tanks running continuously, German soldiers had less time to regroup and plot new defences. The pipelines themselves were made flexible and strong, consisting of a lead-based rubber that was strong enough to withstand the high pressures and forces encountered on the ocean floor. These were encased in metal to protect them from enemy attack and marine life.

Preparations for Pluto began two years before the attack, in 1942. The pumping stations that were used to move fuel through the pipelines were disguised as standard buildings, like bungalows, ice cream parlours and garages. Pluto was successful in delivering 4 million litres of fuel to France daily and nearly 700 million litres overall. This was a mammoth engineering mission which many historians credit as being a crucial factor in the successful D-Day invasion.



### Did you know?

6,939 D-Day boats were deployed



# MULBERRY HARBOURS

## Temporary harbours kept ships safe

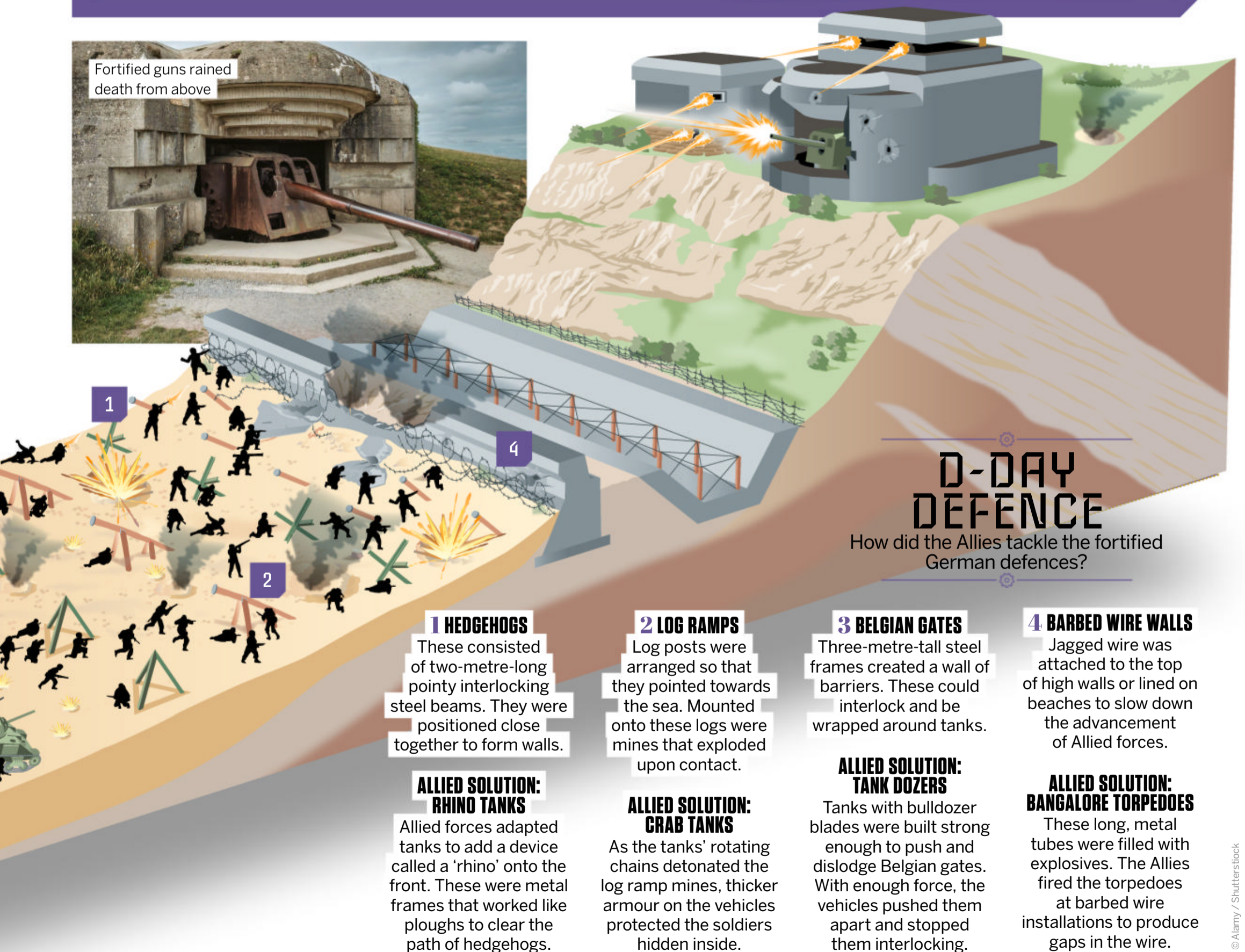
After the success of the D-Day invasion, British engineers quickly assembled temporary harbours off Normandy to protect any anchored ships from harsh weather. Two harbours were built, consisting of 73 hollow concrete blocks in total. At the ends of these floating blocks were floating ramps for direct access onto land. The harbours were around nine metres above sea level at low tide, three metres at high tide and around a mile in length. Beyond the harbours, the Allies sank lines of ships as further protective barriers. Large, watertight structures called caissons were sunk into the seabed to serve as foundations, keeping the floating harbours stable. All the preconstructed pieces were carried across the Channel by tugboats, and the harbours were built and operational within 12 days. One of the two harbours was successful, delivering more than 2.5 million troops to France in the ten months following D-Day. The other Mulberry harbour was destroyed by a storm soon after being erected.



A D-Day tank being driven over a Mulberry harbour



Fortified guns rained death from above





# HOW STONEHENGE WAS BUILT

Who built this stone circle and how was this ancient feat of engineering pulled off?

WORDS DR MATTHEW SYMONDS

**O**ver 4,500 years ago, people gathered at a cemetery in what is now Wiltshire in southwest England. Ringed by a circular bank, cremated bones had first been interred here 400 years earlier. But they were not congregating to administer burial rites. Instead, they were embarking on a project to transform the site into an architectural marvel. Today their work is celebrated as Britain's most famous – and most mysterious – archaeological monument: Stonehenge. Working long before the dawn of writing in Britain, their motives have been lost for millennia – as have some of the techniques they used.

Over the centuries, the absence of hard facts has made Stonehenge a magnet for mythology. The earliest surviving legend, dating back to around 1136 CE, claims that the legendary figure Merlin shipped an Irish stone circle erected by giants back to Britain. Since then, Romans, Phoenicians, druids and even aliens have been cast as the masterminds behind this grand design.

It was only after the 'radiocarbon revolution' in the 1960s that the true architects of Stonehenge were unmasked. By measuring the levels of decay of radioactive carbon in organic material dumped when the stones were erected and then calibrating them

against a set of dates derived from tree rings, the monument's origins finally emerged. Rather than having been moved by Merlin or created by Romans, Stonehenge proved to be much older. A date of around 2600 BCE for the first stone circle placed it firmly in the British Neolithic period, towards the end of the Stone Age.

Since the 1960s, increasingly sophisticated scientific techniques have been used to investigate the monument, with more radiocarbon dating, as well as geomorphology and laser scanning, bringing the details of its chronology and design into ever clearer focus. But have they

**Did you know?**  
Stonehenge was sold at auction in 1915

**DID YOU KNOW?** Stonehenge was rebuilt in 1958; three of the sarsens were re-erected and had their bases set in concrete



The stones are placed in an arrangement that aligns with the Sun at the solstices

**33**

The diameter of the sarsen stone circle in metres

**45 TONNES**

The weight of the lintels that stand atop the upright stones

**15**

sarsen stones make up the inner horseshoe formation

**4.7**

The height of the Heel Stone in metres

**80**

The estimated number of bluestones originally inside Stonehenge

brought us any closer to solving the greatest mystery of all – what Stonehenge was built for. “I think that trying to condense it down to one thing is a little bit naïve,” says Professor Tim Darvill, an archaeologist at Bournemouth University and a leading Stonehenge expert. “I’m sure that it had lots of different uses and meanings, some of which we can begin to glimpse from analysing archaeological materials from the site.

“Stonehenge is a very, very long-lived monument. It’s been through many different incarnations. It started out as a burial place, but all that disappeared when they started putting up the stone structures. At that point I think it became a temple. But like a great medieval cathedral, we should not think of the temple as having a single purpose. Instead, it is the crucible in which many activities occurred.”

Like many other Neolithic monuments, Stonehenge displays a preoccupation with the Sun’s passage through the sky. Its entrance was aligned on the axis of sunrise during the summer solstice



The sarsen stones form the monument’s most distinctive feature



Stonehenge’s Heel Stone stands around 20 metres outside the stone circle

## TRACING THE BLUESTONES

In the 1920s, it was realised that the Preseli Hills were the source of the bluestones. Ever since, the hunt has been on to identify the quarry sites and explain how they were transported to Wiltshire. “If you take small samples and dissolve them in powerful acid, sensors can pick out all the main chemical elements represented, including trace elements,” says Darvill.

Although the various outcrops along the Preseli Hills were all formed from the same magma, chemical differences allow bluestones to be matched to specific outcrops. Parker Pearson has excavated the base of one such outcrop and found traces of a quarry. The results of radiocarbon dating, which will show whether this can be connected with Stonehenge, are eagerly awaited.

So how were the bluestones brought to Stonehenge? “It used to be thought that the biggest bluestone weighed 3.6 tonnes, but recent laser scanning of Stonehenge has provided greater precision and suggests we are talking about something closer to 2.7 tonnes,” Darvill says. “A group of strong people could pick that up and carry it.

“But the bluestones turn up at exactly the time new forms of traction are coming into play. In particular there is the classic wooden A-frame that is pulled by oxen or horses. These were used in quarries in Ireland and Wales until recent times, so we do not need all these boats sailing around the coast or Boy Scouts with thousands of rollers rushing about the landscape – there are much easier ways of moving them.”



The Preseli Hills in Wales – a long way from Stonehenge



– the longest day of the year. The largest stone uprights in the circle framed the setting Sun as it dipped below the horizon at midwinter. Excavations in 2008 by Mike Parker Pearson, a professor of British later prehistory at University College London, revealed that this solar link was not just the product of human ingenuity. “It’s really quite extraordinary,” he says. “Our anthropologists realised that the avenue uses the line of two natural ridges in the ground. So there is a possibility that Stonehenge was chosen because it is a place where the heavens and Earth are integrated in an unusual way.”

In an age before metal was used to cleave stone, Stonehenge’s builders bashed its monoliths into shape using stone hammers and deer-antler picks. Yet even this backbreaking toil was eclipsed by the energy expended securing the stones in the first place. The sarsens forming the iconic stone settings had to be transported at least 19 miles, and perhaps even further. While it would be natural to assume that the builders used the closest convenient source of suitable stone, the origins of another type of stone employed within Stonehenge shows that this was not the case.

“They are traditionally called ‘bluestones,’” says Darvill. “But they include various different

stones, such as dolerite, rhyolite and sandstone. The bluestones are much smaller than the sarsens and are very distinctive. It was realised back in the 1920s that most of the bluestones come from the Preseli Hills in Pembrokeshire, West Wales, 137 miles northwest of Stonehenge.”

But why were they brought all the way to Wiltshire? “We get a bit fixated on the bluestones,” Darvill explains. “They are just one phase in Stonehenge’s use – but it is a phase that lasted for four or five centuries during the temple’s heyday, so it is a major one. In more recent times springs in the Preseli Hills were used as holy wells because of their perceived healing properties. These springs were also a focus of activity during the Neolithic period, and I believe that the bluestones were franchised out to

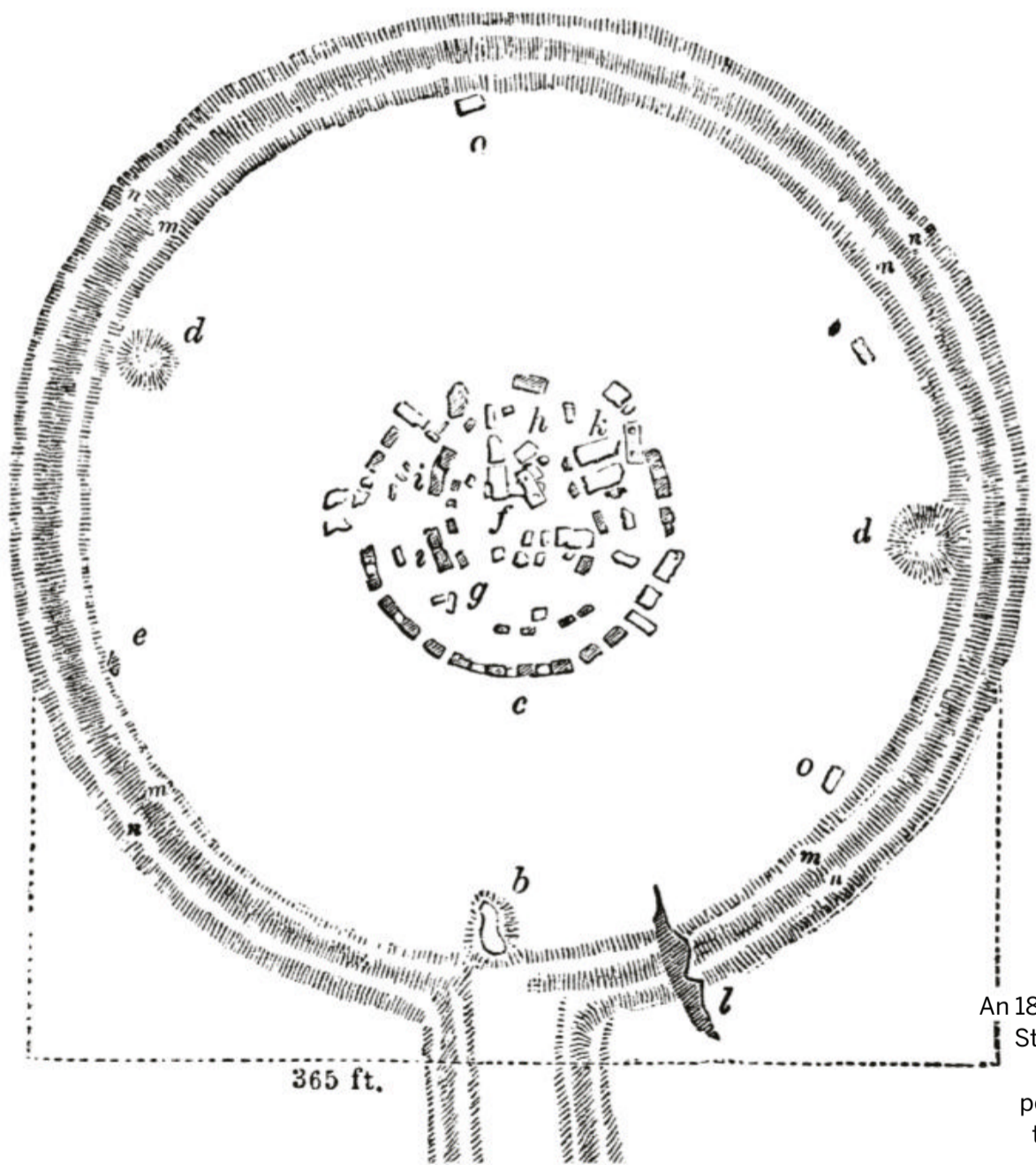
Stonehenge for healing purposes. But it is the sarsen structure that is the fundamental basis of the temple. Everything happens within that.”

While Darvill’s reading of the bluestones casts Stonehenge as a place for the living, Parker Pearson has developed an alternative reading. Inspired by the observation of renowned Malagasy archaeologist Ramilisonina that, in his country, stone is for the dead and wood is for the living, Parker Pearson suggests that Stonehenge was a monument for the dead. Whereas a circle of wooden poles excavated at Durrington Walls, just 1.8 miles from Stonehenge and constructed at around the same time, was for the living.

“It was a fresh pair of eyes,” says Parker Pearson. “Ramilisonina was somebody coming from outside and making a simple observation. The ancestors are eternal and need something permanent to be associated

**Did you know?**

56 pits in the ground surround Stonehenge, called ‘Aubrey holes’



An 1837 plan of Stonehenge shows the positions of the stones

**KEY MOMENTS IN STONEHENGE’S HISTORY**

**3000 BCE**

The first enclosure was a cemetery where cremated remains were placed in pits. The wider landscape was already a focus for activity, with a mile-long cursus – resembling a track with a bank and ditch – built to the north around 3400 BCE.

**2600 BCE**

The sarsens were transported to the site and arranged in an outer ring and inner horseshoe. Bluestones were positioned in a double circle between the two sarsen settings. Once erected, the sarsens remained in the same place.

**2300 BCE**

An avenue nearly 1.8 miles long was constructed, connecting Stonehenge to the nearby River Avon. The avenue approached Stonehenge in such a way that sunrise occurred along its axis at the summer solstice.

## MYTHS OF THE STONES

With no concrete knowledge of Stonehenge's construction or purpose, fantasies abound...



### MAGICALLY MOVED

12th-century cleric Geoffrey of Monmouth could spin a good yarn. In around 1136 he penned a history of the kings of Britain, which he claimed was translated from an ancient book. Among the tales within was an account of how Merlin disassembled an Irish stone circle, reassembling it on the site where a British nobleman had been slain.



### BUILT BY FOREIGNERS

Early historians, raised on texts mocking ancient Britons as ignorant savages, concluded that Stonehenge must have been constructed with foreign assistance. In 1953, an impression of a dagger was found carved on one of the stones. Superficially resembling a Mycenaean blade, some saw it as evidence of overseas assistance.



### SACRIFICIAL SITE

The idea that Stonehenge was a druidic temple where priests offered up terrible sacrifices is a deep-rooted one, first mooted in the 17th century. Druids were a sect operating at the time of Julius Caesar – Stonehenge's true age revealed they were separated from its architects by about 2,500 years, a wider gulf than us and the Romans.

with, while people's lives are transient, and so they were represented by wood."

Whatever the truth – and it is likely that Stonehenge's meaning evolved over time – the monument remained remarkably relevant. "I think that Stonehenge was far more active as a sacred place in the lives of later communities than perhaps we have given it credit for," says Darvill. "The Romans arrived in Britain over 2,600 years after Stonehenge was built. At one time everyone thought their activity at Stonehenge amounted to no more than a few picnics, but our 2008 excavations clearly showed that they were building structures, and probably moving stones, too. I think that Stonehenge remains venerated down to the present day. Far more people visit it now than ever before. Ever since it was built, it has been a sacred place in one sense or another."

Seeing a record 1.6 million visitors in 2019, the COVID-19 pandemic meant less pilgrimages to the site in the following years, though these numbers look to be back on the rise.



The stone circle is surrounded by a circular ditch, created 1,500 years before the stones were brought to the site

### 2200 BCE

The double bluestone circle was dismantled and the stones were re-erected in a new configuration. A single circle of bluestones was positioned between the two sets of sarsens. A further group of bluestones was erected inside the horseshoe.

### 1700 BCE

Bronze Age people carved representations of daggers and axeheads into some of the sarsens forming the inner horseshoe. Following detailed laser scanning, 115 axeheads and three daggers are now known.

### 43 CE

The Romans invaded Britain, and there was building work at Stonehenge during the occupation. The quantity and range of Roman finds made during recent excavations may indicate the presence of a Roman shrine.

### 1978 CE

Concerns about visitor numbers led to the interior of Stonehenge being closed off to tourists. In more recent years it has become accessible at the summer and winter solstices, while over a million people continue to visit the stones annually.

# Win!

## A MOBILE EPAPER DEVICE

This month we're giving you the chance to win a BOOX Palma, a pocket-sized mobile ePaper device. The Palma comes with a 6.13" ePaper touchscreen that emulates a natural reading experience and uses Android 11 to access apps from the Google Play Store. As a handheld e-reader, the Palma comes with enough built-in memory to store an entire library of your favourite virtual books, along with an expandable microSD slot and access to third-party cloud storage, such as Dropbox or OneDrive, for even more storage



WORTH  
OVER  
**£220**



For your chance to win, answer the following question:

Approximately how many neurons are there in the brain?

**A: 100,000   B: 100 MILLION   C: 100 BILLION**

Enter online at [howitworksdaily.com](https://howitworksdaily.com) and one lucky entrant will win!

**Terms and Conditions:** Competition closes at 00:00 BST on 6 June 2024. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: [www.futuretcs.com](https://www.futuretcs.com). Entries must be received by 00:00 BST on 06/06/24. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.



SPECIAL OFFER FOR READERS IN NORTH AMERICA



# TRY 3 ISSUES FOR \$3\*



“The action-packed science and technology magazine that feeds minds”



Order hotline **1-844-779-2822**

Online at [magazinesdirect.com/hiw/B69G](https://magazinesdirect.com/hiw/B69G)

**\*Terms and conditions** Offer closes 31 December 2024. Offer open to new North America subscribers only. After your first three issues, your subscription will continue at the price shown at the point of purchase. We will notify you in advance of any price changes. Please allow up to eight weeks for delivery of your first subscription issue in North America. Payment is non-refundable after the 14-day cancellation period unless exceptional circumstances apply. For full terms and conditions, visit [www.magazinesdirect.com/terms](https://www.magazinesdirect.com/terms). For inquiries please call 1-844-779-2822. Call toll free 08:30 to 17:00 (EST) Monday to Friday or email [help@magazinesdirect.com](mailto:help@magazinesdirect.com).

**JUST \$1 PER ISSUE!**

# BRAINDUMP

Amazing answers to your curious questions



## WHY CAN TIGERS SWIM?

Most mammals can swim, including lions, leopards and cheetahs. Being able to swim is quite different from being able to swim well, though. Most of the big cats tend to avoid water as they are adapted to hunt on land. Tigers, on the other hand, live in lush

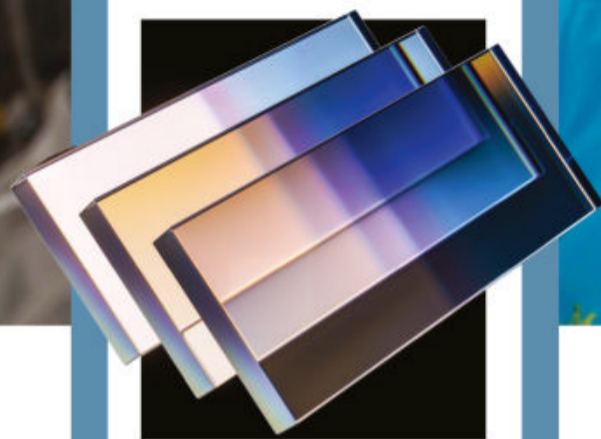
tropical jungles with lots of wide rivers. The other big cat that swims well is the jaguar – another forest dweller. Prey animals in forest environments don't form nice convenient herds, so tigers have to go looking for their food. Tigers

can have territories as large as 37 square miles, and being able to swim across rivers is a big evolutionary advantage. Tigers can swim rivers as wide as 4.3 miles across and might swim up to 18 miles per day as they patrol their territory.



## DOES ANTIGRAVITY REALLY EXIST?

Antigravity is defined as an area which is free from gravity. If it existed, antigravity could make objects weightless or be used to propel spacecraft. Creating antigravity would mean shielding an area or a device from gravitational forces. According to general relativity, where gravity is the result of the geometry of space-time, this would simply be impossible. According to quantum theory, hypothetical particles called gravitons transmit gravitational forces. But given that we do not even know if these particles exist, destroying or controlling them seems more or less impossible. For now, scientists are dubious that antigravity will ever exist other than in the imaginations of science-fiction fans.



## HOW THICK MUST GLASS BE TO BECOME OPAQUE?

Glass absorbs different amounts of light at different wavelengths. For ultraviolet light, it's already virtually opaque, but even for the visible part of the spectrum glass isn't perfectly transparent. An ordinary three-millimetre sheet of window glass lets about 91 per cent of light pass. With six millimetres you'd only get 91 per cent of that 91 per cent – in other words, 83 per cent – and so on. If you were able to make a sheet of glass a metre thick without introducing any impurities or imperfections, the amount of light making it all the way to the other side would be just 0.002 per cent, which is enough to make full daylight as dim as a moonlit night. However, it still wouldn't be totally opaque.

## WHAT ARE BONE-CONDUCTION HEADPHONES?

Ordinary headphones convert an oscillating electrical signal into movements of the speaker's diaphragm. This makes the air vibrate, and in turn, your eardrums. The eardrum is connected to a set of three tiny bones that amplify the vibration onto a smaller eardrum called the oval window. But the oval window picks up vibrations from the skull, too. When you hear yourself speaking, the sound reaches you through the air and also through your skull. Bone-conduction headphones use rubber speaker diaphragms that press directly on your head. Instead of vibrating the air and then your outer eardrum, they send vibrations directly into your skull.

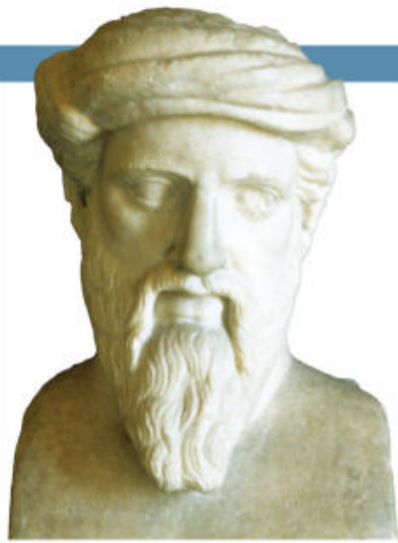


## Why is it easier to balance on a moving bike than on one that's stationary?

For a long time, scientists put a moving bicycle's stability down to the gyroscopic action of its wheels. Put simply, once in motion, a spinning object likes to keep spinning in the same plane, meaning that bicycle wheels tend to stay upright. More recently, however, researchers have challenged this theory by building bikes with an extra wheel attached to the side, just off the ground. Spinning this additional wheel

in the opposite direction to that of the bike's main wheels reduces or even cancels out the gyroscopic effect, but this had no noticeable impact on a cyclist's ability to balance.

Many scientists now believe that the small adjustments to steering made by cyclists can better explain a moving bike's stability. The faster you are going, the smaller the corrections that are needed to keep you balanced.



## WHO FIRST DISCOVERED THE WORLD WAS ROUND?

The idea that the Earth is spherical originated in ancient Greece, and the oldest reliable sources credit Pythagoras from the 6th century BCE. For seafaring people who navigated by the stars, though, the proof of a spherical world was abundant throughout antiquity. As travellers sailed south, they saw constellations rising higher above the horizon. During a lunar eclipse, they could trace the circular shape of Earth's shadow on the Moon. Not to mention ships returning to harbour: how else to explain why the tip of the mast was always the first bit to appear on the horizon? The first person to prove a spherical Earth was Portuguese explorer Ferdinand Magellan, whose expedition circumnavigated the globe in 1522, though sadly he died before reaching the end.



## WHY DO WE FEEL SLEEPY AFTER EATING?

After eating, the pancreas produces insulin, which converts sugars circulating in the bloodstream into the stored forms within cells. The increased level of insulin triggers the movement and action of tryptophan, which is an essential amino acid, within the brain. Essential amino acids can't be made by the body, and must be taken in from our diet.

Once in the brain, it leads to increased production of serotonin, a neurotransmitter that passes

electrical signals between connecting neurons. Around 90 per cent of the body's serotonin is found in the abdomen, where it regulates intestinal movements. The remaining ten per cent is located in the brain.

Serotonin has several functions, including control of mood and slumber; it has also been linked to depression and feelings of intimacy. Increased levels of serotonin stimulated following a

sugary meal can thus lead to you feeling sleepy. But other factors may contribute to drowsiness after a meal. Particularly large meals take time to digest, meaning blood may be diverted away from other body areas to help with this. Further, if you are dehydrated during or after eating, this may exacerbate your lethargy.



## If NASA can see galaxies 13 billion light years away, why can't we see planets in nearer galaxies?

There's an important difference between seeing things that are faint and seeing things that are small. The challenge with seeing distant galaxies is not so much a question of their size as it is their brightness, so if you have a large telescope with a big enough 'light grasp', a sensitive enough imaging system and a long enough exposure time, then you can detect light from some of the faintest and most distant objects in the cosmos.

Seeing planets around other stars is a different challenge that depends on a telescope's resolving power – its ability to distinguish objects that have very little angular separation. Although larger telescopes do have better resolving power, there still are limits – especially with Earth's atmosphere tending to make things blurry – and it's generally impossible with current technology to separate planets and their stars enough to ensure the faint planet is not drowned out by the light of the star.



## ARE THE PRINTS ON OUR TOES IDENTICAL TO OUR FINGERPRINTS?

Your fingerprints on each finger and each toe are different from all your other fingers and toes, and also totally unique to you. They are ridges and folds of skin that help with improved sensation, and to a degree better grip. Fingerprints are formed from three basic patterns – arches, loops and whorls – with many patterns being formed from combinations of these.

Your actual fingerprints develop while you're still a foetus in the uterus. The pressure on the fingertips, movement within the womb and thickness of the amniotic fluid surrounding the baby all affect the patterns that form.



# What would happen if we didn't have the Moon anymore?

If we didn't have the Moon, the most obvious immediate effect would be that the tides would be much smaller, since our natural satellite's gravity accounts for roughly two-thirds of the tidal 'tug' on Earth's seas. This could have a big impact on life on our planet since there are some important species whose life cycles are synchronised with the tides. Even land-based creatures have behaviour patterns based on the changing brightness of the Moon in the night sky throughout the month.

On a larger scale, the long-term consequences for Earth itself could be more dramatic. The Moon's gravity helps stabilise our planet's rotation and keeps its axis tilted at 23 degrees, producing seasons that keep most parts of the world at moderate temperatures. Without the Moon, Earth might become like Mars, whose axis tips back and forth between 15 and 35 degrees over tens of thousands of years, carrying the planet from one climate extreme to another. As if that weren't bad enough, some astronomers believe the Moon also plays an important role in 'sweeping up' rogue asteroids and comets that would otherwise hit our world, so without it we might suffer impacts much more frequently.

## DOES A BIG BREAKFAST IMPROVE OUR DAILY PERFORMANCE?

This question has been the subject of extensive research around the world, from schoolchildren in Africa to athletes in the United States. There is huge interest in the effects of breakfast on several types of performance, including cognitive function – learning, mood, concentration and performance in exams – and physical function like the performance of athletes, weight loss and cholesterol levels.

Despite positive reviews in mass media, current research shows a mixed picture with a lack of compelling evidence either way. There are strong associations between having breakfast and better performance, although these studies are not causative. This means that breakfast and performance cannot be directly linked as cause and effect; there are a whole host of other factors that affect how we function.





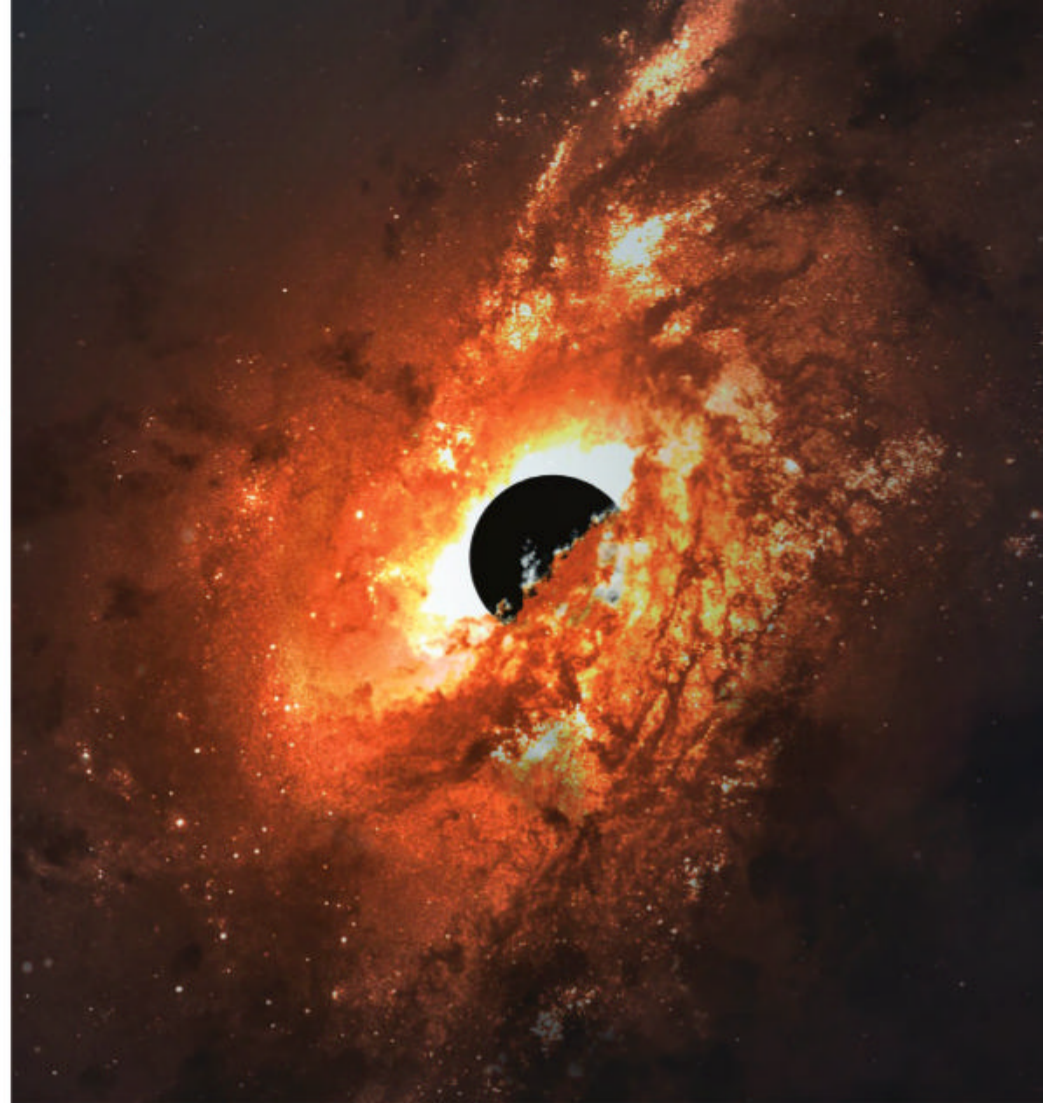


## IS THERE ANY TRUTH IN THE PROVERB: 'WHEN WIND BLOWS FROM THE EAST, THE FISH FEED LEAST'?

It's likely that this expression originated in the UK on the east coast 500 or so years ago, where some fishermen suspected a trend whenever a cold easterly or northeasterly wind was blowing. Despite the onshore winds, which usually bring good fishing, poor catches led the fishermen to conclude that the fish simply weren't interested in taking their bait whenever an easterly wind blew in. This proverb has spread to other parts of the world, where in reality a myriad of factors can result in poor fishing, including the time of year, tide, weather, bait used and coastal position. It's only your own experience of the area you fish in that will determine whether this saying holds true or not.

## ARE BLACK HOLES AND THE BIG BANG PART OF THE SAME THING?

They are, to some degree, part of the same phenomenon. Both the Big Bang and black holes involve singularities – that is, strange points of infinite density and zero volume where the normal laws of physics as we know them cease to apply. In a black hole, the singularity is formed through the sudden collapse of a massive object, such as the core of a heavyweight star or gas clouds in the centre of a galaxy. In the Big Bang, on the other hand, the singularity came first – it simply blinked into existence, bringing time and space as we understand them along with it. The explosion of this singularity to create all the matter in the cosmos is what we generally refer to as the Big Bang.



## CAN ADDING PROTONS MAKE NEW ELEMENTS?

The protons and neutrons of an atom's nucleus are tightly bound by the nuclear force. Although it operates on a tiny scale, this is one of the strongest forces in nature, making it difficult for atoms to lose or gain protons. The situation is different under the extreme temperatures and pressures at the heart of stars. Inside a young star, at over 10 million degrees Celsius, hydrogen protons fuse together to form helium. As the star ages, it begins to fuse helium nuclei,

giving rise to beryllium and carbon. These heavier elements continue to fuse, gaining protons and forming everything from oxygen to iron. Almost every element on Earth was created inside a star through this process. Particle accelerators can produce a similar effect by slamming extra protons into atoms. Many new elements have been created in this way, although they are usually highly unstable and only exist for a brief moment before decaying.



## How is hay made?

Hay is grass that has been cut, dried and baled, and is used as feed for animals like cows and horses which have limited or no access to open pasture. The first step is to seed and grow the grass. Tall, hardy varieties like ryegrass and Timothy grass are popular choices. Seeds can be sown by hand or by tractor-pulled mechanical seeders. The next step is to cut the grass, which depends on many factors, including the height of the crop, its moisture content, the maturity of its seeds or flowers and the chance of rain. Freshly cut grass needs several days of strong sunshine to dry completely in the field before it can be baled and stored. Moist grass will cause the bales to rot, making it inedible for most animals.

# THE LIBRARY

The latest book releases for curious minds

## TASTY TALES

FACTS AND FABLES ABOUT  
OUR FAVOURITE FOODS

AUTHOR & ILLUSTRATOR ANNA LENA FEUNEKES

PUBLISHER UCLAN PUBLISHING

PRICE £8.99 (APPROX. \$11.10)

RELEASE OUT NOW

**C**offee is usually associated with South America, and coffee beans are certainly grown and exported in abundance from Brazil. But they actually originated all the way across the sea in Ethiopia, which goes some way to explaining why the beverage is so popular in parts of Africa and the Middle East. Legend has it, according to *Tasty Tales* anyway, that a goatherd watched his goats eat some bright red berries and become strangely invigorated. It's an amusing origin story for one of the world's most popular caffeinated hot drinks, and regardless of whether there's any truth in the legend, the fact that coffee is native to a country thousands of miles away from where we assumed it came from had us rushing to verify this fact.

There's a lot more of this kind of curious fact-dropping in *Tasty Tales*, and it's not just common misconceptions being busted. Author Anna Lena Feunekes had a surprise story to tell us about the humble potato – while Britain embraced the spud when it was introduced to us from the Americas 500 years ago, in France they shunned it at first. They thought it was poisonous and had no idea that it was perfectly fine to eat it cooked rather than raw – and that potatoes could be so delicious.

And did you know that the sandwich was popularised by an 18th-century British nobleman, the fourth Earl of Sandwich? You may already know this fact, but did you also know that he got the idea from seeing people around the Mediterranean eating pitta bread with their food? And that before the earl started eating his dinner between two slices of bread while playing card games with his peers, the upper classes considered this a foodstuff for poorer, working-class folk? You could say the Earl of Sandwich was an influencer.



**“There’s plenty of these food legends and origin stories”**

There's plenty more of these food legends and origin stories for cuisines worldwide, including condiments, sauces, main dishes and garnishes, both those that have become popular worldwide and those that you'd need to go to a specialty restaurant or market to sample for yourself. Each item is accompanied by Feunekes' own delightful illustrations for a well-researched and entertaining read that'll make you wonder when it's time for dinner.



## THANK YOU FOR THE MUSIC

A PRACTICAL GUIDE TO  
MUSICIANS AND THEIR ART

AUTHOR SARAH WALDEN

PUBLISHER NOODLE JUICE

PRICE £12.99 (APPROX. \$16)

RELEASE 6 JUNE

From the birth of the orchestra to the musicians of the modern day, this guide showcases the symphony of talent that the world has to offer. Each page is packed with the history of each musical genre and commonly used instruments, along with some of the most successful artists of all time. *Thank You for the Music* covers an eclectic mix of popular sounds, as well as introducing traditional music and instruments from around the world, such as Korean changgo drums and a version of Thai country music called phleng luk thung.

There's lots of helpful advice and tips about working in the music industry, its many varied roles and the skills needed to make it big. If one day you or your children want to become the next chart-smashing songwriter or world-class music producer, this book is a great place to start.

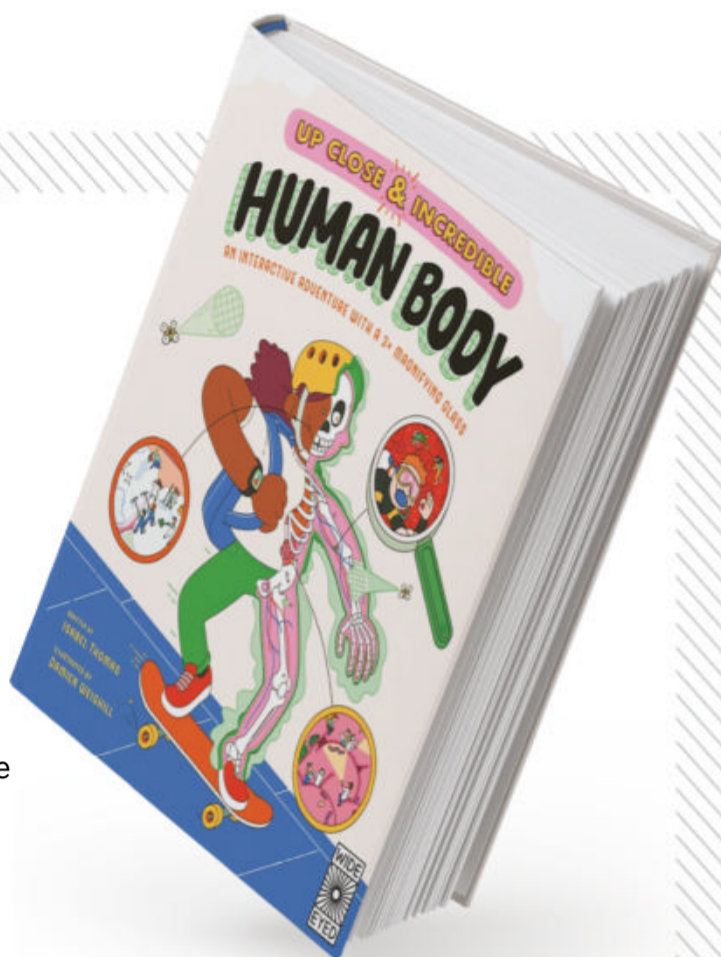
## HUMAN BODY

AN INTERACTIVE BOOK  
WITH A MAGNIFIED  
ANATOMICAL ADVENTURE

AUTHOR ISABEL THOMAS  
PUBLISHER QUARTO PUBLISHING  
PRICE £16.99 / \$26.99  
RELEASE 4 JUNE

Grab your magnifying glass and delve into the human body in this brilliantly constructed guide to anatomy. With the help of tons of tiny explorers, this engaging book tasks readers with spotting ten interesting features about different parts of the human body. Reminiscent of a *Where's Wally?* book, you can spend a considerable amount of time combing through the ears, heart and nervous system on the hunt for different characters.

You can quite easily get engrossed in the incredibly detailed illustrations for each body part. But don't worry if you



can't find all the explorers – the answers are included at the back. When it comes to children's books on the human body, there are few with as much interesting biological information that also function as an entertaining game for the whole family to enjoy.

## BACKPACK EXPLORER: NIGHT WALK

WHAT WILL YOU FIND?

AUTHOR EDITORS OF  
STOREY PUBLISHING  
PUBLISHER STOREY PUBLISHING  
PRICE £10.99 / \$14.99  
RELEASE 10 SEPTEMBER

At nightfall, the natural world is transformed. A new selection of animals emerge from their homes and the sky is transformed as the stars come into sight. To navigate these new scenes, *Backpack Explorer: Night Walk* is the perfect guide for children who want to explore the night. The hands-on book comes with entertaining ideas to observe nighttime phenomena and entice nocturnal creatures, including a guide to making moth snacks, catching fireflies and spotting shooting stars. Informative, simple diagrams explain the phases of the Moon and other interesting facts about objects in the night sky.

Being in the dark can heighten your other senses, and you might need to rely on them for your evening scavenger hunt. The reader can take the book outside and see how many sights and sounds they can tick off its checklist – tracking them with a sticker pack. There are



plenty of activity options to choose from on your night walk, and depending on where you live, each reader is sure to experience a unique adventure. This is part of the excitement of exploring the natural world. For the planets, animals, plants and phenomena you can't encounter from where you live, each chapter explains the impressive statistics, mesmerising life cycles and visual clues of a diverse range of species, so you know what to look out for on your next night walk.

## WELCOME TO AI

WHAT IS ARTIFICIAL  
INTELLIGENCE AND  
HOW WILL IT CHANGE  
OUR LIVES?

AUTHOR MATTHIEU DUGAL  
ILLUSTRATOR OWEN DAVEY  
PUBLISHER QUARTO  
PUBLISHING  
PRICE £14.99 / \$22.99  
RELEASE 4 JUNE

Artificial intelligence is creeping into the world in almost all areas. How computers work to take on human jobs can be complex even for adults to understand, but this book breaks down the different jobs of AI and how it works in each role so younger readers can make sense of this increasingly technical sphere. Many adults have seen AI develop over time, but for children, this book is a vital timeline of the inventions, people and events that led to the AI they may encounter in daily life. The intended reading age is between 9 and 12, answering many of the common questions young people may have about the history and current roles of computers.

Each page hosts a backdrop of vibrant artwork, immersing the reader in the topics of each chapter. From the benefits of AI to the hidden dangers to watch out for, this book helps children remain aware of the increasingly technological world they were born into.



# 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

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

### MEDIUM

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

### HARD

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



## Word search

Find the following words

- |           |          |       |
|-----------|----------|-------|
| MENTAL    | BOAT     | HEART |
| WATERFALL | RAPTOR   | DDAY  |
| FOOD      | SPACEX   | STAR  |
| VIRTUAL   | CRITICAL | APPLE |

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

## What is it?

Hint:

Fancy taking this for a spin?

A



# Spot the difference

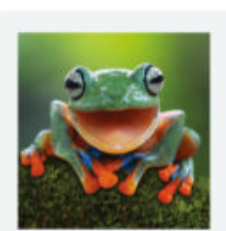
See if you can find all six changes between the images below



## Answers Find the solutions to last issue's puzzle pages

- Q1 ANTARCTICA
- Q2 ACID
- Q3 EARS
- Q4 26,000 YEARS
- Q5 PUMICE
- Q6 5,200 CELSIUS\*

\*NONE OF THE FOUR CHOICES FOR Q6 WERE CORRECT LAST ISSUE



**What is it?**  
FROG

Spot the difference



## QUICKFIRE QUESTIONS

**Q1** What length can a reticulated python grow to?

- 65 centimetres
- 225 centimetres
- 6.5 metres
- 65 metres

**Q2** How old is the oldest land animal, Jonathan the tortoise?

- 131
- 191
- 201
- 231

**Q3** What is the process by which tadpoles turn into frogs?

- Transformation
- Conversion
- Mutation
- Metamorphosis

**Q4** What substance does mosquito saliva contain?

- Antihistamine
- Anticoagulant
- Antibody
- Antidepressant

**Q5** The most massive known black hole has the equivalent mass of how many Suns?

- 33
- 33,000
- 33 million
- 33 billion

**Q6** What weird substance was used to build China's Great Wall?

- Sticky rice
- Superglue
- Sugar water
- Soap

# HOW TO...

Practical projects to try at home

## KIT LIST

A cup of whole milk

A lemon

A pinch of salt

Fine mesh strainer

Saucepan

Two bowls

## TURN MILK INTO CHEESE

By manipulating milk, you can carry out the early stages of cheese-making in your own kitchen

### 1 PREPARE THE INGREDIENTS

Measure out your ingredients before you start to make the process smoother. The lemon juice can be substituted for vinegar if necessary.



### 2 POUR YOUR MILK

Place your saucepan onto a medium heat before pouring in your milk. Boiling milk will kill the bacteria and stop the cheese curd from properly fermenting.



### 3 KEEP CONTROLLED HEAT

Watch the milk as it heats up and keep stirring it. It should begin to gently foam and steam at the right temperature.



### 4 SQUEEZE A LEMON

Cut and squeeze the lemon until you have two tablespoons of juice, which is 1/8 cup. Make sure to keep the seeds out.



### 5 MIX IT IN

Pour the lemon juice into the warm milk and slowly mix the saucepan's contents.



### 6 WATCH IT SEPARATE

Soon after mixing, the contents should look like this, with the lumpy solids dispersed in a thin liquid.



**DON'T  
 DO IT  
 ALONE!**

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



**7 STRAIN AND COLLECT**

Place a strainer over one of the bowls and carefully pour the contents into it. The solid parts should get caught in the strainer while the liquid collects in the bowl.



**8 READY TO SERVE**

The solid content is the cheese. Place this in a bowl, ready to serve. You can add honey or fruit to accompany it, and a sprinkle of salt will help preserve it and dry it out.



**SUMMARY**

No matter which animal your milk comes from, it's mostly made up of water. Mixed into the water there are proteins, fat and a sugar called lactose. To turn milk into cheese, you need to separate the solid parts, called curds, from the liquid, called whey. The curds are made up of proteins called casein, which solidify around the fat. When poured straight from the bottle, the casein in milk is naturally negatively charged, so the molecules repel each other and are evenly distributed. But when you add lemon juice, which has a low pH and is therefore acidic, it changes the charge and shape of casein. As the long casein strings clump together, or coagulate, they trap other solid contents in their net and form large solids – the curds. This is cheese in its first form, before it has been pressed, salted and left to age.

**Had a go? Let us know!**

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

**DISCLAIMER**

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





Continuing to eat after you are full can cause bloating

## FULL OR BLOATED?

Dear HIW,

What does being bloated feel like, and how is it different to just being really full of food?

**Reece Perry**

**Bloating is caused when the intestines and stomach are filled with excess gas. This makes your abdomen feel full and tight. You can feel bloated for more than a few hours. It can be caused by eating too quickly, hormone levels, slow gut movement, reactions to foods or a gut microbiome imbalance. In contrast, feeling full only lasts for a couple of hours. It is caused by nerve receptors in the stomach signalling to the brain that you have eaten enough and your stomach is full. Feeling full is less uncomfortable and doesn't last as long.**

## SEAL SAFETY

Dear HIW,

I saw a single seal come out of the sea onto a busy beach. If it is by itself does that mean it has lost its family or is in trouble?

**Tasha Halliwell**

**This is a common misconception when a seal is spotted by itself. Most of the time it is simply an independent seal. If the seal is moving around freely, it is likely to just be on shore to rest. It is also common to see seal pups alone, as their mothers leave them while they hunt for food. However, if a stranded seal is sneezing, coughing or struggling to move, you should contact a local wildlife group.**



You should stay away from lone seal pups or their mother may not return to feed them



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

### Editorial

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. Joanna Elphick, Peter Ray Allison, Sharmila Kuthunur, Sascha Pare, Stephanie Pappas, Jennifer Nalewicki, Ben Turner, Andrew May, Kristina Killgrove, Harry Baker, Adrian Mann, Ed Crooks, Nicholas Forder

### Cover images

Alamy; Getty; Shutterstock

### Photography

Alamy, Getty Images, NASA, Shutterstock, Wikimedia  
All copyrights and trademarks are recognised and respected

### Advertising

Media packs are available on request  
Graduate Sales Executive **Sophie Dickinson**  
[sophie.dickinson@futurenet.com](mailto:sophie.dickinson@futurenet.com)

Advertising Sales Director **Lara Jaggon**

[lara.jaggon@futurenet.com](mailto:lara.jaggon@futurenet.com)  
07515 961911

### International Licensing

How It Works is available for licensing and syndication. To find out more, contact us at [licensing@futurenet.com](mailto:licensing@futurenet.com) or view our available content at [www.futurecontenthub.com](http://www.futurecontenthub.com).  
Head of Print Licensing **Rachel Shaw**

### Subscriptions

Enquiries [help@magazinesdirect.com](mailto:help@magazinesdirect.com)  
UK orderline & enquiries **0330 333 1113**  
Overseas order line & enquiries **+44 (0)330 333 1113**  
Online orders & enquiries [www.magazinesdirect.com](http://www.magazinesdirect.com)  
Consumer Revenues Director **Sharon Todd**

**Back issues:** If you are an active subscriber, you have instant access to back issues through your iOS or Android device/s. You will only be able to access the digital back issues while your subscription remains active. To purchase single back issues (print only) visit: [magazinesdirect.com](http://magazinesdirect.com) and click on the 'Single issues' tab, or email: [help@magazinesdirect.com](mailto:help@magazinesdirect.com)  
[magazinesdirect.com](http://magazinesdirect.com) is owned and operated by Future Publishing Limited.

### Circulation

Head of Newstrade **Ben Oakden**

### Production

Head of Production **Mark Constance**  
Production Project Manager **Clare Scott**  
Senior Advertising Production Manager **Joanne Crosby**  
Digital Editions Controller **Jason Hudson**  
Production Coordinator **Stephen Turner**

### Management

Managing Director **Dave Clutterbuck**  
Commercial Finance Director **Tom Swayne**  
Head of Art & Design **Greg Whitaker**  
SVP Lifestyle, Knowledge and News **Kevin Addley**

**Printed by** William Gibbons & Sons Limited  
26 Planetary Road, Willenhall, Wolverhampton,  
West Midlands, WV13 3XB

**Distributed by** Marketforce, 5 Churchill Place,  
Canary Wharf, London, E14 5HU  
[www.marketforce.co.uk](http://www.marketforce.co.uk)

ISSN 2041-7322

All contents © 2024 Future Publishing Limited or published under licence. All rights reserved. No part of this magazine may be used, stored, transmitted or reproduced in any way without the prior written permission of the publisher. Future Publishing Limited (company number 2008885) is registered in England and Wales. Registered office: Quay House, The Ambury, Bath, BA1 1UA. All information contained in this publication is for information only and is, as far as we are aware, correct at the time of going to press. Future cannot accept any responsibility for errors or inaccuracies in such information. You are advised to contact manufacturers and retailers directly with regard to the price of products/services referred to in this publication. Apps and websites mentioned in this publication are not under our control. We are not responsible for their contents or any other changes or updates to them. This magazine is fully independent and not affiliated in any way with the companies mentioned herein.

If you submit material to us, you warrant that you own the material and/or have the necessary rights/permissions to supply the material and you automatically grant Future and its licensees a licence to publish your submission in whole or in part in any/all issues and/or editions of publications, in any format published worldwide and on associated websites, social media channels and associated products. Any material you submit is sent at your own risk and, although every care is taken, neither Future nor its employees, agents, subcontractors or licensees shall be liable for loss or damage. We assume all unsolicited material is for publication unless otherwise stated, and reserve the right to edit, amend, adapt all submissions.

We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards.

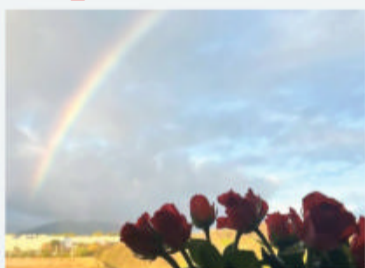


Future plc is a public company quoted on the London Stock Exchange (symbol: FUTR)  
[www.futureplc.com](http://www.futureplc.com)  
Chief Executive Officer **Jon Steinberg**  
Non-Executive Chairman **Richard Huntingford**  
Chief Financial and Strategy Officer **Penny Ladkin-Brand**  
Tel +44 (0)1225 442 244

## WE ASKED YOU

## This month on social media, we asked you to send in your best rainbow photographs

@AMIRAHRAHMAN.\_



© Amirah Rahman

### PHOTOGRAPHS FROM PORTOBELLO BEACH AND ARTHUR'S SEAT, EDINBURGH, SCOTLAND



© Zanjibee1qbal

### DISAPPEARING INTO THE HILL



© aesthetically\_aj

### I SAW THIS RAINBOW CLOUD IN THE WINTER. WHAT HAS CAUSED THE RAINBOW TO FORM JUST IN THIS CLOUD?

This is a nacreous cloud – a rare sight that usually forms in polar regions. The ice particles within the cloud have scattered the sunlight into a rainbow.



© doodlenews

## NEXT ISSUE

## ISSUE 191 ON SALE 6 JUNE 2024

Available in print from all good newsagents and [magazinesdirect.com](http://magazinesdirect.com), or as a digital edition for iOS and Android. To enjoy savings on the RRP and to make sure you never miss an issue, check out our subscription offers on pages 24 (UK) and 83 (US).

© Getty

# FAST FACTS

Amazing trivia that will blow your mind

VENUS SPINS IN THE OPPOSITE DIRECTION TO THE OTHER PLANETS



# BOOKS

# 50

Several dozen people could stand on the tongue of a blue whale



# 1992

The first text message, sent over 30 years ago, said 'Merry Christmas'

The first hard disk drive with over one gigabyte capacity was the size of a large fridge



Hedgehogs have a top speed of five miles per hour – that's two miles an hour faster than the average human



Paper can be recycled quite a few times

**A single glass bottle can take a million years to decompose**

# 9,000

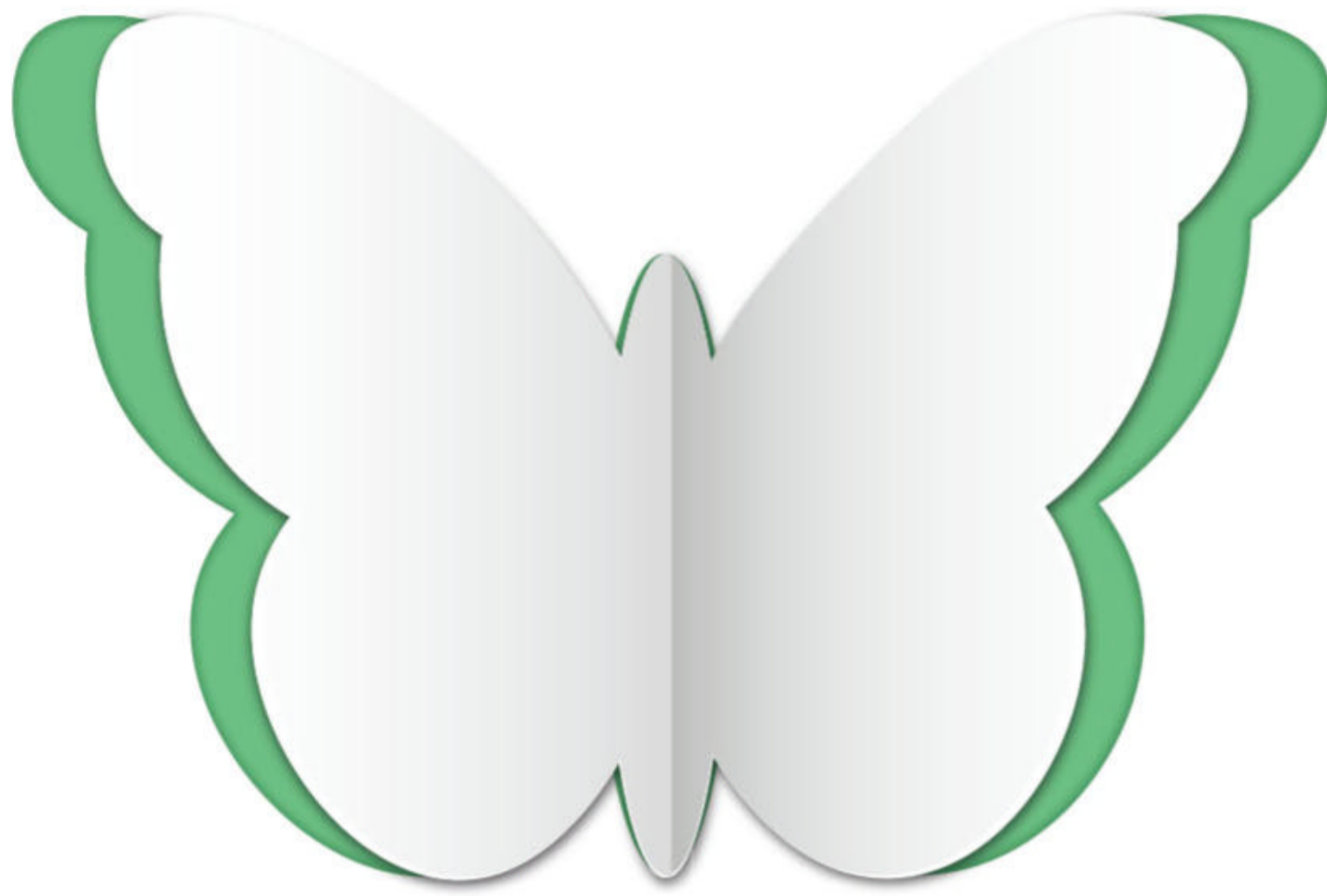
Beijing's Forbidden City palace complex has more rooms than largest hotel in the world

# 1.428 BILLION

India is the most populous country in the world

IN 1975, QUEEN ELIZABETH II FIRED THE ENTIRE AUSTRALIAN PARLIAMENT





# PAPER & BIODIVERSITY

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

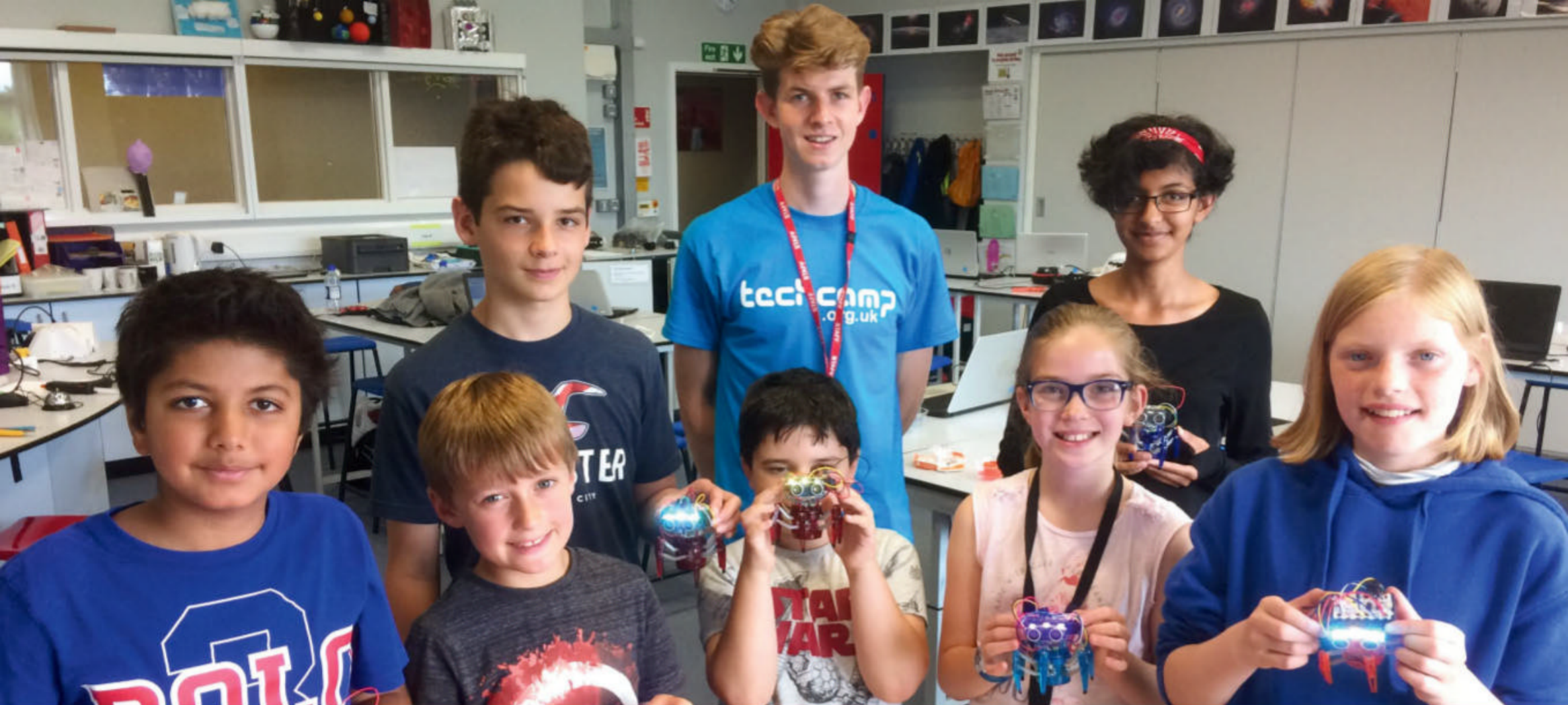
Source: FAO and UNEP, The State of World's Forests, 2020



Discover the story of paper  
[www.lovepaper.org](http://www.lovepaper.org)

Scan for paper facts, activities,  
blogs and much more!





# REAL ENGINEERING FOR KIDS

techcamp  
.org.uk

- The UK's original Tech Camp® for ages 9-17
- Week-long residential & non-residential camps
- Learn coding with real engineering projects
- Trusted for over 15 years

Bookings Now  
Open for 2024

Build your  
Own...

- 3D GAMES
- 3D PRINTERS
- HIGH-SPEED CARS
- DRONES
- ROBOTS
- PYTHON AI COMPUTERS



Reserve Today

[www.techcamp.org.uk](http://www.techcamp.org.uk)  
+44 (0) 118 380 5678

Use Code **HIW24** for £50 Off