MEET THE REAL-LIFE IRONMAN

HOW IT WORKS

FEATURING LIVESCIENCE

THE MAGAZINE THAT FEEDS MINDS

FAKE MEAT
HOW DO THEY MAKE IT?

WIN SPORTS EARBUDS WORTH £199.99

WHAT MAKES A PERSON INTELLIGENT?

DO WE NEED ALL OF OUR BRAIN?

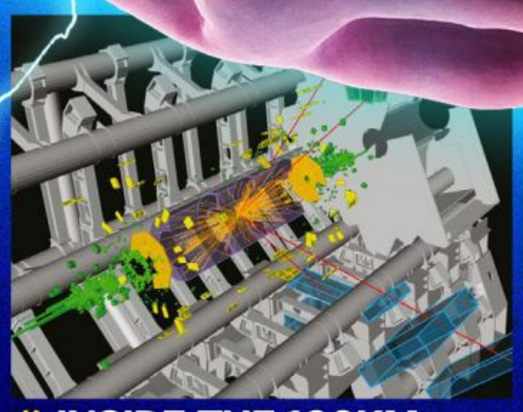
WHAT ARE EMOTIONS FOR?

YOUR BRAIN POWER

20 things you need to know about the human body's computer

HOW DO WE STORE MEMORIES?

SECRETS OF APOLLO 11
What NASA never told you about the Moon landings



INSIDE THE 100KM LONG ATOM SMASHER

WHY WE ENJOY ROLLERCOASTERS

HITLER'S WEIRD WWII WEAPONS

+ HOW WE TASTE THE WILDEST PLACES ON EARTH WHEN GALAXIES COLLIDE

FUTURE
ISSUE 127

ISSUE 127

WELCOME

The magazine that feeds minds!

"The brain is up to 30 times faster than IBM's Sequoia supercomputer"

Your brain power, page 22

Meet the team...

James
Production Editor
It's crazy what the military will dream up to get the upper hand in war. See what weird weapons the Nazis invented on page 62.

Scott
Staff Writer
Discover the world's most poisonous plants and how some leafy species lure their prey into a false sense of safety, on page 38.

Baljeet
Research Editor
On page 32 we look at the FCC, the giant successor to the Large Hadron Collider that will probe the mysteries of the universe.

Duncan
Senior Art Editor
As a fan of Marvel superheroes, I was really pleased to see Richard Browning's 'Iron Man' suit in this issue. Check it out on page 72.

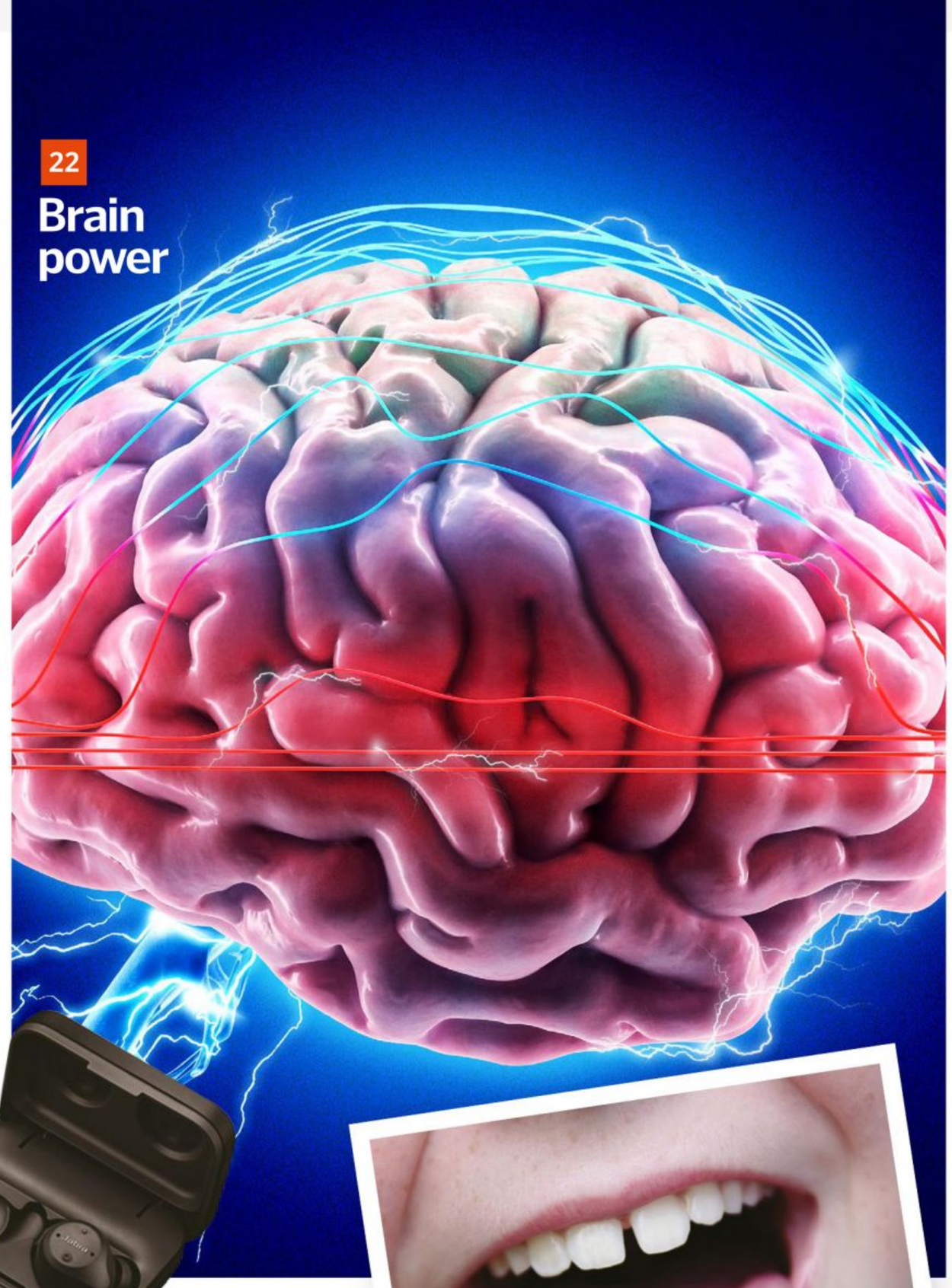
There's a famous 1938 quote by physicist Emerson M. Pugh: "If the human brain were so simple that we could understand it, we would be so simple that we couldn't." If that holds true, then it's an interesting paradox, although we are so far from truly understanding our brains that right now, it doesn't really matter whether we can or not. We have made leaps and bounds since the last century, however, in knowing how that 1.4 kilogram grey mass that we carry around in our skulls makes us who we are. In this issue of **How It Works**, we probe the most curious aspects of your brain and how your mind works, with mind-blowing answers to some questions that, in Emerson Pugh's time, scientists would have struggled to even begin to answer. So turn over to page 22 to discover more.

Ben Biggs Editor

FOLLOW US...

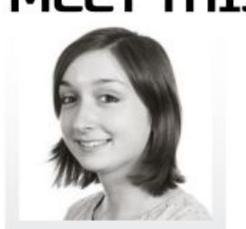
How It Works magazine @HowItWorksmag

CONTENTS



MEET THIS ISSUE'S EXPERTS...

James Horton
Former **HIW** member James is a biochemist and biotechnologist. He is currently doing a PhD in machine learning and evolutionary theory.



Jo Stass
Writer and editor Jo is particularly interested in the natural world and learning about the latest in technological innovations.

Jodie Tyley
The former editor of **HIW** and **All About History** has tackled many topics in her career, from science fiction to science fact, and Henry VIII to honey badgers.

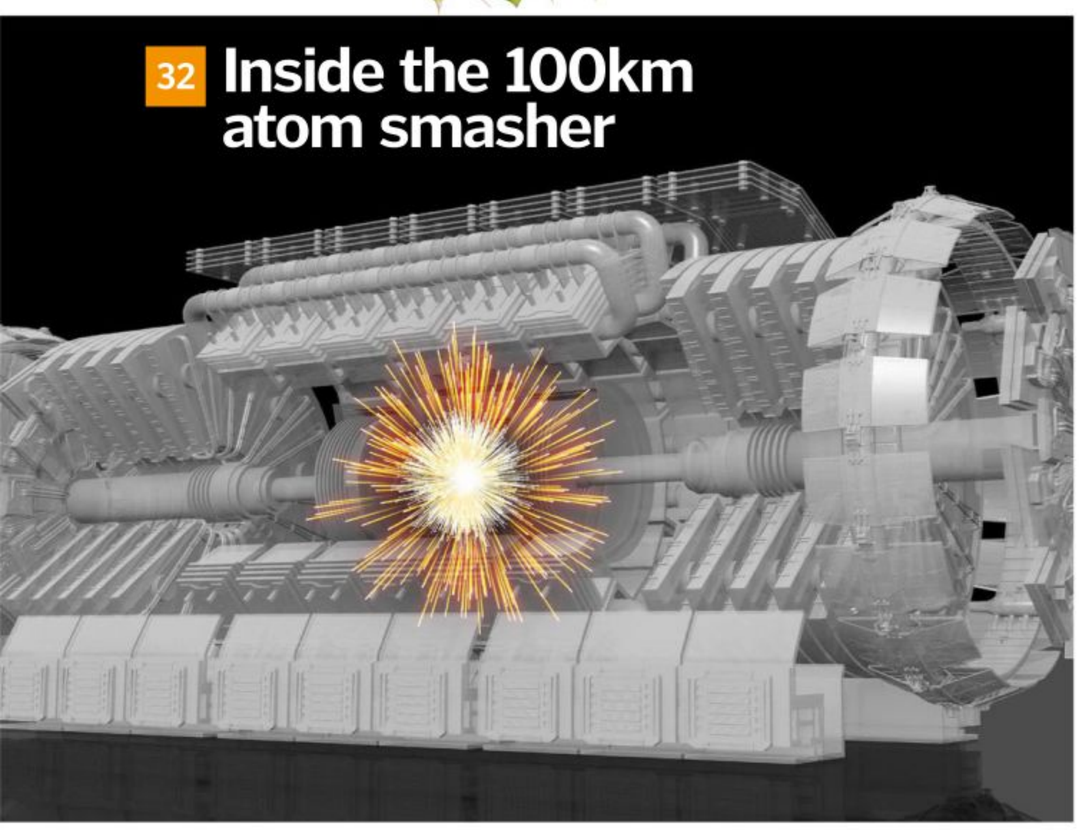
Laura Mears
Biomedical scientist Laura escaped the lab to write about science and is now working towards her PhD in computational evolution.

Stephen Ashby
Stephen is a writer and editor with video games and computer tech expertise. He is endlessly intrigued by Earth science.

Steve Wright
Steve has worked as an editor on many publications. He particularly enjoys history feature writing and regularly writes literature and film reviews.

Tom Garner
History Of War's features editor has interviewed many war veterans and has lectured across the UK on a number of historical topics.

Tom Lean
Tom is a historian of science at the British Library, working on oral history projects. His first book, *Electronic Dreams*, was published in 2016.



REGULARS

Victoria Williams
Evolutionary biologist and science writer Vicky is fascinated by the natural world and is happiest when she's in the outdoors.

Charles Ginger
Charlie has a passion for history and history writing, with a particular interest in the 19th century and the Industrial era.

Dr Andrew May
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and has written several books.

Jack Parsons
A self-confessed technophile, Jack has a keen interest in gadgets and wearable tech, but loves to write about projects with much grander ambitions.

Jonny O'Callaghan
With a background in astrophysics and a love of the mysteries of the cosmos, Jonathan enjoys delving into the wonders of space.

Sun dogs rise at dawn

Pictured here on a cold February morning in North Dakota, US, is pair of equally bright 'sun dogs' that flank the Sun as it rises. This rare optical phenomenon is known in meteorological terms as a perihelion, and happens when sunlight is refracted by ice crystals high in the atmosphere. They can also appear as iridescent and less defined patches in the same place either side of the Sun. Sun dogs are a type of halo and in this example, you can see the arc of the halo passing through each one as a vertical pillar and horizontal line passing through the Sun itself.

A mosquito's scaly foot

Under the close scrutiny of a scanning electron micrograph, this mosquito's leg resembles more a Lovecraftian tentacle nightmare than the tiny tip of an insect appendage. What we can see here is the claw (in red), pad and adhesive hairs surrounded by scales. These scales also cover the rest of the mosquito and are thought to both offer the insect some protection and help support its limbs on water. The image was an entry for The Royal Photographic Society's new Science Photographer of the Year 2018. To enter this year's competition head to **science.rps.org.**

Suitable for Mars?

Inside NASA's HQ in Washington, US, a Jet Propulsion Laboratory technician examines five samples of spacesuit material. This material will have the honour of being flown to the Red Planet as a part of the Mars 2020 mission. The reason for sending five little pieces of material, however hi-tech they are? To see how each one will fare in the extreme conditions of a Mars environment, with its very thin atmosphere, extreme temperatures and enormous dust storms. With this data, NASA can make better suits for a manned mission to Mars at some point in the future.

GLOBAL EYE

Showcasing the incredible world we live in

IN ASSOCIATION WITH

LIVESCIENCE

With over 14 million global monthly users, **Live Science** makes every day a little more interesting by illuminating the fascinating world around us. For the science geek in everyone, **Live Science** breaks down the stories behind the most interesting news and photos on the internet.

© Getty

HEALTH

Human population growth may halt by 2100

Words by **Yasemin Saplakoglu**

Global population growth will nearly grind to a stop by the end of the century, a new analysis by the Pew Research Center suggests. Right now, the world's population is over 7.7 billion people, and it has been growing between one and two per cent every year since 1950, according to the Pew Research Center. By 2100, the centre projects the population will reach around 10.9 billion people and grow by less than 0.1 per cent a year. This is mostly due to a decreasing number of children born worldwide, based on data from the United Nation's report *World Population Prospects 2019*. The U.N. report found that global fertility rates will be less than the "replacement fertility rate," or the number of births per woman that would keep the population the same size, replacing people as they die. The current replacement fertility rate is 2.1 births per woman, which is less than the current global fertility rate of 2.5 births per woman. By 2100, the global fertility rate is expected to dip to 1.9 births per woman. What's more, the U.N. report found that the global median age to which people live will increase from 31 to 42 by 2100. Between 2020 and 2100, people of 80 and over will increase from the current 146 million to 881 million. Latin America and the Caribbean will have the oldest people in the world by 2100. Only Africa is expected to have a strong population growth by the end of the century, increasing from 1.3 billion people in 2020 to 4.3 billion people in 2100. Meanwhile, Europe's population is expected to peak in 2021, and both Europe and Latin America will have declining populations by 2100. Asia will increase in population until 2055, then decline and Northern America's population will continue to increase, mostly because of migration to the area, according to the report.

ANIMALS

An eye for manipulation

Words by **Brandon Specktor**

About 30,000 years ago, a wolf decided to give up the wild life, commit to a steady relationship and become the first dog. Today, dogs and humans are the undisputed best friends of the animal kingdom. According to a new study, that camaraderie may have been propelled by some serious emotional manipulation. In a study published in June, in the journal *Proceedings of the National Academy of Sciences*, researchers looked at the evolution of 'puppy-dog eyes' – the signature, eyebrows-raised look of sadness that any dog can employ to escape virtually any consequence – and found that the expression finds its source in a powerful eye muscle that seems to have evolved specifically to mimic human emotions. In a small survey of dogs and wolves, the researchers found that the muscle is 'uniformly present' in modern dogs, but conspicuously absent in their wild cousins. The ability to make this 'hangdog' expression, which closely resembles the look of confused sadness oft worn by human babies, "may trigger a nurturing response" in humans who behold it, the authors wrote, and could therefore be a evolutionary advantage to dogs.

"We hypothesise that dogs' expressive eyebrows are the result of selection based on humans' preferences," the researchers wrote in the study. "In only 33,000 years, domestication transformed the facial muscle anatomy of dogs specifically for facial communication with humans." To reach these conclusions, the authors examined the eye muscles in six dead dogs and four dead wolves of varying breeds. They found that five of the six dogs had thick muscles capable of lifting their eyebrows intensely. The wild wolves, meanwhile, were either missing that eyebrow-lifting muscle entirely or had a thinner, stringier version of it. The researchers coupled these anatomical studies with a behavioural analysis, in which 27 shelter dogs and nine wild wolves were filmed up close by a human with whom they were unfamiliar for two minutes. The researchers recorded how often the animals raised their eyebrows during the interaction and, unsurprisingly, found that the dogs made puppy-dog eyes about five times more often than the wolves did. The dogs also raised their eyebrows significantly higher than their wild cousins.

The persuasive power of 'puppy-dog eyes' is real, everyone

LIVESCIENCE

TECH

Is the Doomsday Plane a nuclear bunker?

Words by **Yasemin Saplakoglu**

The US Air Force's E-4B, otherwise known as the 'Doomsday Plane' may be able to withstand the force of a nuclear detonation. This mostly windowless Boeing 747 was designed during the Cold War, and it indeed looks like a blast from the past, according to CNBC's Amanda Macias who recently got an inside look at the plane. The craft is equipped with older analogue flight instruments, rather than modern digital technology. The analogue equipment is less likely to be fried by the electromagnetic pulse released after a nuclear blast, they reported. It also has shielding to protect its crew from nuclear and thermal effects during a nuclear war. With its giant fuel tanks and ability to refuel in the air from other aircraft, the Doomsday Plane can stay airborne for several days. It holds 67 satellite dishes and antennae, meaning its crew can communicate with anyone, anywhere in the world, even sending messages to the Navy's ballistic missile submarines, according to *DefenseNews*. That being said, most of its capabilities are classified, according to CNBC. The Air Force has four of these E-4B aircraft, each standing at nearly six stories tall. Sporting 18 bunks, six bathrooms, a galley and a briefing room, among other rooms, each can fly 112 crew members. Currently, one is being used by Acting United States Defense Secretary, Patrick Shanahan, to travel to various parts of the world.

The Doomsday Plane can refuel in flight

©Getty

An illustration showing the probe's approach to Psyche

© NASA/JPL-Caltech/Arizona State Univ./Space Systems Loral/Peter Rubin

SPACE

NASA to explore corpse of an ancient planet

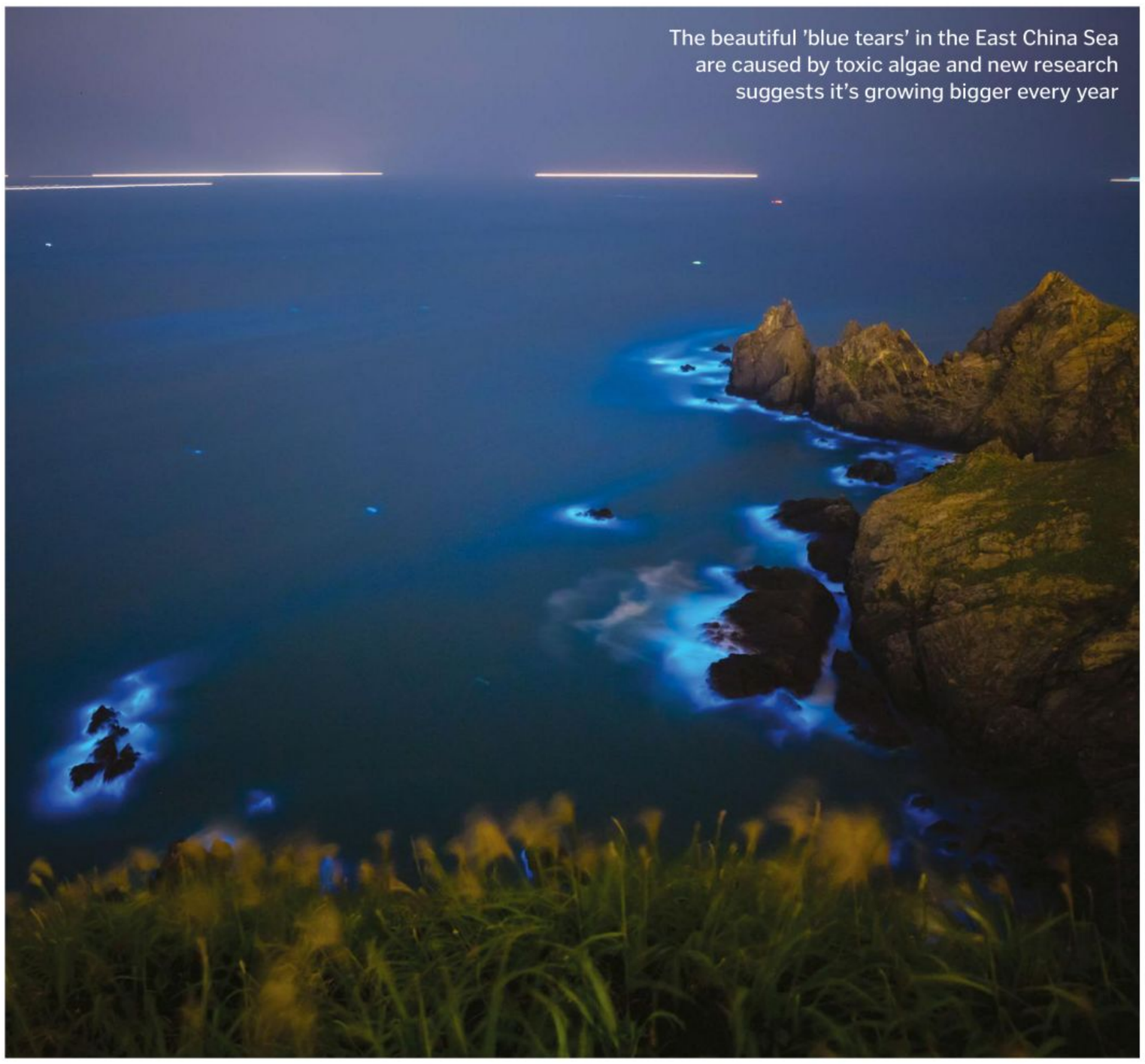
Words by **Rafi Letzter**

On 31 January 2026, a NASA spacecraft should arrive in the neighbourhood of Psyche, to visit this bizarre space rock that's over 200 kilometres wide. Planetary scientists have long suspected that Psyche, made up almost entirely of iron and nickel, might be the exposed core of a long-dead protoplanet from the early days of our Solar System. Psyche has a mass of about 22 billion billion kilograms, making it 0.03 per cent the mass of our Moon. It's is by far the largest known object of its nearly pure metallic type orbiting our Sun. The Psyche probe should orbit the metallic object for a couple weeks, collecting data about its age and how it formed. During this final design phase, engineers will draw up plans and build many of the parts that will make up the final spacecraft. If everything goes according to plan, the mission should launch in August 2022, swing by Mars in 2023 and approach Psyche three years later.

PLANET EARTH

China's glowing 'blue tears' are incredibly toxic

Words by **Isobel Whitcomb**



The beautiful 'blue tears' in the East China Sea are caused by toxic algae and new research suggests it's growing bigger every year

© Getty

The waters surrounding Taiwan's Matsu Islands cast an eerie blue glow, on summer nights. The phenomenon, known as China's 'blue tears', is actually caused by a bloom of tiny, bioluminescent creatures called dinoflagellates. The bloom in the East China Sea may be beautiful, but it's also toxic. And it's growing bigger every year, a recent study finds. "People think this is romantic and beautiful to watch at night," Chanmin Hu, oceanographer and study co-author, told **Live Science**, "It's toxic."

Researchers used satellite data to track the size of the bloom over time. By analysing nearly a thousand satellite images from the past 19 years, the researchers were able to identify a signature unique to 'blue tears'. They found that the bloom, which is typically seen near shore, is extending its reach into deeper waters. That's a problem for marine creatures. The 'blue tears' phenomenon can poison sea life, from fish to sea turtles. The dinoflagellates actually aren't toxic themselves — until they begin chowing-down. Toxic algae is their food of choice, and as they eat, they release ammonia and other chemicals that poison the water around them. Not only that, but these creatures breathe oxygen until there's none left in the surrounding waters. The cause of 'blue tears' isn't certain, but Hu and his colleagues think pollution from agriculture that funnels down the Yangtze River plays a major role. Hu and his colleagues don't expect the bloom to stop growing anytime soon. That means that while the waters will glow more brilliantly, it will continue to pose a threat to marine life.

© NASA/JPL/University of Arizona

NASA's Mars Reconnaissance Orbiter spotted a feature on Mars that looks like the famous *Star Trek* logo

SPACE

'Star Trek' logo spotted on Mars

Words by **Elizabeth Howell**

There's a curious shape on the Martian landscape that bears an incredible resemblance to the iconic *Star Trek* Starfleet logo. The picture was taken recently by the Mars Reconnaissance Orbiter (MRO). Just like the famous 'face on Mars', this Starfleet logo was produced by random chance, as wind, lava and other forces sculpted the Martian landscape. The dune feature is located in Hellas Planitia, a large plain within the Hellas impact basin, in the southern hemisphere of Mars. An interaction of dunes, lava and wind formed the chevron shape visible in the picture, according to a statement. MRO has photographed many other chevrons on Mars, so we're guessing this is not the first time it spotted one shaped like a *Star Trek* logo. While the *Star Trek* feature is a coincidence, we can truly say that MRO has "lived long and prospered" at the Red Planet.

IN ASSOCIATION WITH LIVESCIENCE

'Flesh-eating' bacteria has been responsible for five recent cases of life-threatening infections

HEALTH

'Flesh-eating' bacteria washes up in the US

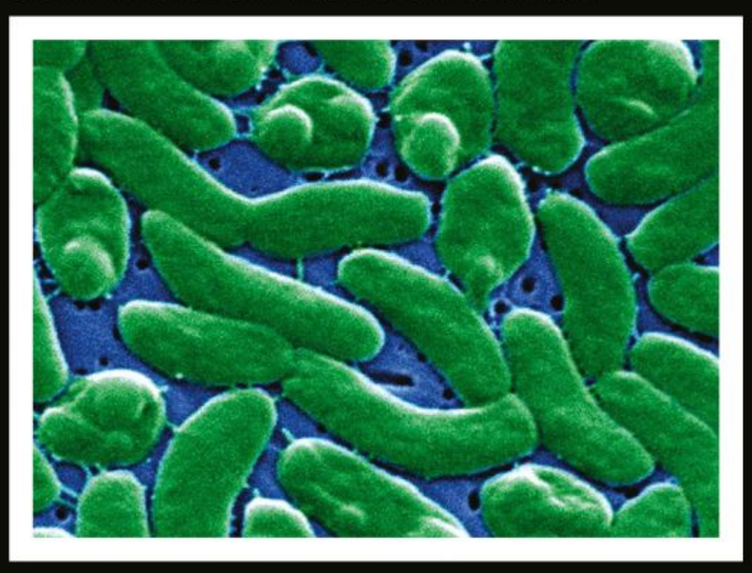
Words by **Rachael Rettner**

Thanks to climate change, 'flesh-eating' bacteria that live in the ocean may be spreading to previously unaffected beach waters, according to a new report. The report authors described five cases of severe flesh-eating bacterial infections in people who were exposed to water or seafood from the Delaware Bay, which sits between Delaware and New Jersey, US. Such infections have historically been rare in the Delaware Bay, as the bacterium responsible for the disease, called *Vibrio vulnificus*, prefers warmer waters, such as those in the Gulf of Mexico. But with rising ocean temperatures, V. vulnificus appears to be moving farther north.

V. vulnificus lives in ocean waters that are above 18 degrees Celsius. People can become infected with the bacteria in two ways: if they consume contaminated seafood, or if they have an open wound that comes into direct contact with seawater containing the bacteria. Although most people infected with V. vulnificus will develop only mild symptoms, some people develop life-threatening skin or bloodstream infections.

V. vulnificus can cause necrotising fasciitis, a rare 'flesh-eating' infection that rapidly destroys skin and muscle tissue. This can result in amputations or even death. The authors noted that from 2008 to 2016, their hospital saw just one case of V. vulnificus infection. But in the summers of 2017 and 2018, that number jumped to five cases. All of these patients had either gone crabbing in the Delaware Bay or consumed seafood from the area, and all of them developed necrotising fasciitis. One patient died. Necrotising fasciitis infections with V. vulnificus usually don't occur in people with healthy immune systems, according to the Centers for Disease Control and Prevention. People are at increased risk of V. vulnificus infections if they have chronic liver disease or other conditions that weaken their immune systems.

The bacteria that's being blamed, Vibro vulnificus, shown under a scanning electron micrograph



"With rising ocean temperatures, Vibro vulnificus appears to be moving farther north"

PLANET EARTH

Arctic permafrost is in premature meltdown

Words by **Grant Currin**

Layers of permafrost in the Canadian Arctic, that scientists expected to remain frozen for at least 70 years, have already begun thawing. The once-frozen surface is now sinking and dotted with melt ponds and from above looks a bit like Swiss cheese, satellite images reveal. "We were astounded that this system responded so quickly to the higher air temperatures," said Louise Farquharson, a co-author of the study and postdoctoral fellow at the Permafrost Laboratory at the University of Alaska Fairbanks. Permafrost is ground that remains frozen for at least two years. It underlies about 15 per cent of the unglaciated Northern Hemisphere and serves a critical role in the transfer of carbon from living things to the atmosphere, Farquharson said. It's believed that higher summer temperatures, low levels of insulating vegetation and the presence of ground ice near the surface contributed to the exceptionally rapid and deep thawing. The most striking evidence is visible to the naked eye. As upper layers of permafrost thaw and ice melts, the land settles unevenly, forming what is known as thermokarst topography. Landscapes in the Canadian Arctic that had been defined by gently rolling hills are now pockmarked with ditches and small ponds. The ground at the northern-most study site sank by about 90 centimetres over the course of the study. Their data allowed the researchers to interpret the topographical changes happening before their eyes. "We were able to tie together air temperature and ground temperature with the formation of this thermokarst terrain," Farquharson said. The thawing has climatic implications for the globe and immediate ecological ramifications for the region. Thawing caused by higher air temperatures threatens to exacerbate global climate change. "Permafrost is like a giant freezer that contains a lot of really delicious plant material and organics that aren't being decomposed by microbes," Farquharson said. "Thawing opens the freezer door" and allows the microbes to start converting that organic material into CO_2. In changing the physical makeup of the landscape, thermokarst also affects local ecosystems and waterways by inviting new plant growth, disrupting stable nutrient cycles and allowing for the sedimentation of streams and possibly coastal systems. Farquharson and her team estimate that about 600,000 square kilometres of permafrost, or about 5.5 per cent of the zone that is permafrost year-round, is vulnerable to rapid surface thawing.

Research in the Artic suggests that the permafrost is thawing too quickly

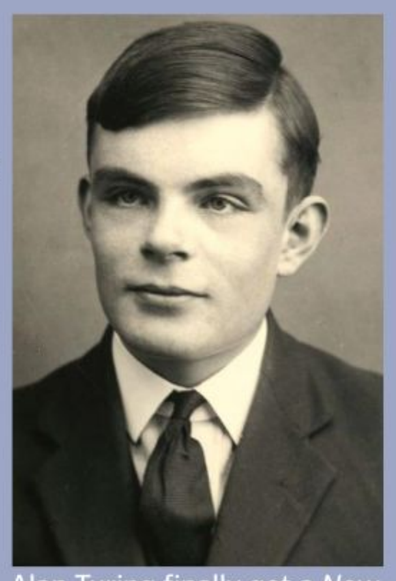
© Getty

HISTORY

Alan Turing finally gets an obituary

Words by **Brandon Specktor**

Alan Turing (1912-1954), the famous WWII code breaker and pioneering computer scientist who was punished in the UK for being gay, has finally received an obituary in *The New York Times* – 65 years after his death. It was published on 5 June as part of the *Times* Overlooked series, which provides belated obituaries for historical figures whose deaths initially were not reported in the newspaper. Today, Turing's signature accomplishments are widely known, thanks in part to the 2014 biopic *The Imitation Game*. His legacy includes overseeing the UK's top-secret efforts to decode messages sent by Nazi Germany's Enigma machine and postwar work on the first functioning British computer. He is most famous, perhaps, for his eponymous 'Turing Test,' a hypothetical evaluation that asked if a computer could pass for a human, which the mathematician proposed in 1950. At the time of Turing's death on 7 June 1954, however, many of his wartime accomplishments remained classified and his successes in thwarting Nazi battle plans remained unknown. His reputation was further smeared in 1952 when Turing revealed he had been in a physical relationship with another man. Turing was charged under Victorian-Era laws with "gross indecency" for his open homosexuality. These events overshadowed Turing's reputation for the remainder of his life (he died of poisoning in an alleged suicide). Only in 2009 did the British government apologise for the way it had treated Turing, and in 2013, he was finally granted a royal pardon by Queen Elizabeth II.



Alan Turing finally got a *New York Times* obituary, 65 years after his death.

© Getty

IN ASSOCIATION WITH
LIVESCIENCE

CULTURE

Tourists flock to Chernobyl following HBO series

Words by **Mindy Weisberger**

Tourists snap photos in the abandoned city of Pripyat, in the Chernobyl exclusion zone

© Shutterstock

Tourism is booming, at the site of what is arguably the most horrific accidental nuclear explosion in history! The success of HBO's dramatic series *Chernobyl* seems to have boosted the region's tourism industry, with leaders of guided tours to Chernobyl claiming that bookings have increased by about 40 per cent compared to last year, Reuters recently reported. HBO debuted the first episode of *Chernobyl* on 6 May. By the end of the month, Ukrainian tour company SoloEast saw a 30 per cent rise in tourists compared to May 2018, and bookings for June, July and August are up by about 40 per cent, company director Sergiy Ivanchuk told Reuters. After the Chernobyl reactor exploded in 1986, radioactive particles quickly dispersed into the surrounding area and approximately 200,000 people were evacuated and relocated. Authorities declared a so-called exclusion zone covering 30 kilometres around the site of the explosion. But in 2010, the exclusion zone was opened to tourists and Ukrainian officials declared that any lingering radiation was "negligible." Ukrainian tour company Chernobyl Tours describes the exclusion zone as "safe for visitors," though it acknowledges that some places in the exclusion zone still have elevated radiation, which could pose some risk. "We definitely would not recommend you staying at them for a long time," their website says. On a Chernobyl Tour, visitors typically see monuments to victims; vacant and overgrown homes; and the reactor that exploded.

Eight individual coffinfish, including this Pink Frogmouth were recorded for the first time holding their 'breath' underwater

© Alamy

ANIMALS

Fish found to hold their breath

Words by **Yasemin Saplakoglu**

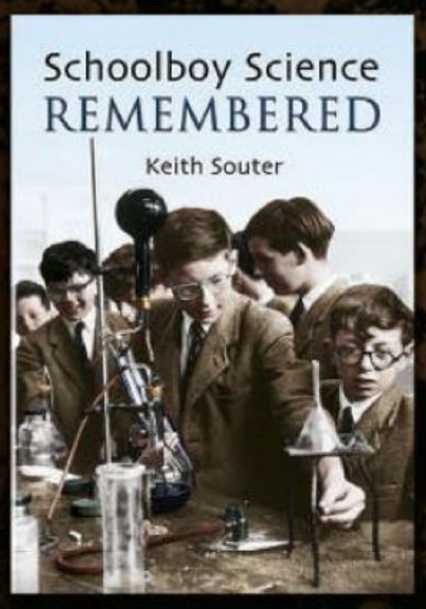
Little wonder that this fish looks like a grumpy, inflated balloon – it's been holding onto a mouthful of water for ages. This odd little creature is known as the coffinfish (*Chaunax endeavouri*), and it lives in the deepest parts of the Pacific Ocean.

Researchers observed this 'breath-holding' behaviour for the first time while combing through publicly available videos captured by the National Oceanic and Atmospheric Administration's (NOAA) remotely operated vehicles, Science reported. The scientists found footage of eight different individual coffinfish holding in the water they had taken in. To get the necessary oxygen to survive, fish gulp down water, extract oxygen and then "exhale" the oxygen-depleted water by releasing it from their gills, *Science* reported. But these fish held onto that water in their large gill chambers for quite a long time, from 26 seconds up to four minutes, rather than releasing it immediately.

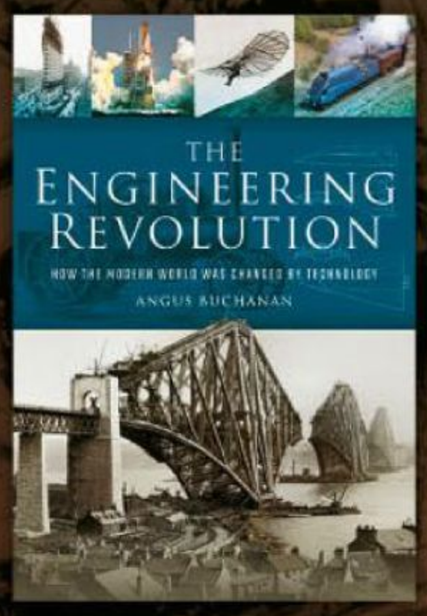
As to why the fish do this, the researchers have some guesses. They said breath-holding may help the fish conserve energy. It could even protect them by making them look bigger to predators, similar to what pufferfish accomplish by pushing out their stomachs. When a coffinfish holds in water, its body volume increases by 30 per cent, according to the study.

PEN & SWORD BOOKS LTD

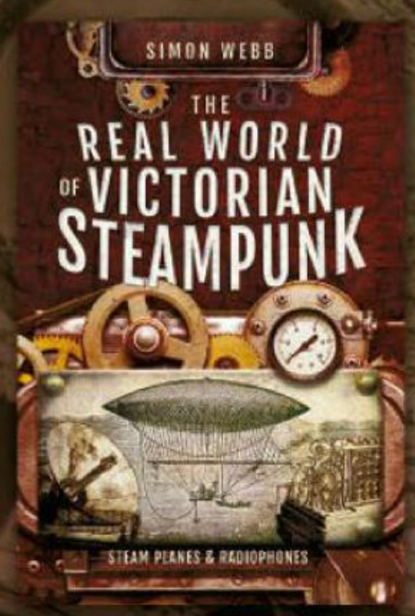
25% DISCOUNT



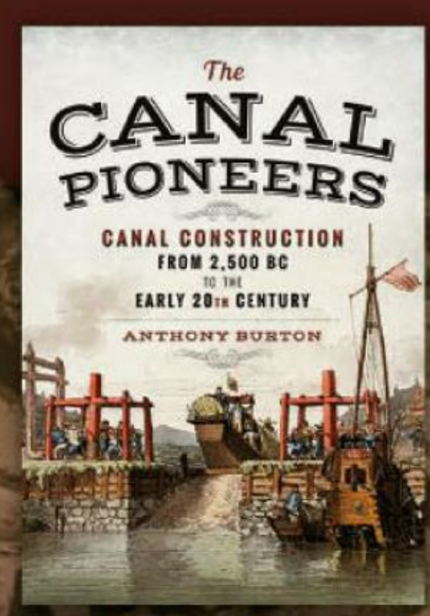
WAS: £14.99
NOW: £11.25
ISBN: 9781844680979



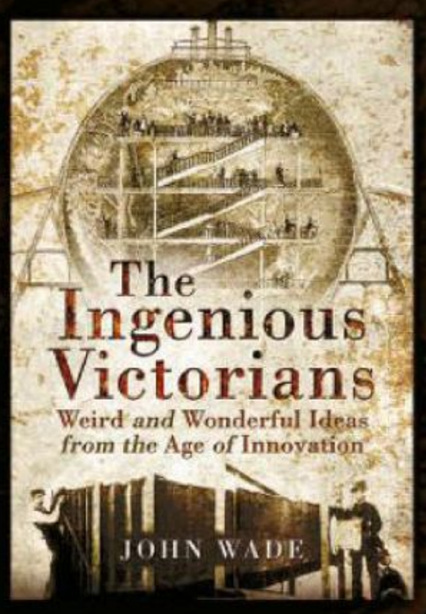
WAS: £25.00
NOW: £18.75
ISBN: 9781473899087



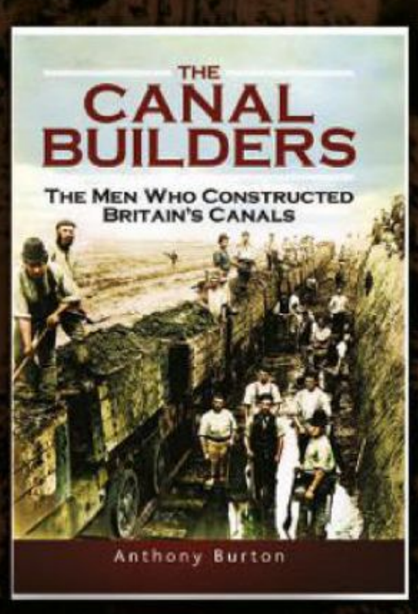
WAS: £12.99
NOW: £9.75
ISBN: 9781526732859



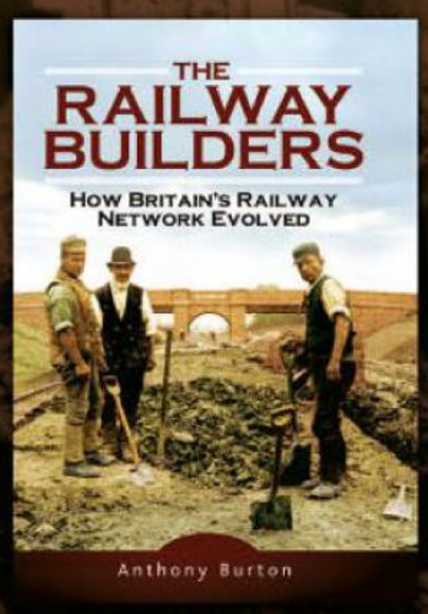
WAS: £25.00
NOW: £18.75
ISBN: 9781473860490



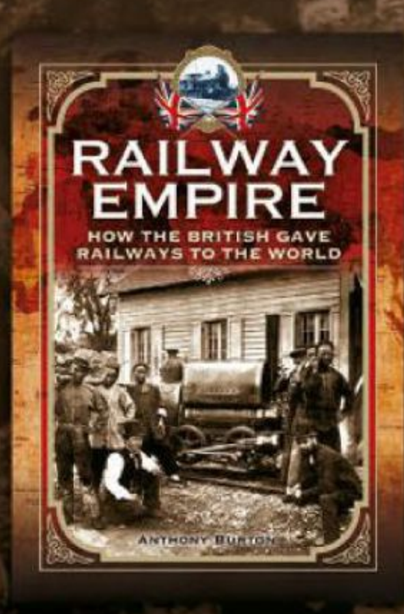
WAS: £14.99
NOW: £11.25
ISBN: 9781473849013



WAS: £19.99
NOW: £14.99
ISBN: 9781473843721



WAS: £19.99
NOW: £14.99
ISBN: 9781473843707



WAS: £25.00
NOW: £18.75
ISBN: 9781473843691

TO ORDER CALL AND QUOTE CODE **HIW127** TO RECEIVE YOUR 25% DISCOUNT:

01226 734222

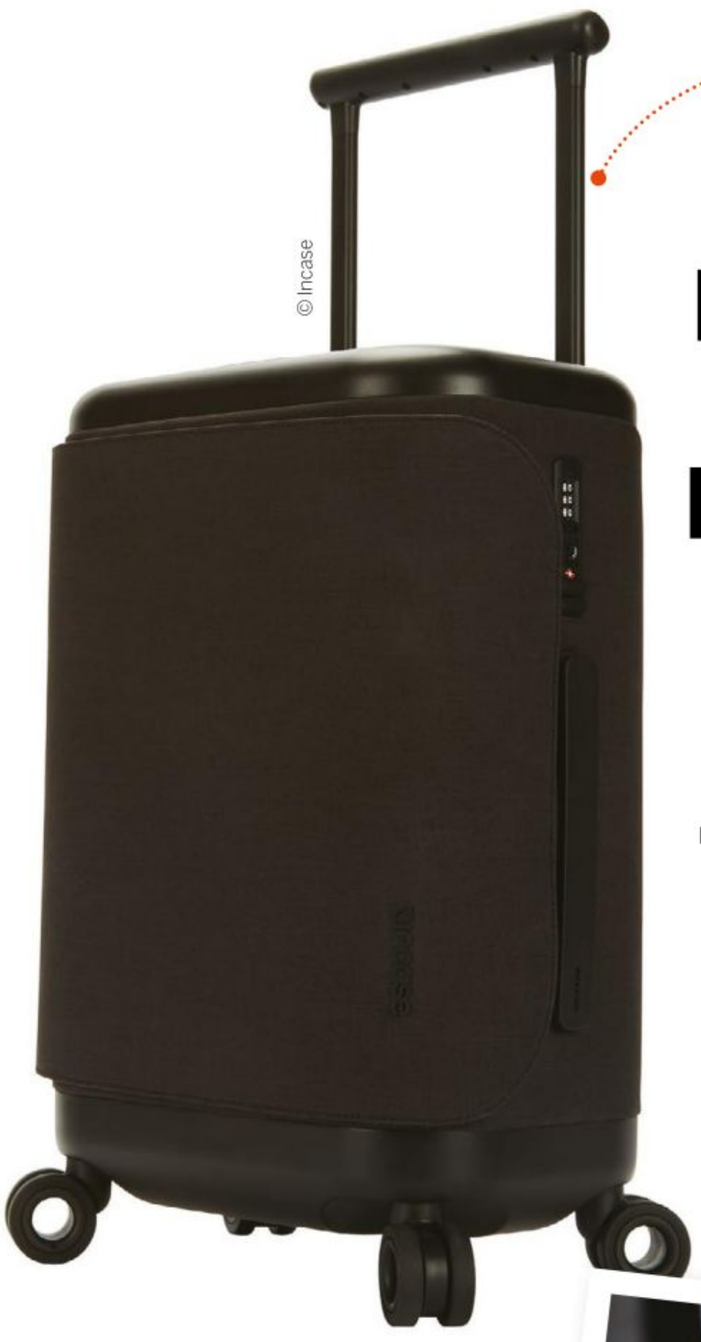
OR ORDER ONLINE

www.pen-and-sword.co.uk

PEN & SWORD BOOKS LTD

WISH LIST

The latest **TRAVEL** tech

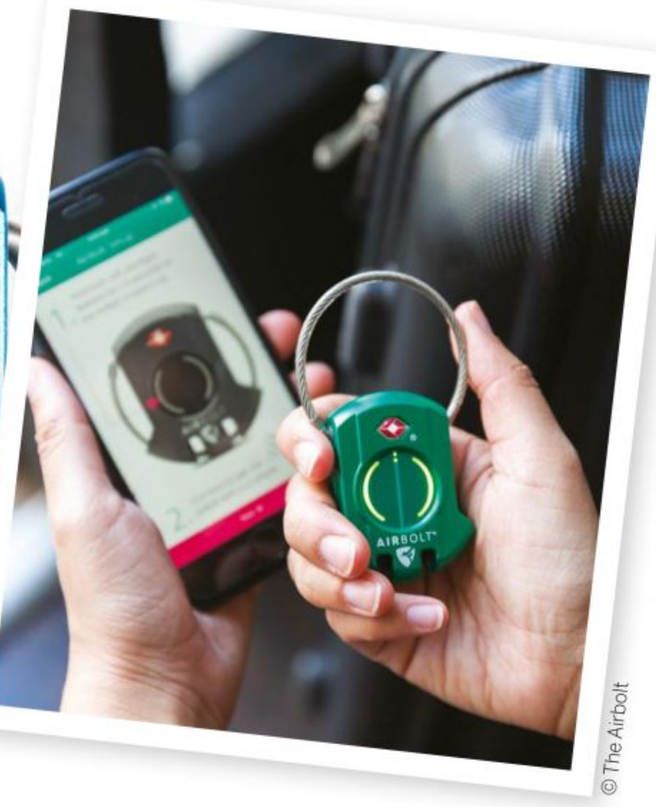


© Incase

Incase ProConnected 4 Wheel Hubless Roller

Price: **$399.95 (approx £320)**
incase.com

Finding a free plug socket at an airport can be as time-consuming as the flight itself. The Incase ProConnected smart luggage offers portable power on four removable wheels. This 32-litre carry-on case comes equipped with a 20,100 mAh/74.37 Wh battery bank and three USB ports. With the accompanying Incase app, users can track their Incase and monitor battery life via Bluetooth.



© The Airbolt

AirBolt

Price: **$59.95 (approx £50)**
theairbolt.com

AirBolt is the app-controlled lock that gives you complete control over your luggage security. The durable stainless steel design can either be unlocked via the accompanying app or with a back-up button code if you lose your phone. The AirBolt also acts as a tracker to locate your belongings if they go missing and is equipped with an alarm. This can be set to sound if your luggage moves too far away from your phone, or activated at the touch of a button. This high-tech lock will also keep a history of the times it's been unlocked so you know exactly when your possessions have been accessed.

CORI

Price: **Approx £35 / approx $45**
coritraveller.com

During a long journey, a travel pillow can be a welcome relief for a much-needed nap. Rarely straying away from the typical horseshoe design, the CORI travel pillow allows the wearer to arrange interchangeable cushions in whichever orientation suits them. With its modular design, CORI can roll up to 12 centimetres, perfect for packing into hand luggage.

© Cori

Sony WH-1000XM3

■ Price: **£329 / $349.99**
sony.co.uk

The world is filled with noise, especially when travelling on public transport or venturing around a busy city. However, with the Sony WH-1000XM3 wireless headphones, background noise becomes a thing of the past. With Sony's industry-leading HD noise-cancelling technology at your fingertips, the world is silenced, leaving you to sit back and enjoy your music. It has 30 hours of battery life, making these headphones a great addition to any long-haul journey.

© Sony

© DJI

Osmo Pocket

■ Price: **£329 / $349**
dji.com

The Osmo Pocket by DJI is a great way to document your travels with cinematic flair. This compact three-axis stabilised camera takes away the jitters of handheld recording to produce seamlessly moving footage. With tracking technology, Osmo can lock onto a moving object gracefully, and while in selfie mode can track your face for the perfect vlog. Osmo can also pair with your smartphone, and with the DJI Mimo app your travel footage and pictures can be edited with ease.

Pocketalk

■ Price: **From $249 (approx £200)**
pocketalk.net

Navigating a new city in a new country can be tricky, especially when you don't speak the native language. However, Pocketalk can take the guesswork out of getting directions. This pocket-sized two-way translator can interpret 74 languages across the globe at the touch of a button. Simply speak into the built-in microphone and Pocketalk will translate your message via audio or text.

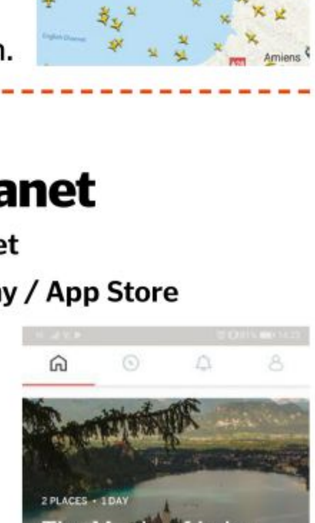
© Pocketalk

APPS & GAMES

NetSpot

■ Developer: **Etwok Tech**
■ Price: **Free / Google Play**

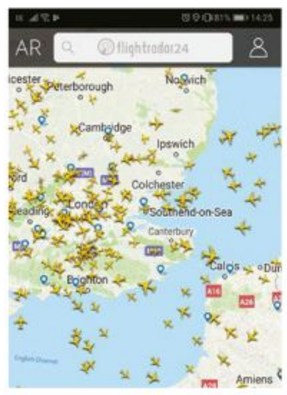
Stay connected during your travels with this Wi-Fi analytics app. This simple app will enable you to locate and compare Wi-Fi speeds and the signal strength of your nearest hotspots.



Flightradar24

■ Developer: **Flightradar24 AB**
■ Price: **Free / Google Play / App Store**

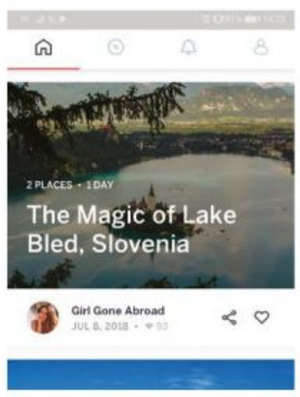
This live aeroplane traffic tracker can keep you up to date with flight information across the globe. From arrivals and departures to airport information and weather reports, this app is packed with information.



Trips by Lonely Planet

■ Developer: **Lonely Planet**
■ Price: **Free / Google Play / App Store**

Create stunning travel timelines, share your stories, capture your adventures, be inspired by the community and discover new places with this app from Lonely Planet.



Duolingo

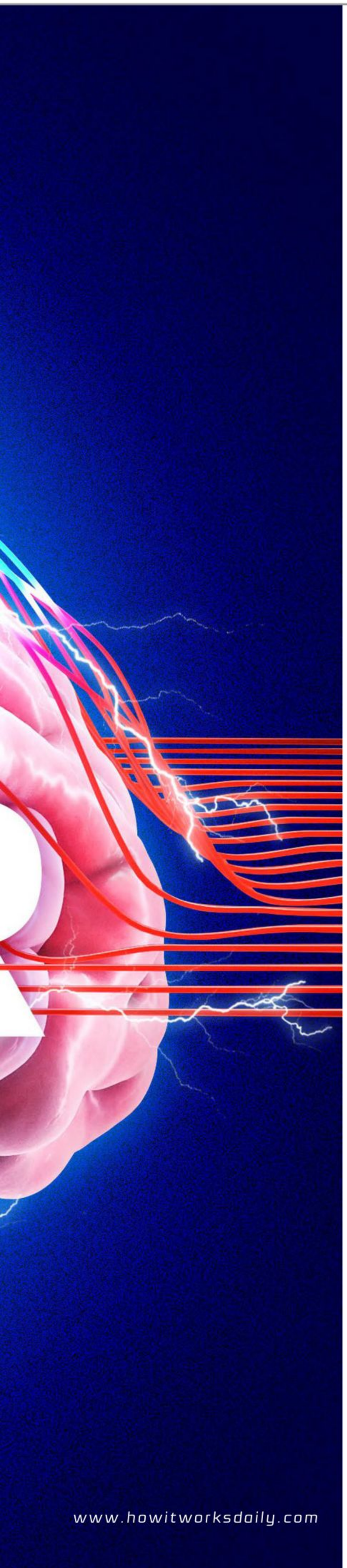
■ Developer: **Duolingo**
■ Price: **Free / Google Play / App Store**

Learn a new language with this simple to follow step-by-step teaching app. From simple phrases to complex sentences, Duolingo is a great tool to help you prepare for your travels.

YOUR BRAIN POWER

20 things you need to know about the human body's computer

Words by **Laura Mears**



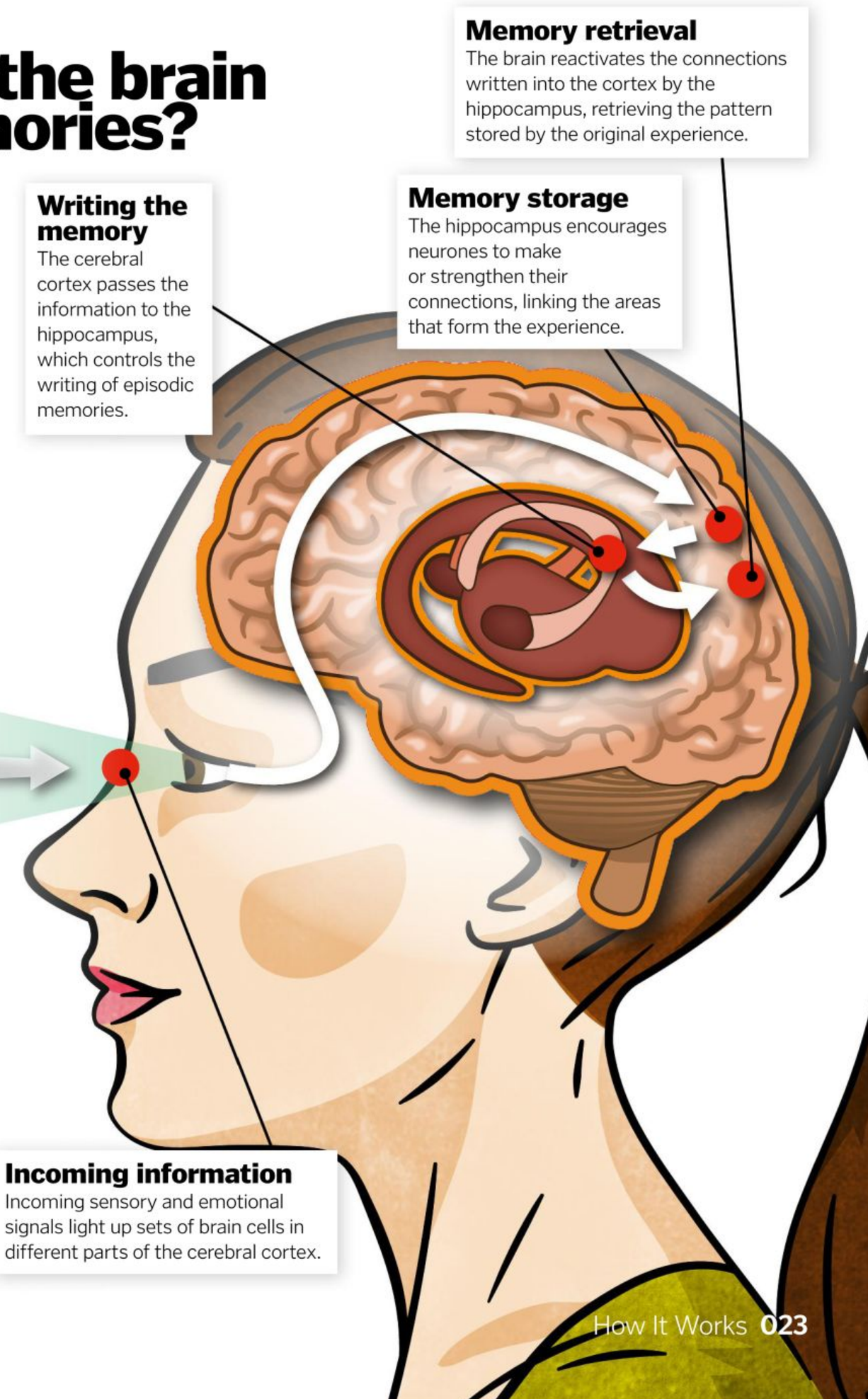
1 How fast does the brain work?

Brain speed is difficult to measure, but scientists from MIT think they have an answer. To test the processing power of the visual cortex, they flashed images for fractions of a second to see if people could recognise them. Before the test, they expected the brain to take 100 milliseconds to decode the information. But afterwards, it became clear that our brains can work almost ten times faster, decoding entire pictures in as little as 13 milliseconds. How does that compare to a supercomputer? Current estimates from benchmarking experts suggest that the brain is up to 30 times faster than IBM's Sequoia.

The human brain still outpaces the fastest supercomputers

2 How does the brain store memories?

The brain's short-term memory storage is in the prefrontal cortex, the part of the brain behind the centre of the forehead. The left side of this region lights up when we're working with words and the right when we're remembering spatial patterns. Longer-term memory storage happens elsewhere and falls into two main categories: implicit and explicit. Implicit memories are unconscious, like muscle memory, and they form in the cerebellum and the basal ganglia. Explicit memories are conscious, and they can either be episodic (things that happened) or semantic (facts). They're formed by the hippocampus, which takes on the role of 'writing' the data into the brain, often when we're sleeping. It does this by strengthening connections in the neocortex, on the very outer surface of the top of the brain. It also talks to the amygdala, the brain's emotional centre, tying in the feelings that the memory evokes.



3 Why do we have emotions?

Emotions have lots of parts. The first is the physical response in the body: the tears, the laughter, the sweating, the heart beating faster. The second is the change in the way we think, like heightened senses when we're afraid or recalling old memories when we're sad. And the third is the change in our behaviour, perhaps avoiding dangerous situations or repeating actions that made us happy. Emotions help us to cope with the situations that triggered them, they help us to prepare for the future, and they send signals to the people around us, strengthening our social bonds.

Developing emotions

3 months
Small babies like to be held. They cry when they're put down and feel safer when they're picked up.

6 months
As they get older, babies start to smile and laugh. They start to get used to being by themselves.

9 months
Older babies start to trust the people looking after them, but begin to show fear around strangers.

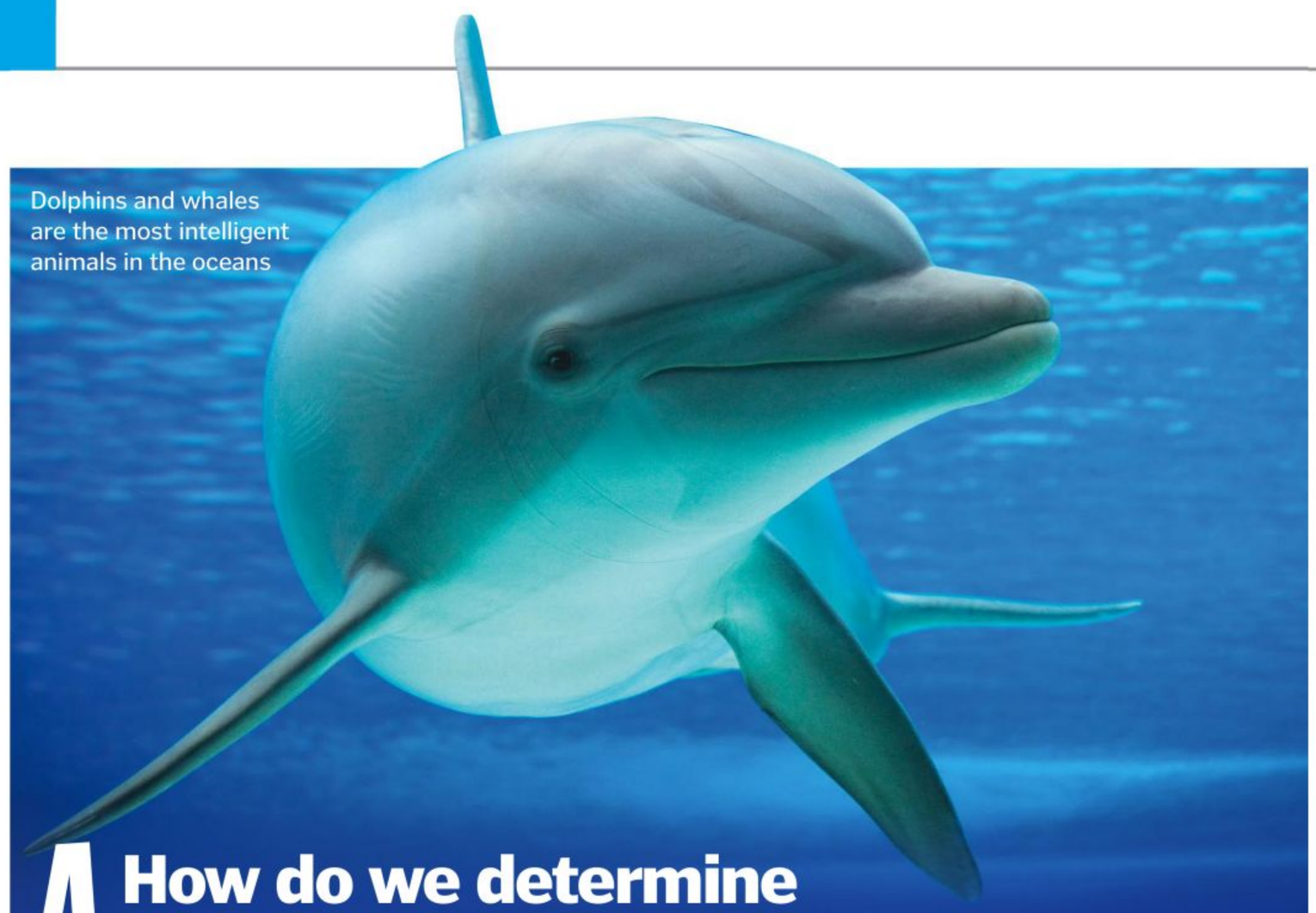
12 months
By their first birthday, babies start to learn to read emotions from facial expressions and tone of voice.

2 years
Toddlers experience strong emotions, but don't always have the words to express what they're feeling.

3 years
Older toddlers begin to learn the names for basic feelings, like happy, sad and scared.

4 years
Young children start to use more words to describe their feelings and begin to develop empathy.

5 years
Five year olds are aware of the feelings of others, and of the different ways people react to the same situations.



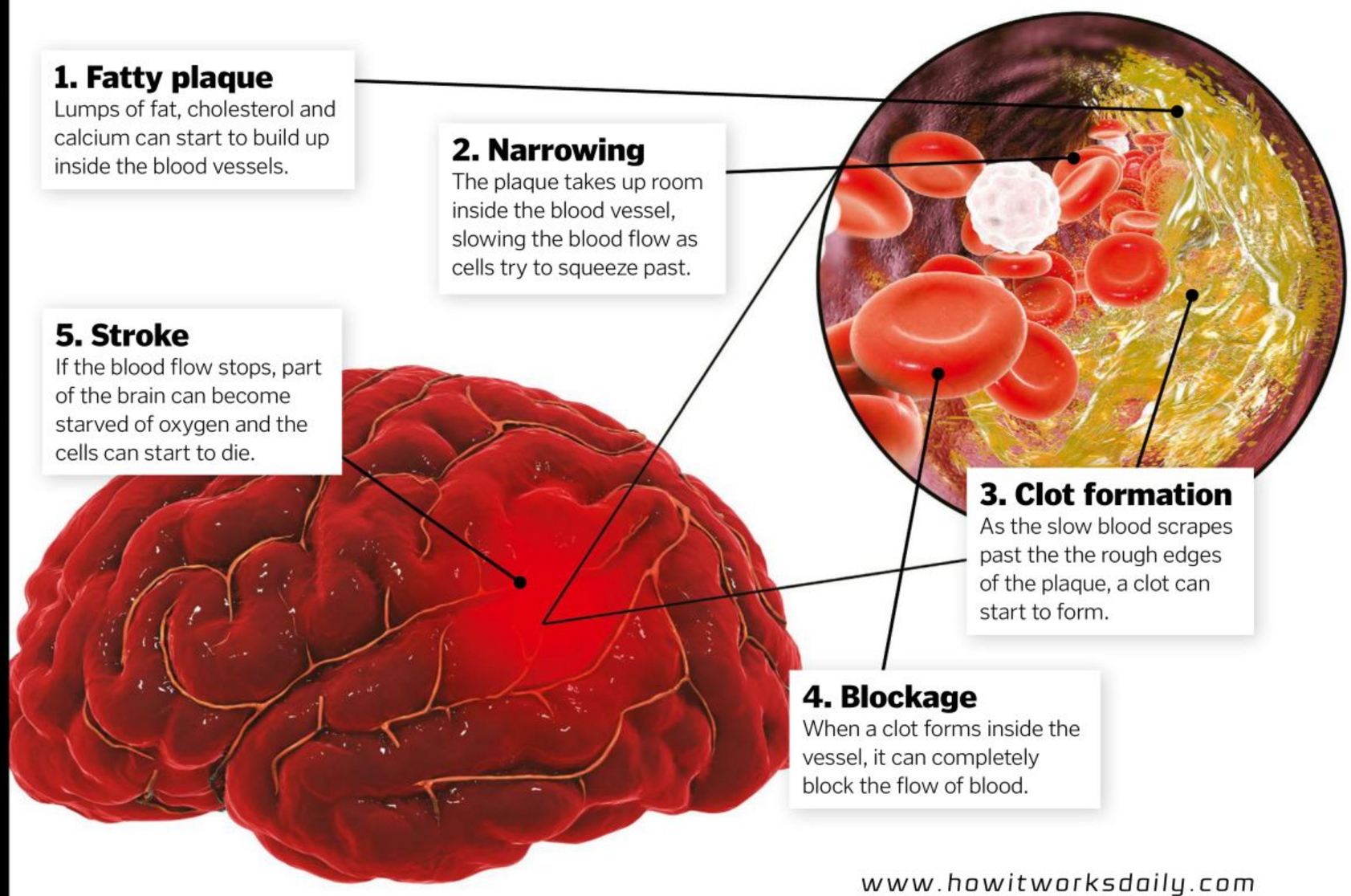
Dolphins and whales are the most intelligent animals in the oceans

4 How do we determine the smartest species?

Designing tests to measure animal intelligence is a challenge that scientists have been working on for decades. The simplest way to assess intelligence is to measure the size of the brain; in general, the bigger the brain, the smarter the animal. But this isn't always the case. Other tests involve looking for signs of intelligence that we recognise in ourselves: the ability to delay gratification, to recognise oneself in a mirror, to make and use tools, to solve problems, and to respond differently to different individuals. The tests try to get at whether animals can make reasoned decisions, or whether they're just learning patterns and responding automatically.

5 What's a stroke?

Strokes are like heart attacks, but in the brain. These medical emergencies happen when the blood supply to a part of the brain suddenly stops, often due to a blood clot or a bleed. Without oxygen, the brain cells start to starve and die, so the faster the blood supply returns to normal, the better. Drugs can be used to help to dissolve blood clots and surgical procedures can help to remove them, minimising the damage. If someone suffers from a small stroke, the brain can sometimes repair itself, but larger areas of damage can have lasting effects. These differ depending on where in the brain the stroke happened.



6 Why do we dream?

Many scientists think that dreaming has something to do with the way the brain makes memories. The brain learns by making and strengthening connections between different neurones. This allows us to make sense of the world around us. During the day, we do this in a way that's guided by incoming sensory signals, but at night, this influx of information stops. With the input turned off, the brain is free to explore new connections on its own. This allows it to make connections between facts that weren't previously linked up, helping us to solve complex problems.

Beta
Fast, low-amplitude waves reveal a brain hard at work. They happen when we're awake and engaged.

Alpha
Slower alpha waves happen when the brain is resting. We're still awake, but we're relaxed.

Delta
These slow, long waves happen when the brain is resting; you're fast asleep but not dreaming.

Theta
Large, slow theta waves, signalling dreaming and daydreaming, occur when the mind is disengaged.

Gamma
When you're dreaming, bursts of gamma waves cut through, representing new connections forming.

7 How different are human and chimp brains?

Chimpanzees are some of the most intelligent animals on the planet, but as smart as they are, chimps' brain power pales in comparison with our own. Our brains are three times bigger than theirs: this huge size difference is down to changes in our cerebral cortex, the region responsible for processing, planning and intelligence. We've got around double the number of brain cells in there, and they make more connections.

8 How much energy does the brain use?

The brain uses around a fifth of our energy: about 400 calories every day. That might sound like a lot, but it's actually surprisingly efficient. Its power consumption is around 20 Watts, barely more than a low-energy light bulb. The brain uses around two thirds of its energy to send messages, and the rest for maintenance and repairs.

9 Why do we become forgetful as we get older?

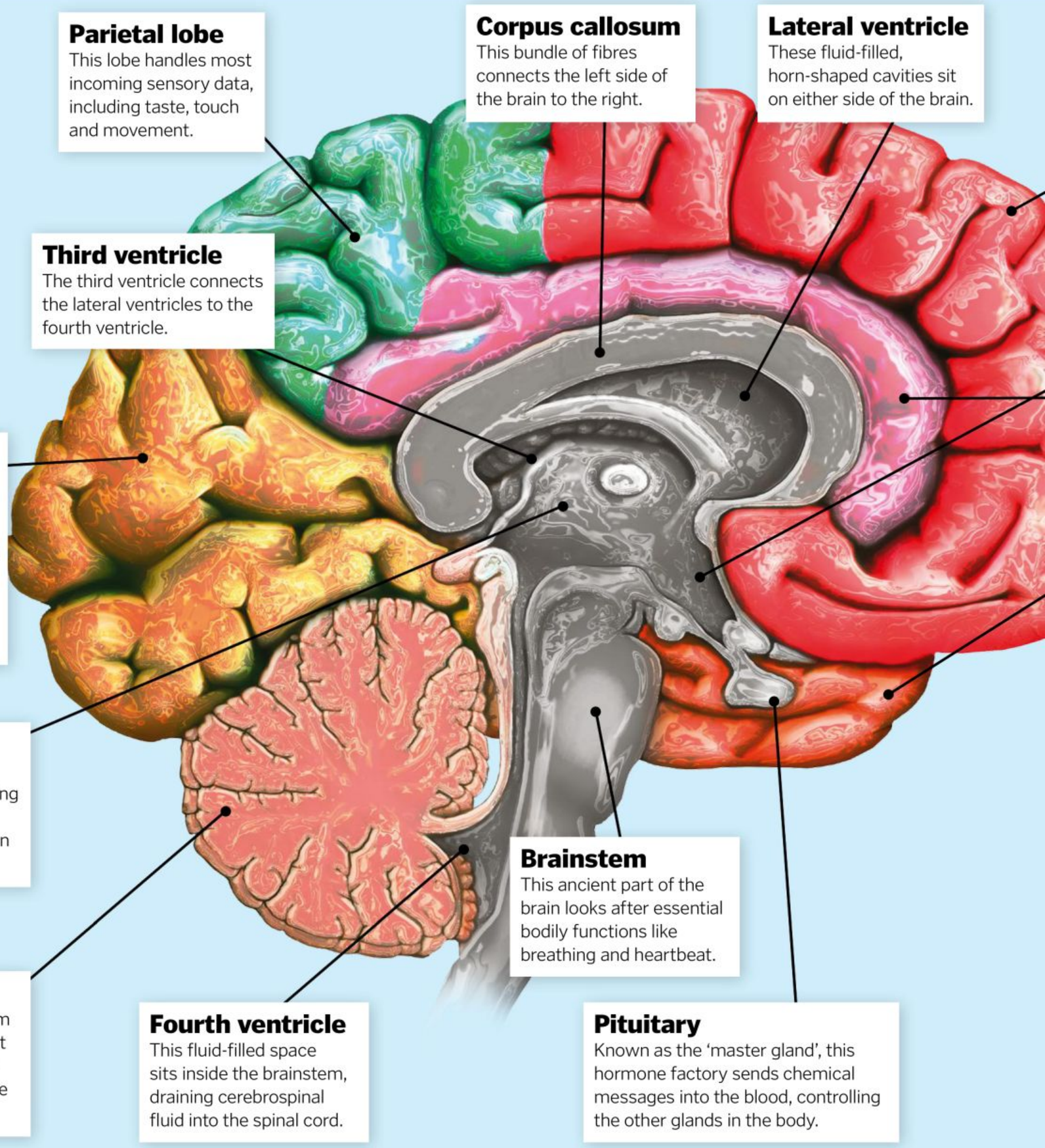
Around two in five people start to lose their memory after the age of 65. The brain gets smaller and levels of serotonin and dopamine start to fall, and this seems to affect our ability to make new memories. Changes in metabolism and blood supply can also affect the way we think.

MRI scans reveal changes in the structure of the brain as we age

10 What do the different parts of the brain do?

The brain has three main zones: the forebrain at the top, the midbrain deep inside, and the hindbrain underneath, close to the spinal cord. The hindbrain is the most ancient part, and it handles the most fundamental parts of our biology. The brainstem controls breathing, swallowing and heartbeat, and the cerebellum looks after fine-movement control and muscle memory. The midbrain coordinates more complex information. The hypothalamus keeps a constant check on the body, making minute adjustments to maintain a steady state. The limbic system handles emotions, and the hippocampus controls our memories. The forebrain looks after the most complex processes of all. The cerebrum is by far the largest part of the brain, and it does the thinking. It has two halves, each divided into four lobes. Together they handle sensory information, reasoning, planning and emotional control.

Inside your brain



Parietal lobe
This lobe handles most incoming sensory data, including taste, touch and movement.

Corpus callosum
This bundle of fibres connects the left side of the brain to the right.

Lateral ventricle
These fluid-filled, horn-shaped cavities sit on either side of the brain.

Third ventricle
The third ventricle connects the lateral ventricles to the fourth ventricle.

Occipital lobe
This lobe, at the back of the brain, primarily processes incoming data from the eyes and handles visual memory.

Thalamus
This part works as a junction box, routing incoming and outgoing information to the right place.

Brainstem
This ancient part of the brain looks after essential bodily functions like breathing and heartbeat.

Cerebellum
The word cerebellum means 'little brain'. It helps to coordinate movement and store muscle memory.

Fourth ventricle
This fluid-filled space sits inside the brainstem, draining cerebrospinal fluid into the spinal cord.

Pituitary
Known as the 'master gland', this hormone factory sends chemical messages into the blood, controlling the other glands in the body.

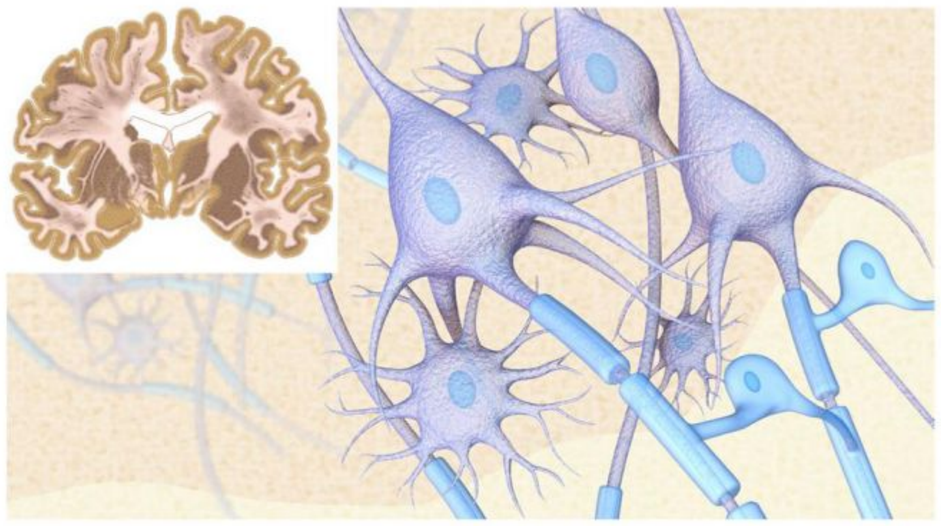
11 Can gut bacteria really control your mind?

There are trillions of microbes in every millilitre of your digestive contents, and they have a direct line to your brain. Changes in gut bacteria influence mood and behaviour. The gut's enteric nervous system sends signals upwards via the vagus nerve, and bacteria seem to be able to interfere with the messages.

Vagus nerves carry sensory data from the internal organs back to the brain

12 What is 'grey matter'?

You can think of the brain as being a bit like a telephone network. The bodies of the brain cells are the callers, sending and receiving the signals, and the axons are the wires, linking the network together. Like real wires, brain cell axons transmit signals using electricity. To stop the signals getting crossed and to help the messages move faster, the axons have insulation. Known as myelin sheaths, this insulation contains layers of white-coloured fat, visible inside the brain as 'white matter'. The bodies of the cells don't have this insulation, so they appear grey.



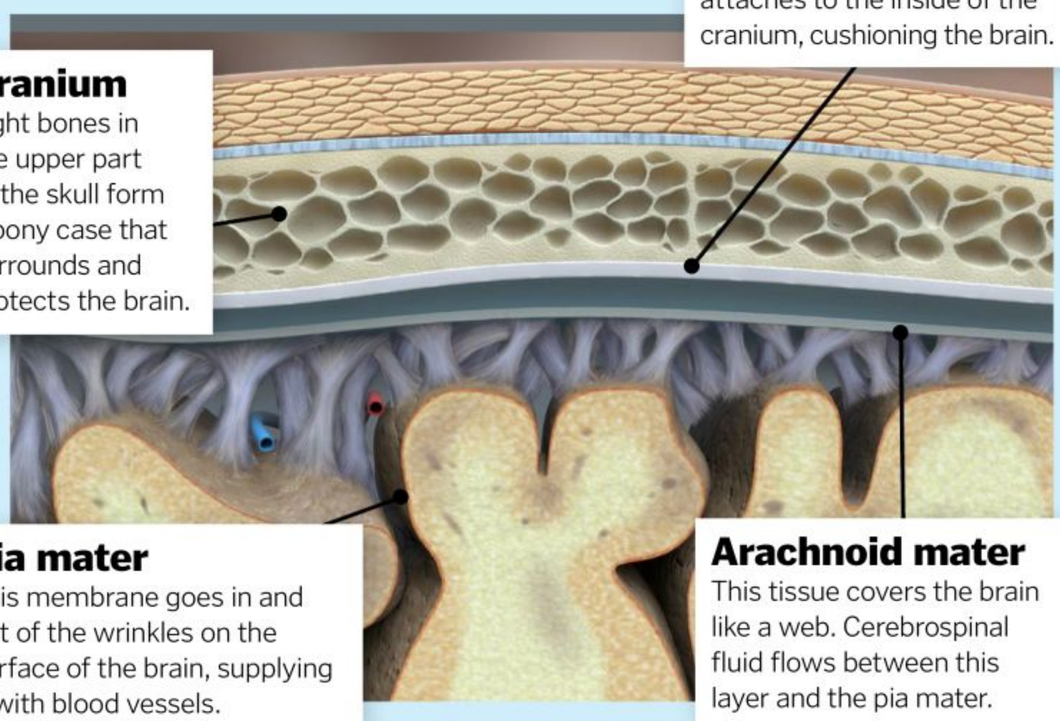
Frontal lobe
This pair of lobes control thought, reasoning and short-term memory. They allow us to imagine, plan and respond.

Hypothalamus
This acts as a thermostat, internal clock, appetite controller, water regulator, and hormone centre.

Temporal lobe
The lobes near the ears process auditory information and also handle auditory memory.

Limbic system
This is the emotional part of the brain. It drives our feelings of pleasure, pain, fear, anxiety and love.

Layers of protection



Dura mater
This two-layered membrane attaches to the inside of the cranium, cushioning the brain.

Cranium
Eight bones in the upper part of the skull form a bony case that surrounds and protects the brain.

Pia mater
This membrane goes in and out of the wrinkles on the surface of the brain, supplying it with blood vessels.

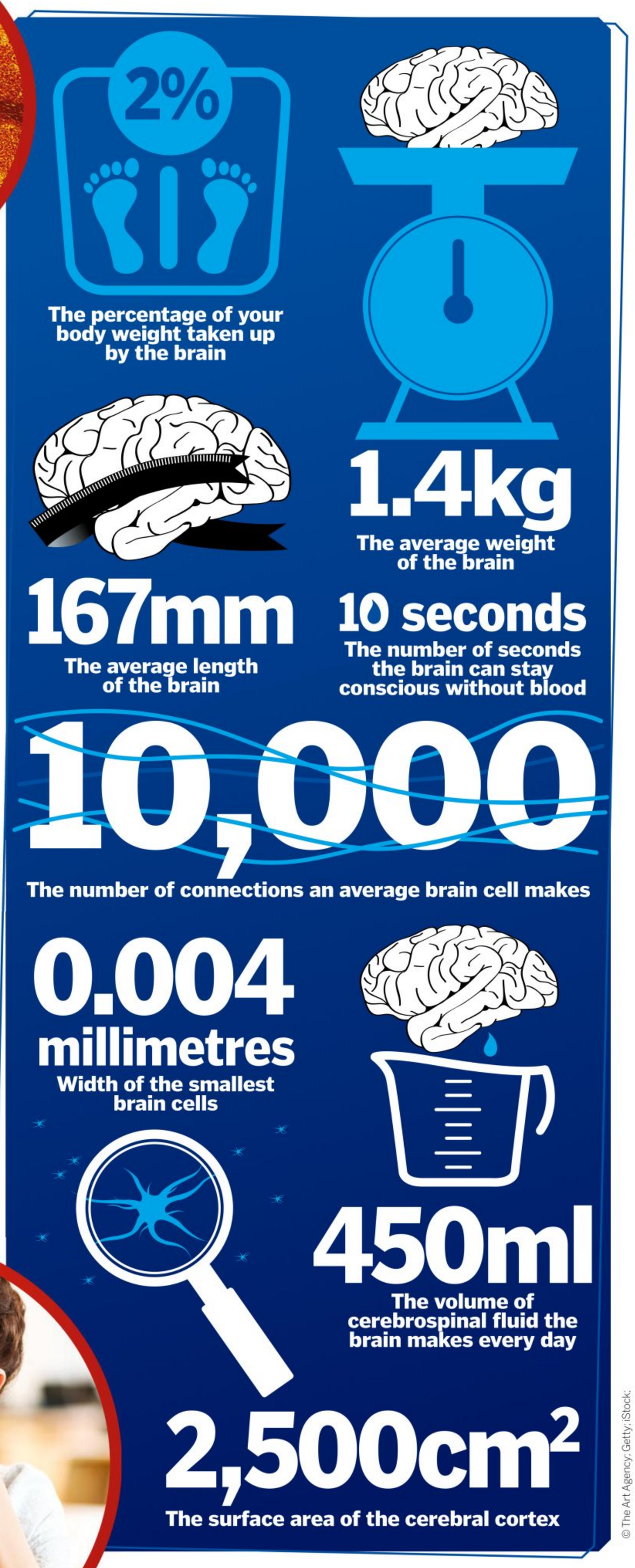
Arachnoid mater
This tissue covers the brain like a web. Cerebrospinal fluid flows between this layer and the pia mater.

13 Can we become brainier?

In total, we have around 86 billion brain cells, wired together by 10 trillion synapses. We learn by making new connections in this network, changing the strength of old connections, and pruning connections we no longer need. Most of this rewiring happens before our tenth birthdays. As we get older, our ability to make new brain cells and new connections decreases, but it doesn't disappear. Take black-cab drivers for example, the memory centre of their brains physically grows as they learn to navigate London's streets. So if you keep on learning, you'll be brainer.

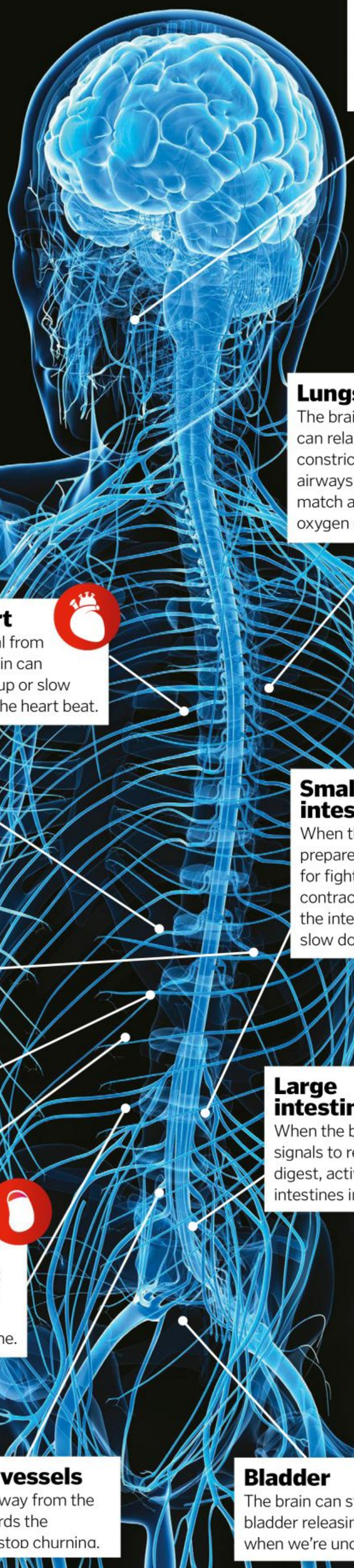
14 How does sleep affect brains?

Sleep lets our brain activate its self-cleaning programme, bathing nerve cells in fluid and sweeping away the molecular debris of the day. Lack of sleep can lead to a buildup of waste, slowing brain cells down in the short term, and increasing the risk of brain disease in the long term.



15 How does the brain control bodily functions?

The internal organs do their jobs without too much help from the brain, but there are times it needs to intervene. Signals from the brain help to ensure the organs are working together to meet the body's current needs. The brain controls the organs using a two-part set of nerves called the autonomic nervous system. The 'sympathetic' part of this system gears the organs up for fight or flight, and the 'parasympathetic' part calms them down so that they can rest and digest.



What can the brain control?

The sympathetic and parasympathetic nervous systems make small adjustments to our internal organs...

Salivary glands
The brain can turn saliva production on when we're resting, or off when we need to run.

Lungs
The brain can relax or constrict the airways, and match airflow to oxygen demand.

Stomach
When the brain triggers a fight or flight response, it tells the stomach to stop churning.

Heart
A signal from the brain can speed up or slow down the heart beat.

Liver
A signal from the brain tells the liver to release glucose into the blood when we're angry or afraid.

Small intestine
When the brain prepares the body for fight or flight, contractions in the intestines slow down.

Pancreas
A rest signal from the brain tells the pancreas that it's time to start making digestive enzymes.

Large intestine
When the brain sends signals to rest and digest, activity in the intestines increases.

Adrenal glands
When the brain sends fight or flight signals, the adrenal glands flood the blood with adrenaline.

Kidneys
The brain can change urine production and alter the amount of salt and water that the kidneys reabsorb.

Abdominal blood vessels
The brain can send blood away from the digestive system and towards the muscles when we need to stop churning.

Bladder
The brain can stop the bladder releasing urine when we're under stress.

16 What does the brain need to stay conscious?

We can try to understand more about consciousness by looking at what happens when it's gone. We tend to lose consciousness when the blood flow to the brain stops. This can happen if blood pressure drops, during a stroke or if there are problems with the heart. So the brain needs oxygen to stay conscious. But we can also lose consciousness as a result of a general anaesthetic. When brain cells send signals, they usually get feedback in response, but under anaesthetic this feedback stops. The effect seems to be strongest in the cerebral cortex, which handles thinking and memory.

17 Why can't we consciously control our bodies?

Voluntary control comes from the cerebral cortex, but not all our systems receive their instructions from that part of the brain. Directions to move our muscles come from the motor part of the cortex, putting them under conscious control. But directions to our internal organs come from deeper structures, like the hypothalamus.

Taking control: the hypothalamus will act to put changes in place to correct any imbalances

18 What makes a person intelligent or stupid?

The most famous way to measure intelligence is the IQ test. Developed in the 20th century, it attempts to assess people's ability to perform certain mental tasks. People who get one question right are more likely to get the others right, even if the questions are of a different type. This is known as the 'general intelligence factor'. It's less about remembering facts and more about being able to think abstractly, use reasoning and solve problems. Studies of twins and studies of adopted children suggest that IQ is an equal combination of nature (genetics) and nurture (environment). So far, scientists have found more than 500 genes with a link to IQ, but we still don't really know what makes some people smarter than others.

There is a huge difference between knowing facts and being able to solve problems

19 What is brain freeze?

The brain can't feel pain, but its outer covering (the meninges) can. When the blood flow here changes, it can really hurt. The main artery that supplies the brain is the carotid artery; it runs up through the neck, close to the blood vessels inside the mouth and throat. When the blood here gets cold, the anterior cerebral artery behind the eyes can start to widen. Cold can also trigger the trigeminal nerve, which also affects the blood supply to the brain. Warming the mouth lets the blood vessels return to normal, helping the pain to subside.

Stop brain freeze pain by pressing your tongue against the roof of your mouth

20 Do we need all of our brain?

In 2009, doctors described a girl in Germany who was living a normal life despite being born without the right hemisphere of her brain. In 2014, a similar story emerged about a woman in China who had been living without her cerebellum. The developing brain has an ability called 'neuroplasticity', which allows nerve cells to take on new roles. This incredible ability enables doctors to perform a procedure called a hemispherectomy. In rare cases of severe epilepsy in children, surgeons can remove half of the brain to stop the seizures. Amazingly, the other half adapts to take on its jobs.

When half of the brain is missing, the other half can adapt to compensate

SUBSCRIBE

to **How It Works** and get a Powerball Supernova Pro*

The ultimate fitness gadget!

Experience stunning icy-blue LEDs powered by a super-spinning rotor as you develop the strength and dexterity of your fingers

FREE GIFT worth £24.99

FASTER THAN AN F1 ENGINE

Computer-balanced rotor is vibration free to 15,000rpm+.

GO SUPERNOVA!

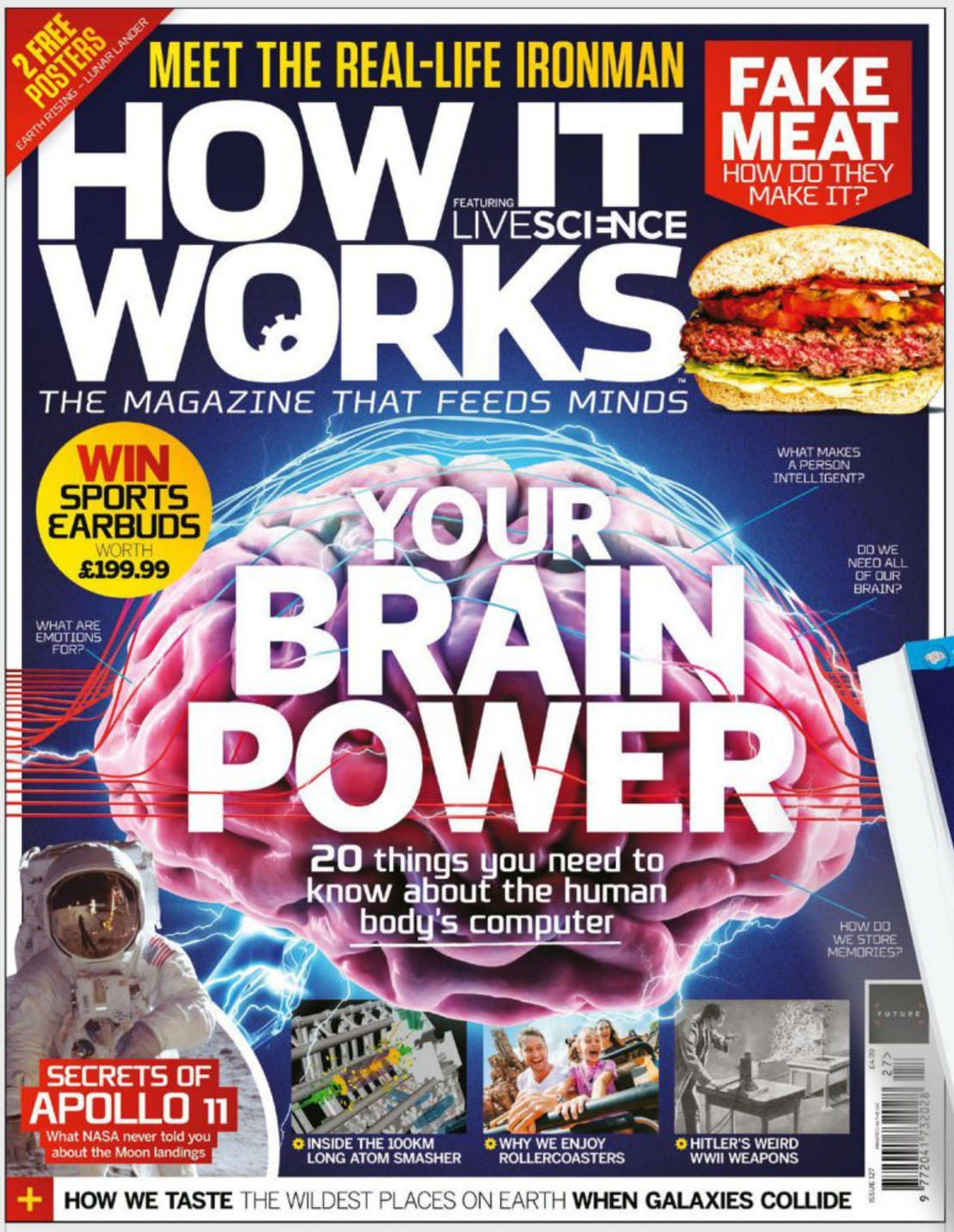
Includes 6 induction-powered blue and white LEDs.

COMPACT TECHNOLOGY

Includes multi-function LCD counter to record spin speed.

CHALLENGE YOUR STRENGTH

Produces 0-15kg of inertial resistance powered just by your wrist.



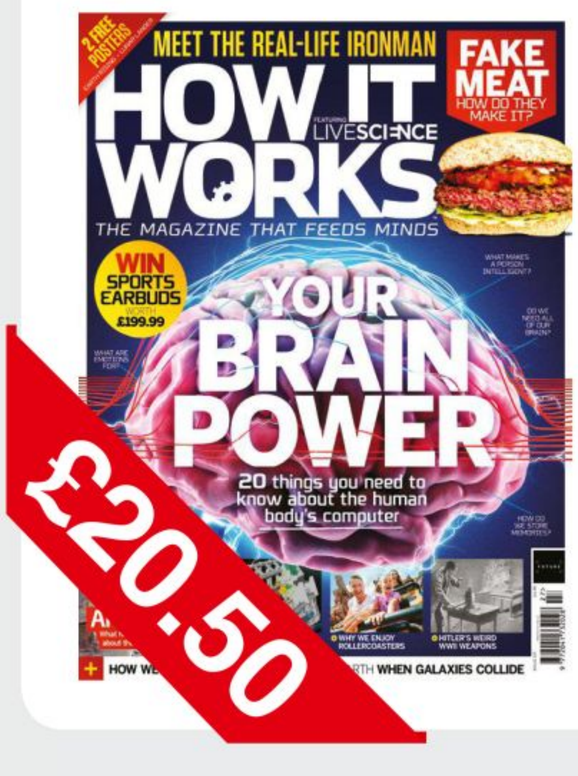
WHY SUBSCRIBE?

- Brilliant value – save money on the cover price
- You'll never miss an issue
- It's delivered direct to your door

Subscribe now

www.myfavouritemagazines.co.uk/hiw/127m

or call 0344 848 2852 & quote HIW127M



PRINT

Six-month subscription to **How It Works** in print, plus a Powerball Supernova

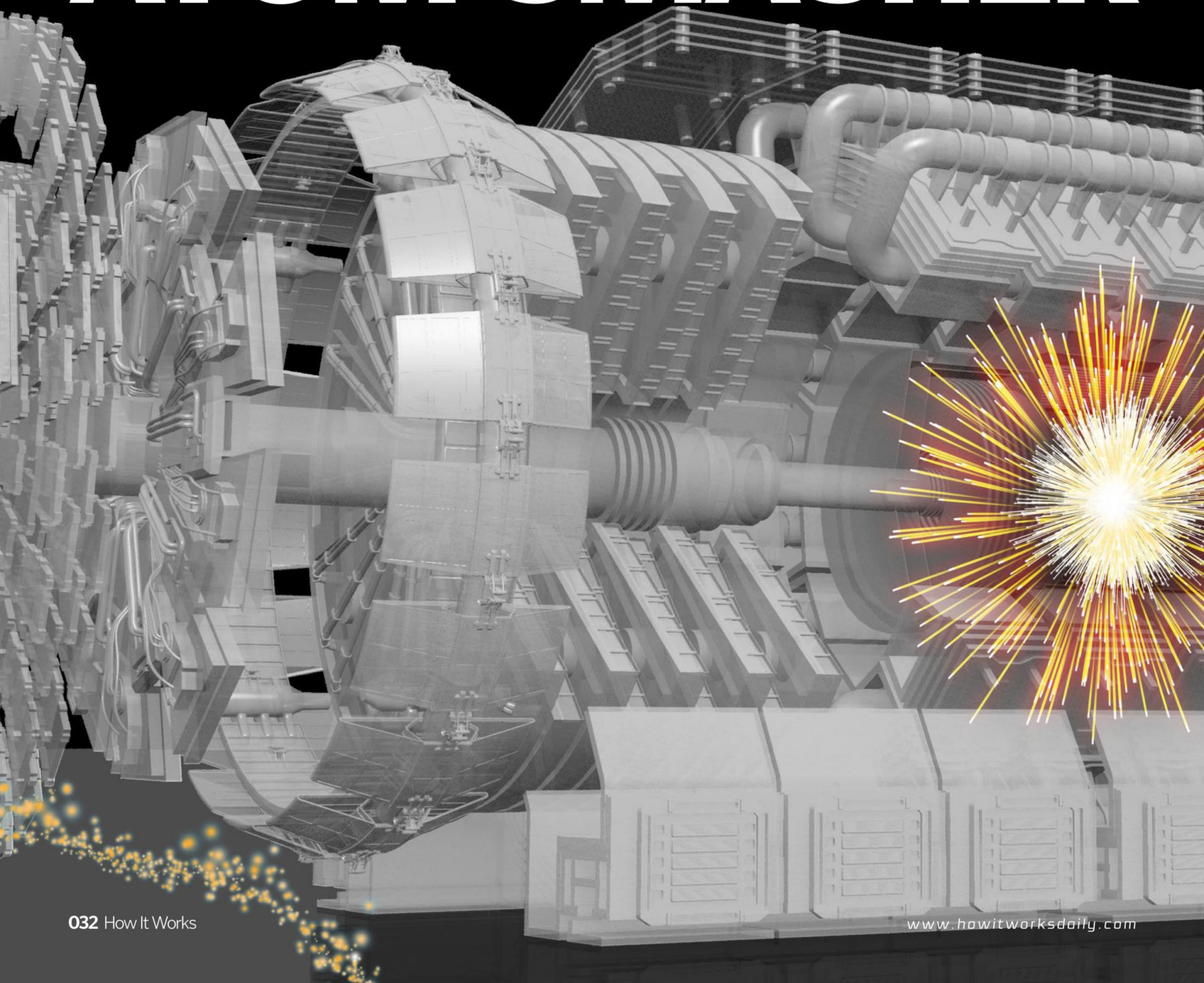
PRINT & DIGITAL

Six-month subscription to **How It Works** in print & digital, plus a Powerball Supernova

*Terms and conditions: This offer entitles new UK Direct Debit subscribers to pay just £20.50 every 6 months plus receive a Powerball Supernova. Gift is only available for new UK subscribers. Gift is subject to availability. Please allow up to 60 days for the delivery of your gift. In the event of stocks being exhausted we reserve the right to replace with items of similar value. Prices and savings quoted are compared to buying full-priced print issues. You will receive 13 issues in a year. Your subscription is for the minimum term specified. You can write to us or call us to cancel your subscription within 14 days of purchase. Payment is non-refundable after the 14 day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices correct at point of print and subject to change. UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) or are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). For full terms and conditions please visit: www.bit.ly/magterms. Offer ends 8th August 2019

Direct Debit Originator's reference 768195

INSIDE THE 100km ATOM SMASHER



What discoveries will the Large Hadron Collider's giant successor be capable of?

Words by **Andrew May**

CERN's Large Hadron Collider (LHC) made headlines in 2012 with the discovery of the Higgs boson – the elusive 'God particle' that completed the cosmic jigsaw puzzle that physicists refer to as the Standard Model. It was an amazing technical feat, achieved by smashing subatomic particles into each other at enormous energies and peering closely at the resulting debris. It required nothing less than the largest machine ever built. Spanning the border between Switzerland and France near Geneva, the LHC is an awe-inspiring 27 kilometres in circumference.

But even the LHC hasn't told physicists everything they want to know. It's clear from astronomical measurements that there's a lot more to the universe than the Standard Model – and yet that's all we know about at the moment. Probing the mysteries that lie beyond it will require a machine that's even bigger, and more powerful, than the LHC.

Everyday matter is made up of atoms, comprising lightweight electrons around a nucleus of neutrons and protons. The latter are examples of hadrons – a type of heavy, composite particle that puts the H in LHC. The task of the LHC is to accelerate two opposing beams of protons close to the speed of light (c in Einstein's famous equation $E = mc^2$) and crash them into each other to produce a cascade of exotic, short lived particles. The higher the collision energy (E), the greater the mass (m) of the particles created.

Particle physicists use a unit called the electron-volt (eV) to represent the energy gained by an electron when it's accelerated by one volt of electricity. In these terms,

How it will probe the dark secrets of the universe

We know there must be more to physics than the familiar particles of the Standard Model. This knowledge comes from astronomical observations, which show that galaxies have stronger gravitational fields than can be accounted for by visible stars and gas. As much as 80 per cent of their mass must be in a form we can't detect. What this mysterious 'dark matter' is, no-one knows – but it may take the form of Weakly Interacting Massive Particles (WIMPs) that lie outside the Standard Model, predicted by a theoretical extension of it called supersymmetry. These WIMPs lie beyond the energy range of the LHC, but could be within the capability of the new collider. Its detectors wouldn't see them, but their presence could be inferred from the 'missing' energy of visible particles.

An artist's impression of a collision event inside the FCC, based on preliminary design studies

The view inside the LHC; the FCC will be constructed in a similar way

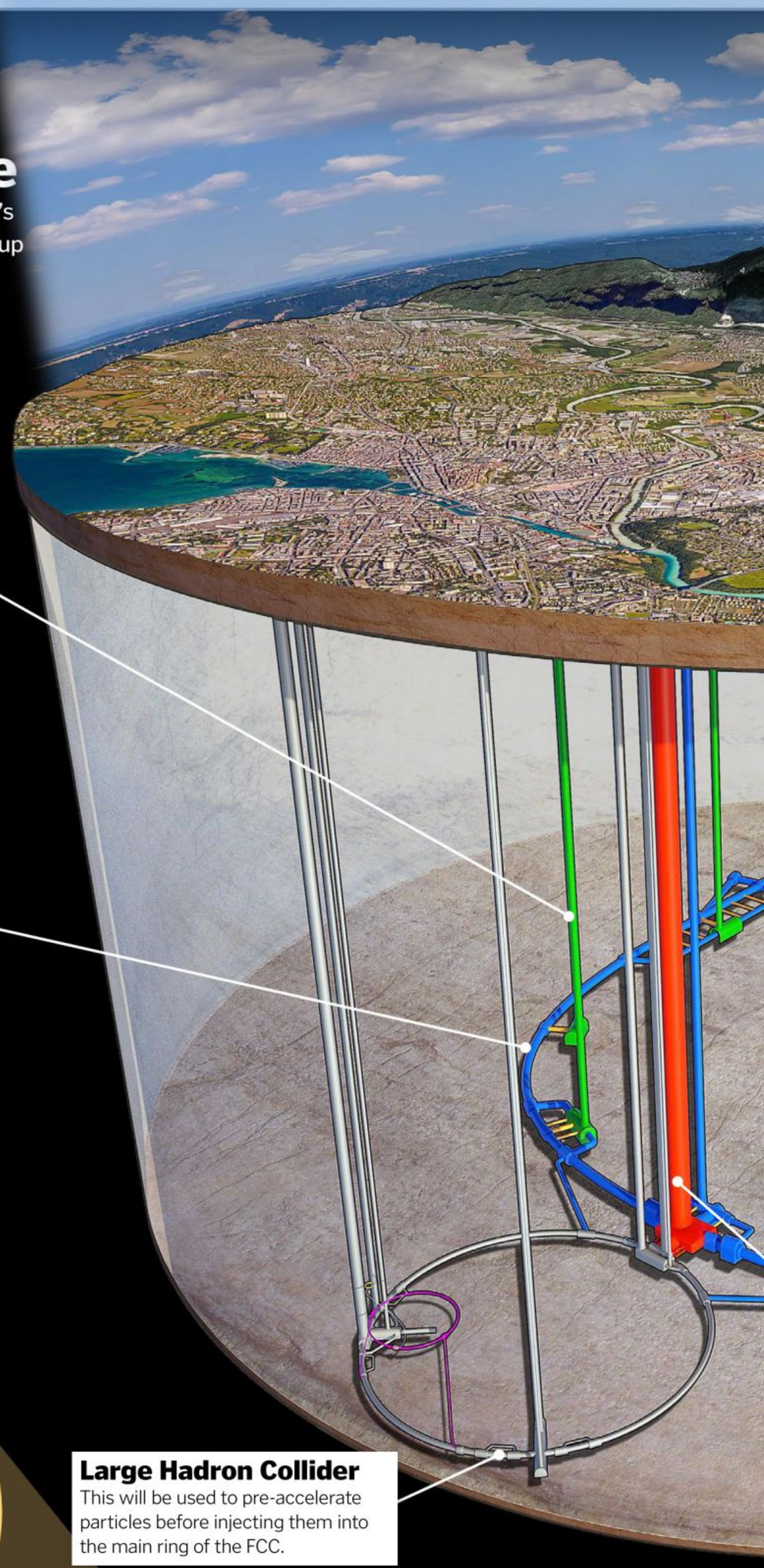
a proton-proton collision in the LHC yields an energy of 14 TeV – where the T prefix, short for tera, means multiply by a trillion.

In January 2019, CERN published a conceptual design report for a successor to the LHC: the Future Circular Collider (FCC). Stretching to more than a thousand pages, the report represents five years' work by scientists from 150 universities and research groups around the world. It describes what the new collider needs to do, how it could do it, and what it would have to look like. The take-home message is simple: the FCC is going to be the LHC on steroids. It will be four times the circumference – 100 kilometres versus 27 kilometres – and capable of collision energies up to 100 TeV, seven times higher than the LHC. It will be built right next to the LHC for a good reason: the old collider can be used as a pre-accelerator to inject hyperfast protons into the main ring of the FCC.

When it's finished, we can expect the FCC to push the frontiers of knowledge beyond the Standard Model, addressing longstanding mysteries such as the nature of dark matter and why there's so much more matter than antimatter. But it took over 20 years for the LHC to progress from a paper concept to a working machine, and the same will be true of the new collider – so we'll have to wait...

What the FCC might look like

Constructed alongside the LHC, it's likely to resemble a vastly scaled-up version of the old particle collider



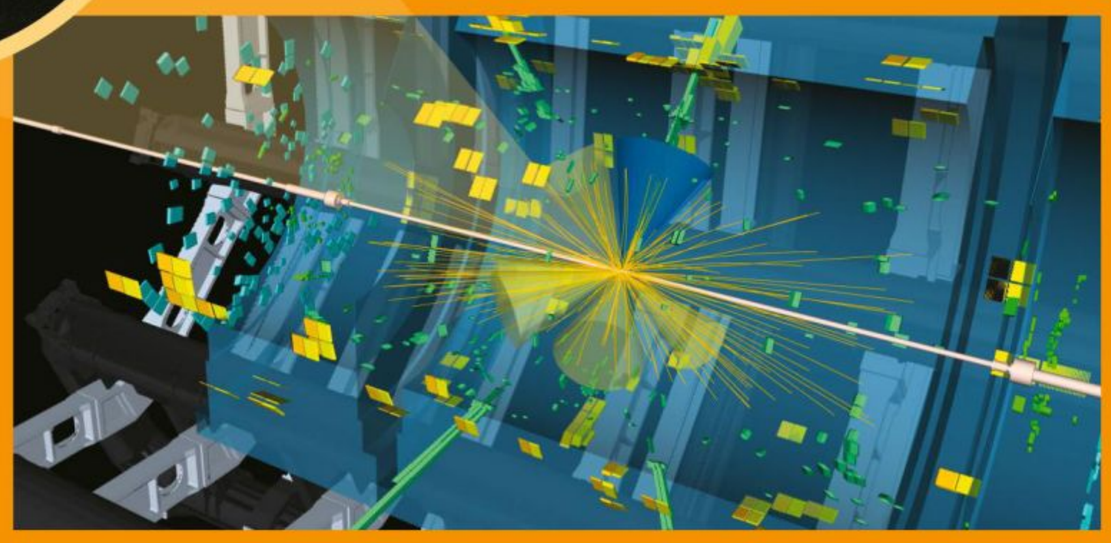
Eight service caverns
These will contain the collider's supporting infrastructure.

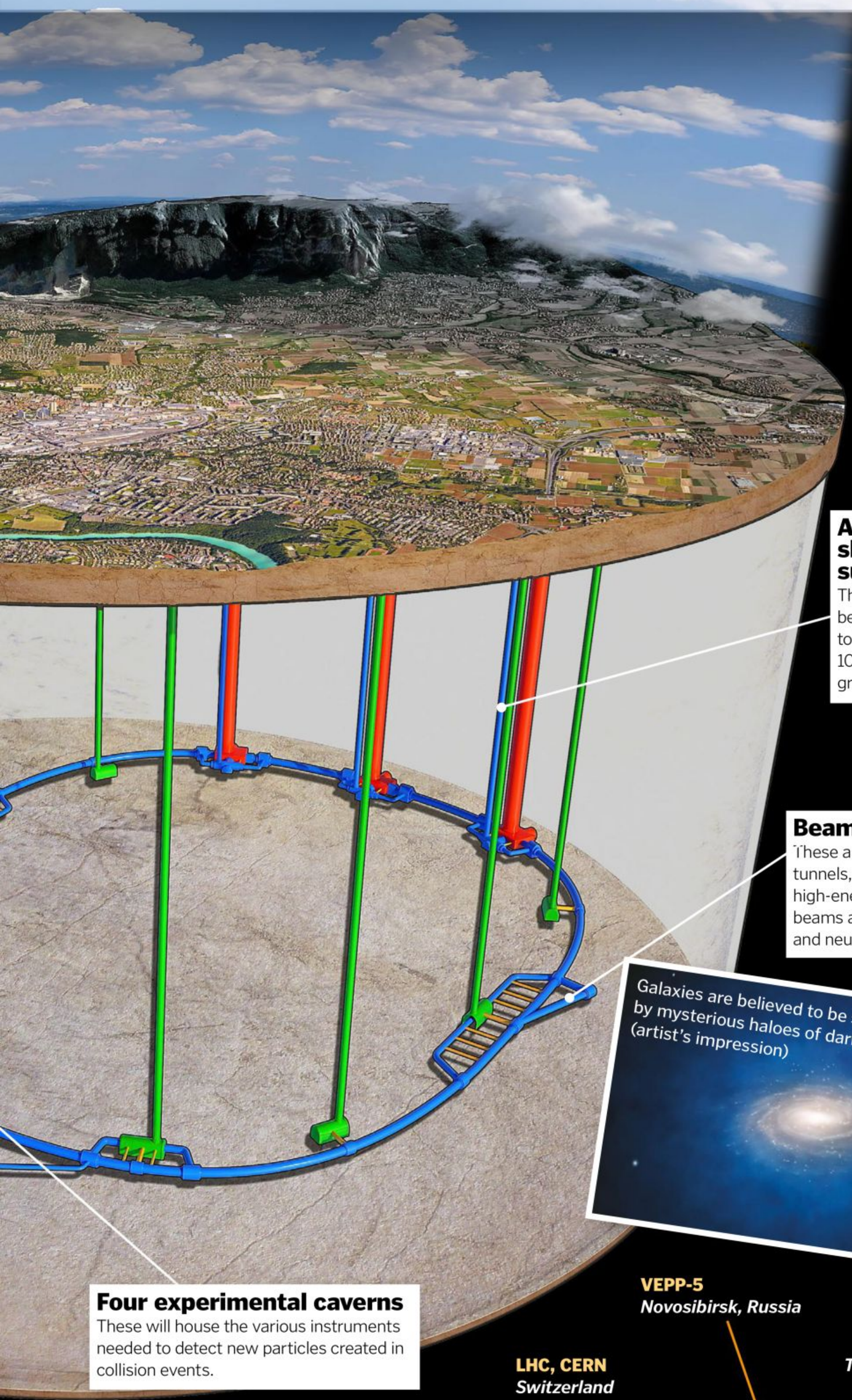
New collider ring
The ring will be housed in a roughly circular tunnel, 100km in length and with a six-metre internal diameter.

Large Hadron Collider
This will be used to pre-accelerate particles before injecting them into the main ring of the FCC.

How a collider works

The basic principle of a particle accelerator is simple enough. In fact, most living rooms had one 30 years ago, inside old-fashioned television sets. The cathode ray tubes inside these TVs used electric fields to accelerate a particle beam to high speed, and magnetic fields to steer it in the desired direction. Colliders use the same physics on a vastly larger scale, with the difference that there are now two beams travelling in opposite directions around a vacuum-filled ring. Bringing the beams together results in the high energy collisions that produce exotic new particles – which can then be observed using suitable detectors, such as the LHC's ATLAS and CMS experiments, which discovered the Higgs boson.





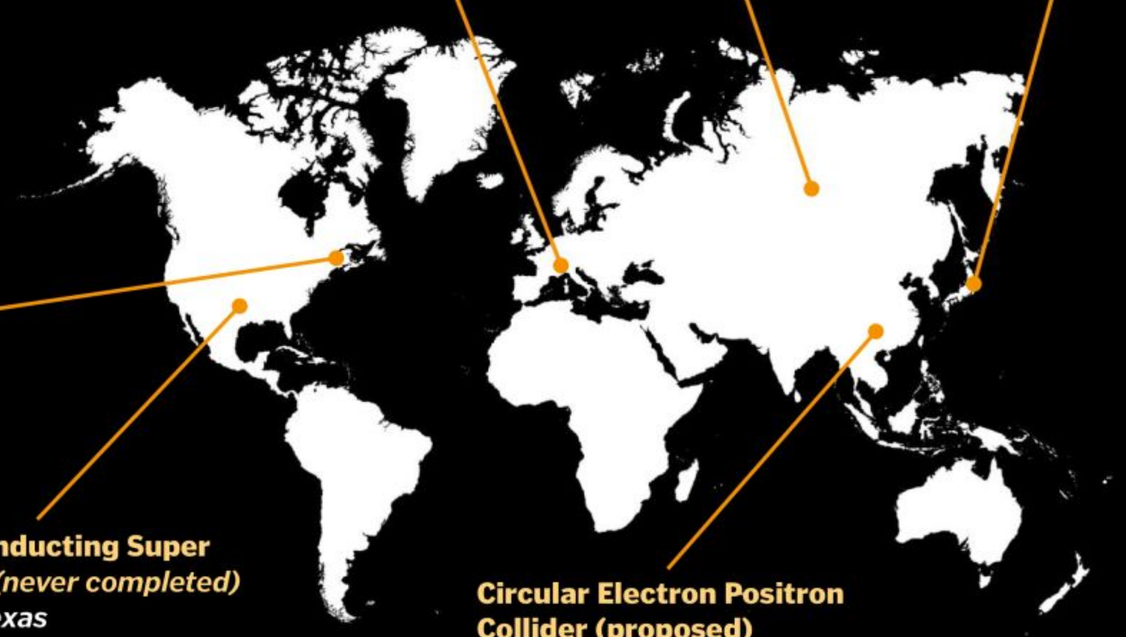
Access shafts to surface
The new collider will be at a similar depth to the LHC, around 100 metres below ground level.

Beam dumps
These are two 4km side tunnels, in which the high-energy particle beams are slowed down and neutralised after use.

Galaxies are believed to be surrounded by mysterious haloes of dark matter (artist's impression)

Four experimental caverns
These will house the various instruments needed to detect new particles created in collision events.

Colliders around the world



2040
The earliest the FCC might start producing useful data

100 megawatts
Likely minimum power drain of FCC

17
Number of fundamental particle types in the Standard Model

-271°C
Temperature of the supercooled magnets inside the collider

100 km
The planned length of the FCC tunnel

34
Countries involved in the collaborative study

299,790 km/sec
Speed of particles inside the collider

€21 billion
Estimated cost to build the FCC

How we taste

Explore the body's fifth sense and how our tongues translate chemical information to our brains

Taste is produced by the body's biological translation of flavour. The responsibility of detecting taste, however, doesn't fall solely on the tongue but works in tandem with the nose.

Before any food has reached the mouth, olfactory (smell) receptors are triggered by volatile odorants (smell compounds) entering the nasal canal. A series of electrical impulses, called action potentials, are created along the adjoining nerve cells, which inform the olfactory cortex of the brain about the scent's identity.

This is when the tongue's role completes the decryption of a food item's taste. Spread across the length and breadth of the tongue are small bumps called papillae. Often mistaken to be your taste buds, these protrusions are the gateways to taste perception. Around 50-100 taste pores/buds are held in the cellular walls of a papilla and detect the chemical composition of food, dividing it into five categories: sweet, bitter, salty, sour and umami (savoury). Foods high in sodium chloride trigger a salty taste, hydrogen triggers sour, sucrose leads to sweet, quinine brings bitter and glutamate (a savoury food compound) results in umami.

However, it is a common misconception that these five tastes are only detected in certain regions of the tongue. In fact, each one can be detected all over. Once a chemical is detected, neurons carry electrical impulses to the brain, informing it of which flavour has been activated.

Together with the information obtained by smell, a conclusion can be drawn about what you're eating and how it tastes. This is why, by pinching your nose while you eat, the brain can detect if the food is sweet or sour, but not its distinct flavour.

The science of spice

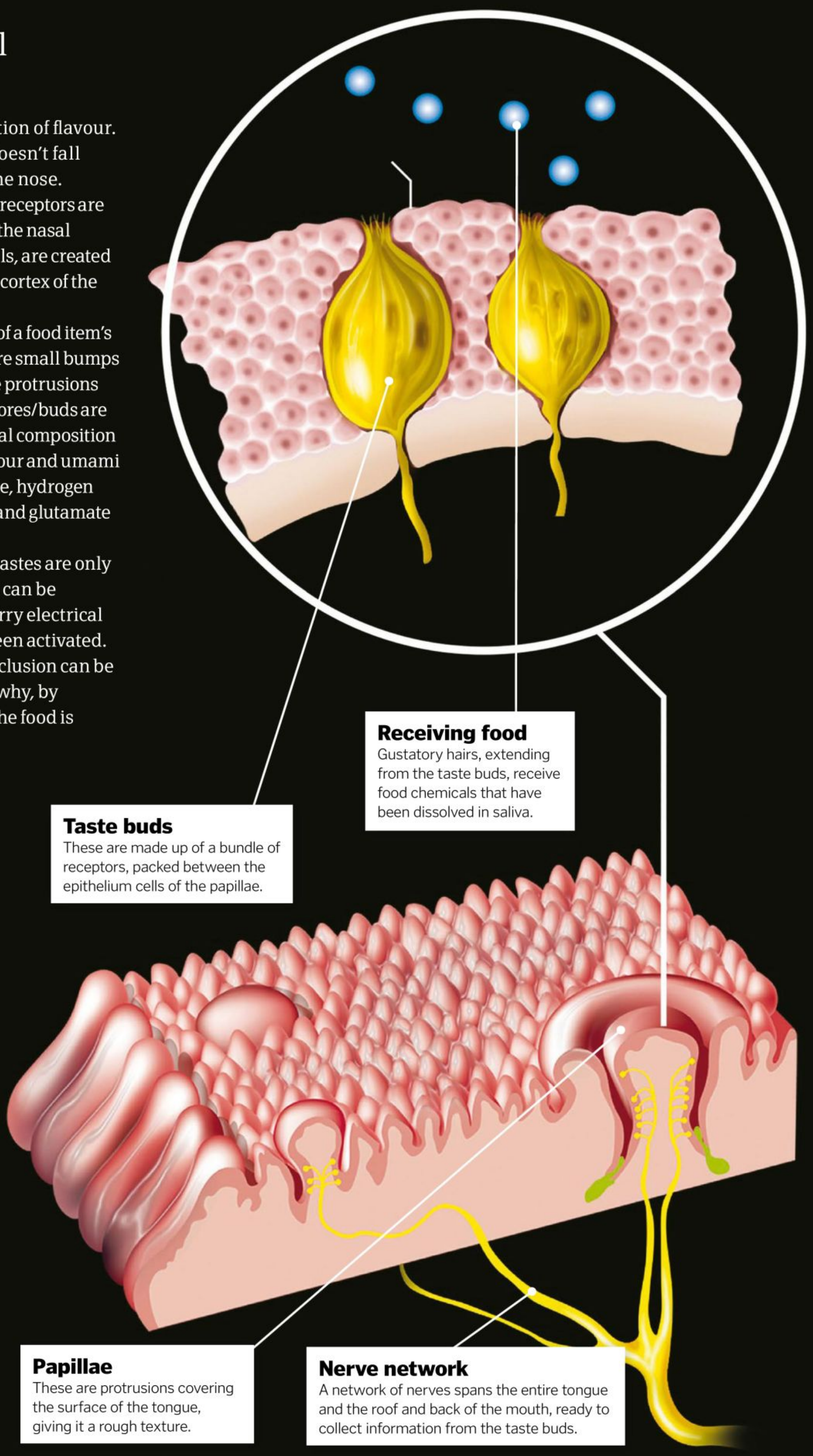
Feeling the initial burn of jalapeño pepper, you might expect spice to be classed as one of the core categories of flavour, alongside sweet and sour. However, the tongue's perception and the body's reaction to spicy food is a result of a chemical crossover. For the purpose of preventing the body ingesting hot (temperature) food, vanilloid/capsaicin receptors on the tongue alert the brain when extreme heat is present in the mouth. Eating chilli peppers has the same effect on the body thanks to their chemical composition.

Varying in degrees of concentration along the Scoville scale, capsaicinoids are a chemical compound found in spicy food and also activate the capsaicin receptors. Just like when you eat hot food, the body's response to spice is to perspire to cool down, release endorphins and increase blood circulation. So rather than being classed as a flavour, spice is merely a chilli's ability to masquerade as heat.

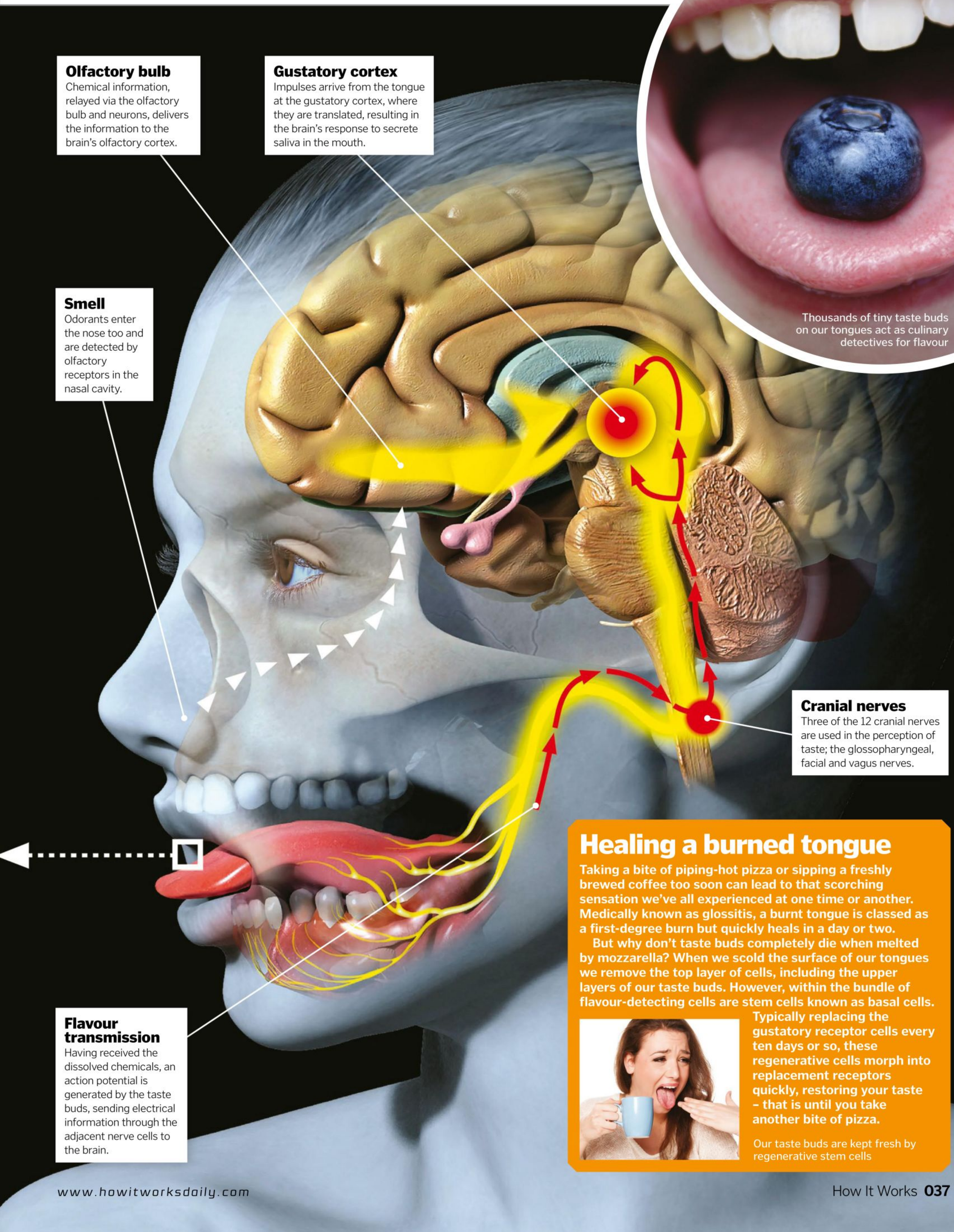
The world's hottest chilli is the Carolina Reaper, 200 times hotter than a jalapeño pepper

From fork to frontal lobe

Discover the chemical journey that triggers our ability to enjoy food



DID YOU KNOW? *There are around 10,000 taste buds on the average person's tongue*



Olfactory bulb
Chemical information, relayed via the olfactory bulb and neurons, delivers the information to the brain's olfactory cortex.

Gustatory cortex
Impulses arrive from the tongue at the gustatory cortex, where they are translated, resulting in the brain's response to secrete saliva in the mouth.

Smell
Odorants enter the nose too and are detected by olfactory receptors in the nasal cavity.

Cranial nerves
Three of the 12 cranial nerves are used in the perception of taste; the glossopharyngeal, facial and vagus nerves.

Flavour transmission
Having received the dissolved chemicals, an action potential is generated by the taste buds, sending electrical information through the adjacent nerve cells to the brain.

Thousands of tiny taste buds on our tongues act as culinary detectives for flavour

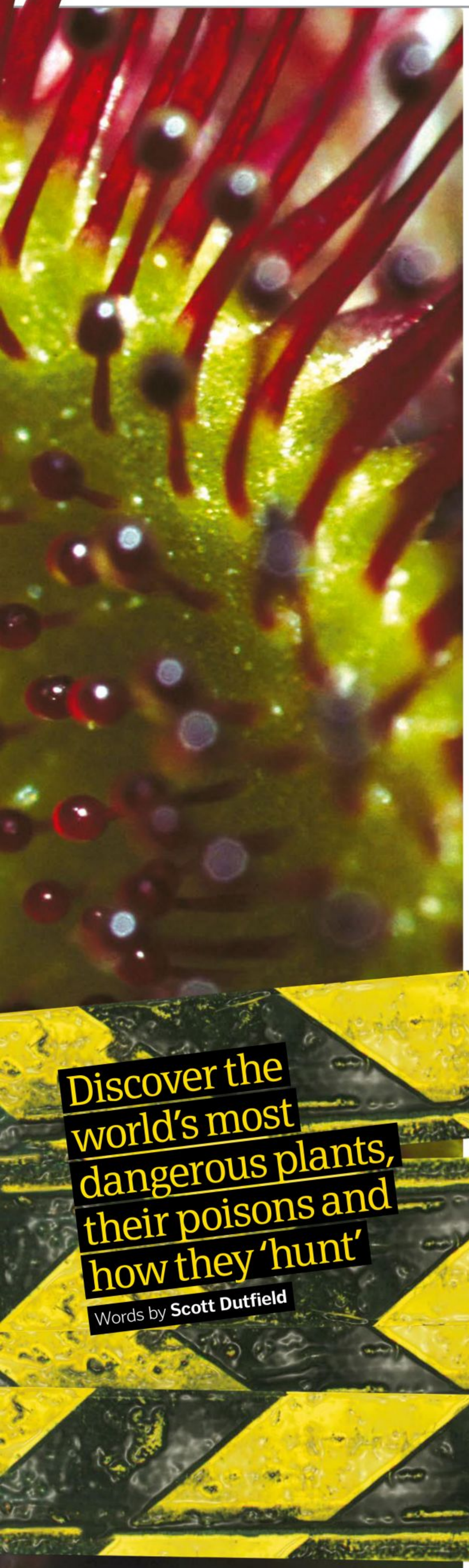
Healing a burned tongue

Taking a bite of piping-hot pizza or sipping a freshly brewed coffee too soon can lead to that scorching sensation we've all experienced at one time or another. Medically known as glossitis, a burnt tongue is classed as a first-degree burn but quickly heals in a day or two.

But why don't taste buds completely die when melted by mozzarella? When we scold the surface of our tongues we remove the top layer of cells, including the upper layers of our taste buds. However, within the bundle of flavour-detecting cells are stem cells known as basal cells. Typically replacing the gustatory receptor cells every ten days or so, these regenerative cells morph into replacement receptors quickly, restoring your taste – that is until you take another bite of pizza.

Our taste buds are kept fresh by regenerative stem cells

DEADLY PLANTS



Discover the world's most dangerous plants, their poisons and how they 'hunt'

Words by **Scott Dutfield**

Whether they're hiding in the depths of the Amazon or growing in our back gardens, deadly plants have spread their roots across the globe. Because they are physically restricted in their ability to defend themselves against becoming a herbivore's dinner, some have evolved to produce nasty chemical compounds for defence.

Most plants considered 'deadly' to humans and animals use poison to protect themselves. A plant is defined as poisonous by its ability to cause harm or a fatality when eaten or touched by a living organism. Over millennia, poisonous plants species have come up with creative ways to defend themselves, each with their own style. Causing anything from cardiac arrests to blistering skin ulcers, a run-in with the wrong plant can send you to the emergency room.

Deadly plant toxins can be generally classified as having either toxic alkaloids, glycosides, oxalates and proteins – each offers their own nasty consequences when touched or otherwise ingested. One of the most poisonous plants on the planet, oleander, contains a deadly cardiac glycoside that can stop the heart after you've ingested only a single one of the flowering plant's leaves.

© Getty

Often seen as a favourite at weddings, lily of the valley can damage the heart if eaten

Since the toxic chemicals are not used in oleander's biological cycles of growth or respiration, they must be present in the plant for the sole purpose of offering protection. Poisonous plants did not evolve alone, however – driven by the ability to adapt to their environment and its edible bounty, some animal species co-evolved to withstand the deadly nature of some plants. The koala is a common example of a species' ability to negate the toxic powers of its meal, eucalyptus leaves. Although

"Causing anything from cardiac arrests to blistering skin ulcers, a run-in with the wrong plant can send you to the emergency room"

Stealing poison power

Immunity to the world's poisonous plants isn't enough for some creatures: some have evolved to take the poison so that they can use it for themselves. Researchers at the Botanical Institute at Christian-Albrechts-Universität zu Kiel (CAU) dedicated ten years to understanding toxic plants and how insects ingest them.

The team found that a collection of insects have evolved the ability to consume toxins called pyrrolizidine alkaloids (PA) within poisonous plants, without harm. This is due to an enzyme within their bodies that prevents the PA causing damage to any of the insects' cells. It not only neutralises the poison's effects while ingested in the beetles' haemolymph (an insect version of blood), the PA is then biologically transported into their defence glands to be secreted when under threat from a predator. These insects literally take the poison out of plants and use it as their own weapon.

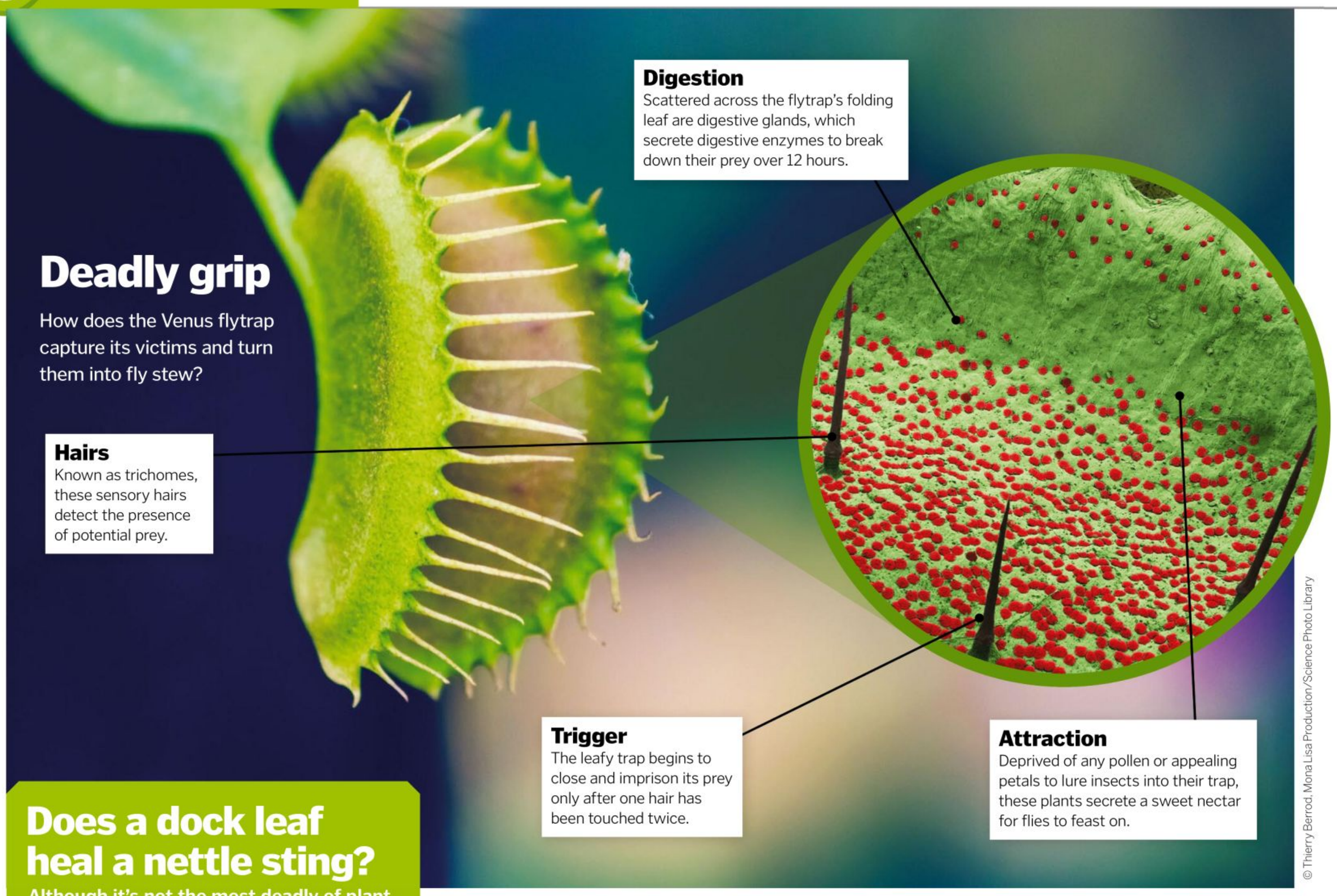
Other invertebrates, such as the cinnabar moth, ingest PA and simply store it within their bodies. Paired with a vibrant appearance – nature's warning signs – predators are alerted that these insects are packing poison.

© Getty

Red markings on the cinnabar moth indicate it will leave a toxic taste behind if eaten

Deadly grip

How does the Venus flytrap capture its victims and turn them into fly stew?



Digestion
Scattered across the flytrap's folding leaf are digestive glands, which secrete digestive enzymes to break down their prey over 12 hours.

Hairs
Known as trichomes, these sensory hairs detect the presence of potential prey.

Trigger
The leafy trap begins to close and imprison its prey only after one hair has been touched twice.

Attraction
Deprived of any pollen or appealing petals to lure insects into their trap, these plants secrete a sweet nectar for flies to feast on.

© Thierry Berrod, Mona Lisa Production/Science Photo Library

Does a dock leaf heal a nettle sting?

Although it's not the most deadly of plant species, a sting from the common nettle can still pack a nasty punch. Coated on each leaf's surface are tiny hollow hairs loaded with a cocktail of irritant formic acid and histamines, which enter the skin when pierced.

To soothe the burning sensation of a nettle sting, rubbing the nearest dock leaf over the wound is often believed to help. Its healing abilities are often attributed to an alkaline sap that neutralises the acidic sting – however, this is simply not the case. It's possible that the evaporation of the broad leaves' moisture on the skin may cool the burning sensation, but its famous healing abilities are a myth.

© Getty

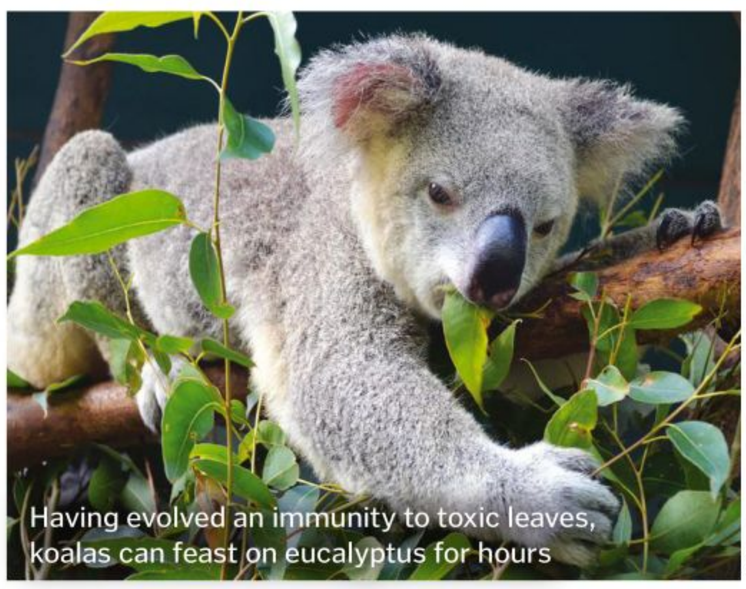
Formic acid in the nettle's spiny hairs penetrates the skin, causing irritation and discomfort

"There is a killer collection of plants that feast on the flesh of passing insects and even amphibians"

they're toxic to most other species, eucalyptus leaves are detoxified by cytochrome P450 enzymes in the koala's large caecum (digestive pouch). These enzymes break down the toxins rapidly, allowing the animals to consume the leaves without fear of injury. However, due to the low calorie value of the eucalyptus, koalas have to consume about 400 grams of leaves and sleep for up to 22 hours every day to survive.

Packing poisons is only one of the many ways plants are some of the most deadly organisms on Earth. Although harmless to human hands, there is a killer collection of plants that feast on the flesh of passing insects and even amphibians. Known as carnivorous plants, Venus flytraps and pitcher plants have evolved to not only take sustenance from traditional methods of photosynthesis, but also actively eat passing prey. Typically these pitcher plants feast on a variety of insects; however, a recent study found that one in five pitcher plants in Ontario, Canada's Algonquin Provincial Park has been chowing down on juvenile salamanders. The way these saxophone-shaped plants digest their prey is by luring them into a pool of collected rainwater. Once the salamanders have taken a dip, they cannot climb the pool's waxy walls and find themselves trapped. The pitcher plant then secretes digestive enzymes into the salamander's watery grave.

Having died naturally from either starvation of overheating, the salamanders decompose in about ten days. The pitcher plant will then absorb its nutrients from this 'salamander stew' as a tasty treat.



Having evolved an immunity to toxic leaves, koalas can feast on eucalyptus for hours

© Getty

DID YOU KNOW? *Castor oil has been used for centuries as a natural laxative*

The 10 most poisonous plants

1 Oleander *(Nerium oleander)*

Native: Eurasia and northern Africa

Generally considered the worst of the bunch, this plant is poisonous from root to petal. Equipped with the toxin oleandrin, oleander can cause vomiting, irregular heartbeats and even death. Ingesting one leaf is enough to be fatal.

©Getty

2 Water hemlock *(Cicuta maculata)*

Native: North America

Don't be fooled by this plant's angelic flower: this is one of the world's most poisonous plants. Flowing through every part of the plant is a cicutoxin that can cause convulsions, muscle tremors and death. Toxins are highly concentrated in the roots.

© Choess

3 Rosary pea *(Abrus precatorius)*

Native: Asia and Australia

Less than three micrograms of the toxin abrin is enough to be fatal, making it deadlier than ricin. Oddly, the toxin is only held in the casing. Once that's broken, the abrin is released, but swallowing the seeds whole is relatively safe.

© Vinayaraj

4 Deadly nightshade *(Atropa belladonna)*

Native: Eurasia and northern Africa

Deadly nightshade has a potent ability to paralyse the body's nerves. It causes injury to the heart and intestinal muscles, and it only takes ingesting 10 to 20 berries to be fatal to an adult.

© Donald Macauley

5 Castor bean *(Ricinus communis)*

Native: East Africa

Although castor oil is safe and used in food and drug production as well as beauty products, the seeds contain the poison ricin. Eating an unprocessed bean can lead to internal bleeding, vomiting and circulation failure.

©Getty

6 Suicide tree *(Cerbera odollam)*

Native: Asia and Australia

The suicide tree is named for its seemingly harmless, yet deadly, fruit. Each seed is highly concentrated in a potent cardiac glycoside called cerberin. The seeds of the tree can slow down the heart's rhythm, sometimes to a fatal extent.

© Vengolis

7 White snakeroot *(Ageratina altissima)*

Native: North America

This plant can cause what is commonly known as milk sickness if ingested by cattle: meat and milk by-products can contain a toxic alcohol, known as trematol, that can lead to vomiting, muscle stiffness and death.

© H. Zell

8 Aconite *(Aconitum napellus)*

Native: UK

Toxic to the touch, aconite can cause numbness and even heart difficulty after contact, thanks to its alkaloid toxins. Often mistaken for horseradish roots, this plant can cause vomiting, high blood pressure and diarrhoea when ingested.

© Léna Gahéry

9 Jimson weed *(Datura stramonium)*

Native: Central America

Jimson weed, also called devil's snare, is a plant in the nightshade family. Ingested in high quantities, its poison can cause seizures or place you in a coma. Its alkaloid toxins have also been known to cause hallucinations.

©Getty

10 Manchineel tree *(Hippomane mancinella)*

Native: Central America

Few poisonous plants can infect their victims by a simple touch. Laced with a cocktail of poisons, this tree's sap will cause irritation to the skin and eyes. Bite into the apple-like fruit and your mouth will quickly blister.

© Jason Hollinger

EXPLORE THE PLANET'S WILDEST PLACES

Where are the planet's pockets of true wilderness, and what plants and animals would we see if we visited?

Words by **Victoria Williams**

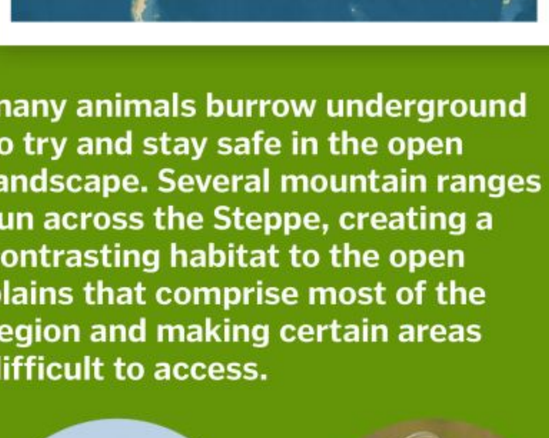
"These remote, rugged and often dangerous areas have been left largely intact because it's just too difficult for the average person to make a home there"

Eurasian Steppe

8,000km across

The Eurasian Steppe, also known as the Great Steppe or simply the Steppe, is a huge temperate grassland ecosystem stretching from Bulgaria to Mongolia. It has been home to tribes and nomadic peoples for thousands of years, its extreme seasons making it a challenging place to live.

Many scientists believe that horses were first domesticated on the Eurasian Steppe, giving the nomads a much more efficient way of travelling between pastures and attacking rivals. Plants here are resistant to fire and grazing, and many animals burrow underground to try and stay safe in the open landscape. Several mountain ranges run across the Steppe, creating a contrasting habitat to the open plains that comprise most of the region and making certain areas difficult to access.



Saiga

Bobak marmot

Saker falcon

Feather grass

Saiga image © Andrey Giljov

Living in towns and cities, sitting in traffic jams and flying to different continents in a matter of hours, it can be hard to imagine that any of the Earth's surface remains untouched by humans. Recent analysis, however, revealed around a third of the land is still wilderness, inhabited by about two per cent of the population. These remote, rugged and often dangerous areas have been left largely intact because it's just too difficult for the average person to make a home there.

Those who brave the extreme conditions, scarce food and water, testing terrain and isolation have developed lifestyles that make their existence possible. But some now face new challenges in the wake of climate change and human activity, such as the extraction of oil and timber.

From the scorching desert to the empty expanses of northern Canada, life can be found in even the most hostile environments. Plants and animals living in these wild places have evolved to survive and thrive, with their adaptations making them some of the most unusual species on the planet. Tourists and scientists travel to the wilderness to escape their busy lives and search for species that can be found nowhere else, but even with our advancing technology and knowledge there are still areas that people can't reach. Here, native wildlife is free to flourish uninterrupted. It's estimated that there are still millions of species on the planet not known to science.

Reclaimed by nature

Humans are responsible for the shrinking of wild areas all over the planet, but given time and an opportunity, nature often finds a way of sneaking back in. Abandoned settlements and facilities will never return to the way they were before people arrived, but they can become wild around the edges.

Fukushima and Chernobyl, the sites of huge nuclear disasters, are now home to the descendants of the pets left behind when their owners were evacuated. The isolated Japanese island of Okunoshima was used for the secret production of chemical weapons in World War II. After the war, the island was turned into a park and is now nicknamed 'Rabbit Island' after the hundreds of animals found hopping around today.

It's not just animals that take over when people leave. Tree roots cover the ruins of Angkor Wat, a Buddhist temple in Cambodia, and mangroves burst from the rusting body of the SS Ayrfield in Australia's Homebush Bay. The Namibian town of Kolmanskop once bustled with diamond miners, but it was abandoned in 1956 and today stands as a ghost town, popular with tourists who come to wade through the sand-filled buildings.

Once a diamond-mining town, Kolmanskop has now been reclaimed by the Namib Desert

Nunavut

2.1 million km²

Nunavut, northern Canada's largest and newest territory, has a population of around 39,000 people. To put this into context, Mexico – a country very similar in size – has a population of 132 million. Because of its high latitude, January temperatures regularly plummet below -30 degrees Celsius. Most of Nunavut's population are Inuit, indigenous peoples who survive the freezing temperatures by consuming a high-fat diet and gathering the few plants that are able to grow in the territory. Little rain falls, so vegetation is incredibly sparse – those species that do survive are tough plants like lichens, moss and berries. With its multitude of islands, Nunavut is popular with visitors keen to see its array of native animals both on land and by water.

Rock ptarmigan

Polar bear

Wolverine

Faroe Islands

1,399km²

Draw a triangle between Scotland, Iceland and Norway, and the Faroe Islands lie almost at the centre. An independent country as part of the Kingdom of Denmark, these 18 subpolar islands are home to just over 50,000 people. Although the recent development of roads and bridges has connected several islands, some are still accessible only by helicopter or boat.

Thanks to the Gulf Stream, temperatures on the archipelago usually remain above freezing, though the weather is regularly wet and windy. Arctic-alpine plants thrive in these conditions, and lowland areas are dominated by grasses and heath. Every tree and land mammal there is the result of human introduction, but seabirds and marine mammals have been regular visitors for many years.

Long-finned pilot whale

Atlantic puffin

Faroe sheep

THERE ARE MORE SHEEP ON THE FAROE ISLANDS THAN PEOPLE

Amazon rainforest

5.5 million km²

The Amazon's tropical trees cover most of South America's Amazon basin. 60 per cent of the rainforest is found in Brazil, with the rest reaching across eight other nations. The most biodiverse place on Earth, it's home to over 40,000 species of plant, 1,300 species of bird and 400 species of mammal. A few thousand indigenous people live in the Amazon; the population is hard to estimate, and it's thought that several tribes remain uncontacted.

Despite the flourishing life of the forest, soil in this region is poor in nutrients and not suited to intense agriculture. Deforestation in this area is a huge concern for many people; not only does it contain thousands of species found nowhere else, it also produces more than 20 per cent of the planet's oxygen.

Pink river dolphin

Hoatzin

"A few thousand indigenous people live in the Amazon; the population is hard to estimate, and it's thought that several tribes remain uncontacted"

Sahara Desert

9.2 million km²

Covering an area only slightly smaller than the whole of the US, the Sahara Desert is the largest nonpolar desert on the planet. The Sahara region has switched between desert and grassland for thousands of years because of the Earth's changing axis; the last time it was lush and green is thought to have been between 5,000 and 10,000 years ago.

The desert stretches across most of northern Africa, and while large areas have been turned into towns and cities, vast expanses remain too harsh for humans; it's estimated that there's just one human inhabitant for every square mile. Plants and animals living in the desert have evolved to withstand extremes of temperature and use water efficiently, with many hunting and foraging at night to avoid the unforgiving midday Sun.

Dromedary camel

Fennec fox

Scarab beetle

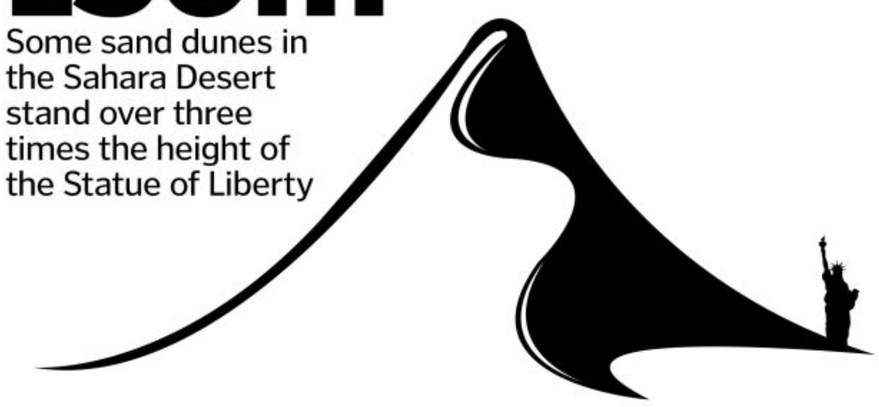
Saharan horned viper

68%

By 2050, it's estimated that over two-thirds of the world's population will live in urban areas

150m

Some sand dunes in the Sahara Desert stand over three times the height of the Statue of Liberty



Papua New Guinea

462,840km²

Papua New Guinea has a population of roughly 8.5 million – 15 people per square kilometre. Under 20 per cent of these people live in urban areas, the majority living in traditional rural communities. Papua New Guinea is part of the humid tropics and has large expanses of rainforest, but the mountains of the Central Range are so high that rare equatorial glaciers can be found among the peaks.

Much of the country is reachable only by foot or by plane because of the rugged terrain and thick forest, and it remains one of the least explored nations in the world. Multiple groups of uncontacted people exist in Papua New Guinea, living self-sustainably and having no contact with other humans. New species of flora and fauna are still being discovered.

Tree kangaroo

Saltwater crocodile

Ulysses butterfly

Pink flowered doughwood

ON AVERAGE, A NEW SPECIES IS DISCOVERED IN THE AMAZON EVERY TWO DAYS

How coral reefs form

Corals are team players, collaborating to build the largest living structures on Earth

Covering just 0.1 per cent of the world's surface, coral reefs are home to around 25 per cent of all the species in the ocean. These seemingly static structures are constantly surrounded by colour and movement, and while they're often mistaken for rocks or plants, the corals themselves are living animals; they belong to the group Cnidaria, along with jellyfish and sea anemones.

Corals can grow to vast sizes, but these aren't enormous individual animals – they're colonies made up of thousands of tiny creatures. On its own, each invertebrate is known as a coral polyp and can be as small as one centimetre in diameter. These polyps are sessile, meaning that they remain in a single spot once they've reached maturity and catch passing food with tentacles around their mouths.

The structure of a coral reef is provided mostly by the stony corals, or hard corals. These reef-building corals grow best in shallow tropical water with fast currents to bring food their way. Polyps slowly aggregate and connect their gastrovascular canals so they can share nutrients. Hard coral colonies gain their stony appearance through the secretion of calcium carbonate, a compound that forms a hard exoskeleton around the delicate polyps.

The hard skeletons and twisting shapes of reef corals provide shelter for a variety of creatures. Animals like shrimps and crabs defend homes made in the nooks between branches, and many species spawn around the reef to protect their young from the strong current. Single-celled algae called zooxanthellae even share the energy they produce from photosynthesis in exchange for lodgings within a polyp's body.

Manta ray
With a wingspan that can exceed 4.5 metres, manta rays are majestic to behold as they swim in search of fish and plankton.

Reef shark
Several species of shark, such as the blacktip reef shark and the grey reef shark, hunt around coral reefs.

Lionfish
Most other animals stay away from lionfish – bright colours warn of the venom within their long spines.

Life on the reef

From sea slugs to sharks, thousands of animals live on and around the coral reef

Coral reef snake
Sea snakes are highly venomous and spend most or even all of their lives underwater.

Nudibranch
Also known as sea slugs, these can be found in a range of remarkable colours and forms.

Tube sponges
Growing slowly over hundreds of years, these can reach over 1.5 metres in height.

The making of a coral colony

Fringing reef
Free-swimming coral larvae settle and attach themselves to submerged rocks.

Barrier reef
Fringing reefs around an island can join up to form a border around the whole coastline.

Atoll
If a volcanic island subsides below the waves, it leaves behind a coral atoll.

The Great Barrier Reef is considered one of the wonders of the natural world

The Great Barrier Reef

Comprised of over 2,500 individual reef systems and hundreds of tropical islands, Australia's Great Barrier Reef is the most extensive reef ecosystem on the planet. It covers almost 350,000 square kilometres; it's so large, in fact, that it can be seen from space.

It has incredible biodiversity. 1,500 species of fish, 4,000 species of mollusc and some 240 species of bird call the reef home. Anemones and sponges add colour, while crustaceans and marine worms fill the reef with movement. Threatened species like the green turtle and dugong can still be found here, and clouds of butterflies head to the islands for the winter.

The Great Barrier Reef is a haven for wildlife. Most of the ecosystem's area has been a World Heritage Site since 1981, but its future is far from certain. Pollution, climate change, unsustainable fishing and coastal development all threaten this iconic reef.

DISCOVER THE UNIVERSE

www.spaceanswers.com

All About Space

Available from all good newsagents and supermarkets

ON SALE NOW

Race to the Moon > The theory of everything > Exomoon discovery > Music of the stars

BUY YOUR ISSUE TODAY

Print edition available at **www.myfavouritemagazines.co.uk**

Digital edition available at **www.greatdigitalmags.com**

Available on the following platforms

Print · Tablet · Phone · Desktop

facebook.com/AllAboutSpaceMagazine twitter.com/spaceanswers

SCIENCE SECRETS OF APOLLO

Incredible feats of ingenuity made the 1969 Moon landing possible – many that you probably never knew about

Words by **Andrew May**

©NASA

1969 Apollo 11

Fifty years ago this July, Apollo 11 carried three astronauts – commander Neil Armstrong, Command Module pilot Michael Collins and Lunar Module pilot Edwin 'Buzz' Aldrin – all the way to the Moon. Once there, Armstrong and Aldrin went down to the surface for a history-making Moonwalk, while Collins stayed in lunar orbit. Then they returned to Earth, splashing down in the Pacific some eight days after they left the planet.

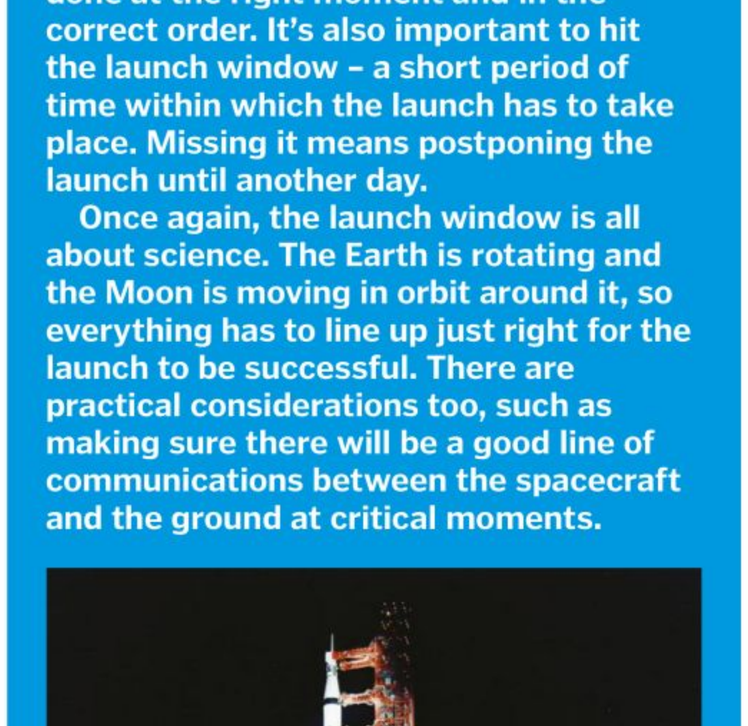
Even from today's perspective, the Moon landing was an astonishing achievement, and in 1969 it pushed the limits of what was technologically possible. Yet the science behind it was 300 years old, going all the way back to Isaac Newton's law of gravity, first formulated in the 1660s. That may sound counterintuitive, because gravity is what holds us to the surface of the Earth. But if you toss a ball up in the air, it travels higher and higher as you launch it with increasing speed. Newton realised the same trend continues out in space. The faster something leaves Earth, the further it travels before coming back. Give it enough speed – sideways as well as up – and it will go into orbit. Even more speed, and it can reach the Moon.

The first humans to reach the Moon – going round it, rather than landing – were the crew of Apollo 8 in December 1968. They understood the science as well as anyone. As one of them, William 'Bill' Anders, said on the journey home, "I think Isaac Newton is doing most of the driving right now." That's not Newton himself, of course, but his law of gravity. It's the reason spacecraft don't need to run their engines all the time, just in short 'burns' to get up to the right speed, and then gravity does the rest.

"I think Isaac Newton is doing most of the driving right now"

Using the world's biggest rocket

The key to getting a spacecraft to the Moon is giving it enough speed – around 11 kilometres per second – to carry it all the way there before it falls back to Earth. The Apollo spacecraft weighed close to 50 tons, so accelerating all that mass to the necessary speed required a lot of energy. The solution: the 111-metre-tall, three-stage Saturn V. Designed by the German-American rocket scientist Wernher von Braun, it remains to this day the largest, most powerful space launcher that has ever flown.



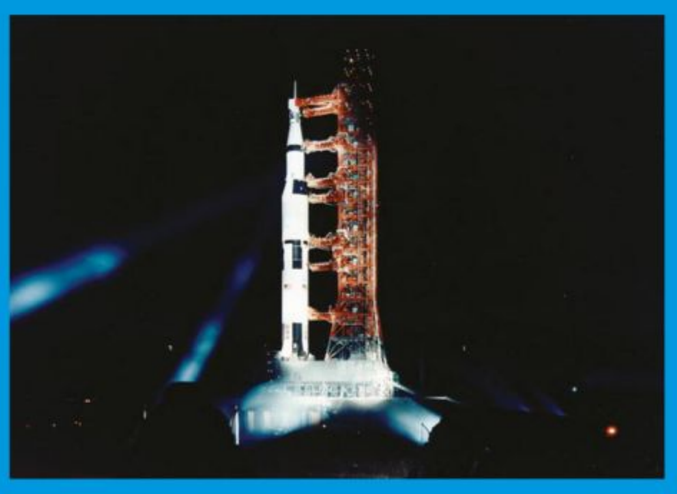
©NASA

The Saturn V's main engines tower over its designer, Wernher von Braun

Launching precisely on time

One of the most dramatic features of any space mission is the pre-launch countdown. But it's not there simply to add edge-of-the-seat excitement for people watching – it's to make sure all the necessary tests and preparations are done at the right moment and in the correct order. It's also important to hit the launch window – a short period of time within which the launch has to take place. Missing it means postponing the launch until another day.

Once again, the launch window is all about science. The Earth is rotating and the Moon is moving in orbit around it, so everything has to line up just right for the launch to be successful. There are practical considerations too, such as making sure there will be a good line of communications between the spacecraft and the ground at critical moments.

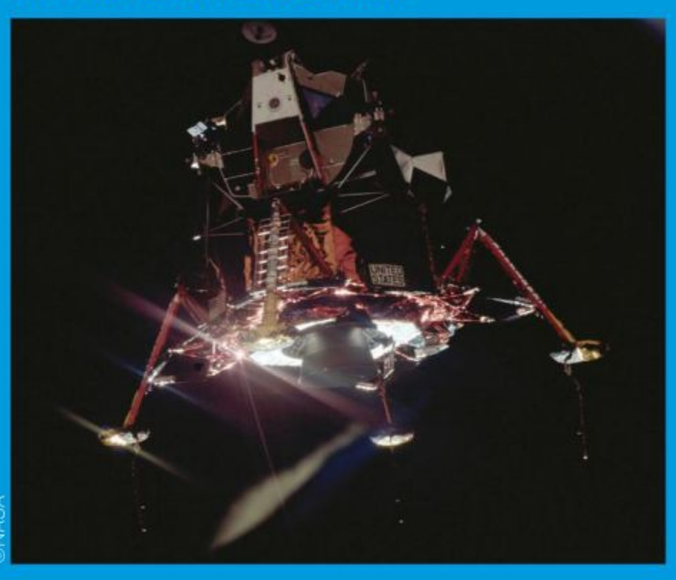


©NASA

Apollo 11 during a night-time countdown test a few days before launch

Combining two spaceships into one

When NASA first conceived the Apollo project at the start of the 1960s, it was assumed the whole spacecraft would land on the Moon and then take off again to return to Earth. But that's really not very efficient. The amount of fuel a rocket needs increases with mass, and if you do things this way you're lifting more mass off the Moon than you need to. You can save fuel by going down to the surface in a separate landing vehicle specially designed for that task. So Apollo effectively became two spacecraft in one: the Command Module (CM) to get to and from the Moon, and the Lunar Module (LM) for the landing itself.

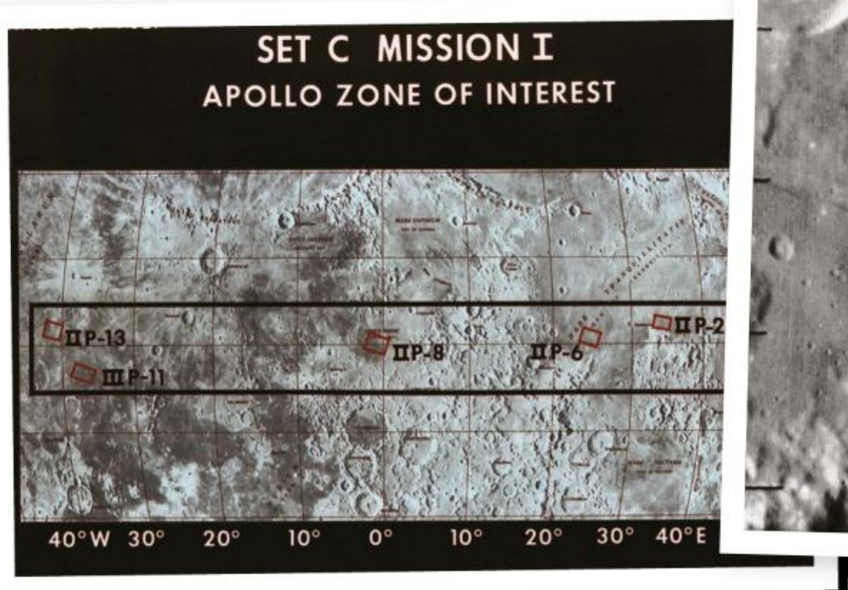


©NASA

The Lunar Module starts its descent to the Moon, as photographed by Collins in the CM

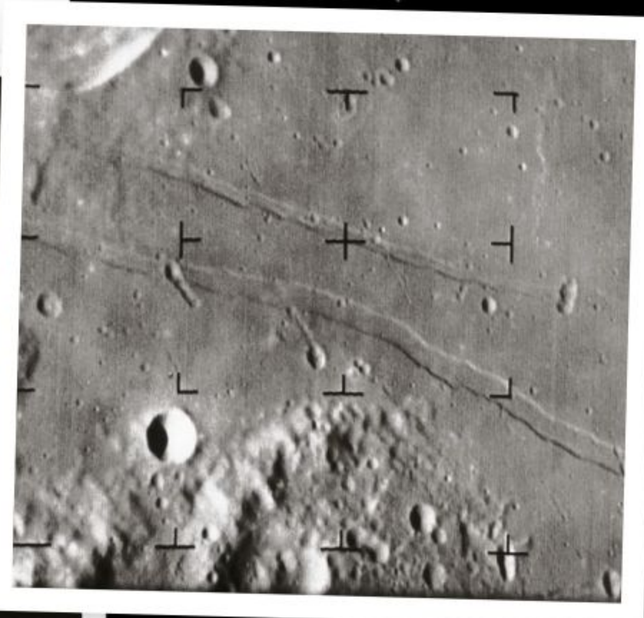
Choosing the right landing site

Apollo 11 headed for a spot in the southwest of the Moon's Sea of Tranquillity – a spot now known as 'Tranquillity Base'. NASA put a lot of thought into a suitable site, coming up with a shortlist of five options. These were all close to the lunar equator, as that provided the least risky trajectory for the spacecraft. Other requirements were for flat, relatively uncratered terrain and good visibility during the approach. These factors were assessed using reconnaissance photos taken by unmanned Ranger and Surveyor probes.



©NASA

Landing options were all near the Moon's equator – IIP-6 is Tranquillity Base



Reconnaissance photo of the area around Tranquillity Base, taken by Ranger 8 in 1965

Apollo 11's flight path

Splashdown
Date: 24 July 1969
Time: 16:50:35
Finally the SM is discarded, leaving just the CM to splash down in the Pacific Ocean.

Lift-off
Date: 16 July 1969
Time: 13:32:00 UTC
The three-stage Saturn V rocket launches Apollo 11 from the Kennedy Space Center in Florida.

Translunar injection
Date: 16 July 1969
Time: 16:22:13
The third stage fires up again, putting Apollo on a trajectory that will take it to the Moon.

Linkup with Lunar Module
Date: 16 July 1969
Time: 16:56:03
The Command Module (CM) docks with the Lunar Module (LM), as the empty third stage is jettisoned.

DID YOU KNOW? *The Apollo guidance computer contained 12,300 transistors. Your smartphone has over 1 billion of them*

Leaving lunar orbit
Date: 21 July 1969
Time: 23:41:31
After the LM is jettisoned, the SM fires up again to put Apollo on a homeward trajectory.

"Apollo 11 headed for a spot in the southwest of the Moon's Sea of Tranquillity"

Initial parking orbit
Date: 16 July 1969
Time: 13:43:49
The spacecraft, still attached to the Saturn V's third stage, orbits Earth while final checks are carried out.

The landing
Date: 20 July 1969
Time: 20:17:39
Armstrong and Aldrin descend to the surface in the LM, before ascending to rejoin Collins in the CM.

Lunar orbit
Date: 19 July 1969
Time: 17:21:50
On arrival at the Moon, the Service Module (SM) engine fires to put the spacecraft into orbit.

Apollo 11 blasts off on its history-making journey to the Moon

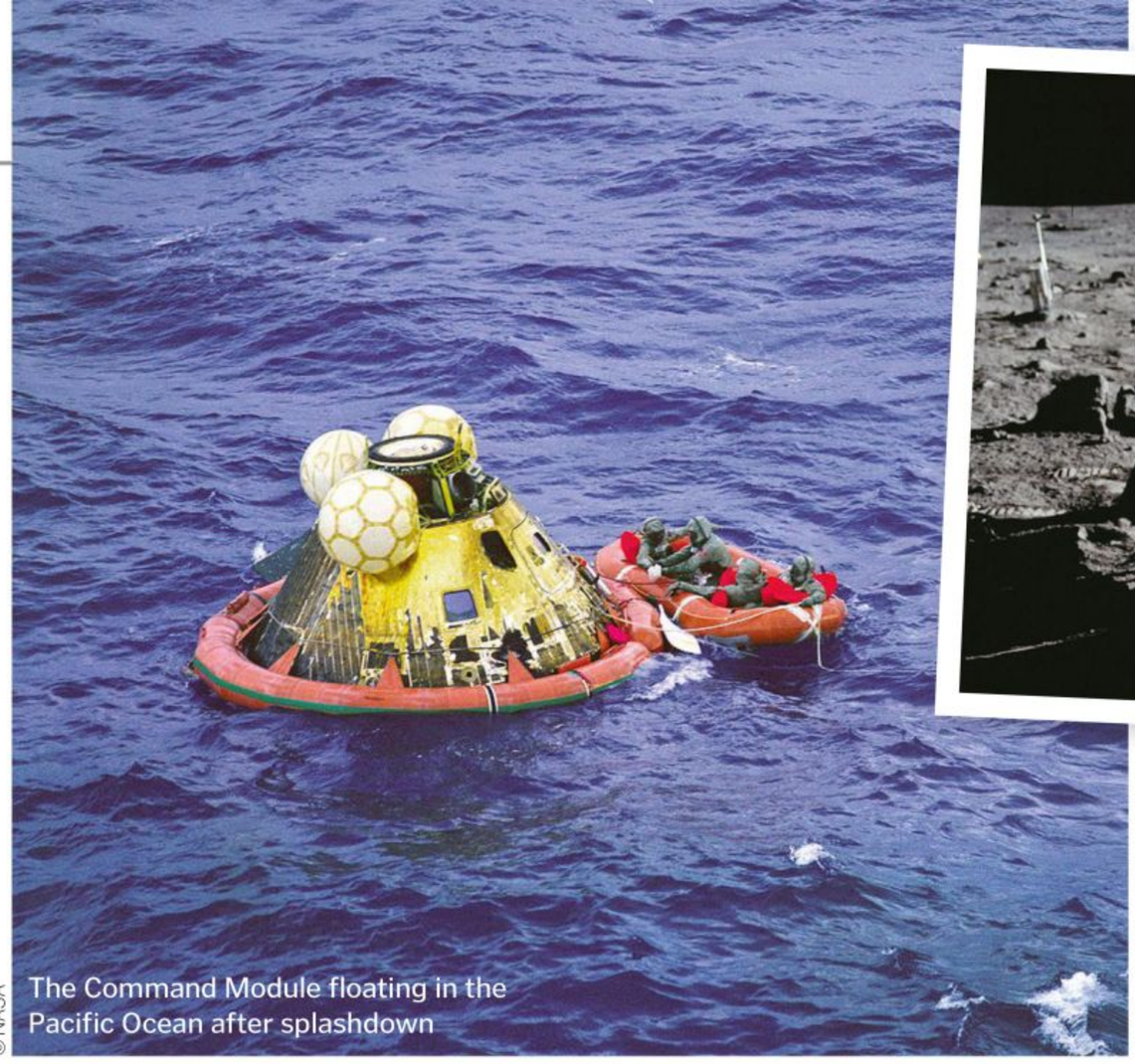
What happened to gravity?

We've seen how gravity is the main driving force in getting to the Moon. Yet one of the most familiar features of spaceflight is the 'zero-g' environment – the way astronauts lose all sensation of weight. How do you reconcile these two facts? As paradoxical as it sounds, the second follows from the first. When an object moves freely in a gravitational field – whether it's falling to Earth, or in orbit around it, or en route to the Moon – it's effectively weightless. If you find that idea difficult, don't worry – Einstein did too. He puzzled over it for years, and when he finally worked it out the result was his famous theory of general relativity.

As the astronauts landed on the Moon, they experienced weight again – but only at a sixth of its strength on Earth. Gravitational fields are generated by mass, and the Moon is much less massive.

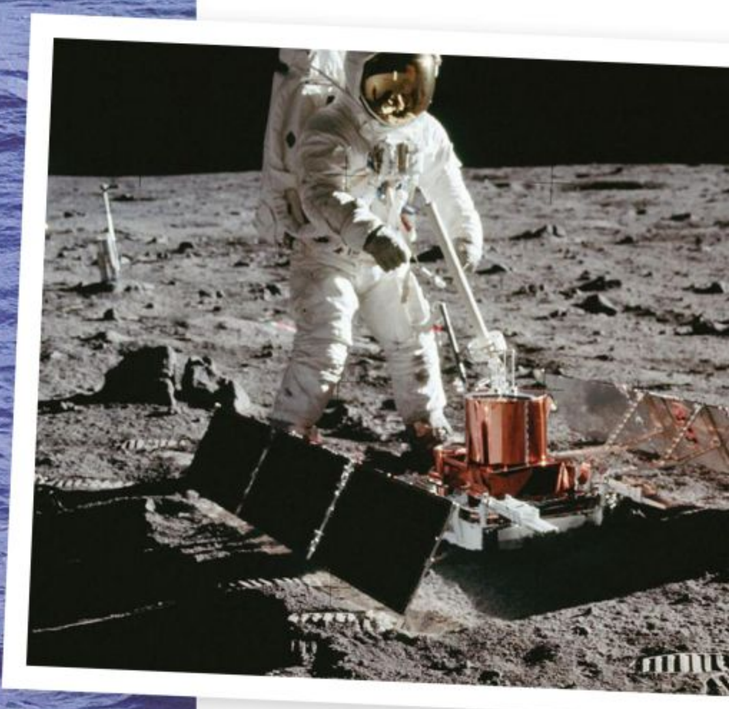
© Getty

Apollo 10 astronauts Thomas Stafford and John Young demonstrate weightlessness



© NASA

The Command Module floating in the Pacific Ocean after splashdown



The astronauts found time to deploy a few science experiments, such as this seismometer

Anatomy of the Apollo-Saturn V Moon rocket

It was made of around 3 million separate parts: here are some of the most important ones

Third stage

The third stage – also hydrogen-fuelled – is fired twice: once to enter Earth orbit, and then to push onwards to the Moon.

Second stage

Using liquid hydrogen fuel, the second stage takes over for another six minutes, getting close to orbital velocity.

Main engines

A cluster of five rocket engines, each over five metres tall, are needed to lift the near 3,000-ton giant off the ground.

First stage

The Saturn V's kerosene-fuelled first stage lifts it to an altitude of 68km in 165 seconds, before falling away.

Instrument unit

It may look small and insignificant, but this is the brain of the Saturn V – its guidance computer.

Lunar Module shroud

On ascent, the LM is stowed inside this protective cover, attached to the Saturn V's instrument unit.

© Science Photo Library

The ascent stage of the Lunar Module returning from the Moon's surface

The 'impossible' lunar liftoff

At first sight, it seems odd that the Lunar Module's ascent stage, with just a single small rocket engine, was able to launch two astronauts off the Moon's surface. Didn't it require the enormous Saturn V to get three of them off the Earth? If you look into the physics, though, there isn't really any contradiction. The Saturn V had to send a 50-ton spacecraft all the way to the Moon, which calls for a speed of around 11 kilometres per second. In contrast, the LM ascent stage only had to lift itself – less than five tons – while the Moon's weaker gravity meant it could get into lunar orbit with a speed of just 1.6 kilometres per second. So a lot less energy was needed, which is why a smaller rocket did the job.

Service Module
An essential part of the Apollo spacecraft, providing power, communications and life support, as well as propulsion.

Service Module engine
Almost as large as the CM itself, this powerful rocket engine is used to enter and leave lunar orbit.

Lunar Module
The LM consists of the crew-carrying ascent stage on top of the four-legged descent stage, which remains on the Moon.

"The Saturn V had to send a 50-ton spacecraft to the Moon"

Launch Escape System
Thankfully not needed, this is there to whisk the CM to safety if the rocket fails on launch.

Command Module
The main crew compartment, where Collins remains while the others descend to the surface.

Earth landing system
A fancy way of saying parachutes – three large ones – to slow the CM to a safe speed for splashdown.

Apollo spacecraft
The Saturn V's all-important payload, this is the part that actually travels to the Moon.

Back down to Earth
The crew-carrying Command Module was the only part of the spacecraft to return to Earth

Access hatch
This is where the crew enter the CM before launch and exit after splashdown.

Surface temperatures

- 2,760°C
- 2,200°C
- 1,650°C
- 1,400°C
- 800°C

Aft heat shield
This has to withstand the highest temperatures during re-entry, as it faces the direction of motion.

Reaction control engines
These are small rocket motors that control the orientation of the CM during re-entry.

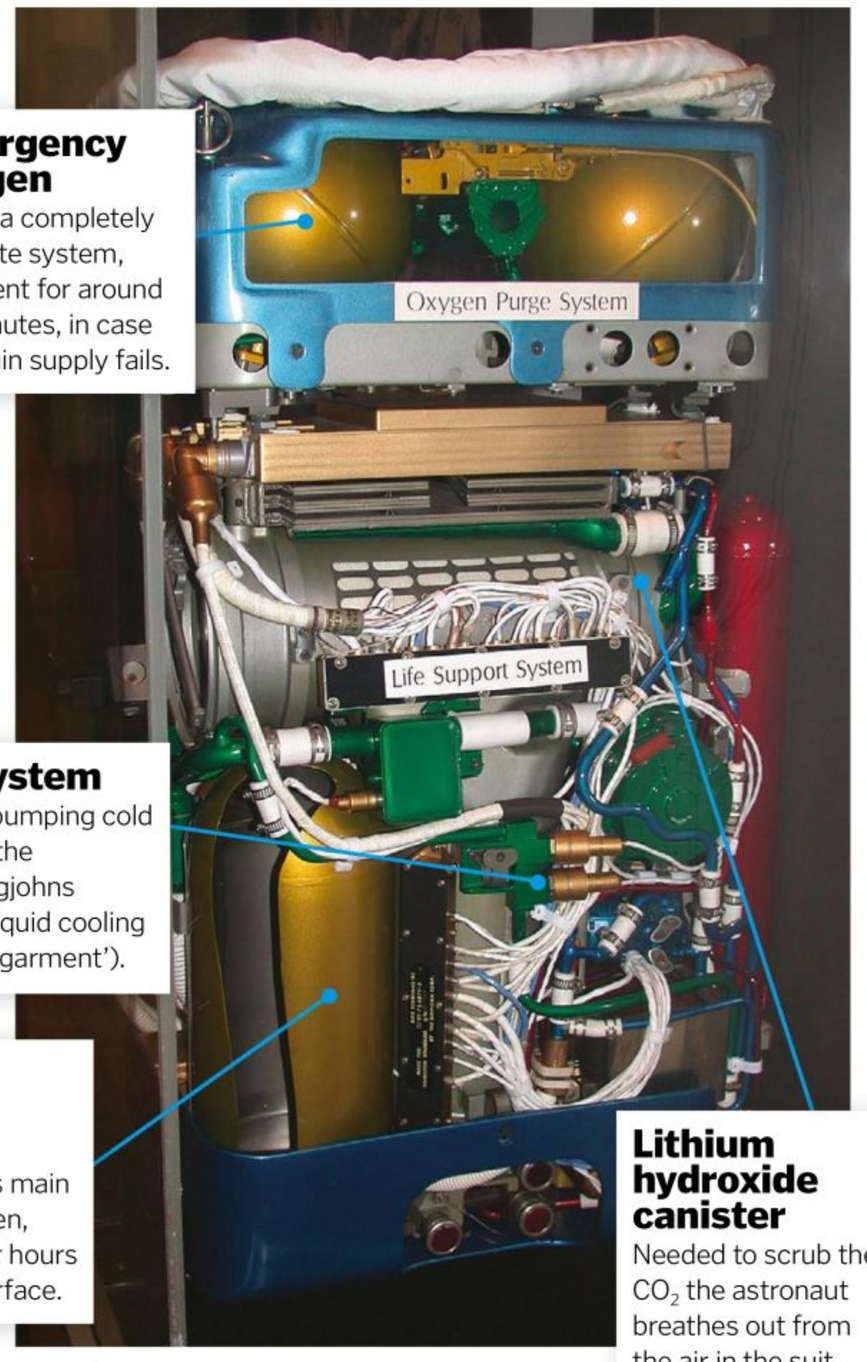
Crew compartment heat shield
The temperatures are less intense here, so the heat shield can be thinner.

Staying alive with multiple life support systems

There's no air in space or on the Moon, so the astronauts needed safe and reliable life support systems. There was one in the CM and one in the LM, as well as a portable life support system (PLSS) in the backpacks Armstrong and Aldrin wore for their Moonwalk. The Earth's atmosphere is around 80 per cent nitrogen, but humans don't need that to breathe, so instead the astronauts used pure oxygen at a third of normal pressure.

That was the easy part. They also needed to get rid of the carbon dioxide (CO_2) they exhaled, which can be very dangerous if it builds up. Fortunately there's a powdery chemical called lithium hydroxide (LiOH) that absorbs CO_2, and the Apollo missions used LiOH canisters to 'scrub' CO_2 from the air.

A rear view of Aldrin on the Moon, showing the bulky PLSS backpack



Emergency oxygen
This is a completely separate system, sufficient for around 30 minutes, in case the main supply fails.

Cooling system
This works by pumping cold water through the astronaut's longjohns (technically a 'liquid cooling and ventilation garment').

Primary oxygen supply
The astronaut's main source of oxygen, enough for four hours on the lunar surface.

Lithium hydroxide canister
Needed to scrub the CO_2 the astronaut breathes out from the air in the suit.

"Viewers around the world remained glued to their sets"

The effects of too much CO_2

0.04% Earth-normal concentration

1% Drowsiness

3% Strain on heart; hearing difficulties

8% Loss of consciousness and eventually death

© NASA

Surviving re-entry into Earth's atmosphere

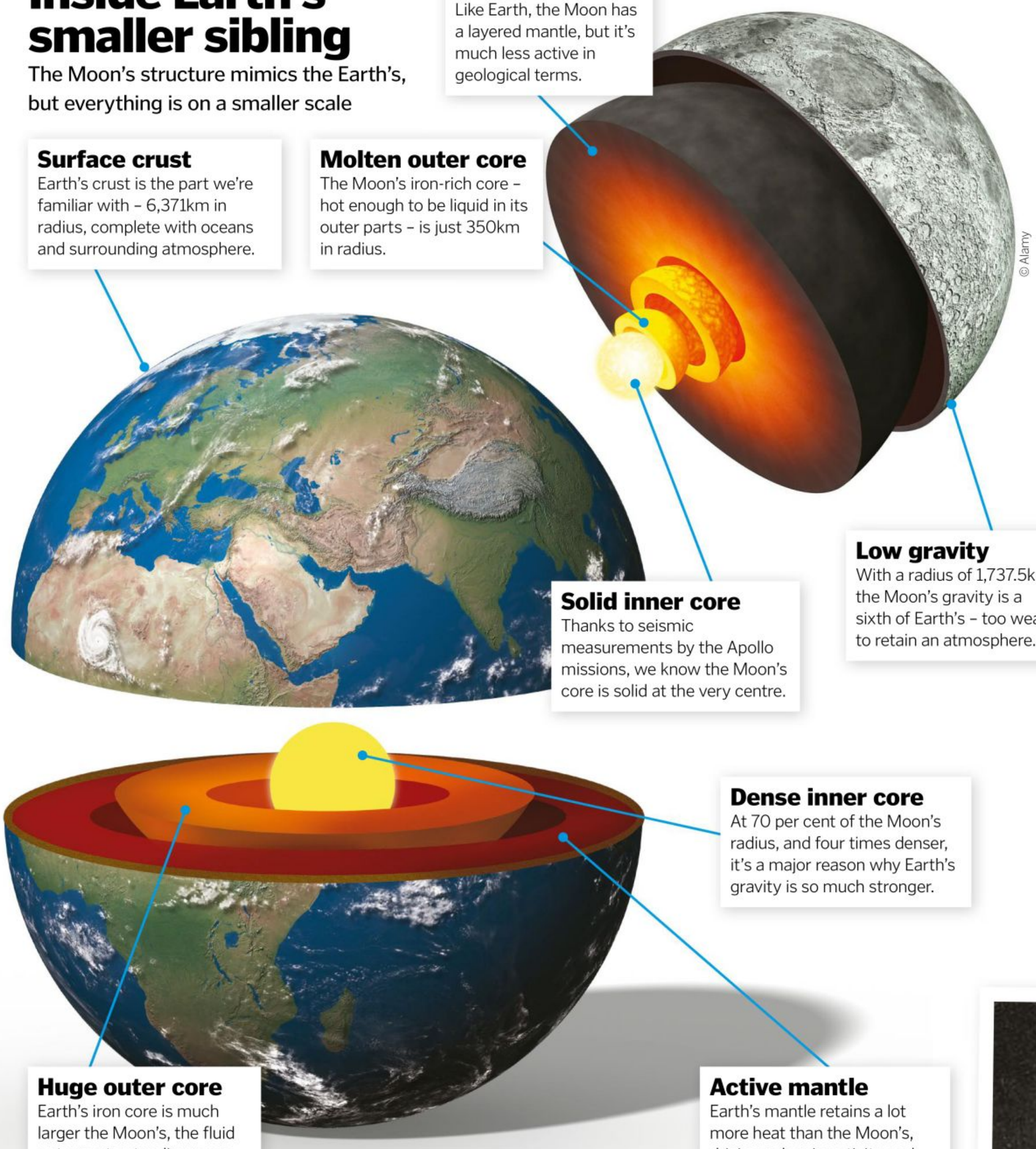
When the returning Command Module hit the Earth's upper atmosphere, it did so at enormous speed – comparable to the speed it left at, around 11 kilometres per second. Although the atmosphere is extremely thin at high altitude, it's compressed by the impact of the spacecraft, and this compression produced a fierce heating effect. The surface of the CM got close to 3,000°C, and it would have burnt up like a meteor if it was unprotected. The outer shell – called an ablative heat shield – did burn off, because that's what it was designed to do. The heat shield not only protected the astronauts inside, but by absorbing the energy of re-entry it slowed the craft to the point it could use its parachutes.

© US Air Force

It looks like a meteor, but it's the Apollo 8 Command Module re-entering the atmosphere

Inside Earth's smaller sibling

The Moon's structure mimics the Earth's, but everything is on a smaller scale



© Alamy

Sluggish mantle
Like Earth, the Moon has a layered mantle, but it's much less active in geological terms.

Surface crust
Earth's crust is the part we're familiar with – 6,371km in radius, complete with oceans and surrounding atmosphere.

Molten outer core
The Moon's iron-rich core – hot enough to be liquid in its outer parts – is just 350km in radius.

Solid inner core
Thanks to seismic measurements by the Apollo missions, we know the Moon's core is solid at the very centre.

Low gravity
With a radius of 1,737.5km, the Moon's gravity is a sixth of Earth's – too weak to retain an atmosphere.

Dense inner core
At 70 per cent of the Moon's radius, and four times denser, it's a major reason why Earth's gravity is so much stronger.

Huge outer core
Earth's iron core is much larger the Moon's, the fluid outer part extending more than half way to the surface.

Active mantle
Earth's mantle retains a lot more heat than the Moon's, driving volcanic activity and other geological processes.

Walking on the lunar surface

20 July 1969 20:17:39 UTC
The LM, with Neil Armstrong and Buzz Aldrin on board, touches down in the Sea of Tranquillity.

21 July 1969 02:56:15
Armstrong steps onto the lunar surface – "One small step for a man, one giant leap for mankind".

21 July 1969 03:15:16
Aldrin joins Armstrong on the lunar surface – initial glitches have been fixed and TV quality is better now.

21 July 1969 03:41:43
The astronauts erect a specially designed flag, which appears to wave in a nonexistent wind.

21 July 1969 03:48:30
Armstrong and Aldrin break off from more important tasks to take a phone call from US President Richard Nixon.

21 July 1969 04:27:42
Time for some science – deployment of passive seismometer, part of the Early Apollo Scientific Experiments Package.

21 July 1969 05:11:13
Armstrong and Aldrin go back into the LM, having spent just over two hours walking on the Moon.

21 July 1969 17:54:00
The LM's ascent stage blasts off on its return trip to the CM in lunar orbit.

Broadcasting live from the Moon

When Neil Armstrong took his first step onto the Moon, he was watched by a worldwide TV audience estimated at around 650 million – the biggest in history up to that point. Yet getting those TV pictures back to Earth in a matter of seconds was pushing the limits of 1960s technology. The main bottleneck was the Lunar Module's tiny antenna, which was limited to a bandwidth of just 500kHz – less than a tenth of a normal TV signal. The result was a grainy, flickering black-and-white picture, made up of 200 scan lines running at just ten frames per second.

To make matters worse, the first images from the surface, as Armstrong began to descend the ladder, were upside down. That was quickly put right, but then an anomaly at the ground station in California produced a thick black bar across the screen, marring the audience's view of Armstrong's 'giant leap for mankind'. But it was one of history's greatest moments, and viewers around the world remained glued to their sets for the entire two hours the astronauts were walking on the Moon.

The UK, of course, was no exception, and both the BBC and ITV covered every moment of the lunar mission throughout the night. That might not sound very exceptional today, but this happened in the days before there was 24-hour television, and the Apollo 11 coverage was Britain's first ever all-night broadcast.

© NASA

The live TV images from the Moon were historic but poor in quality

What happens when galaxies collide?

What a cosmic pile-up will mean for the Milky Way

Astronomers already knew that our galaxy, in which our Sun is one of a hundred billion or more stars, is on a collision course with its slightly bigger neighbour, Andromeda. Now, thanks to detailed measurements of stellar motions by the Gaia space telescope, we've got a clearer idea of when the crash is due to occur: in around 4.5 billion years. That's roughly the age of the Earth, so there's no immediate cause for alarm.

Even when the collision happens, it will be a sedate affair hardly noticeable to any creatures still around in that far distant future – apart from giving them some spectacular night-sky views. In fact 'collision' is a misnomer. A galaxy is mostly empty space, so it's closer to the truth to say they 'pass through' each other. There's little chance of an individual star actually crashing into another star.

We know what happens during a galactic collision as telescopes can see them in action elsewhere in the universe. The most striking effect is on the shape of a galaxy. What started out as a neat disc or elegant spiral can be contorted beyond recognition by tidal forces. If the collision speed is slow, the two galaxies may not have enough energy to separate again, resulting in an eventual merger into a single giant galaxy. Astronomers believe that will happen with the Milky Way and Andromeda – and they've coined the name 'Milkomeda' for the future combined galaxy.

Galactic tides

As distance between galaxies gets smaller, they begin to distort each other via tidal stresses. These arise because the pull of gravity on one side of the galaxy is stronger than on the other, analogous to the way the Moon pulls more strongly on one side of the Earth. Just as the Moon raises tides by distorting the shape of the ocean, so one galaxy can alter the shape of another – on a vaster scale. Stars inside the galaxy can be flung onto completely different orbits, sometimes forming long 'tidal tails'. According to one estimate, the Sun has a small chance of ending up in such a tail, but if so, it's likely to take its retinue of planets with it, so the Solar System would survive unscathed.

The Gaia space telescope's mission is to create a map of the Milky Way

Eight billion years to Milkomeda

How the night sky might change as the Milky Way and Andromeda collide

Present day
The Andromeda galaxy is a faint smudge, about the size of the Moon, to the left of the Milky Way.

After 2.5 billion years
As Andromeda approaches, it becomes a much larger and brighter feature in the sky.

After 4.3 billion years
Andromeda now spans half the sky, rivalling the Milky Way in magnificence.

After 4.4 billion years
As the galaxies begin to overlap, the increased gas density generates star formation.

After 4.5 billion years
The galaxies become an amorphous mass, at the height of the collision; star formation continues.

After 4.6 billion years
As the galaxies move apart, both will show clear signs of tidal distortion, with visible tails.

After 6 billion years
After the frenzy of star formation, little gas is left as the galaxies meet for the last time.

After 8 billion years
Two become one: The the core of a newly merged giant 'elliptical' galaxy – Milkomeda.

AIRFIX

QUICK BUILD

No glue!
No paint!
Just build!

J6032
'Surfin' Camper Van

J6017
'Flower Power' Beetle

Build and Decorate Two Iconic Models

In a trend that started on the California coast, Camper Vans customized with vinyls, bumperstickers or freehand painting have become the number one iconic mode of transport for the world-wide surfing community. The origins of this vehicle started with the 'Type 2', affectionately known as the 'Camper' in the UK, and was the second car model to be introduced by Volkswagen in 1950. The first prototype of the Camper was revealed to the world in November 1949 and the very same prototype can still be seen today at the Volkswagen AutoMuseum in Wolfsburg, Germany. VW's first release, the Beetle, was named 'Type 1' resulting in the Camper being predictably named 'Type 2.' Depending on body style the Type 2 was officially known as the Transporter, Kombi or Microbus.

Another trend that began on the coast of California, second hand VW's beetles (Bugs!) became extremely popular with the emerging counter culture of the 1960's. In a movement that promoted freedom of expression, the charming, little VW Bug became everyones' favourite canvas. The Volkswagen Beetle remained in production throughout the whole period and entered the record books as the best selling single-model car of all time on February 17th 1972 when production reached 15,007,034 units, beating the previous record of the Ford Model T. When production finally ceased on July 30th 2003, Volkswagen had produced a total 21,529,464 and it's unlikely this record will be broken again as cars now rarely remain in production longer than 10 years.

Both of these vehicles have become true icons on roads all over the world! You can create your own versions at home with these Airfix QuickBuild kits. Both models come with an array of colourful stickers to help you customise your own design. You can recreate brilliant scale models of a wide variety of iconic aircraft, tanks and cars with QuickBuild kits. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.

Collect them all! Check out the rest of the range online.

J6019 Lamborghini Aventador

J6025 Yellow VW Beetle

J6020 Bugatti Veyron

Airfix.com and all good retail stockists YouTube

HORNBY HOBBIES
Official Product

HOW WE'LL GET TO MARS

Elon Musk's Starship might one day take humans to the surface of the Red Planet

Words by **Jonathan O'Callaghan**

Starship and Super Heavy, previously known as the Big Falcon Rocket (BFR), are a combined launch system currently in development by US company SpaceX, designed to travel to Mars and possibly beyond. First unveiled by CEO Elon Musk in 2016, the system consists of a large rocket called Super Heavy and a spacecraft called Starship that could carry up to one hundred people per flight to the Red Planet.

Musk's ultimate goal is to colonise Mars, and he hopes that Starship and Super Heavy could be the answer. The vehicles build on the successful Falcon fleet of rockets that SpaceX has operated for about a decade, with both parts designed to be reusable (meaning they can launch and land). Together they would be the largest and most powerful rocket ever built, surpassing even the Saturn V rocket that NASA used to send astronauts to the Moon in the 1960s and 1970s.

In total, the vehicle is designed to be about 118 metres tall and capable of lifting about 100,000 kilograms into Earth's orbit. The bottom part of the rocket is the Super Heavy, and it's 63 metres tall. This large booster will lift Starship into space, before it detaches and comes back to land on Earth.

Starship, meanwhile, is the large spacecraft that sits on top. The idea is that it will be lifted to Earth's orbit, where it will then be fuelled by other vehicles also launched from Earth. Then, it will begin the months-long journey to Mars, carrying only cargo on its first few missions, but ultimately humans too. When it arrives, it will descend through the Martian atmosphere and then land vertically on the surface.

To leave Mars, SpaceX plans to try to produce fuel on the surface itself, by tapping into ice that's trapped beneath the surface. The spacecraft will then lift off from the surface – no small feat, as we've never launched anything from Mars before – and then make its journey home, before re-entering the Earth's atmosphere and landing back on the ground.

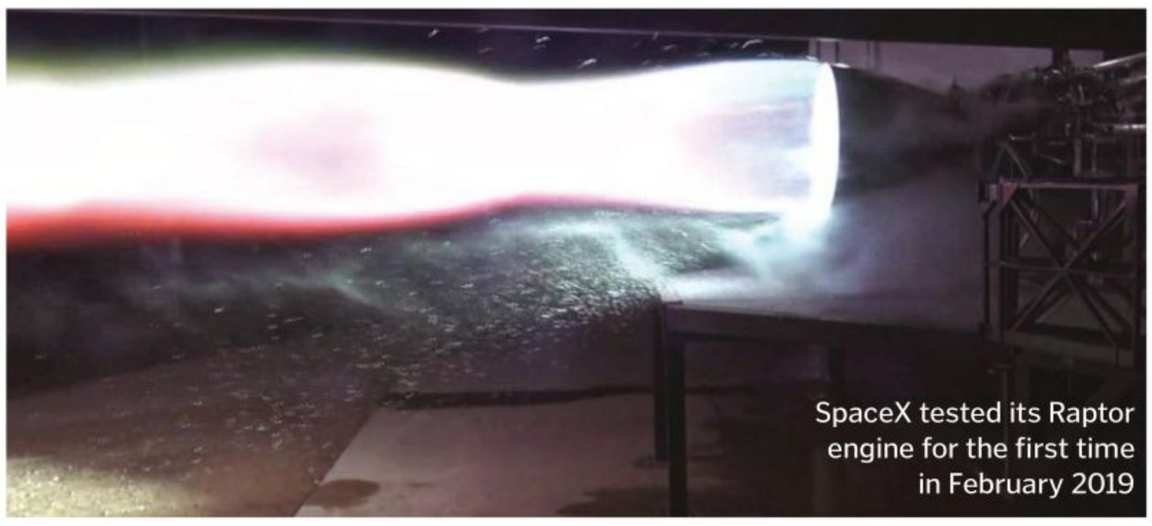
The company tentatively hopes to start cargo missions in the 2020s. Many questions remain, however, including how those crewed missions on the surface will work, and how the mission will be powered while on Mars. But SpaceX continues to make steady progress towards its goals – and, maybe one day, it will be successful.

Inside the Raptor engine

Raptor is an engine being designed by SpaceX that will power both its Super Heavy rocket and the Starship spacecraft on journeys to Mars. It's designed to use liquid methane and liquid oxygen, fuels that can be sourced from the surface of Mars itself.

Each Raptor engine is about 1.3 metres across, and can produce about 200 tons of thrust at full power. On the Super Heavy rocket there will be 31 Raptors, producing enough thrust to lift it and Starship towards space. Starship, meanwhile, will have three Raptors designed to work in Earth's atmosphere, and three more called RaptorVac that will operate in space.

SpaceX has been busy testing its engine, and earlier this year it fired it for the first time successfully.



SpaceX tested its Raptor engine for the first time in February 2019

"When it arrives, it will descend through the Martian atmosphere and land vertically"

The International Space Station (ISS) has its own 3D printer on board

The dangers of interplanetary travel

Going to Mars will not be easy, and some of the biggest problems concern human health complications. This includes exposure to increased radiation when people leave Earth's protective magnetic field, weakened muscles when in the reduced gravity environments of space and Mars, and the risk of disease while on the Red Planet.

Future crews will also need to cope with being so far from Earth, psychologically and logistically. If something goes wrong on the mission, crews will need a way to fix the problem on Mars, or make new equipment, maybe with the help of a 3D-printer. And since Mars is such a hostile environment, the crews will need highly specialised equipment to survive there.

Raptor engines
The spacecraft's specially designed engines will both take it through space and bring it in for landing.

Windows
A large number of windows will afford people views of Earth, space and ultimately Mars.

Sleeping and showering
Crews will have access to sleeping quarters and showers on Starship, so they can stay rested and clean during their journey.

Communal area
A communal area will be used to work and eat, or even enjoy some entertainment.

The bridge
Control of all the critical spacecraft's functions will take place here.

Delta wings
Small wings will help Starship fly through the skies of Earth and Mars.

Farm
Starship will likely have some means to grow food, such as a hydroponics farm, to sustain the crew.

Heat shield
Heat resistant tiles at the bottom of the ship will enable it to pass through the atmosphere of Earth and Mars.

Inside SpaceX's Starship

How crews will live and work inside this spacecraft on their way to Mars

How cement-mixing vehicles work

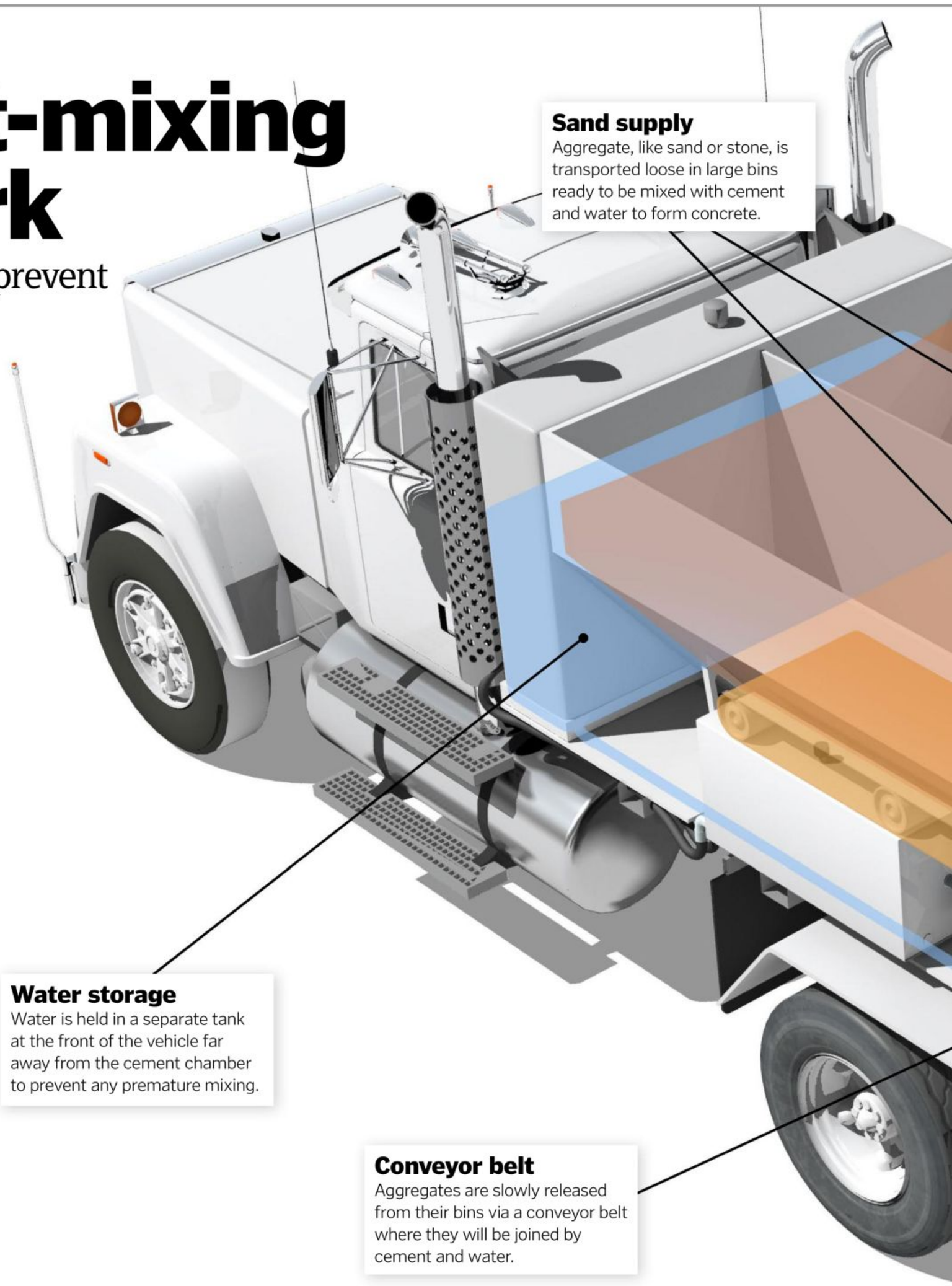
How do these concrete transporters prevent their load from turning rock solid?

Concrete mixer trucks, delivering vital raw material, bear the weight of around 13,500 kilograms of cement. These vehicles have the repetitive task of continually cycling its contents. A cocktail of aggregate (sand or stones), cement and water are hurled into the drum-shaped rotating barrel at a concrete-production plant. Interior fins, shaped and arranged like a screw, fold the ingredients together. During its journey from the production plant to construction project, the drum is constantly turned by an external motor.

Once it reaches its final destination, hydraulics lift the drum and its cement concoction, allowing gravity to pull the freshly formed concrete down a delivery spout. The mixing fins also lend a helping hand, spinning in the opposite direction to that of the mixer, to force the material out of the drum.

This method of concrete creation comes with a race against the clock. Known as 'batch mixing', this traditional way of transporting a pre-made product comes with a quick expiry time: There is a short window of opportunity to distribute the solidifying substance before it sets and hardens, typically around 90 minutes. This constraint is one of the reasons manufacturers have created a portable concrete factory in the form of volumetric cement mixer trucks.

These building behemoths carry uncombined ingredients to a construction site and form fresh concrete at the touch of a button. Using a built-in micro production line, the main ingredients are fed to a mixing auger (rotating screw) via conveyor belts and pipes. The result is fresh, made-to-order, fluid concrete, ready to be laid.



Sand supply
Aggregate, like sand or stone, is transported loose in large bins ready to be mixed with cement and water to form concrete.

Water storage
Water is held in a separate tank at the front of the vehicle far away from the cement chamber to prevent any premature mixing.

Conveyor belt
Aggregates are slowly released from their bins via a conveyor belt where they will be joined by cement and water.

Mobile concrete factory

How do volumetric mixer trucks turn sand and cement into fresh concrete?

©Getty

Essential to the construction industry, concrete-mixer trucks continually spin their contents to prevent it setting in transit

Paving the way

The principle mechanics of the humble drum-shaped concrete mixer has remained relatively unchanged since its creation around 100 years ago. Taking cement mixing from horse-powered to horsepower, the first motorised concrete mixers sprung into action in the early 1900s. The first patent application for a vehicle-driven mixer is believed to have been filed by American inventor Stephen Stepanian back in 1916 and although the design is reminiscent of today's vehicles, the patent was denied. Later creations came from inventors such as Ackert Bickel, who successfully patented the first concrete-mixer truck in 1920. Following the same principles of modern-day machines, Bickel's mixer was also designed to transport premade mixtures onto a site.

Aggregates, such as sand or gravel, and water are used to form concrete

©Getty

Pumping power

To deliver concrete to those hard to reach places, such as at the top of a building, mobile mixers call upon the help of another vehicle known as a concrete pump truck. Acting as an extension cable for concrete, these vehicles often come with an extendable robotic arm or boom to maximise the distance it can be poured. Working in unison, the drum-shaped mixer ejects its concrete cargo into the metal grate at the rear of the pump truck. A hydraulic pump system then forces the fluid material through a large pipe running along the boom arm and out through a delivery hose, which is close to the ground.

©Alamy

Concrete mixers and pumps work together to distribute the concrete around a construction site

©Illustration by Adrian Mann

Cement mix
Essential to concrete creation, cement is made from grinding down rock, such as limestone, shells and chalk.

First mix
A short auger spins to combine the dry ingredients of the concrete mixture (aggregate and cement).

Adding water
By delivery through internal piping, water is washed over the dry cement mixture to begin the process of concrete creation.

"This method of concrete creation comes with a race against the clock"

Mix well
The main auger mixes all concrete ingredients, repeatedly turning to completely combine them.

Ready-made concrete
Fresh off the conveyor belt, viscous concrete flows out of the delivery spout to pour directly on-site.

©Alamy

Volumetric concrete mixers are growing in popularity for their ability to make large amounts of concrete on a building site

HITLER'S WEIRDEST WEAPONS

From death rays to Sun guns, Nazi Germany conceived of some wild and fantastic ways of defeating the enemy. Could they have really worked?

Words by **Charles Ginger**

When the tide of World War II began to turn dramatically against the armies that Hitler had unleashed on Europe in 1939, the Nazis became increasingly desperate to find a miraculous solution (literally a 'wunderwaffe', or 'miracle weapon') that could help Hitler's retreating forces to snatch victory from the closing jaws of defeat.

This frantic scramble for salvation inspired a myriad of daft, dangerous and downright discombobulating inventions. These ranged from explosively charged chocolate to Germany's equivalent of the Death Star in *Star Wars*. And when Nazi scientists weren't busy beavering away on their latest contraptions, they were concocting pills and potions with which to intoxicate (and thereby supposedly enhance the performance of) Germany's soldiers.

While history has shown that neither rocket-fuelled missiles nor intergalactic magnifying glasses actually spared Germany from the ravages of the war it had started, Third Reich's historic downfall doesn't detract from the intrigue that its maddest moments still inspire today. Historians have dedicated decades to trying to get inside the minds and machines of a people on the cusp of chaos.

So just how close did Hitler's henchmen come to realising his unstoppable weapon? Could any of the ideas that you are about to discover really have altered the outcome of the war? And who thought it was a good idea to ply armed men miles away from home with the modern equivalent of highly illegal drugs? It's time to march into the mad world of the Nazis' strangest creations...

Chocolate bar bomb

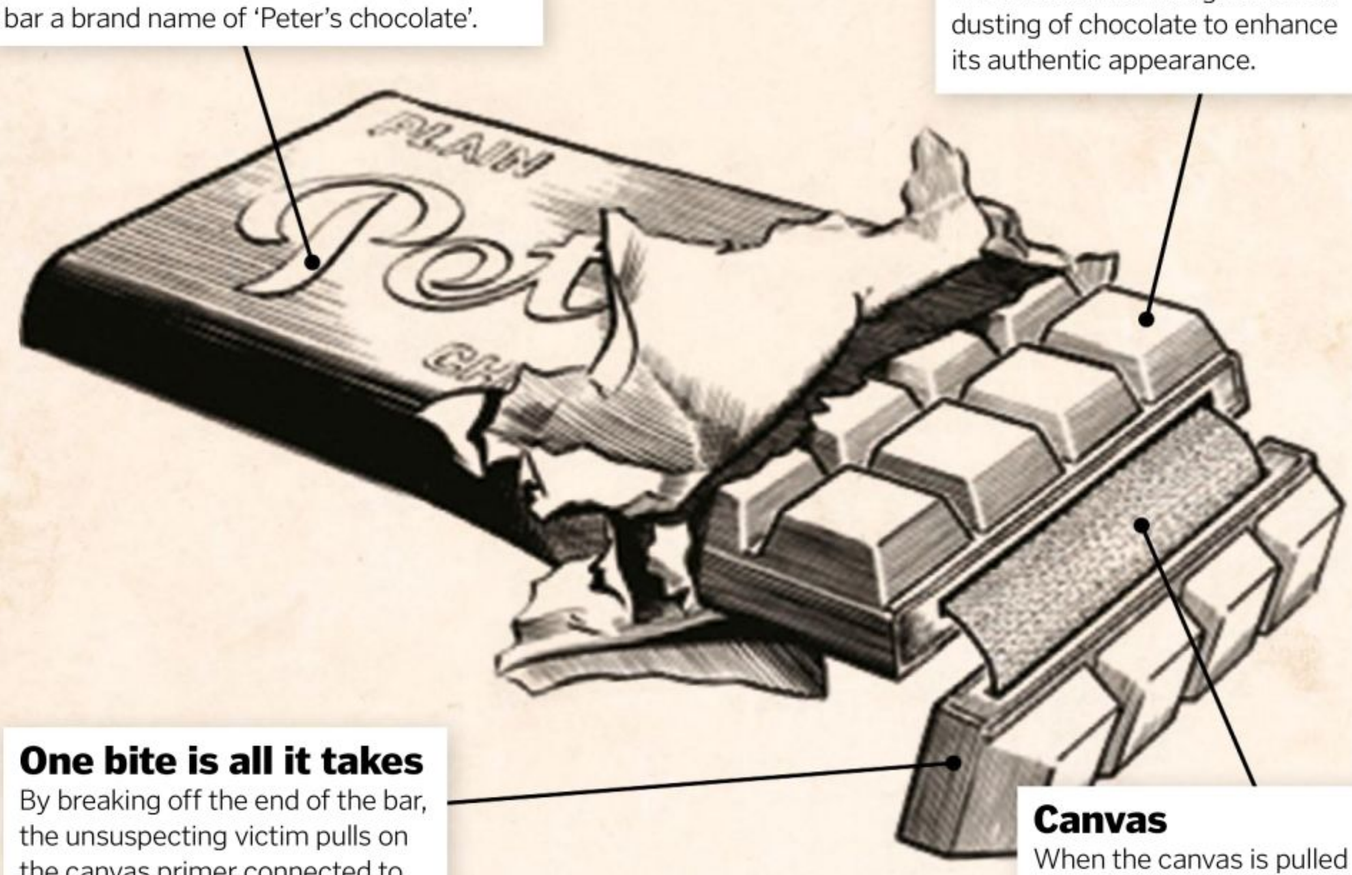
With rationing making luxuries such as sugar increasingly scarce, you'd be forgiven for greedily tucking into a chocolate bar if you were fortunate enough to find one in London in the 1940s. And that's exactly what the Nazis were hoping for – a sugar rush that would leave the unlucky unwrapper with more than tooth decay.

Comprised of a chocolate bar-shaped piece of steel encased in a thin layer of real cocoa, the chocolate bomb was an ingenious weapon that was primed to explode shortly after its oblivious victim broke the end off the 'bar'. First discovered in 1943 by Victor Rothschild of MI5's Explosives and Counter-Espionage Unit, historians believe the Nazis planned to assassinate Winston Churchill with one.

MI5 senior intelligence chief, Lord Rothschild, commissioned Laurence Fish to produce detailed drawings of the chocolate bomb

Chocolate to die for
The Nazis left no detail out when they produced their killer candy, even giving the bar a brand name of 'Peter's chocolate'.

Cocoa coating
The steel bomb was given a real dusting of chocolate to enhance its authentic appearance.



One bite is all it takes
By breaking off the end of the bar, the unsuspecting victim pulls on the canvas primer connected to the explosive.

Canvas
When the canvas is pulled on it sets off a seven-second timer, at the end of which, the bar will explode.

Death-ray weapon

Arguably second only in insanity to the sun gun (see page 65), the various attempts made by the Nazis to construct a 'death ray' powerful enough to damage enemy aircraft and, according to some reports, actually kill pilots, never took off. Scientists Heinz Schmellenmeir, Richard Gans and Fritz Houtermans reportedly worked on a machine known as the 'rheotron' (also referred to later by the Americans as 'betatron'), a small electron accelerator designed to generate X-ray synchrotron beams that could be directed at enemy bombers.

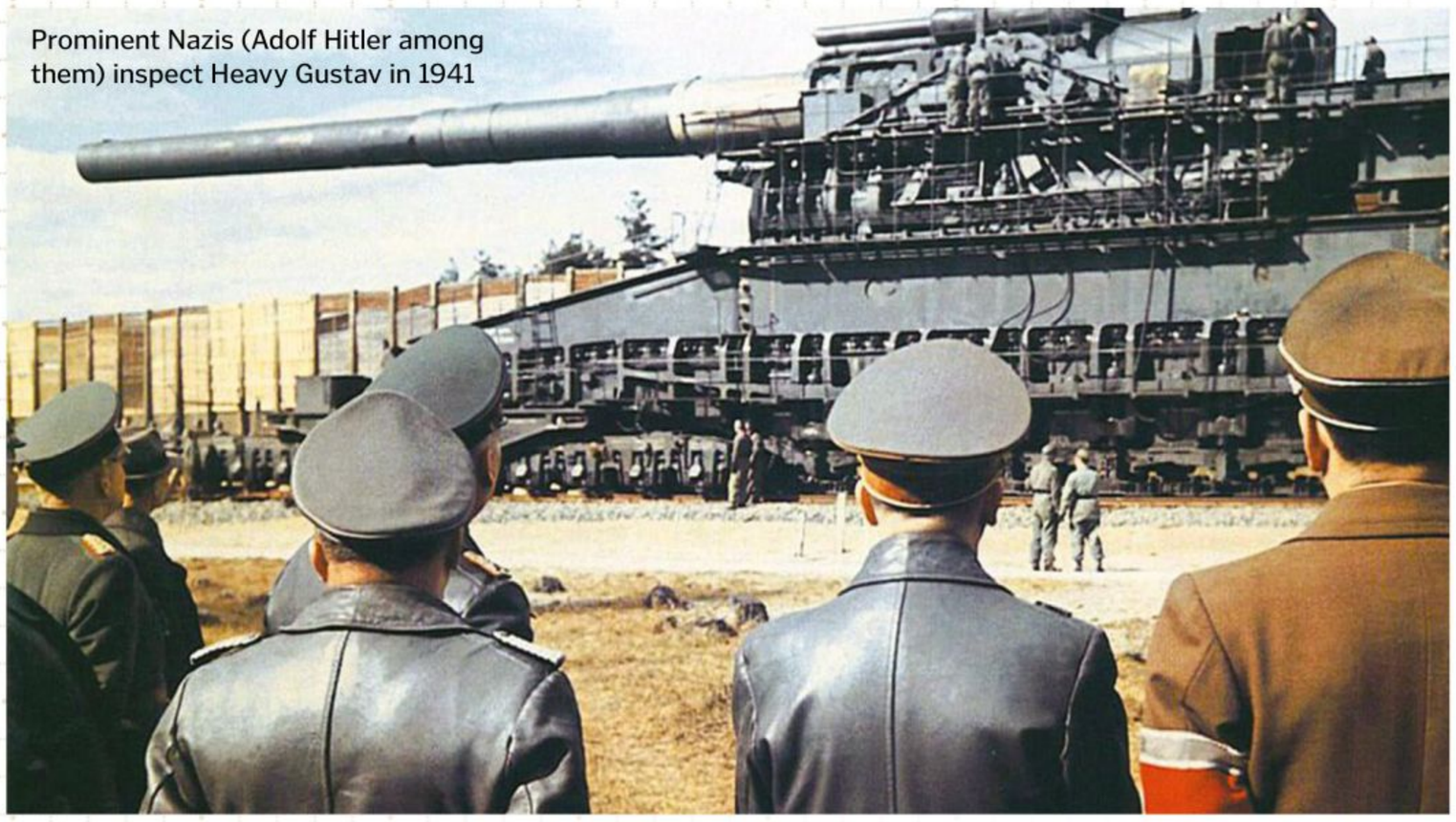
Another proposal, forwarded by Dr Ernst Schiebold this time, was the 'Röntgenkanone'. A similar device to its rival the rheotron, this potentially potent projector relied on a beryllium mirror supporting a particle accelerator with nine beryllium rods positioned in its centre as an anode (the device required to eject the positively charged electrons). Schiebold suggested firing X-rays in concentrated bundles in order to increase the damage inflicted on the intended target, a dose of radiation that he hoped would prove fatal to the Allied pilots.

Aiming at a small model, a scientist attempts to demonstrate the potential of a death ray

Giant artillery gun

The 'Heavy' Gustav was an understatement. Weighing in at over 1,300 tons and measuring 47.3 metres long and 11.6 metres high, this titanic gun is the heaviest-calibre weapon ever used in combat to date and was capable of launching seven-ton shells over 47 kilometres.

Built before the outbreak of WWII, Gustav's original purpose was to help destroy the defensive positions that formed France's formidable Maginot Line. However, such was the speed of Germany's victory in 1940 that this railway gun was surplus to requirements, so the Germans manoeuvred their leviathan to the Eastern Front, where Gustav was used in the Battle of Sevastopol to obliterate a Soviet ammo bunker located 30 metres below ground.



Prominent Nazis (Adolf Hitler among them) inspect Heavy Gustav in 1941

Behemoth barrel
Measuring 32.5m, Gustav's enormous 80cm-calibre gun could fire at a rate of one round every 30–45 minutes.

Ramp
Before the gunners could begin their deadly work they first had to clamber up a sloped gangway to reach the top level.

Operation platform
It was here that the team operating Gustav would load and recalibrate their hulking weapon.

Construction
It took a workforce of 1,420 men three weeks to assemble Heavy Gustav.

Wheel-mounted weapon
Heavy Gustav was mounted on wheels that enabled the Germany army to manoeuvre the gun along railway lines.

A US soldier examines a Sturmgewehr fitted with a krummlauf barrel

A gun that shoots around corners

Well, you can sort of see where they were going with this one! A curved barrel attachment designed to connect to the end of a German Sturmgewehr ('storm gun') 44 assault rifle, the krummlauf sported a periscope to help the shooter aim around corners.

Produced in two designs, one incorporated a 30-degree bend and was intended for the infantry, while its more curvaceous cousin had a barrel angled at 90 degrees and was built to protrude from an armoured vehicle. The barrel would slot into a hole in the armour and the gun could then be manoeuvred from within.

As for the more mobile infantry version, the barrel measured 36 centimetres in total, 14 centimetres of which was curved. Unfortunately for the Wehrmacht, when guns fitted with this barrel were fired in tests, the bullets often shattered.

Supersoldier pills

Considering the Nazis formed the first anti-smoking government in history, it seems remarkable that they were so relaxed about the prevalence of dangerous performance-enhancing drugs on the streets of Germany. But laid-back they were, probably because so many people at the time were abusing Pervitin, a tablet that was effectively the 1930s answer to crystal meth, a dangerously addictive narcotic.

Used by both war-weary troops and citizens alike (35 million pills were shipped to troops and pilots between April and July 1940 alone), this powerful pill could provide a serious boost, however, it wasn't without its side-effects, which included insomnia, aggression and even seizures.

Another so-called pick-me-up that the Nazis began working on before the war's end was D-IX, a methamphetamine-based performance enhancer. When tested on Holocaust prisoners, it was found the drug enabled them to march for 90 kilometres a day in a loop while shouldering a 20-kilogram load. Unlike Pervitin, however, D-IX didn't have the time to become widely used, Germany's defeat in May 1945 meant that only a few submariners ever tried it out.

This cheerfully branded tube of Pervitin contained a powerful narcotic that was widely available in Nazi Germany – but is illegal today

Space Sun gun

It seems that when it came to inventing impractical weaponry, the sky wasn't the limit for the Nazis. In fact, they hoped to go far beyond it, and it would all have been thanks to a concept thought up by physicist Hermann Oberth, in 1923. Effectively a gigantic mirror; parts of the sun gun were to be constructed on Earth and then transported into orbit (approximately 37,000 kilometres above the equator) where it could be assembled. Once operational, the gun would have acted like a magnifying glass to concentrate the Sun's rays and reflect them onto enemy cities or military installations.


The Nazis had hoped to use the Sun's rays to incinerate cities or boil part of an ocean

COULD THIS HAVE WORKED?

It seems highly unlikely, bordering on impossible, that this concept could ever have worked. Oberth not only intended to create a gigantic mirror – he wanted to man it with a crew of astronauts who would live inside a space station fitted out with hydroponic gardens, solar-powered generators and nine-metre-wide docking ports for supply rockets. For all its wonders, even the ISS isn't that advanced!

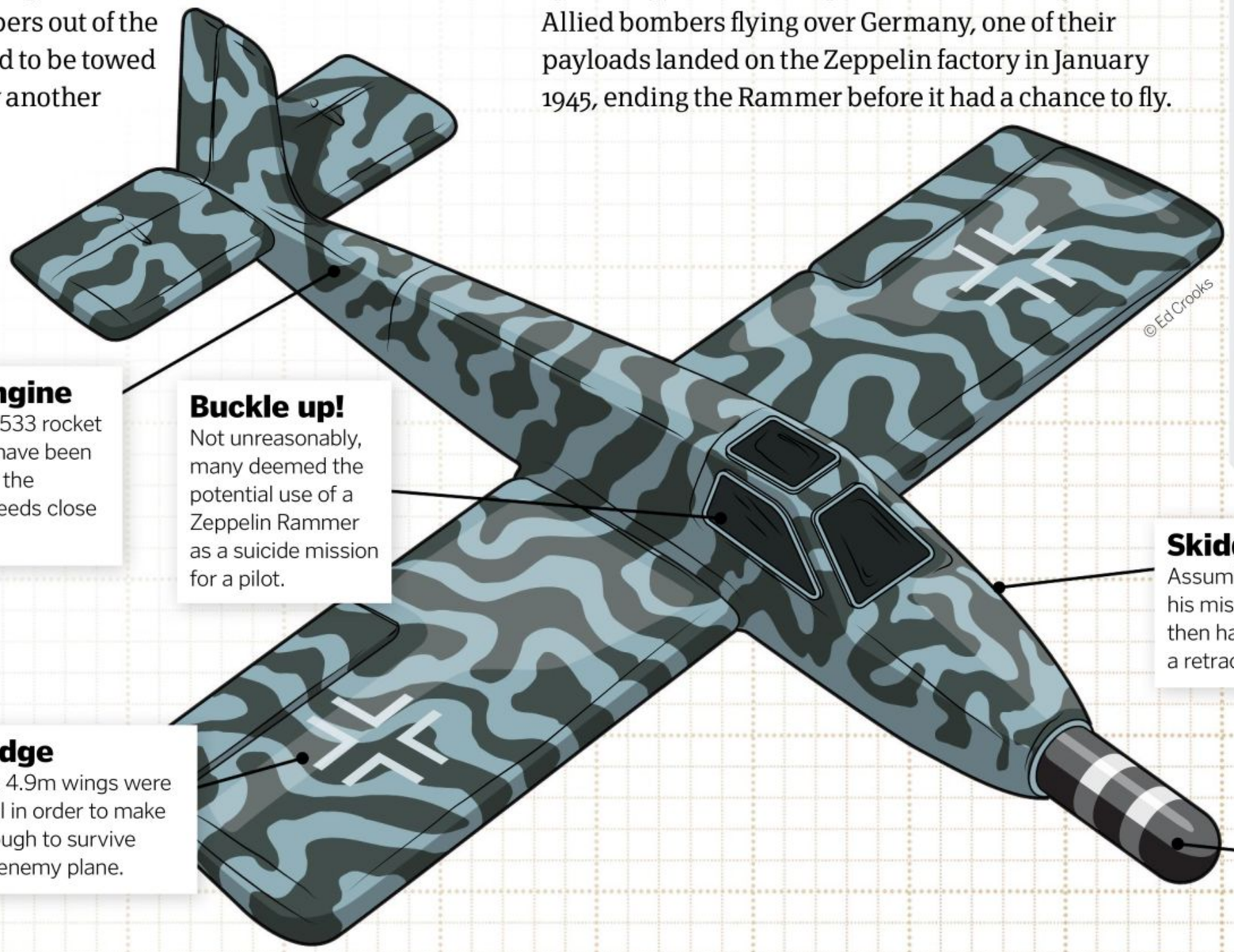
WHAT WOULD THIS COST TODAY?

The Nazis estimated that the sun gun would take around 15 years to build at a cost of approximately 3 million Reichsmarks. Exchange rates for the wartime period are extremely difficult to come by, but 3 million Reichsmarks would have equated to around £850,000 in the mid-1940s (approximately £34.9 million today). Consider that the ISS cost $150 billion and doesn't have aquatic gardens!

Zeppelin Rammer

In November 1944, engineers at Luftschiffbau Zeppelin GmbH had a novel idea: they would build a jet-propelled ramming plane. Named in honour of Count Ferdinand von Zeppelin, founder of the company in the early 1900s, this groundbreaking (or rather, plane-breaking) aircraft would be used to smash enemy bombers out of the sky. Designed to be towed or carried by another plane (most likely a Messerschmitt Bf 109), the Rammer was to sport steel-lined wings that would be sturdy enough to cut into the tail of Allied bombers.

Its independent flight would have relied on a rocket engine, which would have given it an estimated top speed of 970 kilometres per hour. Thankfully for the Allied bombers flying over Germany, one of their payloads landed on the Zeppelin factory in January 1945, ending the Rammer before it had a chance to fly.



Rocket engine
A Schmidding 533 rocket engine would have been used to propel the Rammer to speeds close to 1,000kph.

Buckle up!
Not unreasonably, many deemed the potential use of a Zeppelin Rammer as a suicide mission for a pilot.

Skidding into land
Assuming the pilot had survived his mission, the Rammer would then have been landed on a retractable skid.

Cutting edge
The Rammer's 4.9m wings were lined with steel in order to make them hard enough to survive slicing into an enemy plane.

Bombs away!
Once all the 14 R4M 'hurricane' 55mm rockets had been fired, the pilot was meant to perform a ramming manoeuvre.

5 FACTS ABOUT NAZI WEAPONS OF THE FUTURE

1 Fritz X
Considered the predecessor to today's smart bombs, Fritz X was a radio-guided rocket that packed a 317kg payload. Used to attack difficult targets, it became the first precision-guided missile to sink a ship in 1943 when it downed the Italian vessel, Roma.

2 Horten Ho 229 jet
Taking to the skies in 1944, the Ho 229 was the first flying wing (tail-less, fixed-wing aircraft) to use jet engines. Measuring just under 7.5 metres long and with a top speed of 977 kilometres per hour, the Ho 229's wooden sections were coated in charcoal dust to provide it with a layer of stealth.

3 Amerika Bomber
In 1942, the Nazis began to develop a plane that would be capable of fulfilling Hitler's dream of obliterating New York City. Enter the Amerika Bomber, an aircraft that the Germans hoped would be able to cross the Atlantic and rain death on the US.

4 Goliath Tracked Mine
This diminutive device looked like a miniature tank and was equipped to carry up to 60 kilograms of explosives to a target. Controlled via a joystick, the Goliath was propelled with a gasoline engine and reached a top speed of 9.7 kilometres per hour.

5 Messerschmitt Me 163 Komet
The only jet-propelled fighter plane to see action in WWII, with a top speed of over 1,000 kilometres per hour, the Komet was over 400 kilometres per hour faster than its nearest rivals. However, it was prone to being blown to smithereens by its explosive fuel.

Biggest naval battle ever

Over 2,000 years ago in the Mediterranean Sea, an almighty clash between the ships of ancient Rome and Carthage was about to begin...

In 256 BCE, the Mediterranean was dominated by the states of Carthage and Rome. At that time Carthage was the most powerful and their strength was based on maritime trade. Carthage itself was a Phoenician colony situated on the North African coast in modern Tunisia. The Phoenicians originally came from the Levant (ancient Syria) and were known as highly skilled seafarers. Their settlement at Carthage was highly successful and by the 3rd century BCE Carthaginian naval power controlled much of the Western Mediterranean, including a strong presence in Sicily.

At the same time, Roman forces were expanding down the toe of Italy and they became increasingly anxious about the Carthaginian presence in Sicily. In 264 BCE, the Romans supported the mercenary Mamertines who were fighting both Carthage and Syracuse. This intervention escalated into a full-scale conflict between Rome and Carthage for control over the island of Sicily. It became known as the First Punic War.

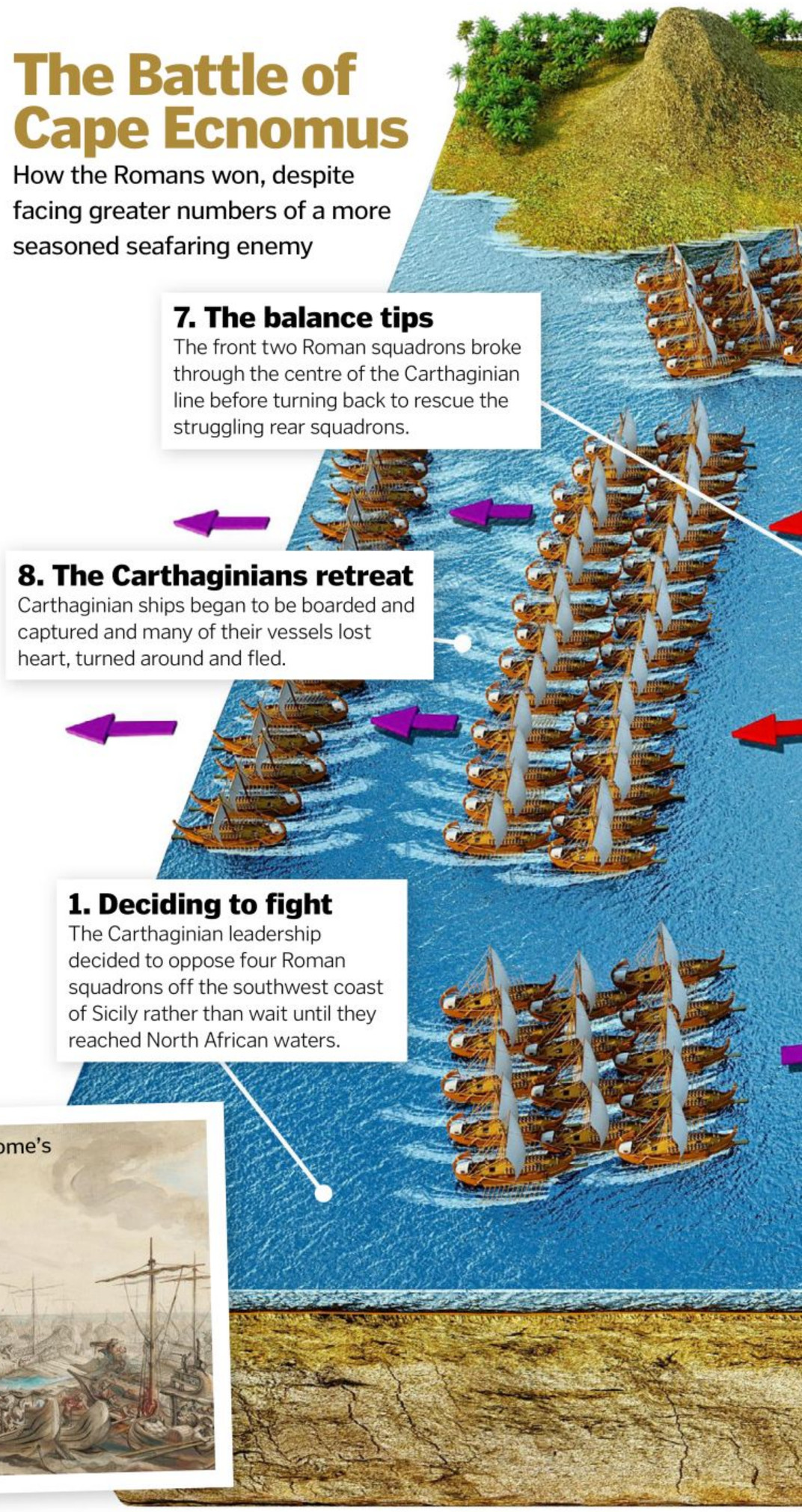
To maintain control over Sicily, the Carthaginians were dependent on maritime supplies and reinforcements from North Africa. By contrast, the Romans had no navy at the beginning of the war but they decided to build one from scratch in 261 BCE. In a remarkable feat of naval construction, the Romans built approximately 120 ships including 100 quinqueremes and 20 triremes in just 60 days. Although the Romans could not match the manoeuverability of the Carthaginian ships, they had an advantage with legionary marines who specialised in boarding vessels.

Consequently, and despite their inexperience, the Romans began to win naval victories including at Mylae (260 BCE) and Tyndarus (257 BCE). In 256 BCE they prepared a seaborne invasion of North Africa with an expanded fleet but the Carthaginians intercepted them off the southern Sicilian coast at Cape Ecnomus. Almost 700 ships and nearly 290,000 men came together for the largest naval engagement that the world had ever seen.

"In a remarkable feat of naval construction, the Romans built approximately 120 ships including 100 quinqueremes and 20 triremes in just 60 days"

The Battle of Cape Ecnomus

How the Romans won, despite facing greater numbers of a more seasoned seafaring enemy



1. Deciding to fight
The Carthaginian leadership decided to oppose four Roman squadrons off the southwest coast of Sicily rather than wait until they reached North African waters.

7. The balance tips
The front two Roman squadrons broke through the centre of the Carthaginian line before turning back to rescue the struggling rear squadrons.

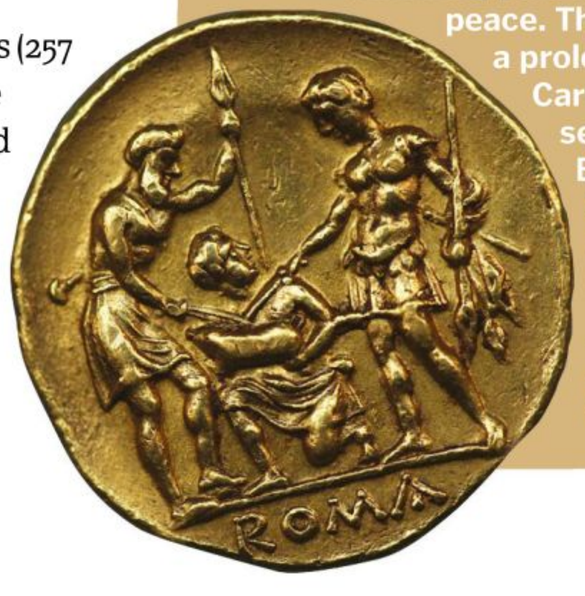
8. The Carthaginians retreat
Carthaginian ships began to be boarded and captured and many of their vessels lost heart, turned around and fled.

The Battle of Cape Ecnomus confirmed Rome's dominance as a naval power

What happened next?

The Romans had won a huge victory and the Carthaginians were rendered incapable of preventing an enemy landing in North Africa. Nevertheless, the Romans had to repair their ships in Sicily and rest their crews. The fleet eventually sailed again, successfully landed and besieged Aspis (Kelibia) in Tunisia. The Carthaginians were forced to withdraw their troops from Sicily to reinforce their army in North Africa.

The Roman Navy defeated the Carthaginians again at the Battle of Cape Hermaea the following year and Marcus Atilius Regulus's invasion forced Carthage to sue for peace. The Roman terms were so harsh that the Carthaginians fought on with a prolonged defensive strategy. The war continued until 241 BCE when the Carthaginians made a desperate attempt to save their remaining settlements in Sicily. A decisive naval engagement was fought at the Battle of the Aegates where the Romans sank or captured 120 heavily laden ships. Carthage agreed to abandon Sicily and paid 60 tonnes of silver to Rome. The First Punic War was over and the Romans became the dominant naval power in the Mediterranean.



This very rare Roman coin was issued after the First Punic War and depicts a Roman oath ceremony with Italian allies. The message was that the war against Carthage was a cooperative effort

10. Carthaginian surrender
Regulus reinforced Lucius Manlinus Vulso's attack, which resulted in the surrender of 50 Carthaginian ships that were trapped against the shore.

9. Closing in
Marcus Atilius Regulus's Roman squadron attacked the disengaged part of the Carthaginian line, which forced them to withdraw.

2. The Romans deploy
Two squadrons formed a wedge formation at the front of the fleet while a reserve squadron formed in a line behind the wedge to protect a rear squadron of galleys that were towing transport ships.

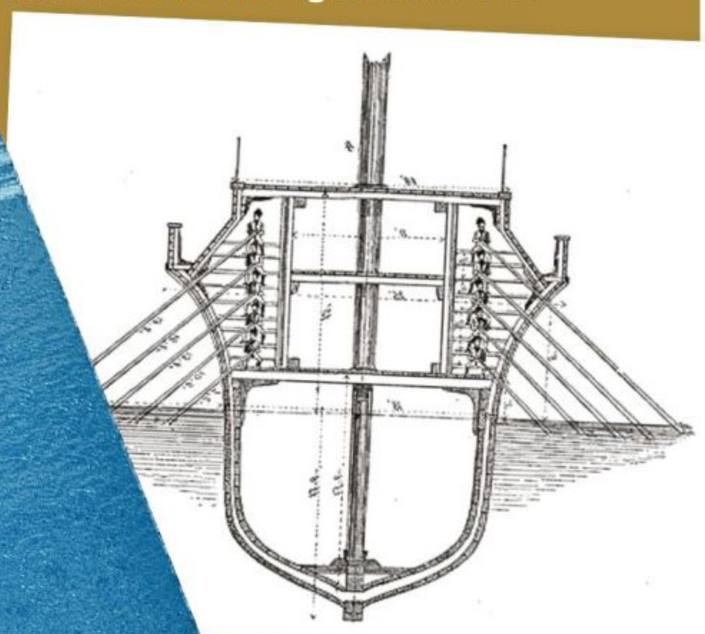
3. The battle begins
The Roman fleet engaged the Carthaginians whose ships were stretched in a line off the Sicilian coast. The Carthaginian intention seems to have been to break up the compact Roman fleet and fight a series of smaller engagements.

4. Carthaginian feint
The Carthaginian centre deliberately pulled back by rowing in reverse and the right flank attacked the Roman reserve squadron while their left flank engaged the transport squadron.

5. Hand-to-hand Fighting
In individual combat sorties aboard the ships, the Romans gained the upper hand over the Carthaginians with determined boarding parties.

6. Roman reserve struggles
The Carthaginians outfought the Romans of the reverse squadron although the latter put up a fierce resistance.

Quinqueremes
The most numerous Roman vessel at Cape Ecnomus was the quinquereme, a large galley warship that was designed by the Greeks. There were bigger warships at the time but the quinquereme was a tried and tested design that offered the best tactical advantage. It is believed to have had three banks of oars, with the top two banks being rowed by pairs of oarsmen. Single oarsmen rowed the bottom bank and the vessel was a good balance between speed, maneuverability and power in battle. The quinquereme was the result of many naval arms races that had occurred between ancient Mediterranean civilisations and both the Romans and Carthaginians used it.



A 19th century cross-section depiction of what a quinquereme may have looked like

ROMANS
Commanders
Marcus Atilius Regulus, Lucius Manilus Vulso

Ships 330

Crew 140,000

Ships sunk 24

Casualties c.10,000 killed

CARTHAGINIANS
Commanders
Hamilcar, Hanno the Great

Ships 350

Crew 150,000

Ships sunk 30

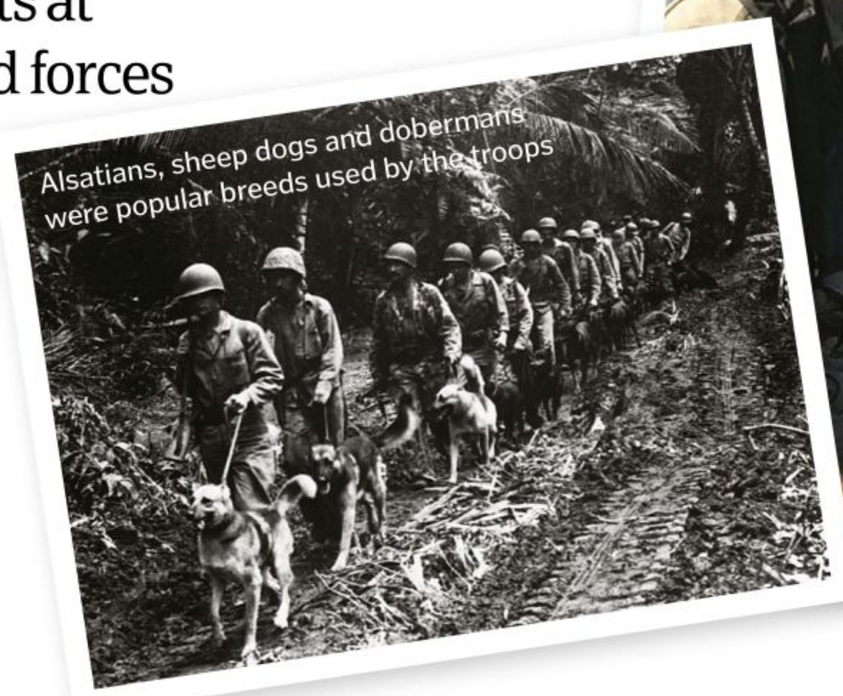
Ships captured 64

Casualties c.30,000-40,000 killed or captured

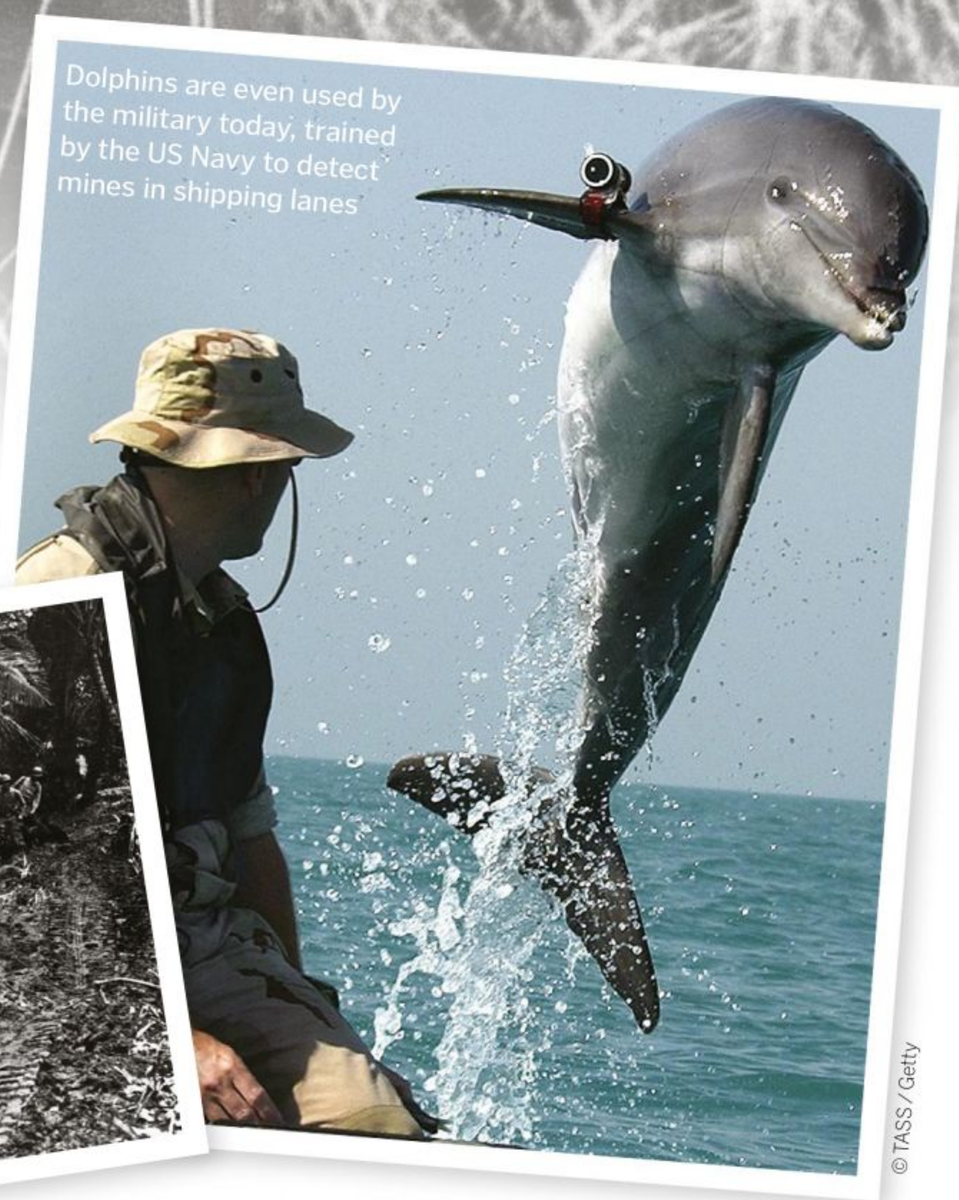
Animal armies

From anti-tank dogs to exploding rats, discover history's failed attempts at drafting animals into the armed forces

Throughout history, humans have enlisted the help of animals to conquer countries, defend territories and defeat adversaries. From gallant horses pulling the chariots of ancient Roman soldiers to the humble homing pigeon sending secrets between nations, animals have played a vital role in securing military success. But during the Second World War, a wave of military innovations saw animals used not as allies but as potential weapons.



Alsatians, sheep dogs and dobermans were popular breeds used by the troops



Dolphins are even used by the military today, trained by the US Navy to detect mines in shipping lanes

© TASS / Getty

Anti-tank canines

Loyal to the end, man's best friend played a vital role in the armed services during the Second World War. From sniffing out landmines to transporting equipment, our four-legged friends were tasked with an array of duties during wartime. However, the Russian military saw an opportunity to utilise a dog's trainability and turn them into weapons. Also known as Hundminen, Alsatians were trained as 'anti-tank dogs' delivering bombs to invading German tanks in an attempt to hold back their advance. At several facilities in Moscow, they were trained to recognise the underside of a military tank as a place to find food. Hardly a threat to an armoured tank alone, when in close contact, these dogs became an active bomb. Strapped to the dogs was a protruding wooden lever mechanism that, once forced back by the dog scurrying under an invading tank, would release a detonation pin in two sidesaddle bombs, destroying the tank and killing the dog. It's estimated that only around 50 tanks met their end at the hands of a kamikaze canine: German soldiers quickly became aware of the animals and their destructive duties, and shot them down before they reached the tanks.

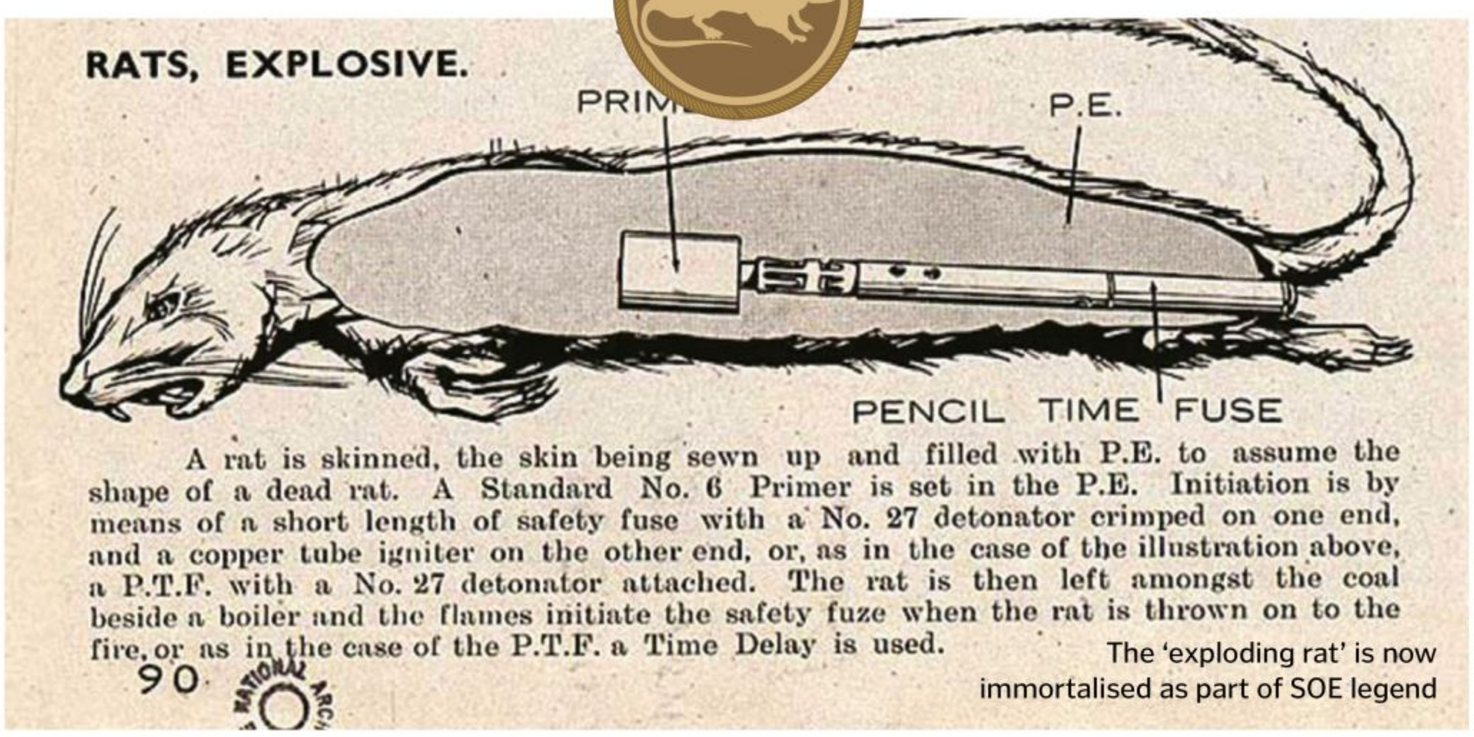
Bearing the weight of around two kilograms of explosives, these anti-tank dogs were trained to unwittingly destroy invading tanks

© Alamy

"It's estimated that only around 50 tanks met their end at the hands of a kamikaze canine"

Exploding rats

In 1941, hundreds of dead rats stuffed with plastic explosives were sent by British Special Operations Executive (SOE) agents with the aim of distributing them across Germany. The principle behind concealing bombs in these critters was to prey upon man's natural disgust when encountering the dead vermin. They were to be placed near coal heaps in German factories, and the novel idea depended upon German workers scooping up the rodent corpses and throwing them into their boiler furnace. Once exposed to the roaring flames, the internal bomb would explode causing a catastrophic chain reaction. However, the delivery of rodents was intercepted by the German military and the British attempt at deception was thwarted. The foiled plan was still seen as a success among the SOE, due to the German paranoia that followed when encountering a recently perished rat.



The 'exploding rat' is now immortalised as part of SOE legend

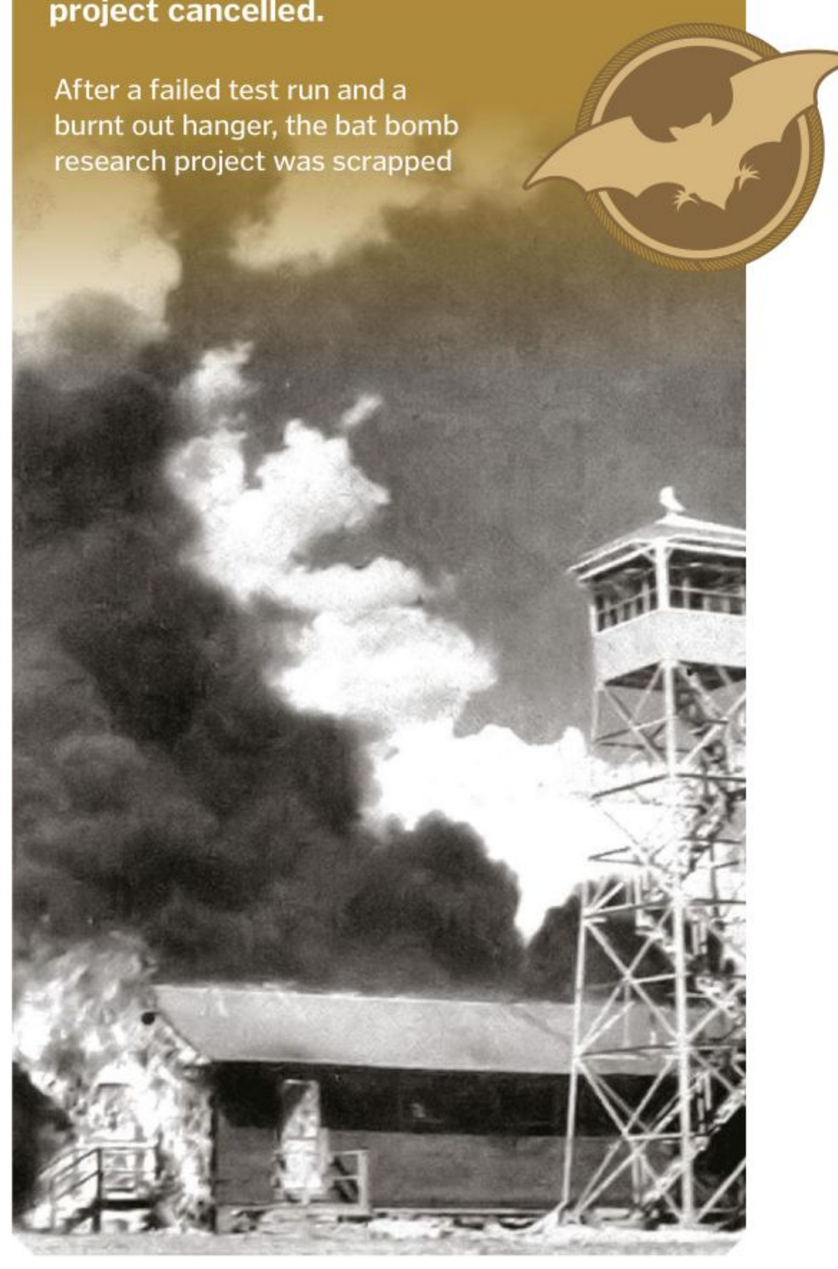
© nationalarchives.gov.uk

Bat bombs

Following the devastation that rained upon Pearl Harbour in 1941, plans to find new and frankly, bizarre ways to retaliate began to emerge from the US. One such military oddity came in the form of weaponised bats. Strapping small incendiary bombs to captured Mexican free-tailed bats, military researchers postulated that these small winged mammals could be deployed over Japan and descend into the nooks and crannies of their buildings. Once roosting, the incendiary bombs would be detonated, causing mass destruction across the country. In order to drop the bats into Japan, a crudely constructed cylindrical chamber, holding around a thousand bats, would be launched by army aircraft, breaking apart before reaching the ground and releasing them. Known as Project X-Ray, this animal exploitation was short lived. During a test run of the collapsible chamber, captured bats escaped and fled into a mock military hanger. Due to the automatic 30-minute detonation following release, both the bats and their bomb accessories exploded, burning the hanger to the ground. The evident security risk the bat bombs posed along with a growing focus on the development of the atomic bomb meant that R&D has its bat bomb project cancelled.

© Time Life Pictures / Getty

After a failed test run and a burnt out hanger, the bat bomb research project was scrapped



Spraying oil around a military camp was common practise to keep swamp-dwelling mosquitoes at bay

© Bettmann/Getty

The ballistic bear

One unlikely soldier to join the military ranks of the Polish armed forces was a Syrian brown bear named Wojtek. Bought from a young boy in Iran, this bear cub became Poland's secret fury force against invading German militants. Fed from a vodka bottle filled with condensed milk, Woytek grew to weigh 400 kilograms and stood at more than 1.8 metres tall. Intended as a mere mascot for the fighting soldiers, Wojtek travelled with his squadron reaching Monte Cassino, Italy, in 1944 where he witnessed the worst of the Second World War. It is reported that during the conflict Wojtek assisted fellow comrades – not by mauling military invaders, but by proffering his paws to help ferry crates. Unfazed by the booms of gunfire, Wojtek continued to offer support in maintaining the flow of ammunition to the gunmen. On capturing Monte Cassino, the 22nd Artillery Supply Company's dedicated their badge to the depiction of a bear carrying an artillery shell, in Wojtek's honour.

Originally procured as a squadron mascot, Wojtek, the brown bear, became a useful ally when the time arose

© Alamy

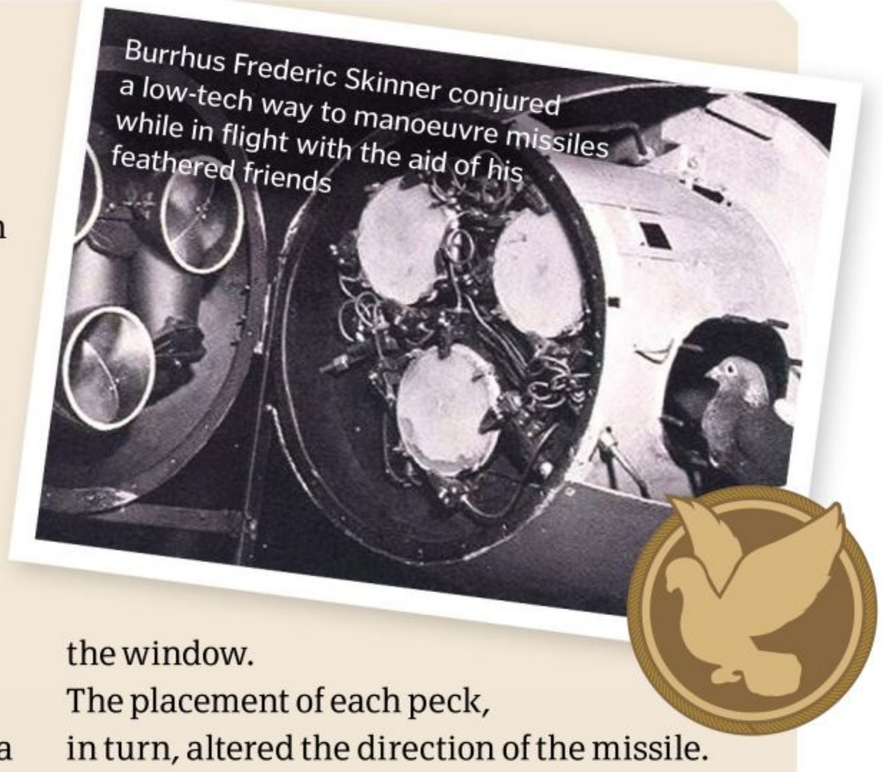
Insect infiltrators

The use of chemical or biological warfare is strictly prohibited under the 1925 Geneva Protocol, however, it is believed by some historians that during the later years of the Second World War, German forces executed a plan to spread malaria among invading troops. Swamps and marshland are the perfect breeding grounds for the malarial mosquito, *Anopheles labranchiae*. Before Italy was overthrown by German forces in 1943, one such mosquito oasis the Pontine Marshes, had been drained to control malaria outbreaks among Italian civilians. However, now under new management, the order was given to refill the swamp, creating a deadly biological barrier to slow any opposing advances. These insects were successful in their mission, however, in a war between men, the mosquitoes held no allegiance to either side. In the battles around Pontine Marshes that followed, soldiers in both German and Allied forces fell as outbreaks of malaria spread.

"These insects were successful in their mission, however, in a war between men, the mosquitoes held no allegiance to either side"

Pigeon pilots

The use of pigeons as military messengers took off during the Second World War, with an estimated 250,000 recruited by the UK alone. Their keen sense of direction and ease with which they could be trained, allowed American animal behaviourist and professor of psychology, Burrhus Frederic Skinner, to create a pigeon-driven missile, called Project Pigeon. At a time where guided missile technology was in its infancy, Skinner designed a system whereby pigeon pilots could 'steer' a cruising missile into German enemy battleships. Strapped into the head of a missile, the system called for pigeons to face a set of three windows for a view of its trajectory. Using a training method known as operant conditioning, pigeons were taught to recognise a battleship through the window and furiously peck at a thin screen covering the window.

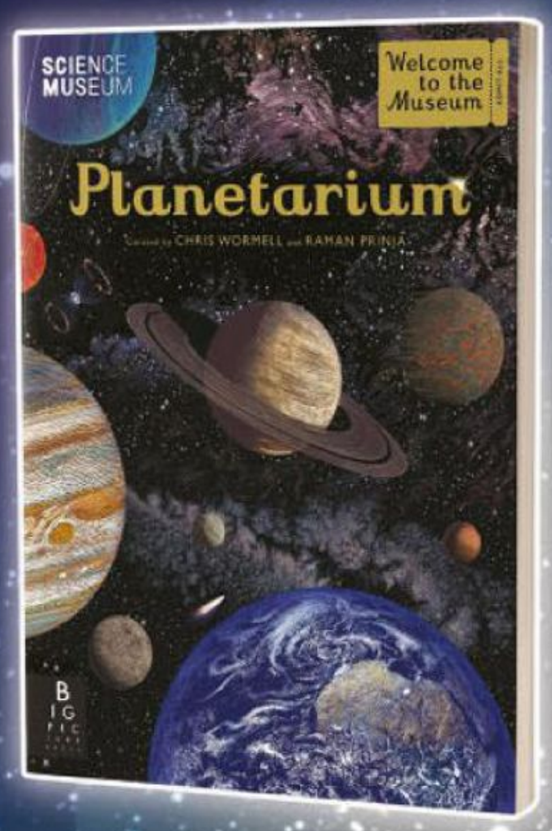


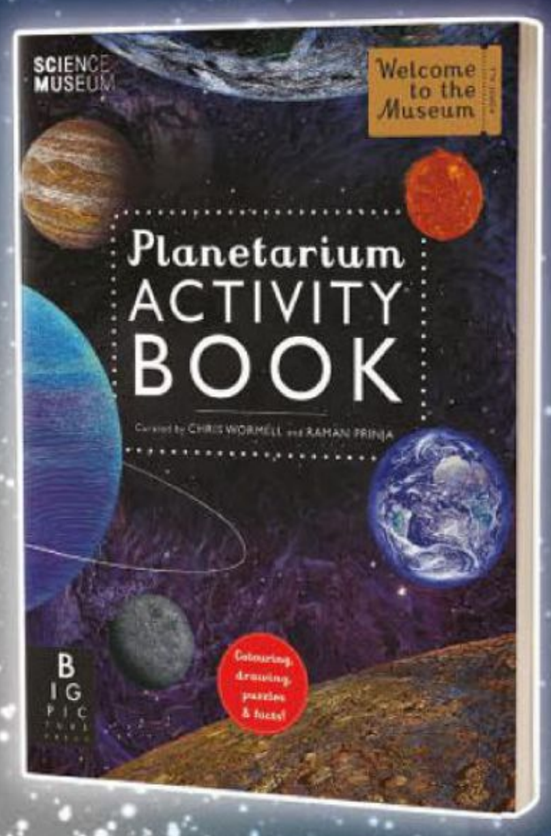
Burrhus Frederic Skinner conjured a low-tech way to manoeuvre missiles while in flight with the aid of his feathered friends

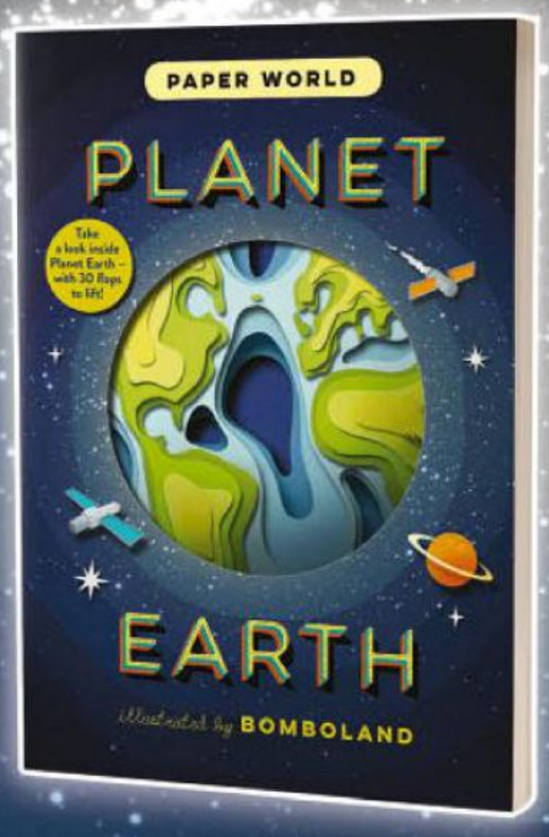
The placement of each peck, in turn, altered the direction of the missile. For example, a centre peck would result in the missile staying on course; pecking to the right or left would alter the direction accordingly. Although it presented promising results during development, Project Pigeon never made it off the ground and terminated in 1944.

SET TO LAUNCH...

IN TIME FOR THE MOON LANDING'S 50TH ANNIVERSARY







OUT OF THIS WORLD BOOKS!

'MOVE OVER TIM PEAKE I THINK I HAVE BEEN TO SPACE'

- *TOPPSTA* REVIEWER, AGE 9, *PLANETARIUM*

Creator Rich Browning combined his passion for aviation and fitness to create his jet suit

REAL-LIFE IRON MAN

Meet Richard Browning and discover how he's defying gravity with a super-powered, jet engine suit

Words by **Scott Dutfield**

DID YOU KNOW? *Buy your own Gravity Industries Jet Suit from Selfridges&Co, a bargain at £340,000 (around $430,000)!*

CEO of Gravity Industries and inventor of the Gravity Jet Suit, Richard Browning has spearheaded grassroots innovation to become a global sensation. Having recognised the potential of his jet suit back in 2015, Browning launched Gravity Industries in 2017 and have ever since been seen zipping through the air, showcasing his creation around the world.

The ability to fly is something we've all dreamt about doing as a child, how would you describe the feeling of flying in the suit?

It's a pretty massive rush every single time, it's visceral in every sense. When you put the suit on you see the heads-up display fire up, you can feel for over 80 seconds all the engines fuel up, autonomously. You can feel the fuel being fed in, feel the ignition taking place and all the engines accelerating. Once five green lights light up in the heads-up display indicating five engines being ready and idle, your throttle trigger becomes live.

As you start to squeeze that trigger, you can feel the engine roar from 30,000 up to 120,000 RPM (revolutions per minute). It sounds like a hurricane, but when you're inside it, it's actually calm. All you do is just feel that thrust and gradually lower your arms and feel the weight come off your feet. There's this kind of second degree of calm where you are now floating about in free space and strangely, a bit like a bicycle, where you don't think about steering and pedalling, your brain kind of sorts the rest out. You just feel yourself going where you decided to go. In a three dimensional sense, that's exactly what it's like flying a jet suit. It's a huge credit to the human brain, being able to repurpose itself to this unusual form of balance and control.

What sparked your passion for developing the Gravity Industries jet suit?

My grandfather on my mother side ran Western, the helicopter company, my other grandfather was a wartime aviator and civil airline pilot, and my late father was an aeronautical engineer and maverick. So I suppose I've always had a passion for speed, flight and horsepower. I also spent about six years in the Royal Marines reserve and alongside running ultra marathons, doing callisthenics training and weight training, it inspired me to think about the human brain and body being a pretty amazing machine. So I thought, why not blend all of these interests together? See if I could re-imagine how flight could take place for human beings. And rather than sitting inside a vehicle like a helicopter or an aeroplane, what about actually adorning the human mind and body with a minimal amount of technology and approaching a challenge in that way. And that's where I then embarked on playing with micro gas turbines as a very small compact system of thrust.

How does the jet suit lift off the ground?

So the way it flies, is that there are two micro gas turbines on each arm and a large one around the back. If you consider the arm jets as being like one large one on each arm, then you've got three different thrust vectors. Therefore, thrust is coming out of each arm and one around the back. It's like a three-legged camera tripod in that way. To take off, simply point your arms down with those thrust vectors, lined up vertically, then the thrust will exceed the weight of the equipment and your body making you lift off the ground. The engines create very rapid expansion of hot gas, which is going out the back end of the engine and passing the turbine wheel. That turbine wheel is spun round and runs the compressor in the front of the engine which compresses the air to go into the engine to increase the violence of the combustion. It's a nice self-contained system. We used a hyper gas turbine that has a centrifugal compressor rather than an in-line one, which is what you have on a normal jet engine in a modern jet fighter or aircraft.

Essentially you're in the business of turning air and fuel into hot air in an extremely violent way and blowing it all out of the back of the nozzle. The air leaves the nozzle at about 1,000 miles an hour (around 1,609 kilometres per hour) and each little arm engine that I use, of which I've got four, produces about 22 kilograms (49 pounds) of thrust. A crude way of representing this power is that each one of those little engines on my arms is equivalent to about 170 horsepower [the power of a medium-sized car]. Add up all four engines

The real-life Iron Man jet suits are demonstrated at shows around the world

Taking flight

How does Gravity Industries' flying jet suit stay up in the air?

Balance
During flight, the pilot's entire upper muscular system, such as the deltoid, triceps and pectoral muscles, are engaged to maintain balance.

Fuel supply
The turbine jet suit uses kerosene, also known as Jet A1 fuel for combustion within the engines.

Heads-up display
A series of five lights placed in the suit's helmet indicate the status of the engines. Once they're all on, the pilot is allowed to pull the trigger.

Feeling the force
Following Newton's third law, the downward force generated by the turbine engines is matched by the amount of upward force applied to the suit, lifting the pilot into the air.

Compressor
Air is pulled into the turbine engine via a compressor fan, increasing the pressure within.

Combustion chamber
The site of the fuel's volatile reaction where it encounters compressed oxygen.

Shaft
Connecting the compressor fan and turbine, the shaft spins both components during combustion. In turn it hoovers up a large amount of air for further combustion.

Exhaust nozzle
Hot air is expelled through the jet's nozzles, generating thrust and increasing the pilot's manoeuvrability.

DID YOU KNOW? *The Jet Suit has an altitude limit of about 3,660 metres*

Printing metal

To create the perfect size and shape for the suit's handheld jet casing, Gravity Industries uses a method known as direct metal laser sintering (DMLS). As a way of 3D printing metal, DMLS takes computer-generated models and builds them out of powdered aluminium or titanium. A high powered laser is fired at the metal powder to melt or 'sinter' two dimensional layers of the final model. Once a single layer is drawn out by the laser, a fresh coat of powder is rolled over the top of the previously sintered layer. This cycle of sintering continues layering slices of melted metal on top of one another until the final three-dimensional casing is complete.

The gravity suit is made up of five turbine engines, two on each arm and the third mounted on the pilot's back

"Add up all four engines and the one on my back - that comes to a theoretical 1,050 horsepower"

and the one on my back – that comes to a theoretical 1,050 horsepower. That's even more powerful than a formula one racing car.

How many versions of jet suit were created before reaching the current example?

Gosh, I would say hundreds. It's not a question of just building one and then trying it, throwing it away and starting with an entirely new one, there is lots of morphing of various different aspects. It's quite hard to draw a line between different models. But I mean, some of the core steps were achieving the first flight in March 2015 with a little jet engine on each leg and two on each arm. That was a major breakthrough and the very first time we actually flew. Then quite quickly, we realised you had to move the leg engines gradually up your body around to the rear end area, so the engines didn't destroy the ground too much and were more stable. If you attach jet engines to your legs, it's like balancing a pool on the palm of your hand, fundamentally hard to balance.

The Times named the jet suit as the best innovation in 2018, what has been the reaction from the public?

I'm the first to admit that I started this entirely out of exploring a challenge that looked impossible and that could be pretty damn exciting. Having got it to work and having then decided to share it with the world under the headline of 'Gravity', and the company that we formed, we've done 75 events in 23 countries. The effect on audiences all over the world has been remarkable. People lose their minds when they see a thousand horsepower jet suit flying around where the human form is not lost.

What are the next steps for Gravity Industries and future flight suits?

It's really about a mixture of massive amount of fun. I have to say, I don't watch Marvel films and think "that's what I'm going to go and build". But it is fun to note that science fiction manifests pure human creativity, where you don't care about physics or money, you just imagine how cool it will be to see something. We're on a journey to push the boundaries of what's possible. We are working on an electric version and a winged version as well, which has just smashed our speed record, by hitting 90 kilometres per hour (around 56 miles per hour). So there's tons going on at the minute, we've kind of opened the door to a whole new kind of realm of opportunities.

Your work on the jet suit has led you to write Taking on Gravity. What can people expect from the book?

Aside from what I think are quite blunt, no waffle lessons around how you can properly innovate – I distil down some pretty pertinent rules around how you take controlled risks and manage the downside. Innovating is all about taking controlled risk, being able to get back up again, to keep trying. But it doesn't work all the time. I'd say there is a pretty strong narrative around that area.

There's also quite a strong linkage to my kind of unusual childhood, which catapulted me towards this whole boundary-pushing desire. So there's a mixture of the human story behind this and the innovation journey. And a lot of behind-the-scenes of how you're not only proving this concept and getting it to fly, but almost a harder challenge of how you build that into something that can be revenue-

Images: Gravity Industries

How fake meat is made

From veggie burgers that bleed to lab-grown steaks, the future of food is an imitation meat arms race

Burger King announced in April that it's rolling out the Impossible Whopper to all of its 7,300 restaurants in the US. This vegan burger isn't your normal black bean meat substitute. What makes it seemingly 'impossible' is that its looks, feels and tastes like ground beef – but is entirely made from plants.

Engineered by Silicon Valley-based Impossible Foods, this fake meat makes clever use of vegetable fats and proteins so that it even bleeds and sizzles when you cook it. And it's becoming big business. As well as Burger King, Impossible Foods is partnering with other fast food chains. Meanwhile its rival, Beyond Meat – which also makes fake sausages – is signing up supermarkets on both sides of the Atlantic.

However, while plant-based burgers become more meat-like, the bleeding-edge of biotech research is redefining what meat is entirely. In 2013 the Dutch scientist Mark Post served up a lab-grown hamburger. No animal had to die to make it – instead lab technicians grew it in a vat from a handful of cells in just three months. The downside was that it cost about £250,000.

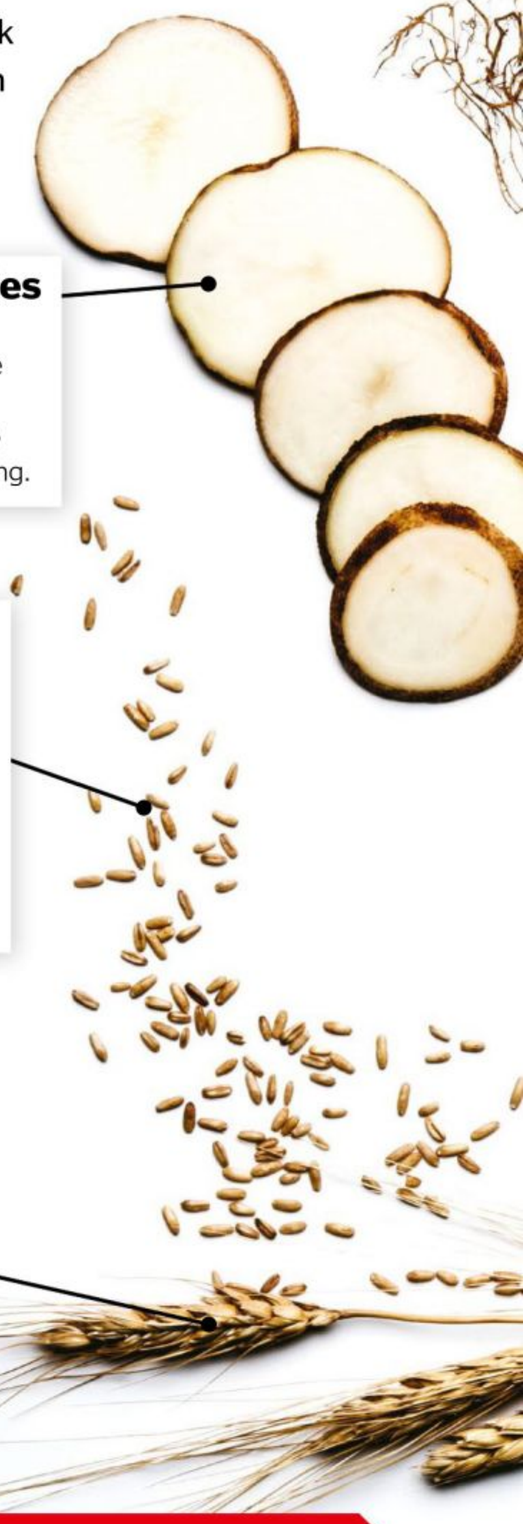
Six years later, so-called 'cultured meat' startups have slashed that price by 99 per cent. And they've diversified, growing beef, chicken, turkey and tuna. Milk made without cows and eggs without hens are also in the works. It's expected that affordable animal-free meat will arrive from 2020.

The driving force for both plant-based burgers and cultured meat is a need to feed an exploding global population while having less of an environmental impact. Animal-based meats, as we need to start calling them, require unfathomable amounts of food and water and take up vast stretches of land. And all the while they produce methane emissions, contributing to global warming. Just possibly, fake meat is a real solution.

"The bleeding-edge of biotech research is redefining what meat is"

A 'Bleeding' burger in the flesh

Here's a bitesize look at what goes into an Impossible Burger



Do you want fries with that?
Potato protein helps the food hold water and transition from a soft to solid state during cooking.

Look on the sunny side
To cut down on saturated fats, the Impossible Burger 2.0 recipe, launched in January, replaced a portion of coconut oil with sunflower oil.

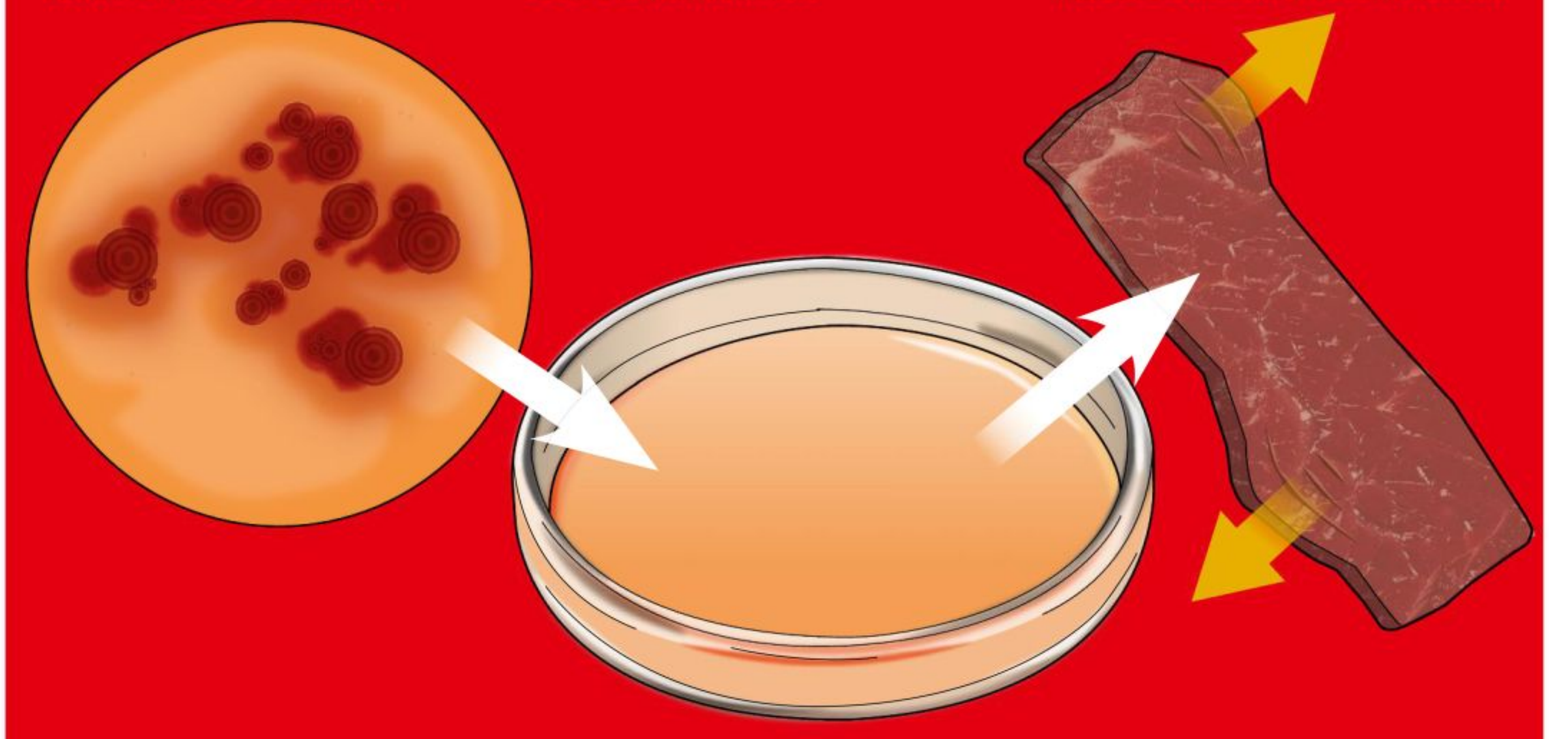
Chew on this
While Impossible Foods originally used wheat to give the burger the familiar firmness of meat, it now uses gluten-free soy.

How synthetic meat is grown

1 To start, stem cells are taken from an animal. To make burgers, you extract them from the muscle of a cow. For fake foie gras, you'd take a sample from a duck's liver. The animal is given anaesthesia so it feels no pain, and it survives the biopsy.

2 The cells are fed a nutrient-rich serum to help them multiply. This protein-rich juice is made from the blood of foetal horses or cows, so synthetic meat is not suitable for vegetarians – yet. Researchers are now developing serums that aren't derived from animals.

3 As the cells grow, they are encouraged to form strips, much like how muscle cells form fibres in living tissue. These fibres are attached to a sponge-like scaffold that stretches them, 'exercising' the muscle cells to increase size and protein content.



The secret ingredient in 'cultured meat'

Most cells have a particular function: red blood cells carry oxygen around our bodies and nerve cells transmit electrical signals, for example. Stem cells are different. They divide again and again to produce new cells. As they divide, they can change into other types of specialised cells – red blood cells, skin cells and more. This helps bodies to grow and recover when injured.

To make lab-grown meat, we extract stems cells from livestock. These divide over and over to become muscle fibres. One stem cell sample can produce 800 million muscle fibres, enough for 80,000 quarter-pounders.

Familiar flavour
Iron-rich haem gives the Impossible Burger its blood-red colour and makes it taste like meat.

Packed with protein
Soy beans also give the synthetic food the same protein level that's in 20 per cent fat ground beef.

Essential sizzle
Coconut oil – minus it's familiar milky flavour – gives the burger a juicy sizzle when it hits the pan.

It's not a health snack
While it contains less cholesterol than beef, and more fibre and vitamins, the Impossible Burger is also higher in salt and carbohydrates.

Holding steady
To hold everything together, Impossible Foods uses methylcellulose, a bulk-forming binder that also serves as a great source of fibre.

Farm free
None of the ingredients in the Impossible Burger are derived from animals, so it's fine for vegetarians and vegans to eat.

What makes vegan burgers bleed?

As gross as it sounds, biting into a plant-based patty and seeing it run red is what drives many to try fake meat. While Beyond Meat uses beetroot for this effect, Impossible Foods has gone one step further: they use haem. This iron-containing compound is found in both plants and animals. It's the reason our own blood is red.

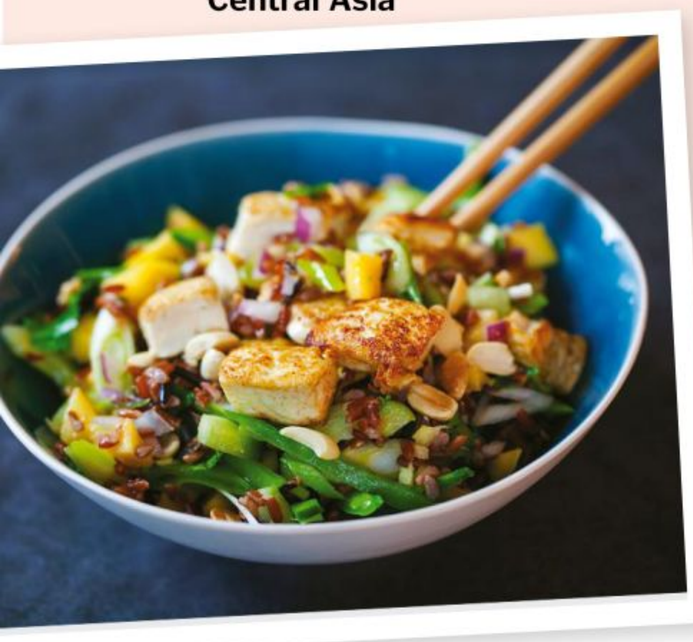
Impossible Foods used to harvest haem from soy plant roots. But the eco-conscious company switched to genetically engineered yeast so it didn't have to intensively farm crops. Containing the soy gene for haem, this yeast is fermented in giant vats. It's a bit like beer-brewing, but instead of alcohol, it makes this gory secret ingredient.

1.4 billion
Cattle farmed worldwide – 11 per cent in Europe and Central Asia

£1.1 billion
Value of the Beyond Meat company on 2 May 2019

14.5%
The percentage of greenhouse emissions caused by livestock

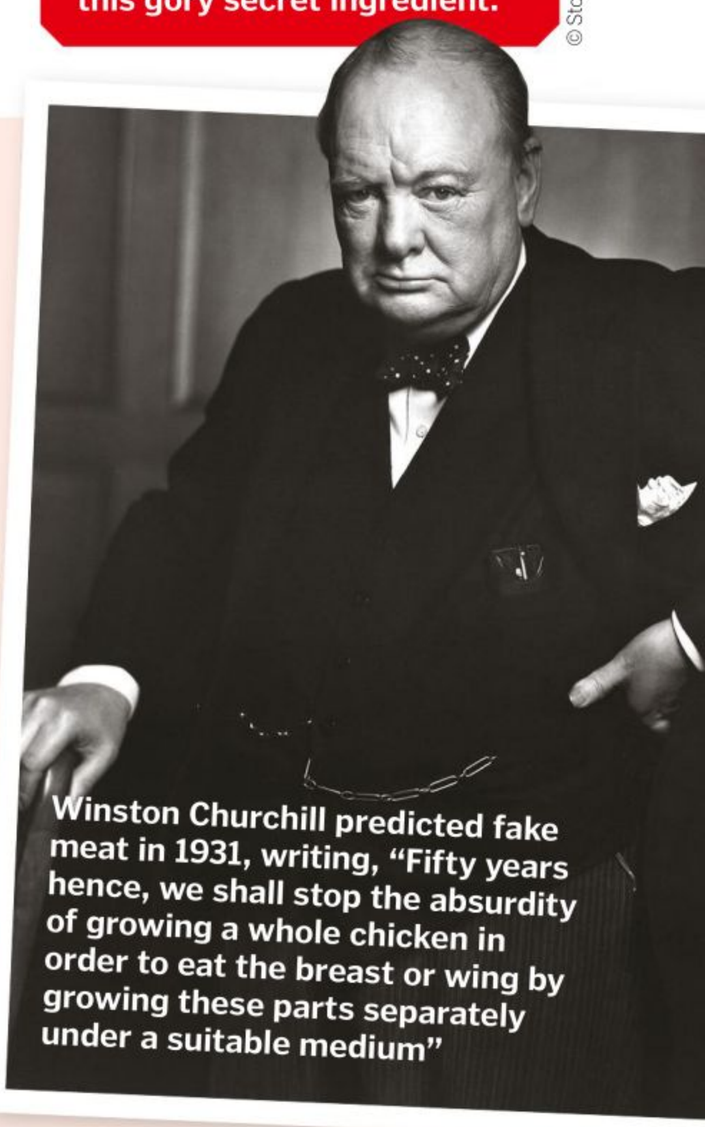
26
Companies developing lab-grown meat worldwide



454,000kg
Quantity of plant-based burgers Impossible Foods' factory makes each month

The earliest known reference to the first 'meatless meat', tofu, was recorded in China in 965CE

30%
Calories consumed by humans worldwide from meat



Winston Churchill predicted fake meat in 1931, writing, "Fifty years hence, we shall stop the absurdity of growing a whole chicken in order to eat the breast or wing by growing these parts separately under a suitable medium"

How roller-coasters work

Discover the physics that drive these rides and why we find them so thrilling

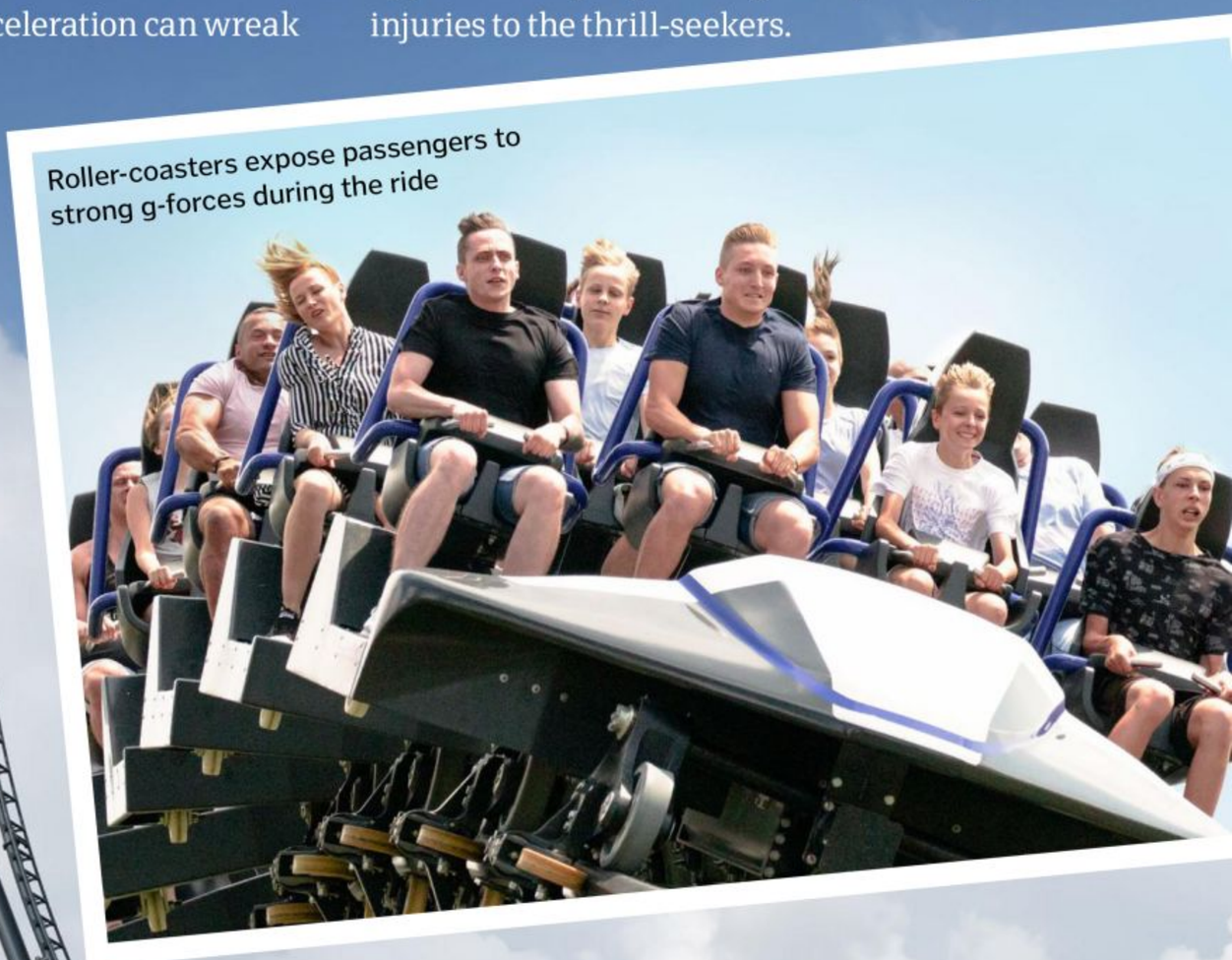
There's no feeling quite like the anticipation you experience when crawling up to a roller-coaster summit, waiting for the inevitable high-speed drop on the other side. Their thrill-inducing prowess is the main reason for their popularity across the globe. Exploiting the fundamental laws of physics, engineers and designers have been able to create rides driven almost solely by natural forces. The rides follow Newton's first law of motion – that an object in motion will remain in motion and in a forward velocity unless compelled to stop by another force.

With a mechanical push, roller-coaster cars are typically launched in one of two ways. The first method employs a 'lift hill', whereby a chain is temporarily attached to the coaster car, pulling it up a tracked hill, releasing the car to freefall on the other side. The second method is with a hydraulic launch. Rapidly zipping along a track, the roller-coaster's cars and passengers are experiencing conversions in energy from potential to kinetic. Potential energy is the energy stored in relation to its position. In the case of roller-coasters, this stored energy accumulates while climbing loops or hills against the pull of gravity. In the same action as pulling a slingshot, when gravity pulls the car back down the other side of a hill or loop, the speed you feel is generated kinetic energy (motion).

"The rides follow Newton's first law of motion"

This continual conversation from potential to kinetic energy is what drives the roller-coaster car around the track. The higher a roller-coaster's hills and loops, the more stored energy is generated and the more kinetic energy released, thus the quicker the car will travel around the track.

But the rate of acceleration can wreak havoc on the human body if it's too high. Roller-coasters have been around since the 1800s and were made predominantly from wood. Early examples applied that same law of physics to propel cars around a track. However, the inventors greatly underestimated their effects on the human body. G-force is generated during an object's rate of acceleration or deceleration. Accelerate or decelerate too quickly and the riders may lose consciousness or suffer internal injuries. Typically, a healthy human can tolerate around six gs without any negative effects, other than a case of travel sickness. However, these early attractions exposed passengers to the force of approximately 12 gs during a ride, causing injuries to the thrill-seekers.



Roller-coasters expose passengers to strong g-forces during the ride

5 FACTS ABOUT ROLLER-COASTERS

1 Fastest
Found at Ferrari World in the United Arab Emirates, the Formula Rossa holds the record for the world's fastest roller-coaster, reaching 240 kilometres per hour in only 4.9 seconds.

2 Longest
Spanning 2.48 kilometres, the Steel Dragon 2000 in Nagashima Spa Land amusement park, Japan, holds the record for the world's longest roller-coaster.

3 Tallest
Towering 139 metres in the air, the U-shaped Kingda Ka at Six Flags theme park, US, is the world's tallest roller-coaster.

4 Most g-forces pulled
The world record for most gs pulled on a roller-coaster belongs to the Tower of Terror in Gold Reef City, South Africa, which pulls an impressive 6.3 gs.

5 Oldest
The oldest roller-coaster still in operation is the wooden Leap The Dips in Pennsylvania, US. It was built in 1902.

Why do we enjoy roller-coasters?

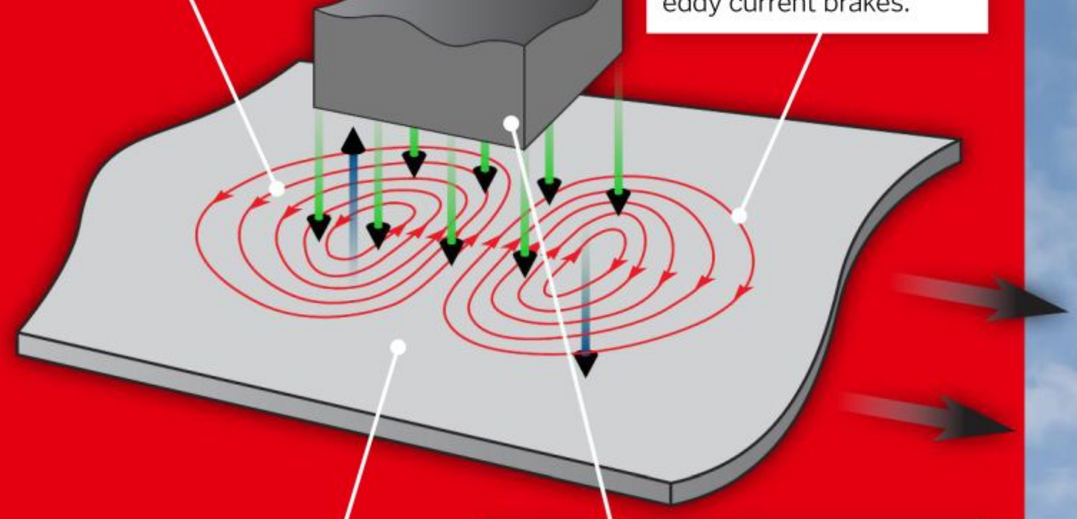
Strapped into a cart that's wedged on a metal track with dips, loops and turns, travelling at hundreds of kilometres per hour and only gravity as your driving force, it's a wonder we enjoy roller-coasters. But several biological and psychological responses to these thrills help explain their popularity.

Much like watching a scary film or eating a spicy meal, being glad to be sad has been termed by psychologists as 'benign masochism'. This human phenomenon is the enjoyment of something the body falsely deems a threatening experience. It's this realisation that the body has been fooled that leads to the perceived pleasure of 'mind over body'. The thrill of a roller-coaster evokes our innate 'flight or fight' behaviour. In turn, euphoric hormones are released, such as adrenaline and dopamine, giving passengers a chemical roller-coaster rush.

Brake power

How do roller-coasters come to a sudden halt? Two methods have been used to stop a speeding roller-coaster car. The first is similar to those used in many vehicles, creating friction between the moving roller-coaster car and the brake. Metal clamps along the end of the track are hydraulically controlled to close against metal fins beneath the car, stopping it.

The second uses magnetic forces called 'eddy currents'. Non-magnetic metals like copper or aluminium are placed adjacent to the roller-coaster car. When stationary these metals don't interact with the magnets, but while moving and expelling kinetic energy as they pass through these magnets, eddy currents are created, stopping the metal's further movements. This process also uses up the kinetic energy and converts it into thermal energy. By removing the energy propelling the car forward, it's stopped in its tracks.



Eddy currents
As electrically conductive metal passes through the magnet's magnetic field, electrical eddy currents form, moving in both an anticlockwise and clockwise direction.

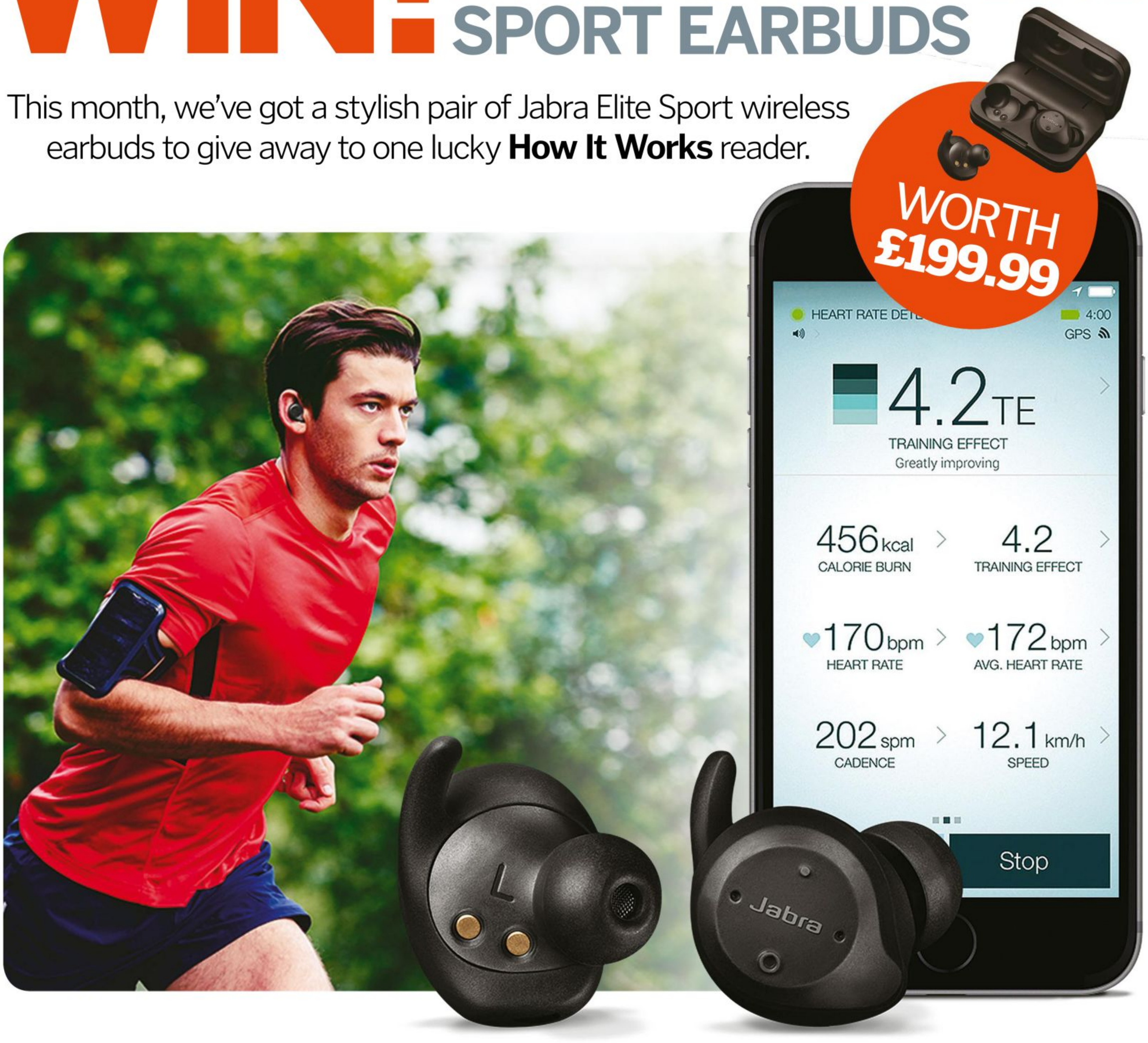
Energy conversion
During braking the kinetic energy used to propel the roller-coaster car is converted to heat energy upon passing through the eddy current brakes.

Metal strips
Along the sides of a roller-coaster car, conductive metal is positioned to pass between magnets.

Magnets
Electromagnets create strong magnetic fields, which interact with the magnetic fields created by the eddy currents. These opposing magnetic fields slow the car.

WIN! A PAIR OF JABRA ELITE SPORT EARBUDS

This month, we've got a stylish pair of Jabra Elite Sport wireless earbuds to give away to one lucky **How It Works** reader.



For your chance to win, answer the following question:

Which land mammal has the biggest brain?

a) **Human** b) **Elephant** c) **Gorilla**

Send your entries by email to **howitworks@futurenet.com** with the subject 'Competition 127', or write to us at:

How It Works, Future Publishing, 33 Richmond Hill, Bournemouth, Dorset, BH2 6EZ

Special offer for readers in **North America**

4 FREE issues

When you subscribe*

"The action-packed science and technology magazine that feeds minds"

Order hotline **+44 (0)344 848 2852**

Online at **www.myfavouritemagazines.co.uk/hiwusa**

***Terms and conditions** This is a US subscription offer. 4 free issues refers to the US newsstand price of $9.99 for 13 issues being $129.87, compared with $87 for a subscription. You will receive 13 issues in a year. You can write to us or call us to cancel your subscription within 14 days of purchase. Payment is non-refundable after the 14-day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices are correct at point of print and subject to change. Full details of the Direct Debit guarantee are available upon request. UK calls will cost the same as other standard fixed-line numbers (starting 01 or 02) included as part of any inclusive or free minutes allowances (if offered by your phone tariff). For full terms and conditions please visit: **bit.ly/magtandc**. Offer ends 31 October 2019.

OFFER EXPIRES 31 Oct 2019

BRAIN DUMP

Because enquiring minds need to know...

MEET THE EXPERTS

Who's answering your questions this month?


JODIE TYLEY


TOM LEAN


LAURA MEARS


JAMES HORTON


JO STASS

Why is all life on Earth carbon-based, and would it be possible to have life that's not carbon-based?

James Dark

Life needs to be able to store information, and to do this it has to construct large, complicated molecules that stand the test of time. One of the only elements that can do this is carbon. Carbon can make four bonds to other elements. This allows it to form the long, branching chains that make up our most useful molecules, from the DNA that carries our genetic code to the fats that surround our cells. The most viable alternative is silicon; it sits directly under carbon in the periodic table and can also make four bonds. However, because it's bigger than carbon, its unpaired electrons are further away from its nucleus. This means the bonds it makes are weaker, so biological molecules based on silicon would likely be less stable. **LM**

Want answers?

Send your questions to...

How It Works magazine

@HowItWorksmag

@howitworks@futurenet.com

Carbon forms the backbone of all biological molecules, including DNA

Has Britain always been a monarchy?

Sebastian Rusescu

Britain hasn't always been a monarchy. After Charles I lost the English Civil War to Parliament in 1649 England and Wales, and later Scotland and Ireland, were ruled as a republic of sorts until 1660, when the monarchy was restored. **TL**

© Pixabay

Is my phone listening to me?

Sangita Mandal

Technically, it is possible that your phone is recording your conversations while it is in your pocket. However, most of the big tech companies are insistent that they only listen to what you are saying after a voice search command and do not use any other recorded audio for advertising, selling to third parties or other purposes. **JS**

Current laser equipment, like Lockheed Martin's HELIOS system, is heavy and requires a lot of power

Why doesn't the military use laser guns instead of bullets?

Joshua Morrison

The US Navy is backing the use of lasers in a big way, having recently announced plans to mount its HELIOS laser weapon on destroyers by 2021. These beasts will be able to knock drones out of the sky and set boats ablaze, possibly paving the way for them to replace ballistic weapons. The main drawback with mounting lasers on all vehicles and giving them to ground troops is their current weight and energy requirements. So for the immediate future at least, only the juggernauts of the battlefield will host them. **JH**

How small were *T. rex*'s arms?

Aaron Michaels

At around one metre in length, *Tyrannosaurus rex*'s arms only appear comically small because the rest of the creature was so big – towering approximately six metres off the ground and stretching the length of a bus. However, there is still debate around what their two-fingered forearms were used for. **JT**

BRAIN DUMP

There's no evidence that skipping breakfast leads to weight loss or snacking later on

Is breakfast really the most important meal of the day?

Maggie Hansen

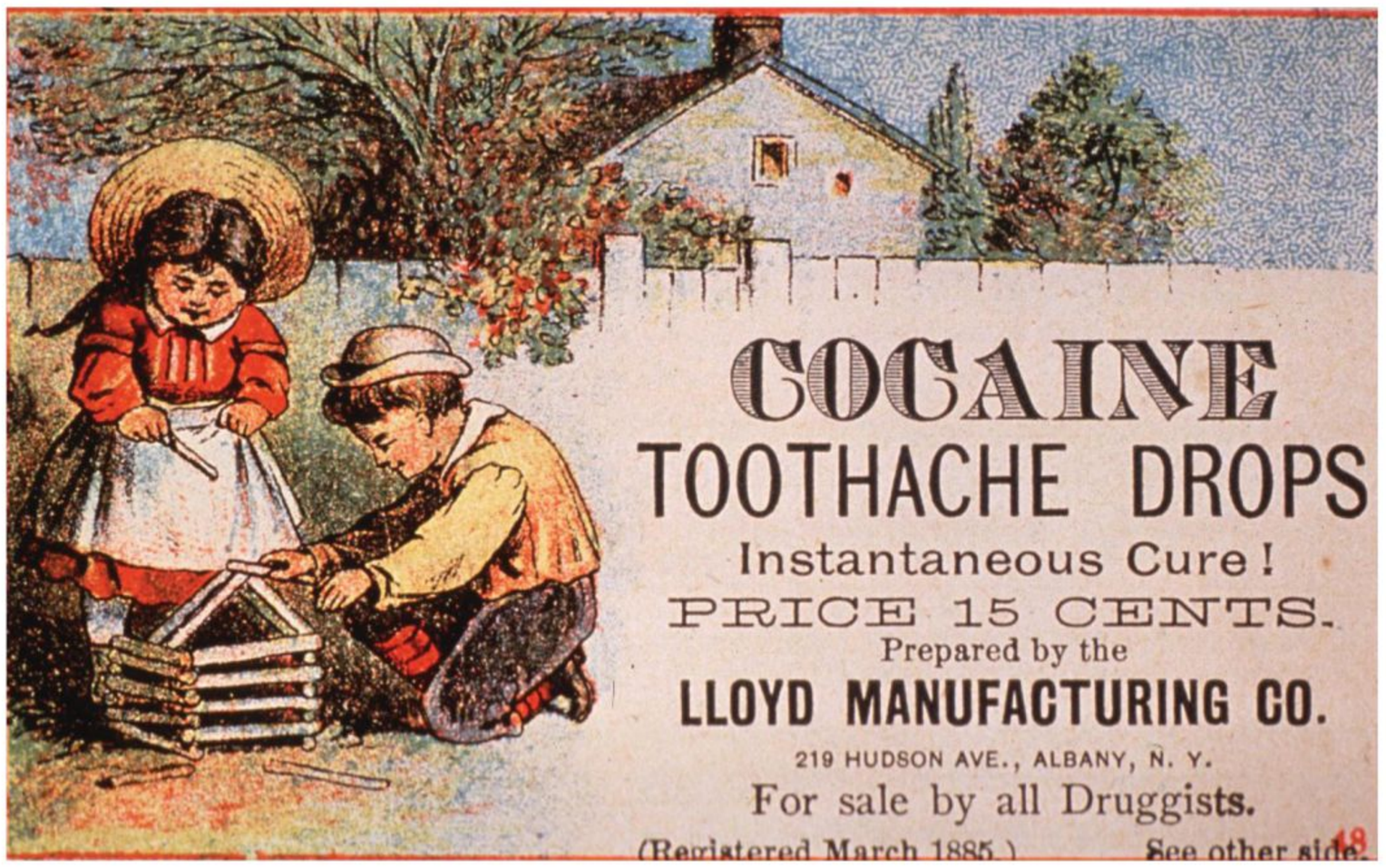
A recent study put this age-old adage to the test and found that eating breakfast had little impact on metabolism or eating patterns later in the day, compared with those who fasted until midday. The subjects neither lost nor gained weight, but researchers did find that those who ate breakfast were likely to be more physically active and have more controlled blood sugar levels than those who didn't eat until noon. Ultimately, more studies are needed before we can really say how important this meal is, but health experts don't recommend missing out – it could mean you spend all morning feeling 'hangry'. **JT**

Are there prisons for animals?

Ryan Swan

There are no prisons for animals, but some human prisons allow inmates to keep pets as a reward for good behaviour. There are also some rehabilitation schemes where prison inmates train dogs from animal shelters until they can be rehomed. **JT**

© Getty



Cocaine was quite a common ingredient in 19th-century medicines

Were illegal drugs ever legal?

Louis Evrard

Many drugs that are illegal today were legal in the past, as their dangers were not well understood or society did not view them as a problem at first. Opium and cocaine, for instance, could be bought at chemists in Victorian Britain and only became more regulated, and eventually illegal, after World War I. Hallucinogenic LSD, invented in 1938, was legal in many countries until the 1970s. **TL**

How does my inbox know when an email is spam?

Eva Klein

Incoming mail is filtered by your email provider, which checks if it's from an address known for sending spam or if the message contents or heading match the sorts of things typical of spam emails. If so, it will be marked as spam or sent to your trash folder. **TL**

What happens when you get a stitch in your side?

Zsuzsi Kovács

This is a matter of hot debate in the scientific and medical communities. There are lots of possible explanations. A stitch might be a kind of cramp in the diaphragm. It could be a full stomach pulling on ligaments in the abdomen. It might be the movement of the organs irritating a membrane called the peritoneum. It's possible that it's an increase in blood flow agitating the spleen or liver. And there's a chance that interference with the phrenic nerve is the cause of the pain. **LM**

Scientists aren't sure what causes the pain of a stitch during exercise

Why aren't there more nuclear-powered vehicles?

Melissa Bradley

People have designed nuclear-powered cars, trains and even planes, but nuclear vehicles have never really caught on. Nuclear reactors are very expensive, large and technically complex, making it impractical to use them in everyday vehicles. Nuclear fuel and radioactive waste are also very hazardous to people and the environment, meaning that nuclear power plants are carefully regulated to control the risks and keep them secure from criminals, restricting the wider use of nuclear power. The only nuclear vehicles are some big ships and submarines, where the size, safety issues and costs of a nuclear power plant can be better accommodated. **TL**

The Ford Nucleon from the 1950s was one of several unrealised concepts for a nuclear-powered car

© Getty

BRAIN DUMP

Why hasn't the Sun burned out yet?

Brooke Stevens

Scientists in the 19th century asked a similar question. At the time, the only method of creating solar energy they could fathom was gravitational compression – where the Sun would continuously shrink and release energy – and combustion, like the fires we start on Earth. But when they ran the numbers they realised the Sun couldn't possibly have lasted the 4.5 billion-year lifespan of the Solar System up until that point. We now understand that energy is released from the Sun by nuclear fusion, when atoms of hydrogen are smashed together and combined to form helium. Each kilogram of helium releases as much energy as 20,000 metric tons of coal, so we think that the Sun still has plenty of fuel left to burn. **JH**

Scientists believe that the Sun has several billion years' worth of fuel remaining

If everyone became vegetarian, would the planet actually be better off?

Howard Little

The way we produce meat has a major impact on the environment, not only through land and water use but also the carbon footprint, as livestock accounts for an estimated 14.5 per cent of greenhouse gas emissions worldwide. Switching to vegetarianism is predicted to reduce a person's carbon footprint by 30 per cent, but there is still an environmental impact if the food has been transported a great distance. **JT**

How much exercise do we get from talking?

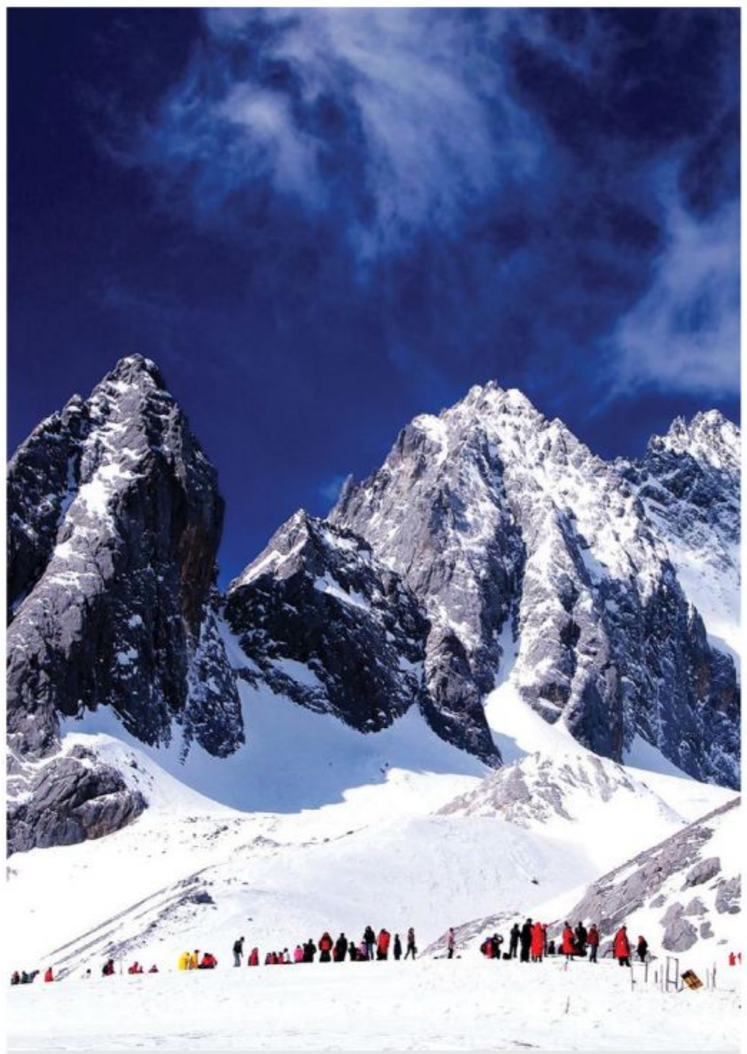
Elisabeth Leigh

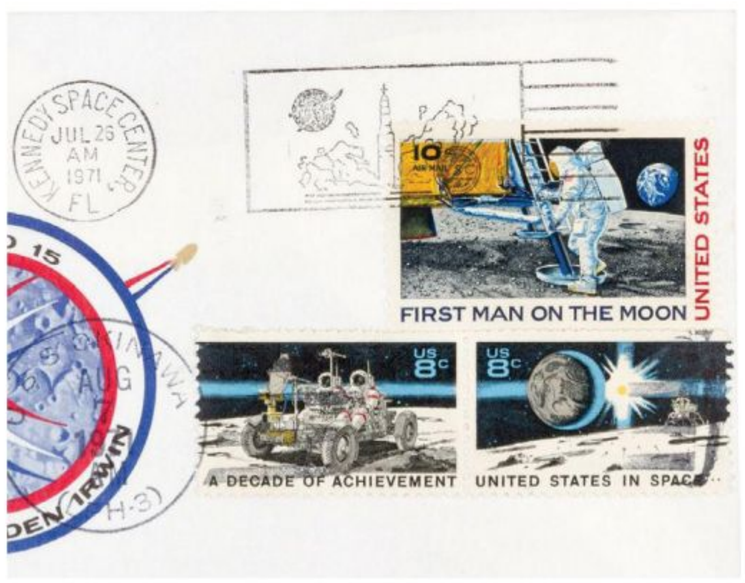
In 1998 scientists monitored participants who were asked to talk continuously – either quietly, normally or loudly. Perhaps unsurprisingly, they found that talking at a normal volume is as taxing as merely sitting in silence. But making an effort to lower or raise the voice caused participants to intake up to 20 per cent more oxygen, which could be considered very modest exercise over prolonged periods. **JH**

What's the highest ski resort in the world?

Malo Nicolas

The world's highest ski resort is at Jade Dragon Snow Mountain in Lijiang, China. At an altitude of 4,700 metres above sea level, it takes four ski lifts to reach the top. **JH**





What was the Apollo 15 postal covers incident?

Arne Lambert

Astronauts regularly took items with them to space that they could sell on their return, and postal covers (envelopes with a postage stamp) were a popular choice as they were collector's items. The Apollo 15 crew did this too, but as well as taking around 200 NASA-authorised postal covers, they also took around 400 non-authorised covers to the Moon. These were sold to a German collector on the condition that they would not appear on the market until the Apollo program was over. The collector broke the agreement, NASA found out and reprimanded the astronauts for causing embarrassment to the space program. **JS**

How thick is the ice on top of the land of Antarctica?

Charlotte Reynolds

The mean thickness of the ice is 2.16 kilometres – about two-and-a-half times the height of the Burj Khalifa in Dubai. The maximum known thickness is 4.77 kilometres, six times the height of the Burj. **JS**

Want answers?

Send your questions to...

How It Works magazine
@HowItWorksmag
@howitworks@futurenet.com

300 million years ago, dragonflies had wingspans of 65 centimetres across

Why are insects so small?

Zara Reeves

There is no definitive answer to this, but the most likely theory is the way they breathe. Insects take in oxygen through tiny tubes called tracheoles, which diffuse it directly into their cells. In bigger insects, these tubes would need to be really long and would therefore be less efficient at diffusing oxygen, limiting their growth. It's thought that insects grew much bigger in prehistoric times because there were higher levels of oxygen in the air. **JS**

Is my glow-in-the-dark watch irradiating me?

Robin Gleeson

Only if your watch is more than 50 years old. Before people knew the dangers of radiation, glow-in-the-dark watches contained the radioactive element radium. Now, glow-in-the-dark paints contain non-radioactive chemicals called phosphors. **LM**

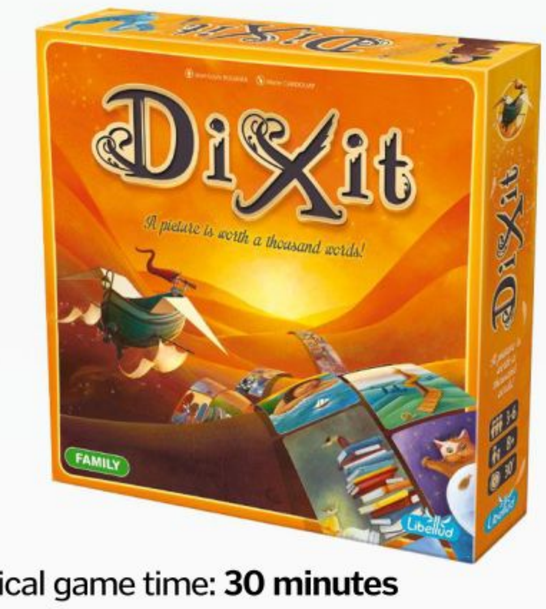
Can being cold give you a cold?

Ramesh Bapu

No, this is a myth! Colds are caused by viruses (around 250 different types), and the only way to get one is by encountering infectious virus particles. **LM**

Dixit

Exercise the creative side of your brain in a board game that's all about storytelling



■ Publisher: **Asmodee / Libellud** ■ Price: **£29.99 / $34.99** ■ Number of players: **3-6** ■ Recommended age: **8+** ■ Typical game time: **30 minutes**

Spinning a good yarn lies at the heart of this game, which weaves imagination and a small amount of social strategy to create a very distinct experience. The core of Dixit is the storytelling deck – 84 large picture cards that have individual illustrations on each, depicting a scene from a story. These scenes can be as simple as an anchor on the sea floor, or fantastic as a knight on horseback encountering a demonic hand reaching out of a black chasm.

Each player is dealt six cards, and the group picks a storyteller, who chooses one of their cards to describe in a short sentence. Each of the other players picks one of their six cards that they think most closely matches the storyteller's sentence, then hands it to the storyteller. The storyteller shuffles them with the card they've described and deals them out for all to see.

Using their numbered voting tokens, players show which of the cards they think the storyteller was describing. Here's where the strategy plays out: if everyone guesses correctly and places their number '1' token on the card the storyteller was describing, or if no one guesses correctly, then everyone but the storyteller scores two points. Otherwise, if a player guesses correctly, both the storyteller and the player scores three points. It's a balancing act the storyteller has to play, being cryptic enough in their description to throw some players off but obvious enough that at least one player places their number '1' token on the right card.

Dixit is a fun, accessible and very social game. There is a shelf life, limited by your growing familiarity with the cards, but you'll get your money's worth long before it becomes too easy.

Once upon a time...

Prepare to engage your creative brain and inner storyteller

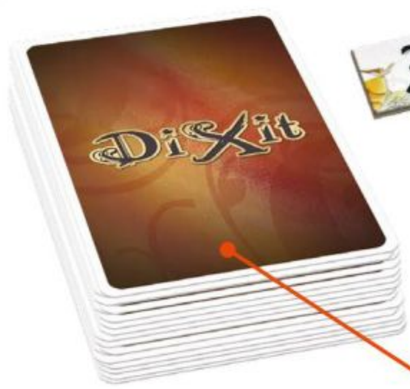
Gorgeous illustrations
Dixit's card artwork is appropriately imaginative and fun. Some of the illustrations can be wildly surreal.

Multiplayer
Players have four to six sequentially numbered voting tokens, depending on how many people are playing.

Bunny rabbits
Players advance one space for every point scored. The first to 30 points wins the game.

Voting tokens
These are placed face-down on a card according to the likelihood of which illustration the player thinks the storyteller described. When all tokens have been placed, they're then turned face-up.

Player deck
Each player is dealt six picture cards at the start of the game.



Main deck
After they've used a picture card, the players take a replacement off the top of the main deck to bring their hand back up to six cards.

BOOK REVIEWS

The latest releases for curious minds

Apollo 11: Owners' Workshop Manual

In case you wanted to repair the one in your garage

- Author: **Dr Christopher Riley & Phil Dolling**
- Publisher: **Haynes**
- Price: **£22.99 / $35**
- Release: **Out now**

It's hard to believe that it's been 50 years since man first walked on the Moon. And as scientists from around the world are planning missions to return to our only natural satellite, Haynes is celebrating with an updated version of its Apollo 11 manual. While it's mostly the same as the version that was released ten years ago, Haynes has added an extra 16 pages that tell the story of man's recently renewed interest in space travel. It includes big names like Elon Musk's SpaceX and Jeff Bezos's Blue Origin, and shows how the first successful Moon landing inspired the latest quests to the stars.

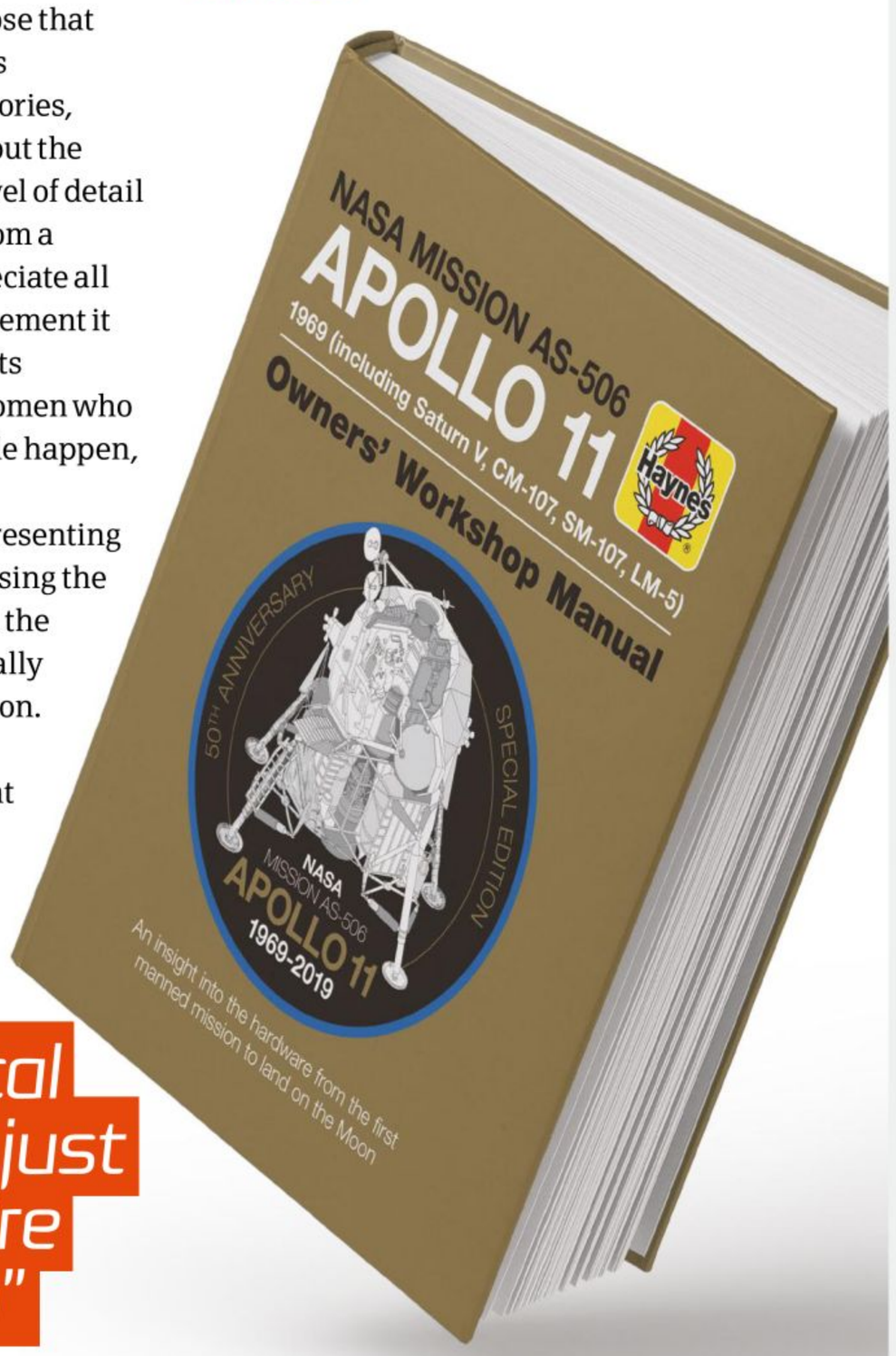
While the limited changes mean it's probably not worth the upgrade for those who own the original version of this manual, for those that don't it's well worth a read. The book is absolutely packed with astonishing stories, science and technical information about the mission, the rockets and more. The level of detail is exceptional, as you would expect from a Haynes manual, and makes you appreciate all the more just what an amazing achievement it really was. From the scale of the rockets themselves to the 400,000 men and women who helped make the seemingly impossible happen, there's plenty here to impress.

The authors do an excellent job of presenting the stories behind the mission, discussing the bureaucratic battles, the setbacks and the tragic failures NASA faced before it finally succeeded in putting a man on the Moon.

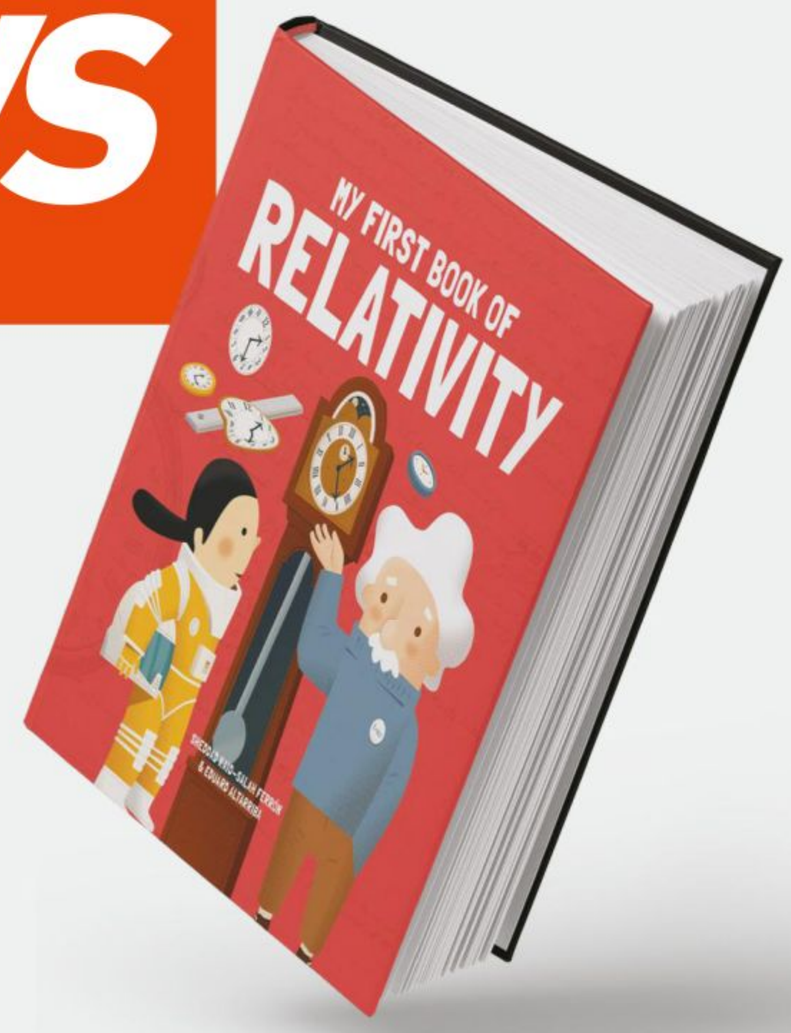
The main focus, of course, is on the machines and technical hardware that went into the landing, and that's where the book's magic lies. By using photos to document the evolution of the Apollo rockets, pressurised space suits and more, the manual neatly takes readers through every step of the long journey to the lunar surface. Those technical drawings aren't just detailed, they're awe-inspiring, showing just how complex every aspect of the mission was. In particular, the control panel that Neil Armstrong, Michael Collins and Buzz Aldrin used in the Command Module will blow your mind and make you appreciate the skill of those famous astronauts.

With Moon fever kicking off again, this is the perfect time to revisit NASA's achievement, and this manual is the ideal way to do it.

★★★★★



"Those technical drawings aren't just detailed, they're awe-inspiring"



My First Book of Relativity

Our favourite theory

- Author: **Sheddad Kaid-Salah Ferrón, Eduard Altarriba**
- Publisher: **Button Books**
- Price: **£12.99 / $17.99**
- Release: **Out now (UK) / 1 August (US)**

We're all in favour of books that simplify areas of study for a younger audience, but a few eyebrows were raised at this one. Is it even possible to simplify something like the theory of relativity?

As it turns out, yes it is. By breaking down time and space into their purest definitions and working from there, Sheddad Kaid-Salah Ferrón and Eduard Altarriba give real breathing space to Albert Einstein's theory. Paired with a series of genuinely beautiful illustrations, and what we have is something truly remarkable.

Sometimes children's science books are guilty of breaking things down a bit too much, but that isn't the case here. Sure, the explanations are grounded in relatable concepts, but the science behind the theory isn't neglected. Everything stands up to scrutiny when placed under the **How It Works** microscope.

Inevitably for such complex subject matter, readers may require a bit of guidance, but that doesn't disguise just how much of an achievement this is. Get hold of your copy as soon as you can.

★★★★★

Balloon to the Moon

The race to the stars

- Author: **Gill Arbuthnott, Chris Nielsen**
- Publisher: **Big Picture Press**
- Price: **£16.99 (approx $20)**
- Release: **Out now**

Nothing says 'science lover' more than a foreword that contains loving references to Isaac Asimov and Ray Bradbury, and this optimistic spirit is carried on throughout the book.

As you might expect, *Balloon to the Moon* chronicles humanity's journey towards space, starting with the invention of the air balloon in 1783, then detailing nine other advances that nudged us closer to our spacefaring destiny.

The price is steep for such a slim volume, but look past that and you have an enlightening chronicle of an adventure a few hundred years in the making – and one that isn't over yet.

★★★★☆

Missions to the Moon

Space is ace

- Author: **Rod Pyle**
- Publisher: **Carlton Books**
- Price: **£25 (approx $30)**
- Release: **Out now**

Released ahead of the 50th anniversary of the Apollo 11 Moon landings, *Missions to the Moon* provides a coffee table-friendly guide to one of humanity's most groundbreaking achievements to date.

To give it a tech-savvy twist, the creators of this guide included an interactive element. If you have a smartphone or tablet then at certain points you can access added features, such as video footage, fully rotating images and official documents relating to the landings. If you've got a good enough internet connection then it's certainly experience-enhancing stuff.

Even if you don't have access to this extra-curricular info then there's still plenty to enjoy. The story of this decisive step in the space race never gets old and never ceases to be an inspiring tale of human endeavour. You'll have heard much if it before, but that won't matter.

More than ever, the story of humanity's quest to the stars stands as evocative and enrapturing in equal measure, and this guide provides a worthy touchstone.

★★★★★

Sean Yeager and the DNA Thief

Almost a young Bond, but not quite

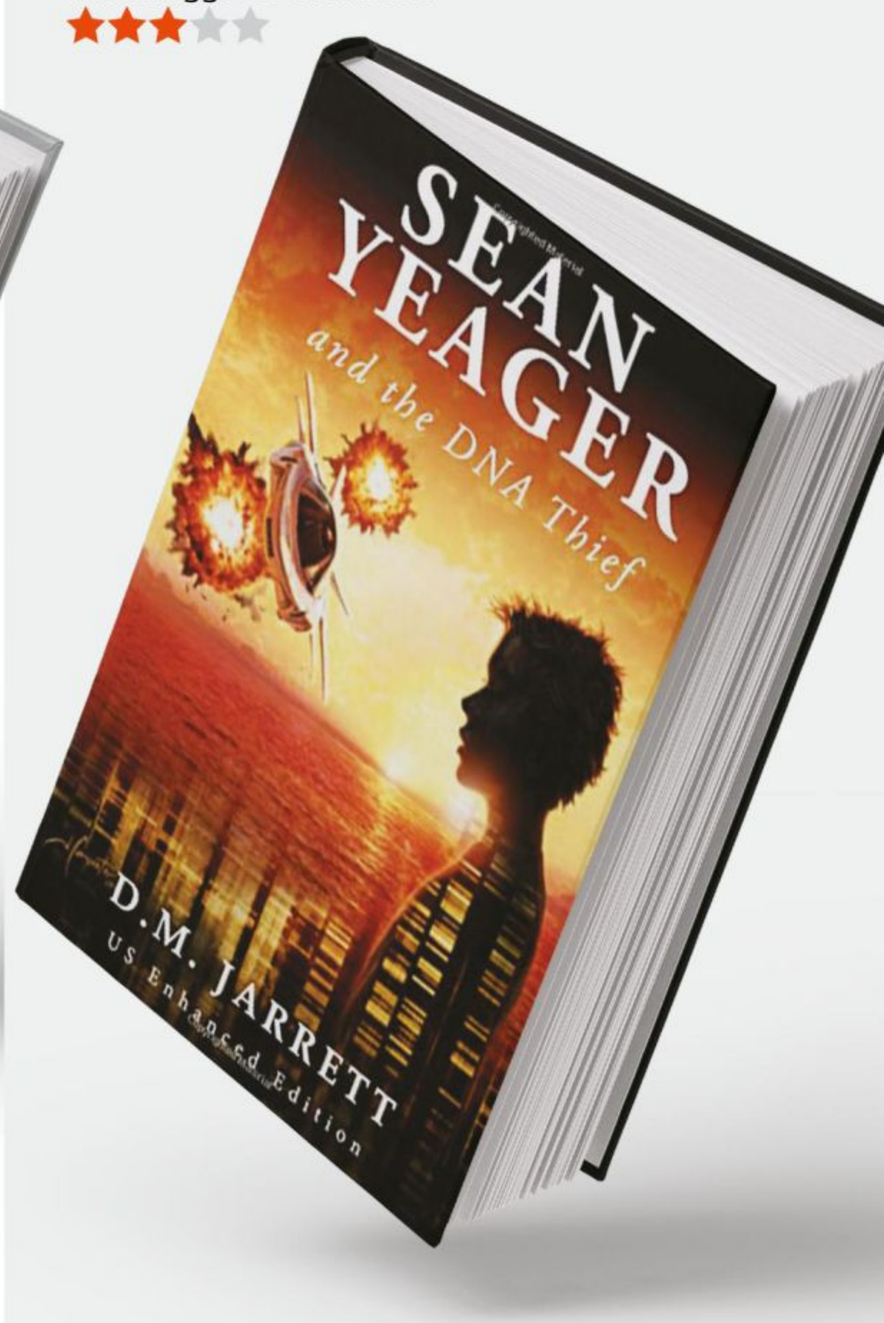
- Author: **D M Jarrett**
- Publisher: **Aenathen Omega**
- Price: **£7.99 / $9.99**
- Release: **Out now**

Coming across as Alex Rider meets young James Bond through a sci-fi prism, *Sean Yeager and the DNA Thief* sees the young protagonist embark on an adventure involving flying cars, underwater lairs and aliens.

Author D M Jarrett packs a lot in, and his love for the subject matter is clear. But this doesn't manifest in a particularly good story. The plot tends to be scattershot and the protagonist's personality is only vaguely sketched out – indeed, he often seems like a bystander in what should presumably be his own story.

Top marks for the scale of the author's imagination, but there's plenty of competition in the genre, and this Sean Yeager adventure will struggle to stand out.

★★★☆☆



BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

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

FIND THE FOLLOWING WORDS...

APOLLO
ATOM
EMOTIONS
GALAXIES
HITLER
HUMAN
INTELLIGENT
IRONMAN
MEAT
MINDS
ROLLERCOASTER
WEAPON

Quickfire questions

Q1 How many brain cells does an adult human have?

- 86 million
- 86 billion
- 100 billion
- 1 trillion

Q2 Who piloted Apollo 11's Command Module?

- Neil Armstong
- Charles Conrad Jr.
- Edwin Aldrin
- Michael Collins

Q3 Which of these countries is the least densely populated?

- Greenland
- Mongolia
- Iceland
- Australia

Q4 A trireme is a type of ancient...?

- Bronze sword
- Galley ship
- Civilisation
- Roman soldier

Spot the difference

See if you can find all six changes we've made to the image on the right

Sudoku

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

EASY

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

DIFFICULT

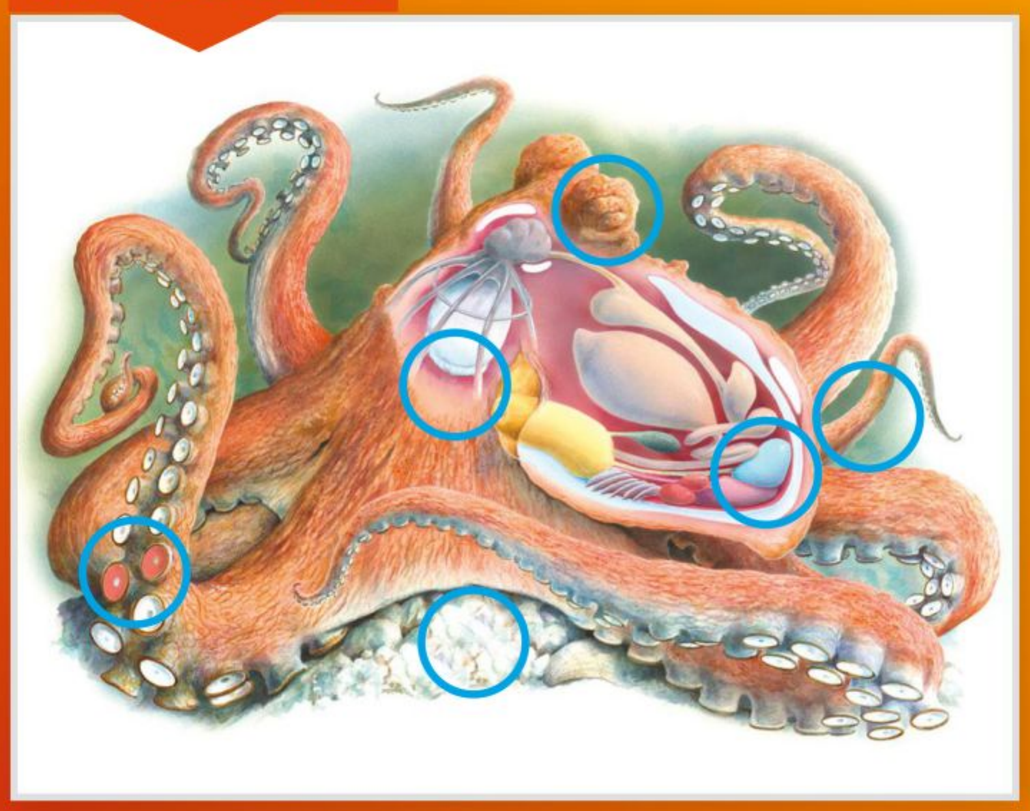
5		2			1			
		6						3
3	1		4					6
				9		6		
	9			2			3	
		3		1				
4					8		9	1
2						5		
			7			3		4

What is it?

Hint: Turns out, it's not made out of green cheese after all.

A. .....

Spot the difference



Check your answers

Find the solutions to last issue's puzzle pages

Quickfire questions

Q1 72kph

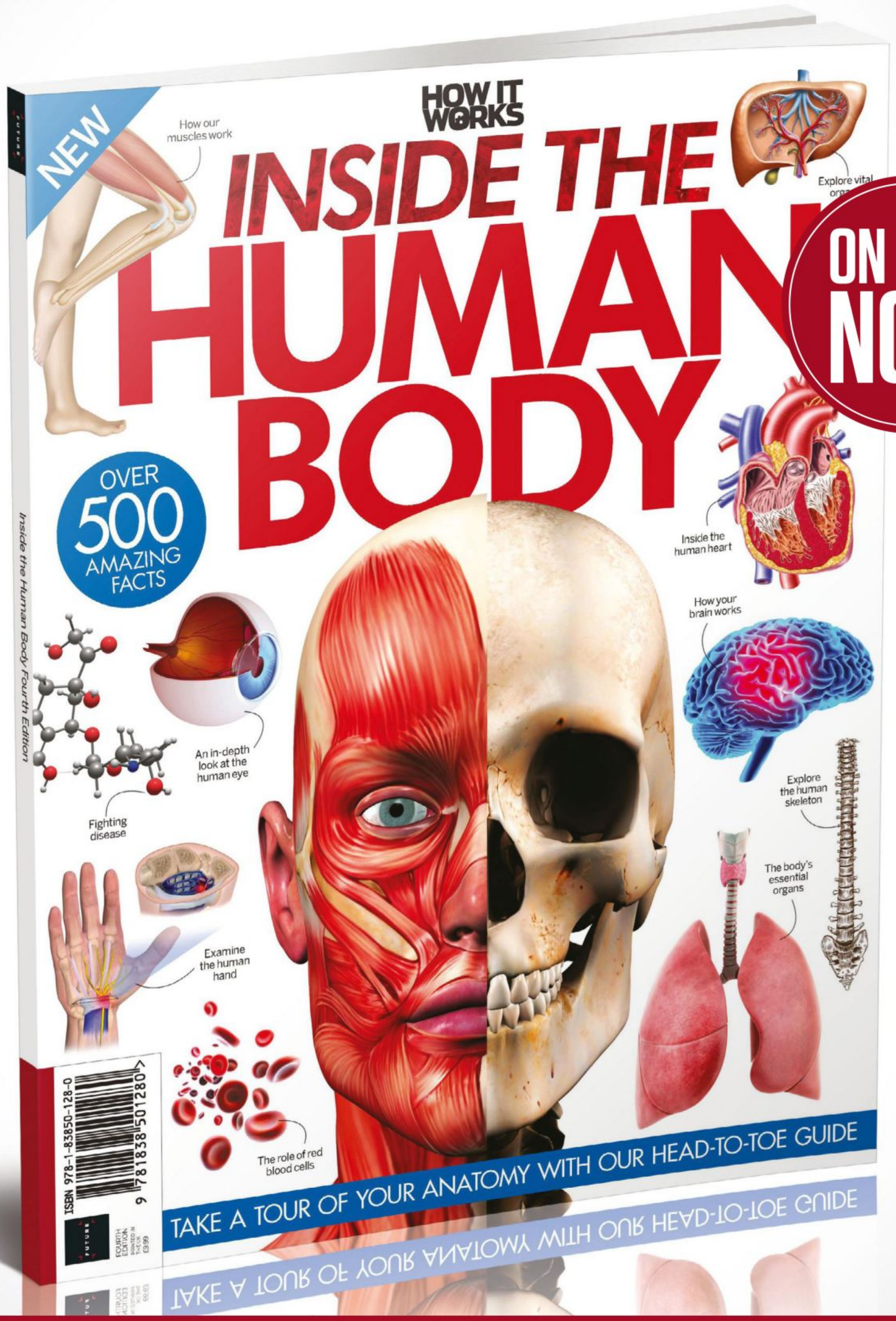
Q2 A nucleus

Q3 13.8 billion years

Q4 31 per cent

EVERYTHING YOU EVER WANTED TO KNOW ABOUT THE HUMAN BODY!

Baffled by the human brain? Eager to learn about the lungs? Inside The Human Body will answer all the questions you've wanted to ask about how the wonder that is the human body functions.



FUTURE

Ordering is easy. Go online at:

www.myfavouritemagazines.co.uk

Or get it from selected supermarkets & newsagents

NEXT ISSUE
How to dust for invisible fingerprints

Create a rainbow

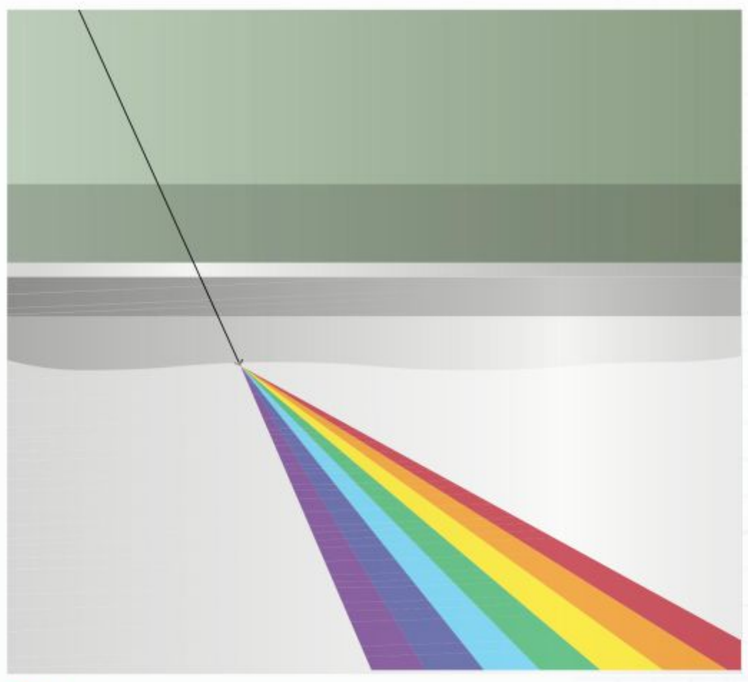
With a few simple items, you can create a rainbow on your wall at home

1 Set up your bowl

To create your rainbow, the first step is to find a shallow bowl and fill it about half-full. Then place a small mirror into the bowl so that it's submerged in the water at an angle.

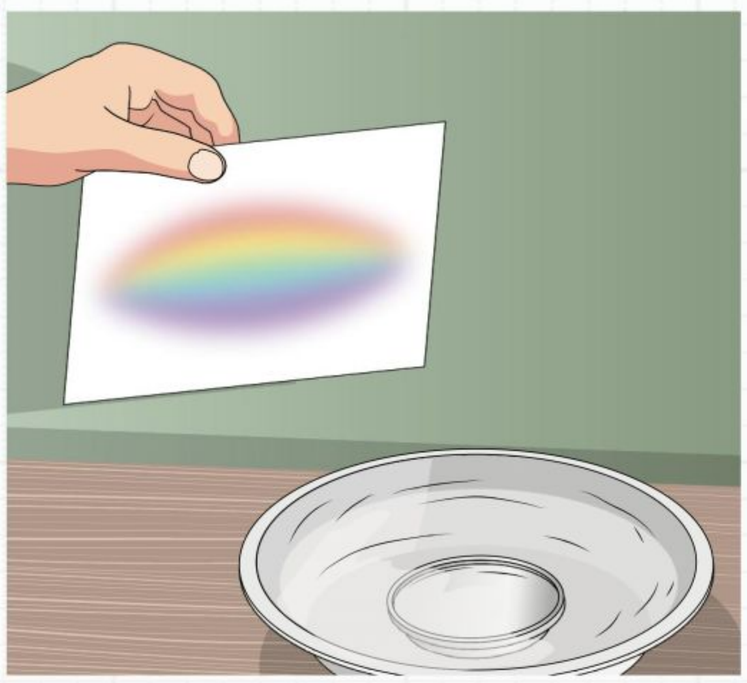
2 Shine a light

Find a light source to shine into the bowl and onto the mirror at an angle. You could use sunlight coming in through a window, or just the LED light on the back of a smartphone.



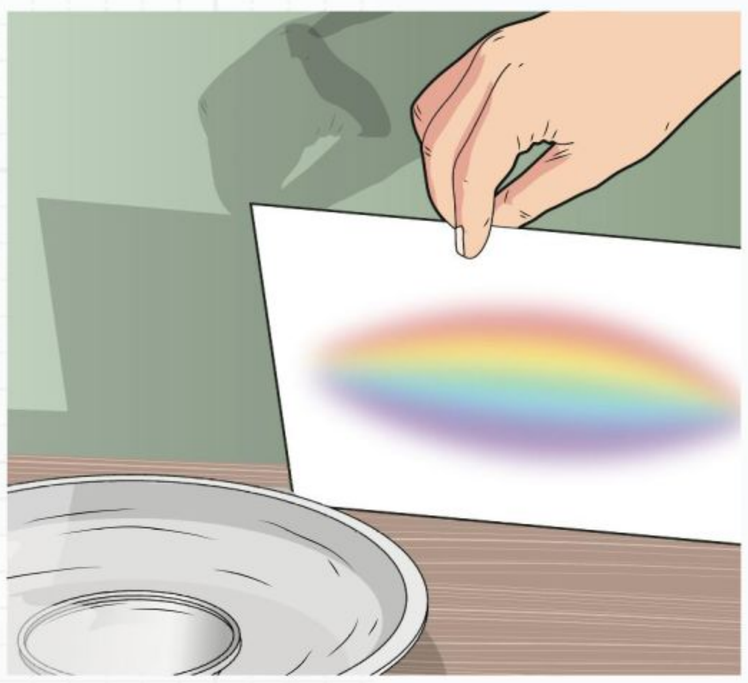
3 Light bending

When the lightwaves from the light source move from one medium to another medium of a different density (in this case, from air into water), the light bends. This is known as refraction.



4 See the rainbow

When the light bounces off the mirror, it is reflected back out of the water. Hold a piece of paper near the bowl so the rainbow appears on it. If it's hard to see anything, make the room darker.



5 Spot the colours

Unlike a rainbow outside in the rain, you shouldn't have trouble seeing all seven colours of the rainbow on the sheet. If you're struggling, bring the paper closer to see them more vividly.

6 Move the mirror

Try moving the mirror deeper into the water or changing the angle of it. What happens to the rainbow? Try moving the light, too. Does it make the rainbow easier or harder to see?

SUMMARY...

Light from the Sun or from a phone's LED might look white, but white light is actually made up of different coloured lights of different wavelengths combining into one beam. When it enters a material of a different density – the water – the different wavelengths are split apart slightly, or refracted, to create a rainbow effect.

Get in touch

HAD A GO? LET US KNOW! If you've tried out any of our experiments, conducted some of your own or have ideas for us to try – let us know! Share your photos or videos with us on social media.

How It Works magazine @HowItWorksmag

@howitworks@futurenet.com

INBOX
Speak your mind...

Get in touch
If you have any questions or comments for us, please send them to:

How It Works magazine @HowItWorksmag howitworks@futurenet.com

Salt isn't just a great addition to your fish 'n' chips but a vital part of our global ecosystem

Letter of the month

Saltless seas

Dear **HIW**,
What would happen to the Earth's ecosystem if all the salt in the oceans suddenly disappeared?
Jess Rochefort

If the planet suddenly went on a low sodium diet, life as we know it would cease to exist. The immediate consequence of losing the ocean's salt would be the demise of marine life. Millions of years of ocean evolution means saltwater fish would certainly die, as their cellular make-up is not equipped to exist in freshwater conditions. In turn, without saltwater fish there would be no food for other sea life. Each trophic level of the world's marine ecosystems would collapse. It's not just beneath the waves that life would fall, but on land as well. Salt plays an imperative role in Earth's global ecosystem, not only for the fish that swim through its oceans but also for maintaining its underwater currents. The water that flows through our oceans is divided into two categories, surface and deepwater currents. Together they form swirls of water known as gyres and a conveyor belt of water circulating warmth to the world. Surface currents are predominantly driven by the wind, whereas deepwater currents are driven around the world by their density, known as thermohaline circulation. This is where salt plays an important role. The more salt that dissolves in water, the denser it becomes. When water reaches colder regions, such as at the poles, dense salt water sinks to the ocean floor. As more water flows overtop and begins to sink, it pushes down on the water below it, forcing it to move and so creating a current. The world's oceans has a salinity of around 3.5 per cent – for every litre of seawater there are 35 grams of salt dissolved in it. Without the salt, these currents wouldn't circulate or distribute heat, leaving Earth and its oceans cold. This would lead to a domino effect on climate change and weather patterns, which would affect global agriculture and habitability.

© Getty

WIN! VOYAGE THROUGH SPACE
See space as you've never seen it before. Join one little astronaut and her dog as they voyage through the Solar System.

Busy as a beaver

Dear **HIW**,
I'm a keen animal lover and one of my favourite creatures is the beaver. I think they are very clever animals because they can build dams. But I wanted to know, why do they have such flat tails?
Wren Tolstoy

The tail of a beaver has many different uses that benefit these furry foresters, especially when it comes to moving around their environment. As keen swimmers, their flat paddle-like tails act as an ore, steering their movement through the water. Beavers are renowned for their fondness of felling trees and creating dams, and their tails act as a balance when moving heavy logs. Beavers also use their tails to slap the water's surface, to alert others to the presence of a predator, or to actually scare the predator off.

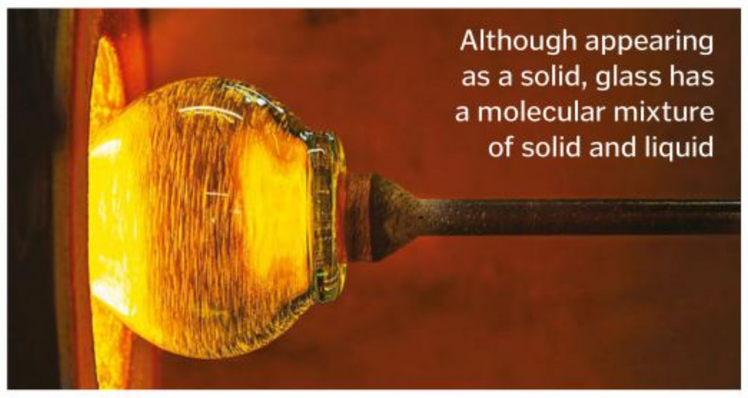
© Alamy

Beavers are agile: they can turn their tails in four directions to act like a rudder while swimming

Liquid glass

Dear **HIW**,
Why does glass never set?
Thanks, **Sam Pring**

This is an interesting question. It's not that glass doesn't set, but rather, after supercooling from its molten form, the resulting brittle solid doesn't act like other solids. Glass is known as an amorphous solid, sitting in limbo between a solid and liquid, though leaning more on the side of a solid. Due to its molecular composition, it doesn't hold a well organised crystalline structure you find in 'solid' objects. Instead, weak bonds between molecules allow them to form structures like a solid. However, their order is more random, like a liquid. The misshapen and weak relationship allows the molecules to move, at an incredibly slow rate. It is a misconception that glass flows; it doesn't sag in window panes.



Although appearing as a solid, glass has a molecular mixture of solid and liquid

© Getty

A single punch to the jaw can rattle your brain enough to pass out

© Getty

"Eight, nine, ten... you're out!"

Dear **HIW**,

When a boxer gets hit, why are some of them knocked unconscious? **Danielle Doyle**

At the professional level, boxers can deliver a blow to their opponent's head at a force of around 400 kilograms, rendering them unconscious. When experiencing a blow to the head the brain will ricochet back and forth against the inner wall of the skull. Overloaded with neuron stimulation, the brain temporarily turns off resulting in a blackout. A strike to the jaw, can jolt the sinus (a hollow cavity within the skull) and restrict the levels of blood and oxygen delivered to the brain.

Man's best friend uses evaporative cooling to tackle hot weather

© Getty

Puppy panting

Dear **HIW**,

I was wondering if you could tell me why dog pants? I know it happens when they are hot, but how does it help them get cooler? **Avary Belando**

Dogs have two biological ways to keep as cool as they can during a heatwave. Firstly, by sweating through their paws and secondly – and most effectively – by panting. Sticking your tongue out might seem a strange way to get cool, but for dogs is a method of evaporative cooling. By breathing heavily our canine companions allow water to evaporate from the tongue, nasal cavity and lungs, which in turn lowers their internal body temperature.

www.howitworksdaily.com

What's happening on... social media?

This month, we asked if you'd rather visit the depths of the ocean or stand on the moon...

@Tracywaller72

"Definitely stand on the moon to see everything from a different view. Would be very beautiful and mind blowing! Would take my children so they can see the what their generation has to save!"

@giddyypixie

"The ocean. It would be amazing to see all the sunken ships and crashed planes from years gone by, not to mention the weird and wonderful creatures!"

@Quackerjill

"I would rather stand on the surface of the moon, because to follow in Neil Armstrong's footsteps would be amazing and I would also bring some moon rock home as a souvenir."

@SmilyJWT

"Definitely the ocean there's a lot more to see down there, the moon is just dust and maybe some American equipment."

@LuckBeALady3

"I'd love to explore the depths of the oceans. All the undiscovered creatures that live down there fascinate me."

NEXT ISSUE...

Issue 128 on sale **8 AUGUST 2019**

Available in print from all good newsagents and **myfavouritemagazines.co.uk**, 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 30 (UK) and 81 (US).

HOW IT WORKS

Future PLC Richmond House, 33 Richmond Hill, Bournemouth, Dorset, BH2 6EZ

Editorial
Editor **Ben Biggs**
Senior Art Editor **Duncan Crook**
Research Editor **Baljeet Panesar**
Production Editor **James Price**
Staff Writer **Scott Dutfield**
Editor-in-Chief **Gemma Lavender**

Contributors
James Horton, Joanna Stass, Jodie Tyley, Jonathan O'Callaghan, Laura Mears, Stephen Ashby, Steve Wright, Tom Lean, Jack Parsons, Tom Garner, Victoria Williams, Dr Andrew May, Jon Wells, Kym Winters, Curtis Fermour-Dunman, Nicholas Forder, Ed Crooks, Adrian Mann, The Art Agency, Will Ireland

Cover images
Getty; NASA; Impossible Foods; Alamy; CERN;

Photography
Alamy, Getty Images, NASA, Science Photo Library, Shutterstock, Thinkstock, Wikimedia
All copyrights and trademarks are recognised and respected

Advertising
Media packs are available on request
Commercial Director **Clare Dove**
clare.dove@futurenet.com
Group Advertising Director **Mark Wright**
mark.wright@futurenet.com
Advertising Manager **Toni Cole**
toni.cole@futurenet.com
01225 687368
Media Sales Executive **Jagdeep Maan**
jagdeep.maan@futurenet.com
01225 687353

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities
Head of Print Licensing Rachel Shaw **Rachel Shaw**
licensing@futurenet.com

Subscriptions
Email enquiries **contact@myfavouritemagazines.co.uk**
UK orderline & enquiries **0344 848 2852**
Overseas order line and enquiries **+44 (0)344 848 2852**
Online orders & enquiries **www.myfavouritemagazines.co.uk**
Head of subscriptions **Sharon Todd**

Circulation
Head of Newstrade **Tim Mathers**

Production
Head of Production **Mark Constance**
Production Project Manager **Clare Scott**
Advertising Production Manager **Joanne Crosby**
Digital Editions Controller **Jason Hudson**
Production Manager **Vivienne Calvert**

Management
Managing Director **Alastair Lewis**
Chief Content Officer **Aaron Asadi**
Commercial Finance Director **Dan Jotcham**
Editorial Director **Paul Newman**
Head of Art & Design **Greg Whittaker**

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 Tel: 0203 787 9001

ISSN 2041-7322

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. The manufacturing paper mill holds full FSC (Forest Stewardship Council) certification and accreditation

FAST FACTS

Amazing trivia to blow your mind

YOU CANNOT SEE YOUR TASTE BUDS, THOSE BUMPS ON YOUR TONGUE ARE PAPILLAE

120 METRES

DEPTH OF THE FOUNDATIONS OF THE PETRONAS TWIN TOWERS, IN KUALA LUMPUR, MALAYSIA

23 WATTS

POWER GENERATED BY YOUR BRAIN WHEN YOU'RE AWAKE

220,000 LIGHT YEARS

THE DIAMETER OF THE ANDROMEDA GALAXY

60%

OF YOUR BRAIN IS MADE OF FAT

HISTORICALLY, CATS HAVE SERVED OFFICIAL MILITARY ROLES, BUT ONLY AS RAT-CATCHERS

65.45 MILLION TONNES

THE AMOUNT OF CONCRETE USED TO CONSTRUCT CHINA'S THREE GORGES DAM

10 SQUARE METRES

THE AMOUNT OF CORAL A CROWN-OF-THORNS STARFISH EATS ANNUALLY

1 MHZ

THE SPEED OF APOLLO 11'S COMPUTER (TODAY'S CPU CORES ARE TYPICALLY 4,000 TIMES FASTER)

322KPH

THE TOP (CLAIMED) SPEED OF GRAVITY INDUSTRIES LTD. JET PACK

ONIONS AND GARLIC ARE *TOXIC* TO BIRDS

300 VOLCANOES IN RUSSIA'S KAMCHATKA WILDERNESS

20th of July

50th Anniversary of the 1969 moon landing

Introducing two beautiful non-fiction children's books that'll carry the wonder of the moon landings to a whole new generation.

Examine the Apollo missions in the context of the wider US/Soviet Space Race

£12.99 64 pages

A view of the Apollo missions with a focus on the Astronauts and their own accounts

£12.99 80 pages

Quarto Kids

Available online and in all good bookshops

SCALEXTRIC®

OWN THE TRACK

To view the full Scalextric range and to find your local stockist please visit www.scalextric.com

/officialscalextric /scalextric @scalextric /officialscalextric

HORNBY HOBBIES