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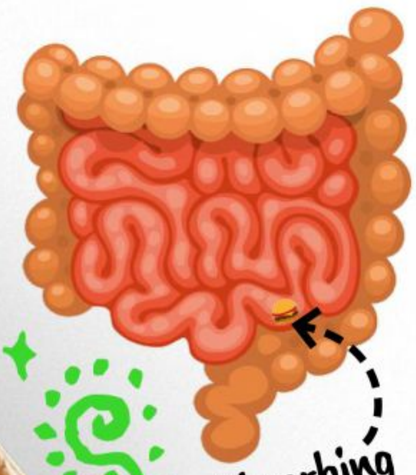
Journey through the

HUMAN BODY'S DIGESTIVE SYSTEM



DISCOVER WHY YOU ARE WHAT YOU EAT

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WHY THE SAVANNAH NEEDS LIONS

+ WHY WWII ENDED SPIDER ANATOMY MEET THE OCEAN TRENCH EXPLORER

FUTURE
ISSUE 128

Alan R. Moon

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ISSUE **128**

WELCOME

The magazine that feeds minds!

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"This massive collection of neurons is often called 'the second brain'"

The human body's digestive system, page 22

Meet the team...

James
Production Editor
On page 34 we reveal how crime scene investigators can uncover and use even the tiniest piece of evidence to catch criminals.

Scott
Staff Writer
What role does the king of the jungle play in Africa's circle of life, and how can we be prepared to ensure lion survival? Find out on page 48.

Baljeet
Research Editor
We've probably all dreamed of having a flying car at some point – and now engineers are making it a reality. See how on page 40.

Duncan
Senior Art Editor
The Black Death was one of the most terrifying diseases to hit Europe and Asia. Discover what this deadly plague was on page 74.

Chances are that, unless you've just had something to eat, the sight of our 'word burger' on the front cover of this issue's **How It Works** has already triggered the process of digestion in your body. If not, then merely suggesting that it's a juicy, delicious and savoury lunchtime treat should be making your mouth water and your stomach growl. Just the power that visual and verbal imagery has on your digestive system is amazing, let alone the processes that the smell and taste of your favourite foods activate. In this issue's cover feature we're going to take you on a journey through the digestive system, from one end to the, err... other end! Discover how food is broken down, how nutrients eventually become part of your body, and how your brain plays a pivotal role in every stage of digestion.
Enjoy the issue.

Ben Biggs Editor

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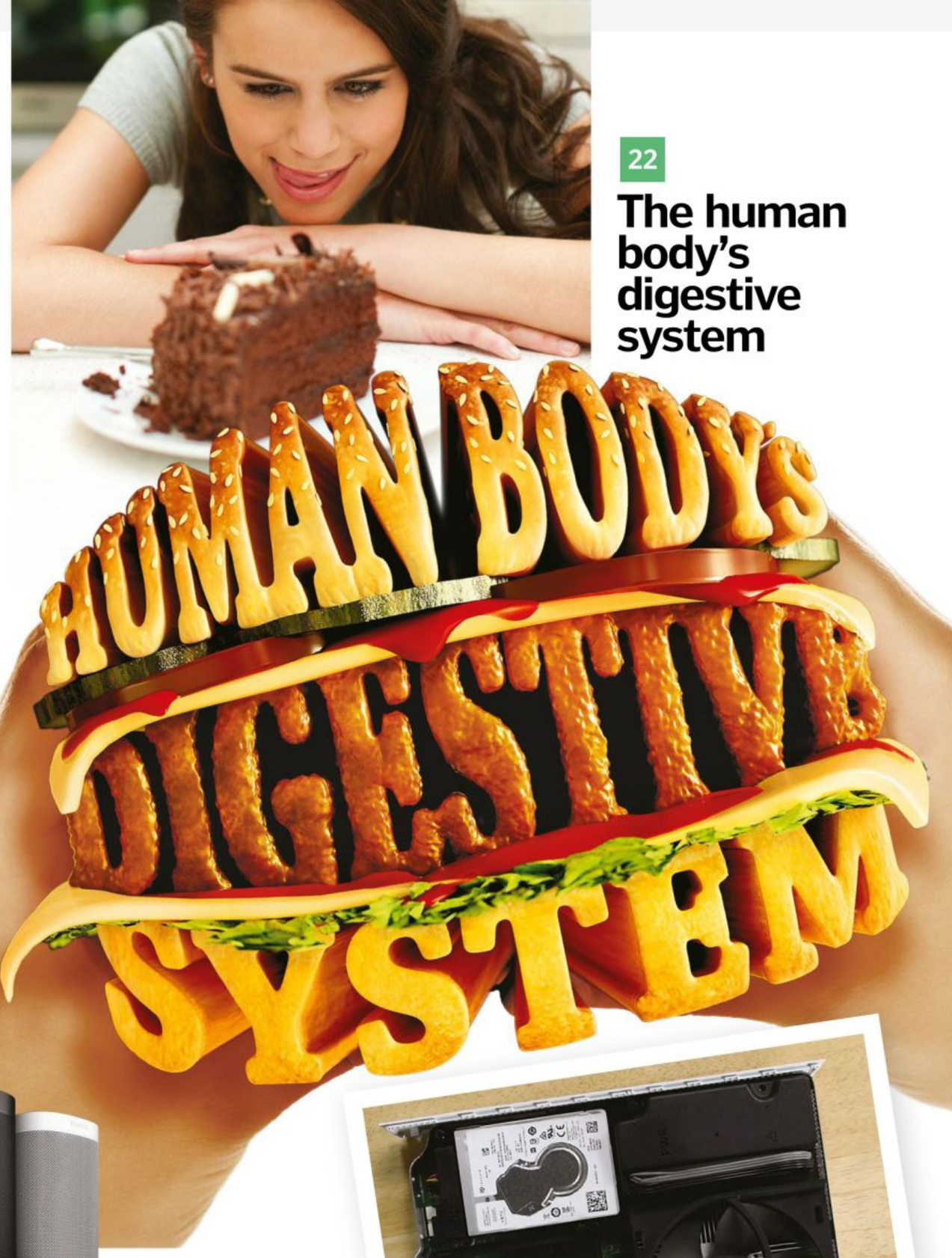
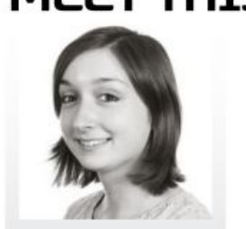
CONTENTS



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 game 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.

Amy Grisdale
Volunteer animal worker Amy has an enormous breadth of experience on animal and conservation projects. She specialises in environmental 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.

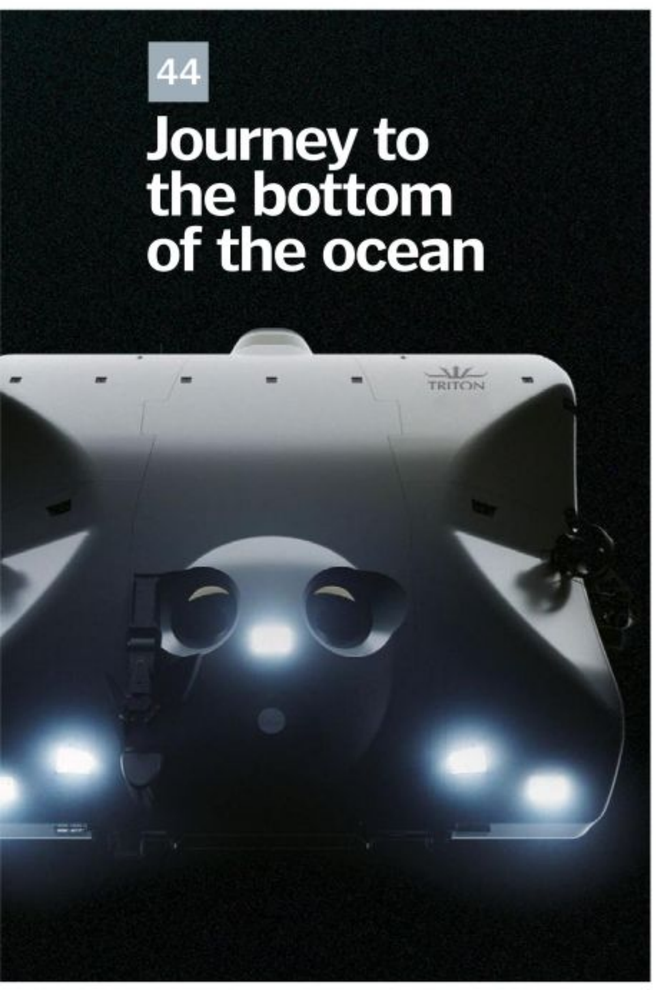
56
Anatomy of spiders

58
Formula E: race to the future

REGULARS

40
How flying cars work

34
How to catch a criminal



44
Journey to the bottom of the ocean

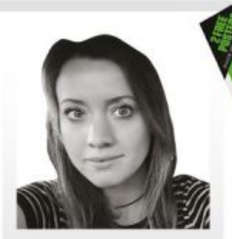
74
How the black death spread

Joanna Elphick
Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She's the author of several true crime books.

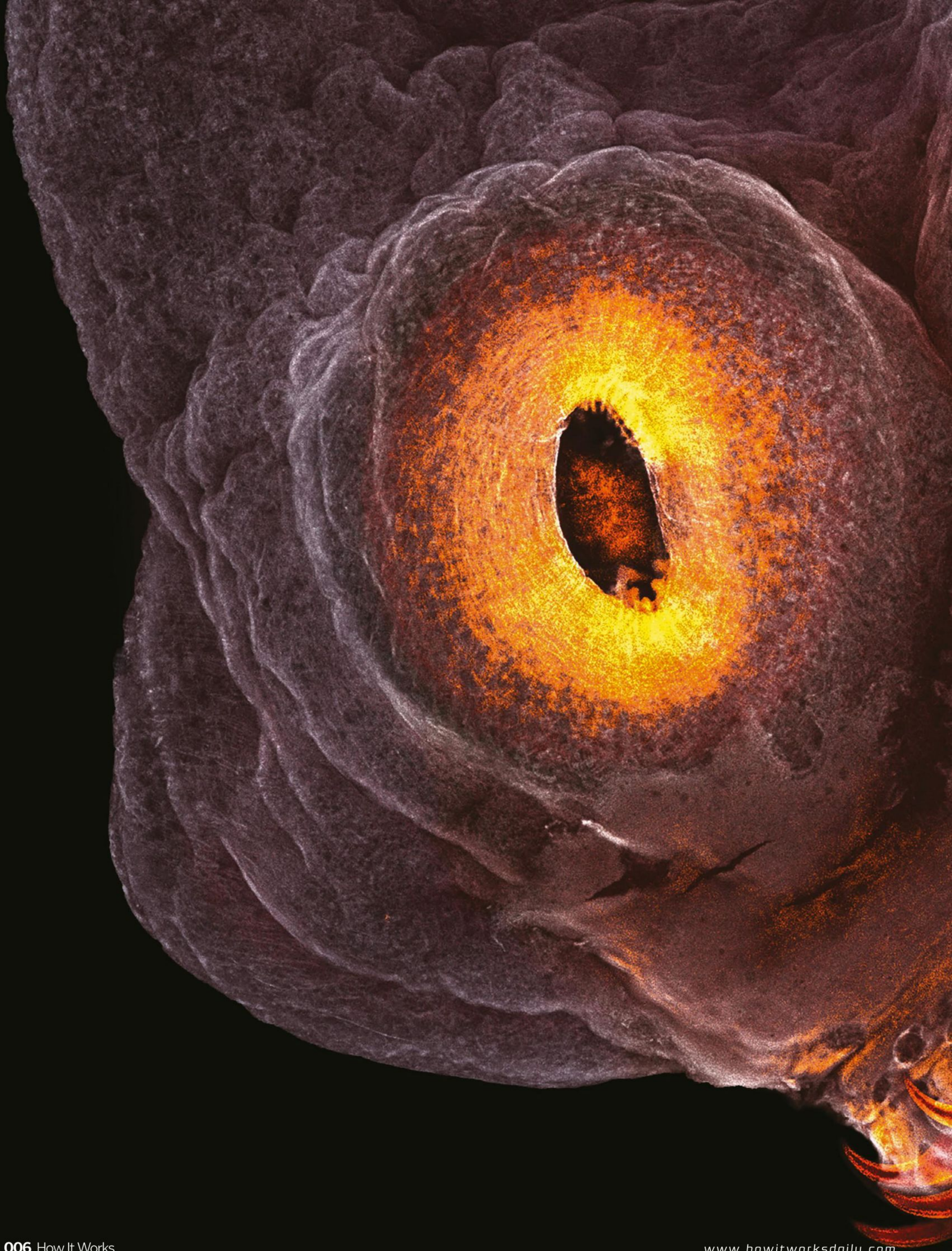
Jack Griffiths
Former **HIW** staff writer-turned freelancer Jack now works in the medical industry and loves to escape on a science and technology press event.

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

Mike Jennings
Mike is a freelance technology journalist who is fascinated with gaming, futuristic technology and motorsport. He dreams of becoming a rally driver.



Beth Lily Georgiou
Motorsport professional Beth is a passionate electric vehicle advocate, writer, presenter, commentator and STEM ambassador.



The face of a tiny monster

This is the head of a pork tapeworm (*Taenia solium*), a human parasite that can be transmitted through eating pork that hasn't been cooked properly, or by drinking contaminated water. The adult worm develops from a larva and can live in the small intestine, growing up to three metres in length. This image was taken with a confocal laser microscope. It shows the tapeworm's two suckers (which look like eyes) and its hook-filled rostellum. This image was taken for the Royal Photographic Society's Science Photographer of the Year competition. Learn more at **science.rps.org**.

Testing the ‘Fat Man’ bomb

In this historic photo, bomb assembly group leader Norris Bradbury stands next to the ‘Gadget’. This nuclear bomb was detonated on 16 July 1945 at the Trinity test site in New Mexico, as a trial for the ‘Fat Man’ bomb that would be dropped on the Japanese city of Nagasaki on 9 August 1945. Gadget’s explosion at 5.30am was felt 160 kilometres away and sent a mushroom cloud billowing over 12 kilometres high. Because of the secrecy surrounding the US atomic bomb project a cover story was issued, telling the press that an ammunition store had exploded.

Watching wildfires from space

At a safe distance from the surface, beyond the 100-kilometre-high Kármán line that marks the border between Earth's atmosphere and space, a NASA satellite snaps this photo of a wildfire blazing over California. These satellites effectively act as extremely tall fire towers that are able to tell firefighters on the ground where new blazes are springing up, and give a broad overview of the extent of the wildfire. The data provided by fire-watching satellites can also help with wildfire forecasting by showing where the driest patches of unburned ground are, and where tall grasses and scrubland could spread fires to forests.

GLOBAL EYE

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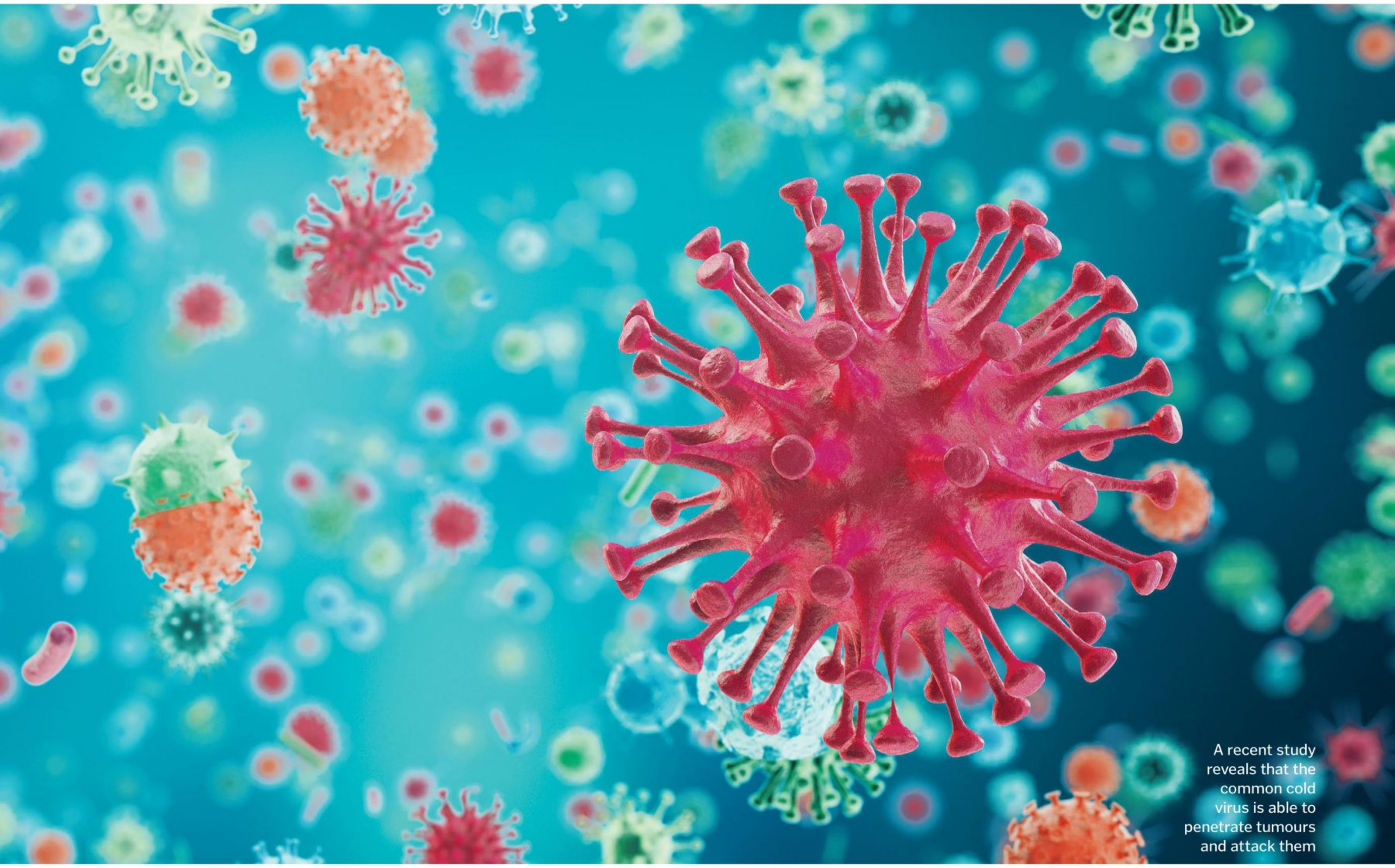
With over 14 million global monthly users, **Live Science** makes every day a little more interesting by illuminating the fascinating world around us. For the science geek in everyone, **Live Science** breaks down the stories behind the most interesting news and photos on the internet.



A recent study reveals that the common cold virus is able to penetrate tumours and attack them

HEALTH

Common cold virus clears cancer in one patient

Words by **Yasemin Saplakoglu**

A simple cold virus has been found to cure tumours in a form of bladder cancer, a small new study suggests. Though the idea of using viruses to fight cancer isn't new, this is the first time a cold virus effectively treated an early-stage form of bladder cancer.

In one patient, it eliminated a cancerous tumour, it was reported in the journal *Clinical Cancer Research*. Researchers conducted an early-stage clinical trial in which they infected 15 bladder cancer patients with coxsackievirus A21, one of the viruses that causes the common cold. It is not a genetically modified virus; it's "something that occurs in nature," said principal investigator Hardev Pandha, a professor of medical oncology at the University of Surrey. The researchers gave patients the virus through catheters that had already been inserted for other treatments. They left it in for an hour to pump the virus and fluids into the bladder, and repeated this treatment. Then the patients underwent surgery to remove what was left of their bladder tumours.

In one patient the virus completely destroyed the tumour. In the other 14 patients the researchers found evidence that the virus had damaged the tumours and had spurred the immune system to send an army of immune cells to the tumours. None of the patients displayed any significant side effects, Pandha said.

Researchers thought this method would work because the outer membranes of cancerous bladder cells contain a gateway for the coxsackievirus: a molecule called ICAM-1. As healthy cells don't carry this molecule, the coxsackievirus doesn't attack them. Once the virus gets into the cell, it hijacks the cell's machinery and ends up killing it. More cancer cells die when the immune cells are recruited.

This is an early-stage trial, and there's still a long way to go before the method can be used in treatment, Pandha said. "This would be the foundation for much larger studies where we'd build on this," he said. Newer studies will try to make the treatment more effective and stop the cancer from coming back, he added.

Just getting a common cold won't treat the cancer on its own. Pandha's team gave a much higher dose of the virus than you would get if someone coughed on you and you got sick, for example. Interestingly, the patients who were given the virus through the catheter did not get symptoms of a cold.

© CIRA/NOAA

The Moon's shadow passes south of Hurricane Barbara during the total solar eclipse of 2 July 2019

SPACE

Satellite captures eclipse and a hurricane in one shot

Words by **Mike Wall**

A shadow reached the Chilean coast at around 8.40pm (GMT) on 2 July and kept on going, heading east across South America's narrow southern wedge towards the Atlantic.

The event was the first total solar eclipse since August 2017's 'Great American Solar Eclipse', which crossed the US from coast to coast. The next such skywatching spectacle won't occur until December 2020, when southern South America again will play host.

Total solar eclipses occur about once every 18 months. But the US won't be treated to another total solar eclipse until April 2024. But that will be a good one, with the diagonal path of totality extending northeast from Mexico all the way up through Canada's maritime provinces.

The photo was captured by GOES West, a weather satellite that's a joint project of the National Oceanic and Atmospheric Administration (NOAA) and NASA.

STRANGE NEWS

WWII-era submarines have vanished from the seafloor

Words by **Brandon Specktor**

A Dutch submarine that sank in the South China Sea in 1941 has recently disappeared from the seabed. Scavengers may be to blame

© Dutch National Archive

More than 100 World War II-era shipwrecks rest on the seafloor around Indonesia, Malaysia and Singapore – but now, two are gone. According to Dutch media reports, a pair of submarines that sank off the coast of Malaysia in 1941 mysteriously vanished, leaving behind only broken scraps and ghostly outlines. The wrecked subs – Dutch vessels HNLMS O 16 and HNLMS K XVII – also contained the remains of 79 crewmen, which are now missing along with the vessels.

How does a shipwreck simply disappear? According to Dutch government officials, the subs were likely stolen by scrap-metal scavengers, who have made a habit of pilfering old wrecks from the region. As many as 40 World War II-era ships have been partially or completely dismantled by scavengers, a 2017 report by *The Guardian* found, resulting in the desecration of the remains of 4,500 crewmen who went down with their vessels.

Wartime shipwrecks are protected under international treaties as the unmarked graves of soldiers, but that hasn't stopped salvagers from destroying the wrecks resting in southeast Asian waters.

LIVESCIENCE

An artist's illustration of a potentially habitable exomoon orbiting a giant planet in a distant solar system

SPACE

Giant moons orbiting hot stars are finally given a name: 'ploonets'

Words by **Mindy Weisberger**

What do you call a runaway exomoon with delusions of planethood? You call it a 'ploonet', of course. Scientists had previously proposed the endearing term 'moonmoons' to describe moons that may orbit other moons in distant solar systems. Now another team of researchers has coined the melodious nickname ploonet for moons of giant planets orbiting hot stars. Under certain circumstances, these moons abandon those orbits, becoming satellites of the host star. The former moon is then 'unbound' and has an orbit like a planet.

Ploonets, and all exomoons, are yet to be detected. But ploonets may produce light signatures that planet-hunting telescopes could identify, researchers reported in a new study. Their findings were published in the preprint journal *arXiv* and have not been peer-reviewed. For the study, the scientists created computer models to test scenarios that might transform a planet-orbiting moon into a star-orbiting ploonet. The researchers found that if a moon is circling a type of exoplanet known as a 'hot Jupiter' – a massive gas giant close to a star – the gravitational tug of war between star and planet could be powerful enough to wrest the moon from its planetary orbit and send the object circling around the star instead.

Orbiting a nearby star would be stressful for a tiny ploonet; during its transit, the ploonet's atmosphere could evaporate, and it would lose some of its mass, creating a distinctive signature in the light emitted from the star's vicinity, the study said. That's the signature that telescopes might be able to detect. Recent observations of mysterious light emissions around hot stars could be explained by the appearance and drawn-out deaths of wayward ploonets, the study said.

> *"Researchers have coined the melodious nickname for moons of giant planets orbiting hot stars"*

Some ploonets could sustain their orbits for hundreds of millions of years. By accreting material from the disc of dust and gas around its star, a ploonet could even build up its body until it eventually became a small planet, the study authors wrote.

However, most ploonets would likely be relatively shortlived, the simulations showed. The majority disappeared within a million years and never became planets; instead, they disintegrated during collisions with their former host planets, were gobbled up by stars in acts of 'planetary cannibalism' or were ejected from orbit into space, the researchers reported.

ANIMALS

Japan's whalers are hunting once again

Words by **Brandon Specktor**

Japanese whalers brought ashore their first catches on 1 July as they resumed commercial hunting after a three-decade ban

© Getty

Japan officially resumed commercial whaling on 1 July after more than 30 years of limiting whale hunts for 'scientific' purposes – a policy that still resulted in the deaths of hundreds of whales every year.

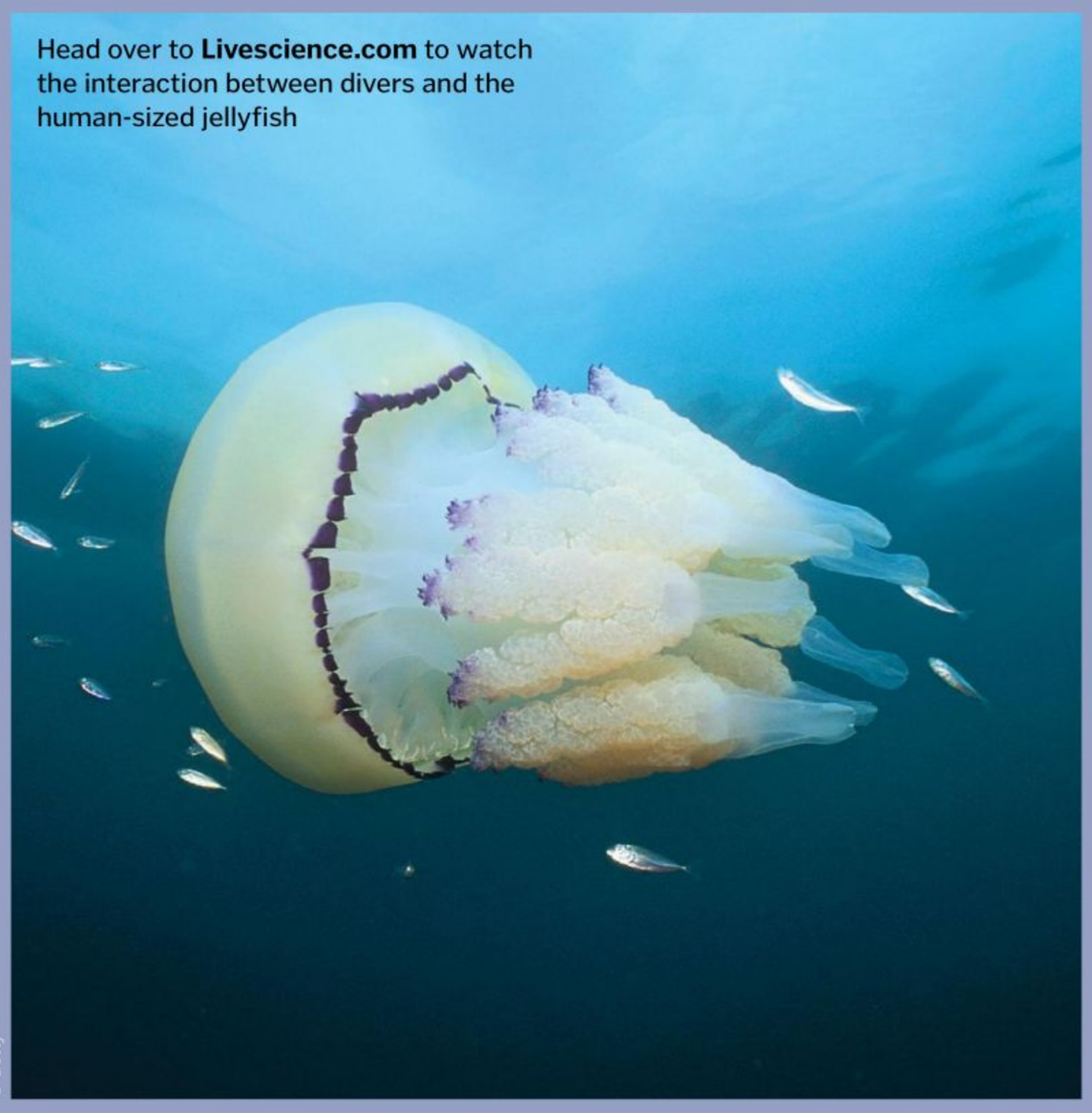
In December 2018, Japan announced that it would withdraw from the International Whaling Commission (IWC) moratorium on commercial whale hunting, which began in 1986 to give endangered and over-hunted whale species a chance to rebound. Japan joined the compact in 1988, agreeing to only hunt whales for scientific purposes (such as collecting population data). However, according to *Reuters*, the gesture did little to curb commercial whaling in Japan. From 1988 to 2017, Japanese vessels caught and killed nearly 17,000 whales, whose meat often ended up for sale in stores and restaurants after any research had concluded.

Whales living near Japan include minke and Bryde's whales (considered to be of 'least concern' of extinction by the IUCN Red List of Threatened Species, which monitors animal populations around the world), as well as sei whales, which are listed as endangered.

The Japanese Fisheries Agency has set a hunting quota of 227 whales for 2019. This is conservative compared to previous hunting activities; in the 2017–2018 whaling season, for example, Japanese whaling vessels killed a total of 333 minke whales in Antarctica alone – 122 of which were pregnant females.

While whaling has been a part of Japanese culture for hundreds of years, modern demand for whale meat is extremely low. According to *Reuters*, whale makes up only about 0.1 per cent of all meat eaten in Japan in a year.

Head over to **Livescience.com** to watch the interaction between divers and the human-sized jellyfish



© Getty

ANIMALS

Human-sized jellyfish spotted off English coast

Words by **Brandon Specktor**

A pair of divers swimming off the southwestern tip of England hit the jelly jackpot last month after crossing paths with a hulking barrel jellyfish (*Rhizostoma pulmo*) – a rarely seen species that can grow about as large as an adult human. Luckily, they filmed the whole thing.

The divers – biologist Lizzie Daly and underwater cinematographer Dan Abbott – shared the encounter in a Facebook video posted on 13 July as part of the Wild Ocean Week campaign – a series of videos showcasing the oddities of the deep to help raise money for the UK's Marine Conservation Society.

Daly and Abbott were diving off the coast of Cornwall when they saw the giant jellyfish emerge from the murky water. Also called the dustbin-lid jellyfish, the species is characterised by eight puffy arms capped by stinging tentacles and a large, globular head that lends the creature its unglamorous nickname. Barrel jellyfish sometimes wash up on the shore, Daly told *Vice*, but it's rare for a diver to swim face to faceless-head with one of the massive blobs.

IN ASSOCIATION WITH LIVESCIENCE

PLANET EARTH

Rapid 'Ice slides' bad news during climate change

Words by **Yasemin Saplakoglu**

Greenland's ice sheet is sliding more than previously thought, according to a new study. This means the ice sheet can change shape faster in a warming climate, researchers reported in *Science Advances*.

"Understanding ice flow is quite important to predicting future melt from Greenland," said the study's lead author, Nathan Maier, a doctoral candidate at the University of Wyoming. Ice flows bring ice from the cold interior regions of the Greenland ice sheet to its warmer edges, where the ice melts. Ice flow happens through two different processes: the first is the sliding of ice across the bed, while the second is deformation, which turns the ice into "flowing molasses," Maier said.

Understanding the relative scale of these two different types of movement helps scientists determine how much ice will move to high-melt areas along the edges of the ice sheet. Maier and his team drilled boreholes into the ice using a large drill. They also installed 212 tilt sensors, which measure the amount of deformation and sliding. The researchers took measurements of ice movement from 2014 to 2016, finding that the Greenland ice sheet is sliding very fast over the underlying bedrock. "This is quite surprising as these regions are thought to have much slower sliding velocities than regions that are resting on slippery mud," Maier told **Live Science**. "Even more surprising is that we recorded this behaviour during winter, when there is no surface melt, which can further lubricate the bed and increase the rate of sliding."

What this means is that "even over these relatively boring, slow-moving regions of the ice sheet resting on rock, ice can be rapidly brought down to the high-melt zones," Maier added. The researchers even found that Greenland's main continental ice sheet slides more than parts of the fast-moving glaciers on the periphery, such as Jakobshavn in west Greenland.

Past work revealed that global warming has changed ice motion along the ice sheet's edges, resulting in more thickening or thinning, which in turn causes changes in surface melt. "Now that we have essentially found high rates of sliding everywhere we have looked on the ice sheet, even in the least-likely locations, like ours, we know that ice can be moved around very efficiently," he said. "Thus, the rates of thickening and thinning are likely to occur more rapidly than previously thought." That means the ice might change faster in a warming climate than currently thought, he said.

"Understanding ice flow is quite important to predicting future melt"

Greenland's ice slides are moving quicker than previously anticipated

© Getty

The new Cretaceous lizard species was found in the abdomen of a microraptor fossil (indicated by the white box)

ANIMALS

Specimen of a Cretaceous lizard found inside a dinosaur's belly

Words by **Mindy Weisberger**

About 120 million years ago a small dinosaur gulped down a lizard, swallowing the reptile whole. The lizard's story might have ended there, but the dinosaur died soon after and was preserved as a fossil. Millions of years later, palaeontologists discovered the scaly meal in the dinosaur's belly.

Scientists found the lizard when they examined the fossil of a feathered dinosaur named *Microraptor zhaoianus,* a small carnivore from the early Cretaceous period (145 million to 101 million years ago) in what is now northeastern China. In the Microraptor's abdomen was a near-complete skeleton the researchers identified as a previously unknown lizard species. The "exceptional specimen" paints a clearer picture of the animal diversity in this region during the Cretaceous, and it hints at what was on the menu for dinosaur predators like microraptors, scientists reported in a study.

The fossilised lizard's skeleton was still whole and nearly complete, and it appeared to belong to a juvenile. Its position inside the dinosaur's gut showed that it was gulped down head first, "consistent with feeding behaviour in extant carnivorous lizards and birds," the study authors wrote. They dubbed the ingested lizard '*Indrasaurus wangi*'. The species name honours palaeontologist Yuan Wang, director of the Paleozoological Museum of China, and 'Indrasaurus' refers to a legend from ancient Indian texts about the deity Indra, who was swallowed whole by a dragon.

"Its position inside the dinosaur's gut showed that it was gulped down head first"

Close examination of the lizard's teeth revealed that they were widely spaced, short-crowned and nearly square. They were unlike the teeth in other Cretaceous lizards, and their unusual shape suggests that the lizard may have had a diet that differed from that of its close relatives, the scientists said in the study.

This microraptor and its lizard lunch provide a rare glimpse of direct interactions between predators and prey in ecosystems that vanished millions of years ago. They were found alongside other microraptor fossils that hold the remains of mammals, fish and birds in their bellies, according to the study.

IN ASSOCIATION WITH
LIVESCIENCE

Eta Carinae, a distant star spouting red, white and blue gas

SPACE

Nebula emits gas in red, white and blue

Words by **Brandon Specktor**

Like the United States of America last month, the universe celebrated its own existence with fireworks. Now, 243 years after the US came into existence and 13.8 billion years after the universe did, NASA researchers have discovered a distant star system exploding in festive red, white and blue light, roughly 5 million times brighter than our Sun.

In a new ultraviolet photo taken by the Hubble Space Telescope, twin bulbs of light explode out of a gargantuan star system called Eta Carinae. Located about 7,500 light years from Earth, Eta Carinae actually consists of a pair of stars, one roughly 50 times the mass of the Sun and the other as much as 250 times more massive. They have been blowing their tops for about 170 years. This eruption of gas and dust was first seen in 1837, when astronomers noticed that Eta Carinae had grown significantly brighter overnight. This was the start of an 18-year period known as the Great Eruption, during which Eta Carinae briefly became one of the brightest objects in the sky.

Astronomers still don't know what sparked the fireworks, but thanks to Hubble's observations, scientists do know what some of that gas is made of. In the image above, a red halo of hot nitrogen gas streaks away from the nebula's twin bulbs of dust. Where there should be an empty cavity of space signifying the end of the Great Eruption, a blue ring of warm magnesium streaks into space closely behind the nitrogen. Studying the gassy debris ejected by Eta Carinae will give astronomers a better idea of what the Great Eruption looked like, maybe even hinting at what caused that event in the first place.

Although safe for human consumption, xylitol can be fatal to man's best friend

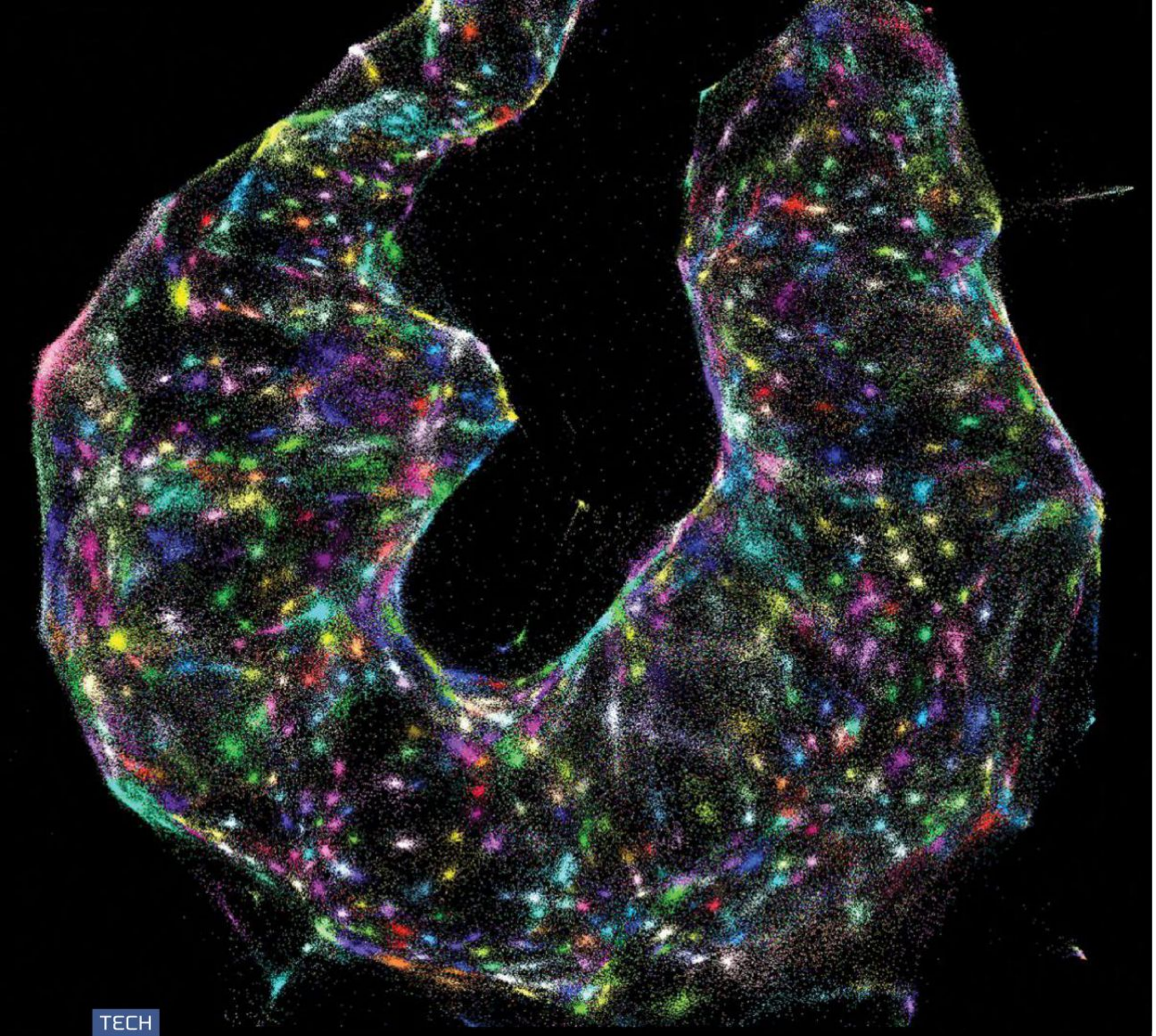
HEALTH

Sugar substitute could be deadly for dogs

Words by **Rachael Rettner**

You should always be careful about what you let your dog eat. A common sugar substitute found in everything from chewing gum to peanut butter can be deadly for man's best friend, according to the US Food and Drug Administration (FDA). Xylitol, a type of sugar alcohol that is sometimes found in sugar-free foods, is safe for humans, but it can be poisonous to dogs. It can be found in many foods and consumer products, including gum, sugar-free chocolate, breath mints, baked goods, sugar-free (or 'skinny') ice cream, toothpaste, cough syrup and some peanut and nut butters.

When dogs eat xylitol, it is quickly absorbed into the bloodstream and causes a rapid release of insulin, the hormone that helps sugar enter cells. This insulin spike may cause dogs' blood sugar levels to plummet to life-threatening levels, a condition known as hypoglycemia, the FDA said. In humans xylitol isn't dangerous because it doesn't stimulate the release of insulin. Signs of xylitol poisoning in dogs – including vomiting, weakness, difficulty walking or standing, seizures and comas – typically occur within 15 to 30 minutes, and deaths have occurred in as little as one hour, the FDA reported.



TECH

Cells appear as disco lights in new 'DNA microscope' images

Each of these glowing dots represent an individual cell

Words by **Laura Geggel**

What looks like a kaleidoscope of glowing ice cream sprinkles or disco lights is actually something even more astonishing: an unfettered and detailed view of the exact locations of DNA and RNA inside a living cell. The method that opened the doors for this unprecedented look inside living cells – known as DNA microscopy – was perfected over a period of six years, according to a new study.

"DNA microscopy is an entirely new way of visualising cells and captures both spatial and genetic information simultaneously from a single specimen," study lead researcher Joshua Weinstein, a postdoctoral associate at the Broad Institute of MIT, said in a statement. The technique allows researchers to see the exact order of nucleotides, the 'letters' that make up DNA's double helix and RNA's single strand, within each cell. "It will allow us to see how genetically unique cells – those comprising the immune system, cancer or the gut, for instance – interact with one another and give rise to complex multicellular life," Weinstein said.

In essence, the method uses tags made out of customised DNA sequences each about 30 nucleotides long, which latch onto every DNA and RNA molecule in a cell. The tags replicate until there are hundreds of copies within the cell. As these interact with one another, they combine and make unique DNA labels.

The interactions between these DNA tags is key. Once researchers collect the labelled biomolecules and sequence them, they can use a computer algorithm to decode and reconstruct the tags' original positions in the cell, creating a colour-coded virtual image of the sample.

The technique may help researchers to better understand different kinds of human disease. In the study the researchers showed that DNA microscopy could map the locations of individual human cancer cells in a sample.

WISH LIST

The latest **SCHOOL** tech

Ember Travel Mug

■ Price: **£159.95 / $149.95**
ember.com

Keeping your coffee hot in the mornings is a must for many students travelling to and from class. The Ember Travel Mug, a temperature control smart mug, aims to tackle this problem. In communication with the accompanying smartphone app, the Ember mug will notify you when your beverage has reached your ideal drinking temperature. Then to keep the hot drink fresh, the Ember mug will maintain that temperature for two hours. Able hold 355ml of liquid, the mug is set at a temperature from 50 to 62.5 degrees Celsius. It can then be repowered on a rechargeable base.

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Rocketbook Everlast

■ Price: **From £32.99 / $29.99**
getrocketbook.co.uk

Keeping track of your school notes can sometimes be as challenging as the information written on them. Over the course of the academic year paper notebooks can pile up, but with the Rocketbook, class notes can be uploaded straight to the cloud for easy storage. Once you're done solving an equation or sketching out a design, simply take a snap with the Rocketbook app and send your notes to online storage like Dropbox or Google Drive. When you're finished with a page, wipe away your notes made by the Rocketbook's accompanying pen and start again.

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Lifepack

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Rushing between classes, it's easy to lose track of your smart devices' power levels. However, with Solgaard's solar-powered backpack, an integrated power bank makes sure you're fully charged throughout the day. Lifepack is also an anti-theft bag, keeping valuable items safe with its integrated coiled lock.

Spark Plug wireless dongle

■ Price: **£14.99 / $19.99**
scalextric.com

Scalextric has gone wireless! Zipping around the race track, Scalextric race cars have long been driven by the iconic single-trigger controller. However, now with the Spark Plug wireless dongle, these self-assembly tracks have gone digital. Using the Android or Apple app, you can tackle turns and race to the finish line at the touch of a button. With boost and restrict options, racers can send their cars flying while holding back their opponents.

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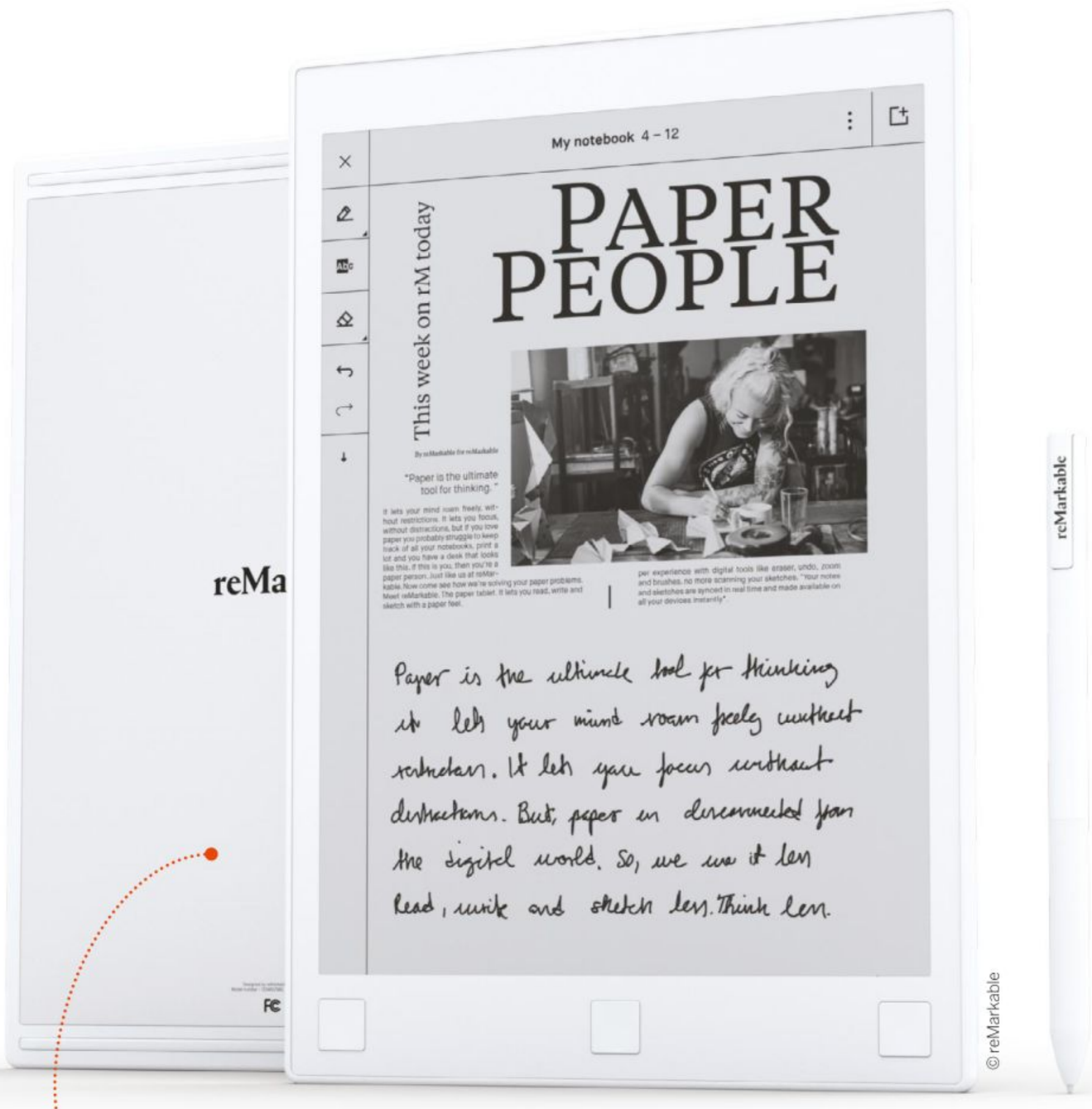


reMarkable paper tablet

■ Price: **£449 / $499** **remarkable.com**

If you like the practicality of a smart device but prefer the feel of paper then the reMarkable paper tablet is a must-have. Combining the readability of Kindle and the high-tech prowess of an iPad, the reMarkable tablet hosts a unique canvas display that feels and even sounds like paper when using the accompanying pen. Annotate textbooks, write notes and draw freehand designs with ease, then save your work straight to the cloud.

Varidesk ProPlus™ 30

■ Price: **£275 / $295**
uk.varidesk.com

School and university assignments can lead to many hours spent sitting in front of a computer. However, with the Varidesk ProPlus™ 30 standing desk, you are free to stretch your legs without having to step away from your work. This two-tiered desk extension takes seconds to move from a sitting to standing position, and can simply be placed on your existing desk.

APPS & GAMES

TED

■ Developer: **TED Conferences LLC**
■ Price: **Free / Google Play / App Store**

Find out about the latest research and tech from more than 3,000 inspirational talks within this app, which is bursting at the seams with information across a whole host of topics.

SimpleMind

■ Developer: **ModelMaker Tools / xpt Software & Consulting B.V.**
■ Price: **Free / Google Play / App Store**

If you enjoy creating mind maps this is a must-have. From constructing simple to complex maps, it's easy to navigate and edit.

Exam Countdown Lite

■ Developer: **ROOT38 LIMITED**
■ Price: **Free / Google Play / App Store**

Keep on top of your exam schedule with this easy-to-use countdown app. Just enter your upcoming exams, and the app will keep a count of how much revision time you have left.

myHomework Student Planner

■ Developer: **instin / Rodrigo Neri**
■ Price: **Free / Google Play / App Store**

Staying organised is the key to success during school time, and with this planner app you can easily keep track of your homework, classes and events so that you never miss a deadline for your school work.

JOURNEY THROUGH the

From your mouth to your cells – how you are what you eat

Words by **James Horton**

DID YOU KNOW? *A sword swallower tested one of the first endoscopes – cameras that look inside the GI tract*

Digestion starts here!

Chewing and salivation combine to mechanically and chemically break down food in the mouth

Tearing
Sharp canine teeth grip and tear into tougher items of food.

Chemical digestion
Starch molecules, contained in many foods like pasta, potatoes and bread, are digested by the enzyme amylase, found in saliva.

Stensen's duct
The solution from the parotid gland is released into the mouth, via a duct that opens from the cheek walls near the second upper molar.

Parotid gland
This salivary gland mainly produces a serous, watery solution composed of water, electrolytes and protein – including the enzyme amylase.

Chopping
The narrow set of incisors sat at the front of the jaw specialise in slicing food into smaller chunks.

Wharton's duct
Solutions from the sub-salivary glands are secreted at the base of the tongue.

Mixing
The tongue shifts food around the mouth, coating it in saliva and ensuring that it can be ground into small chunks by the molars.

Chomping
The large set of flat molars crush and grind food, providing a large part of the mechanical digestion that occurs in the mouth.

Sublingual gland
A thicker, mucosal form of saliva is predominantly produced here.

Submandibular gland
This set of glands creates a mixture of watery serous and thicker mucosal solutions.

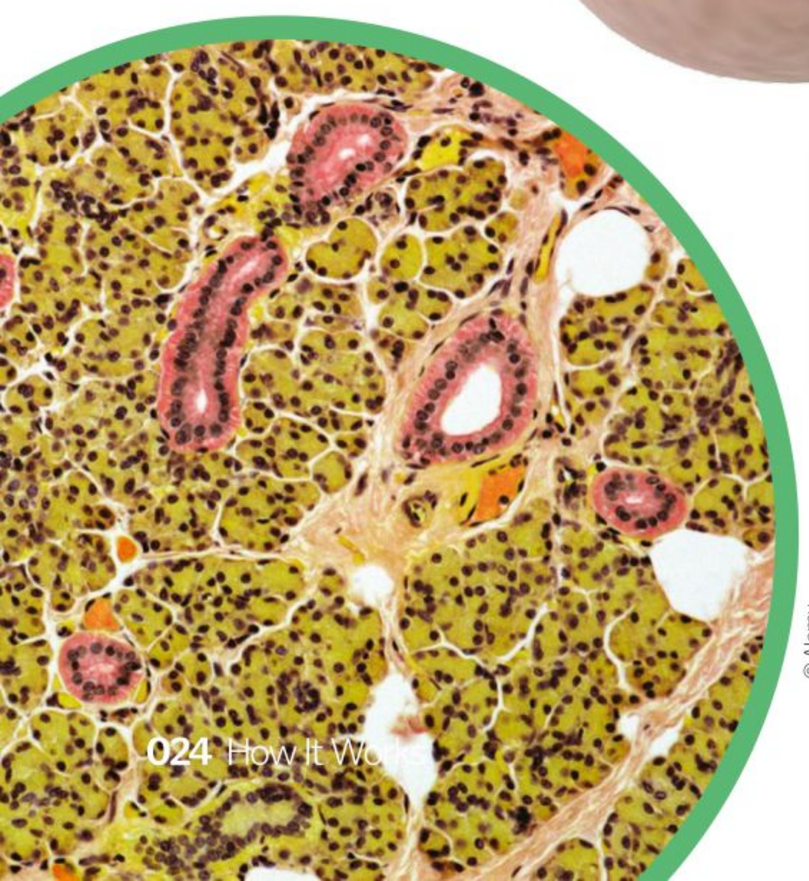
NERVE IMPULSES

AROMATIC SUBSTANCES RELEASED FROM FOOD

SALIVA ENTERING MOUTH

FROM TEETH AND TONGUE

FROM BACK OF TONGUE



© Alamy

The parotid gland is stuffed with serous acini – secretory units that produce isotonic, watery fluid

CHEWING, SALIVA & SWALLOWING

It took the evolution of life billions of years to arrive at the level of sophistication of the human being. Our bodies are home to trillions of cells all doing simple jobs on tiny scales, unaware that they're part of something so much greater than the sum of their parts. But as with any life, for their work to continue they need energy. And how do we fuel and continue to build this gargantuan machine? We drink and we eat.

Zooming out to you, we can see this quest for energy beginning as soon as you sense something delicious wafting in the air, spy a burger on a poster board or simply wait until your stomach gurgles at you unhappily. This desire for food is a summoning cry for billions of cells, collected into sophisticated organs, arranged into a stretch of tract that spans around nine metres in adults. From your mouth to your anus runs the gastrointestinal tract – the space where a banana, a yogurt or an apple pie are broken down into their component parts and either absorbed or eliminated. The absorbed molecules are then ready to be used as building blocks for maintaining, recycling and enhancing the world that is you.

> "This quest for energy begins as soon as you sense something delicious wafting in the air"

Let's begin our journey with the summoning cry. A hormone known as ghrelin, which is produced mainly by the stomach, can be triggered when we so much as look at an image of a tasty meal or read the description of one on a menu. This sends a signal to our brain that increases our appetite, setting us on the path towards ingesting some precious energy.

The next part is the best – it's time to eat. Chewing and tasting food may be the moment of peak satisfaction for our brain, but the voyage for the food has only just begun.

© Getty

Just looking at a tasty bit of food can be enough to trigger our appetite

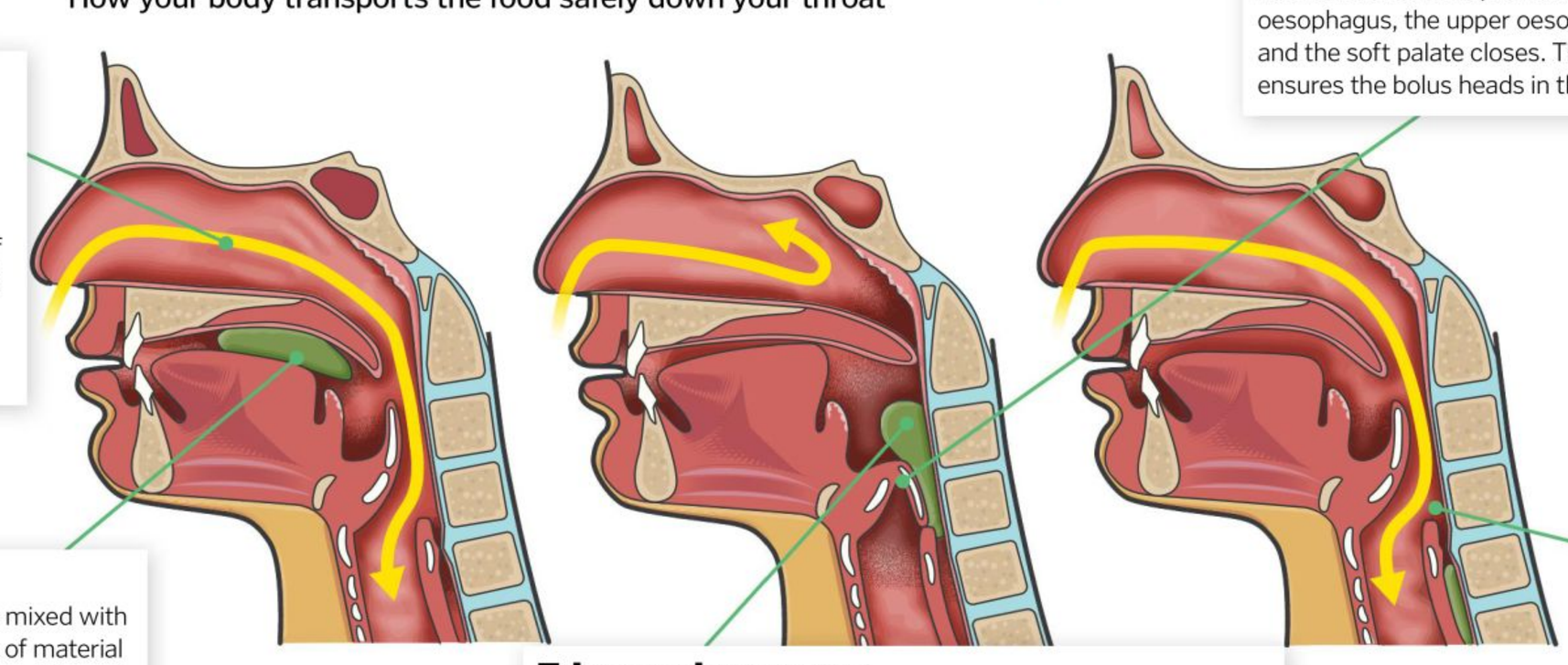
How the brain coordinates eating

The act of swallowing is one of the most delicate and complex processes performed by the human body, even though we rarely offer it a second thought. Like many crucial processes, much of swallowing is an involuntary action. This ensures that lubricated food is moved from our mouth to our stomach without getting stuck, coming out of our nose or blocking our windpipe.

The key control centre for swallowing is the brain stem, home of the medulla oblongata. This network is connected to a collection of cranial nerves that perform important functions, including sensing and controlling chewing, tasting, salivation and swallowing. The cranial nerves report the location and texture of the food bolus to the brain stem as it moves from the mouth to the pharynx to the oesophagus, triggering muscle contractions along the way.

The essential sequence of swallowing

How your body transports the food safely down your throat



No entry
At this stage the airways are open and the upper oesophageal sphincter – a ring of muscle that acts as a gateway to the oesophagus – is firmly shut.

Away we go
Chewed food that's mixed with saliva forms a lump of material known as a food bolus. The act of swallowing begins as the tongue pushes the food bolus towards the throat.

Triggered response
The arrival of the food bolus initiates a response known as deglutition. This involves a synchronised series of contractions of head and neck muscles to squeeze food into the oesophagus.

This way, please
As the food bolus is pushed towards the oesophagus, the upper oesophageal sphincter opens and the soft palate closes. This obstructs airflow but ensures the bolus heads in the right direction.

No return ticket
As soon as the food bolus has cleared the array of sensory receptors that coat the pharynx, the upper oesophageal sphincter clamps shut and the soft palate relaxes. Sequential muscular contractions continue in the oesophagus, pushing the bolus on and towards the stomach.

© Illustration by The Art Agency/Nick Sellers

STOMACH, DUODENUM, BILE DUCT & PANCREAS


© Getty

Human stomach lining is highly regenerative and can renew itself once every week

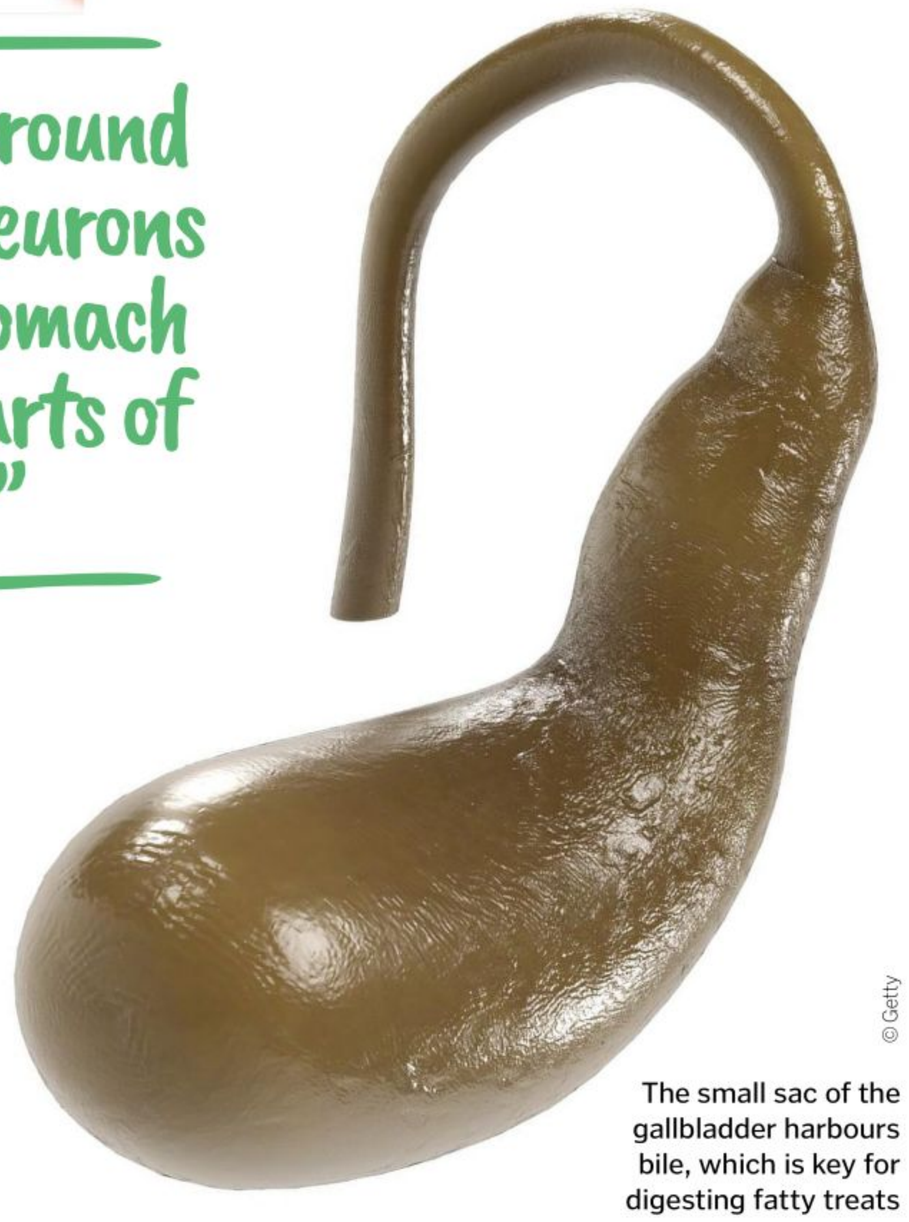
The period after we've just finished a meal is a crucial time for digestion. The recently arrived food bolus has already been partially digested in the mouth, but next comes exposure to an onslaught of digestive enzymes that will prepare the food's molecules for absorption in the intestines. The bolus first arrives through the pyloric sphincter into the stomach – a hostile alien environment where molecules are continuously secreted from the walls and activated by the pool of gastric acid that fills the chamber.

> "There are around 100 million neurons lining the stomach and other parts of the gut"

Alongside the stomach, a collection of other organs are busily producing and secreting their own cocktail of digestive enzymes. These will unite with the partially digested food in the duodenum, the organ that follows the stomach.

The stomach is a fascinating organ because one of its main jobs is storing and slowly releasing food into the small intestine. Without this limiting point, food would rapidly travel through the digestive tract, and we'd miss out on a huge amount of precious nutrients simply because our intestines wouldn't have time to absorb them. But the stomach is able to stretch and hold onto food for hours, methodically churning the material and setting upon it with its powerful stomach acid.

By the time the converted food leaves the lower chamber of the stomach and greets the awaiting digestive enzymes secreted by the neighbouring organs, it has been thoroughly prepared for its next step. It's nearly time for the food to become a part of you.


© Getty

The small sac of the gallbladder harbours bile, which is key for digesting fatty treats

THE MANY POWERS OF STOMACH ACID

1 Bacteria killer
The highly acidic environment is harmful to most microorganisms, including pathogenic bacteria.

2 Pepsin switch
Hydrochloric acid in the gastric juices converts pepsinogen, which is secreted from the stomach's walls, into protein-digesting pepsin.

3 Protein unraveller
Available pepsin in the acid breaks down protein structure, cutting the molecule into smaller chains of amino acids.

4 Vitamin absorption
Gastric acid helps stimulate the secretion of a glycoprotein known as intrinsic factor into the stomach, which will later bind to vitamin B12 in the small intestine.

5 Bile delivery
The presence of stomach acid in the small intestine helps to stimulate the release of fat-digesting bile.

6 Blocks acid reflux
The acidity of gastric juices helps to trigger the contraction of the lower oesophageal sphincter, helping to keep harmful acid away from the unprotected tubing.

7 Aiding migration
The pressure from the volume of stomach acid helps to open the pyloric sphincter briefly, transferring chyme and acid into the small intestine.

The gut-brain connection

There are around 100 million neurons lining the stomach and other parts of the gut. This massive collection of connections is so expansive that it's often given the colloquial name of 'the second brain'. We've already seen that the brain can impact the stomach as soon as the optic nerves detect food, but this relationship goes both ways. The stomach and other parts of the gut are constantly informing and guiding the brain while we're eating and digesting. If you've ingested a particularly large meal and feel the need to lay down, that's because your digestive tract has drawn away blood supply from other organs. And have you ever had 'butterflies' in your stomach? That signal actually comes from the stomach as a sign of protest when blood is drawn away from the organ.

Inside the stomach

Meet the food's storage chamber and accompanying organs that get digestion started in earnest

Bile storage
Bile is held and concentrated in the gallbladder until it's needed in the small intestine.

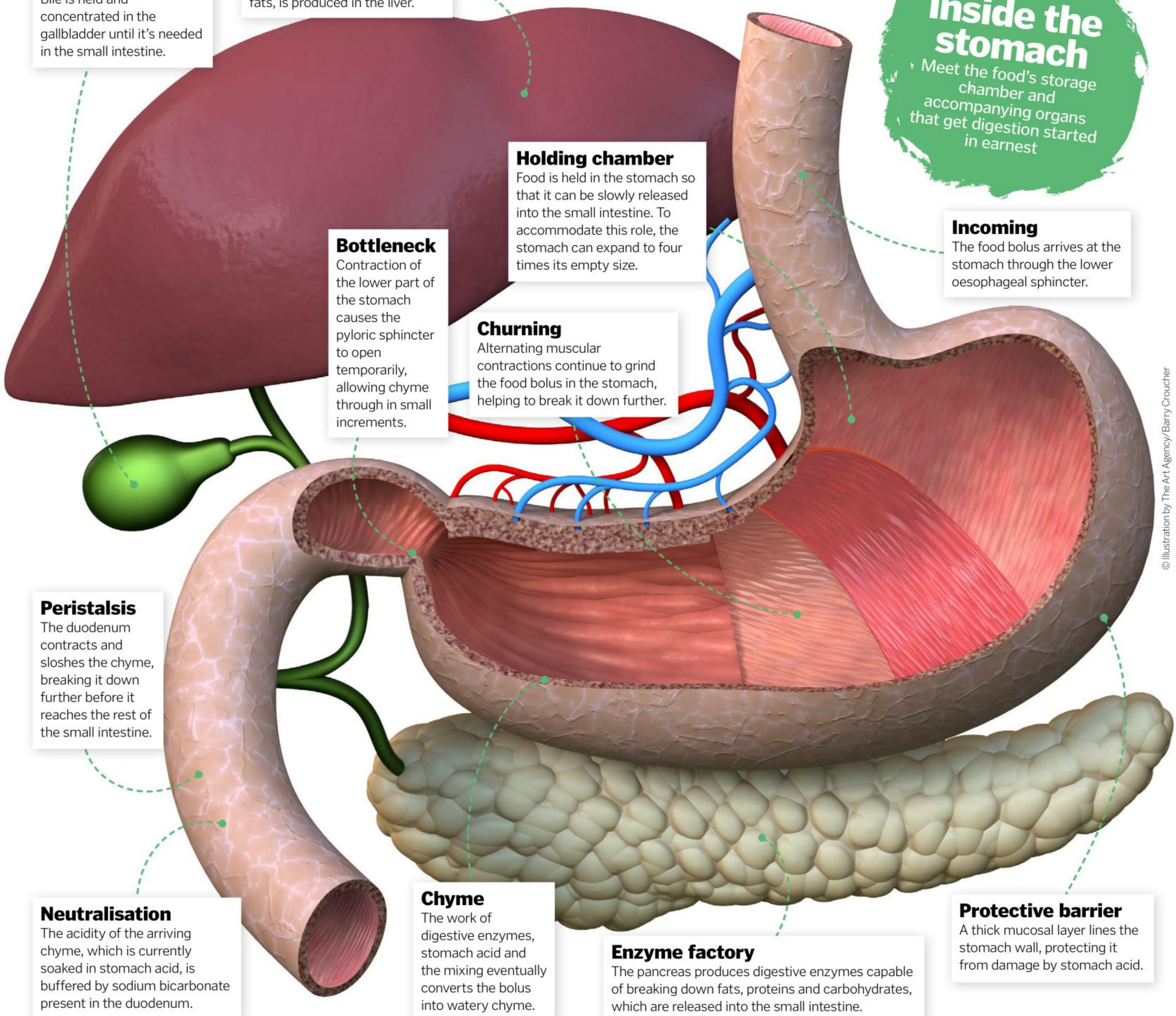
Bile production
An important fluid known as bile, which helps digest and absorb fats, is produced in the liver.

Holding chamber
Food is held in the stomach so that it can be slowly released into the small intestine. To accommodate this role, the stomach can expand to four times its empty size.

Bottleneck
Contraction of the lower part of the stomach causes the pyloric sphincter to open temporarily, allowing chyme through in small increments.

Churning
Alternating muscular contractions continue to grind the food bolus in the stomach, helping to break it down further.

Incoming
The food bolus arrives at the stomach through the lower oesophageal sphincter.



Peristalsis
The duodenum contracts and sloshes the chyme, breaking it down further before it reaches the rest of the small intestine.

Neutralisation
The acidity of the arriving chyme, which is currently soaked in stomach acid, is buffered by sodium bicarbonate present in the duodenum.

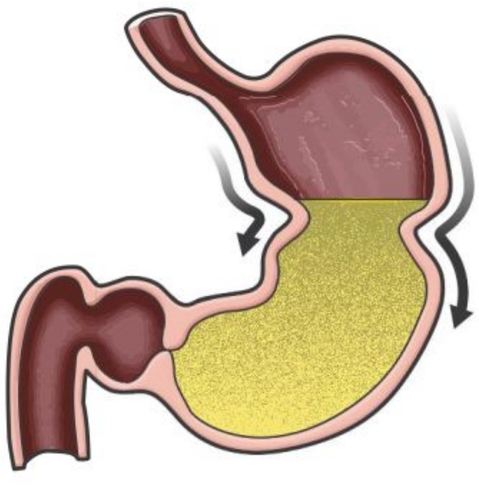
Chyme
The work of digestive enzymes, stomach acid and the mixing eventually converts the bolus into watery chyme.

Enzyme factory
The pancreas produces digestive enzymes capable of breaking down fats, proteins and carbohydrates, which are released into the small intestine.

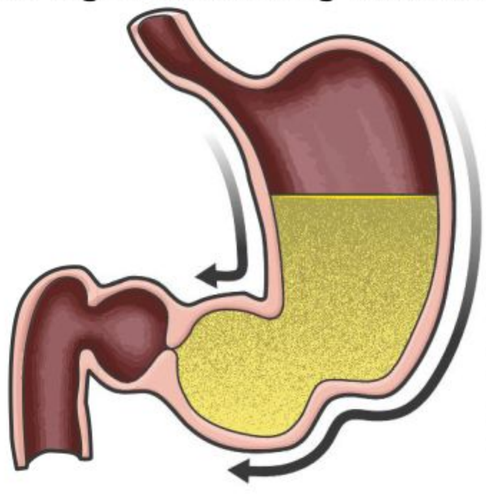
Protective barrier
A thick mucosal layer lines the stomach wall, protecting it from damage by stomach acid.

What happens in the stomach?

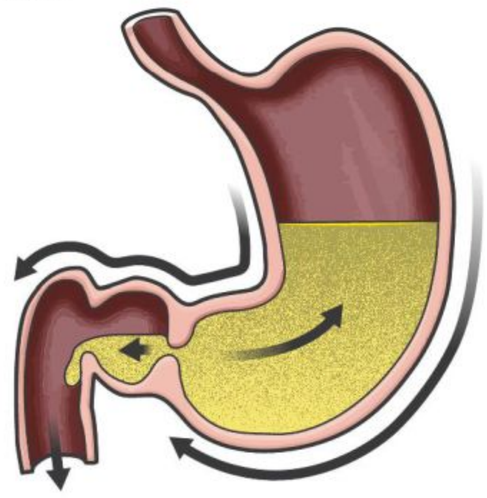
This hollow organ is the mixing-machine of the digestive system



Propulsion
From the oesophagus, peristaltic waves move the food bolus into the stomach, where it collects and meets the stomach acids.

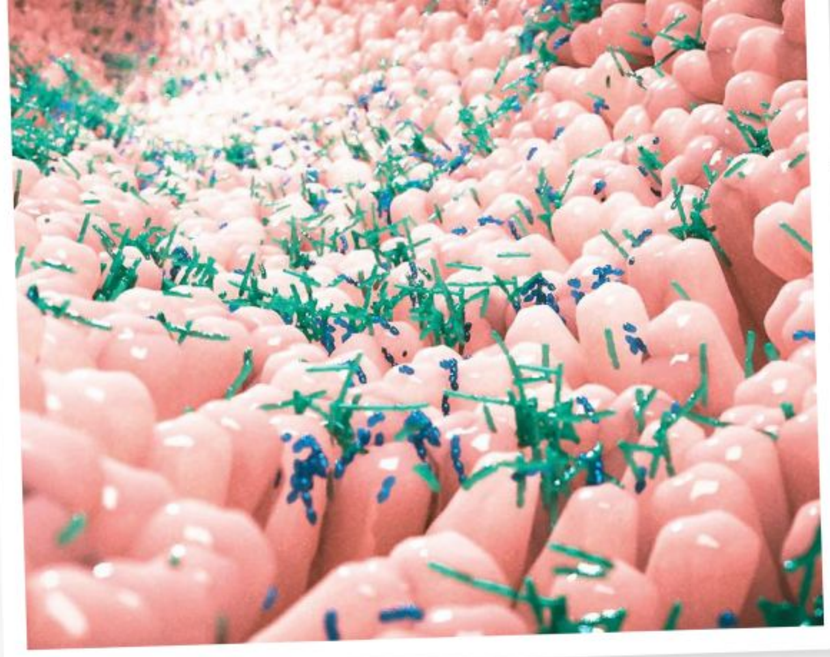


Grinding
Waves of peristalsis move from the fundus (top of the stomach) to pylorus (bottom of the stomach), churning the acids and food into a mixture called chyme.



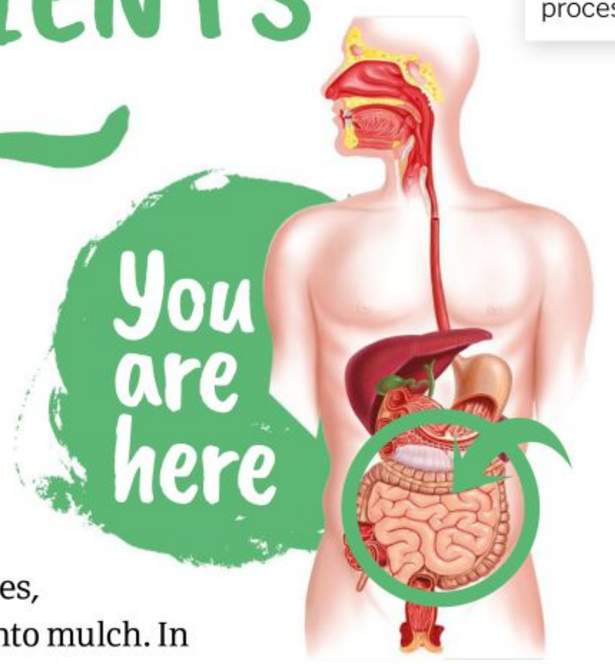
Retropulsion
Eventually the chyme is pushed through the pylorus into the duodenum, small amounts at a time, while the rest of the contents is pushed back into the stomach.

SMALL + LARGE INTESTINES, BLOODSTREAM & USE OF NUTRIENTS



Your intestinal tract is home to trillions of microorganisms that help in digestion and gut health

© Shutterstock



By the time your meal arrives in the small intestine, the delicious feast that it once was has been completely lost. In your mouth, the amylase in your saliva broke down long chains of carbohydrates, and your teeth crushed it into mulch. In your stomach, the food bathed in gastric juices that tore its proteins to pieces while being mashed by the organ's muscles. Now it arrives in the small intestine as a watery mixture with an entourage of fat-digesters, protein-choppers and carbohydrate-gobblers ready to strip any remnants of the form it had once been. In its wake will be left only the component parts – the building blocks that are needed by your cells. These molecules will be absorbed and shepherded around the body.

The importance of the intestinal tract is reflected in its size. Of the roughly nine metres of gastrointestinal tract in the body, six metres is taken up by the small intestine and another 1.5 metres by the large intestine. This leaves plenty of room for molecules to be absorbed as they migrate through the small intestine. Once they've been collected, the proteins, fats, sugars and some vitamins, minerals and salts are transported to the liver for processing.

Now material in the large intestine is approaching the end. This is the last processing point before it will be eliminated as waste.

Duodenum
Stomach acid is neutralised, and digestive enzymes join the procession in the duodenum.

Jejunum
About 40 per cent of the small intestine has vigorous muscle contractions – which moves the chyme – and an extensive network of blood vessels for absorption.

Ileum
The final region of small intestine is narrower, thinner and has less blood supply than the preceding regions.

Time to go
Remaining food matter that enters the large intestine is destined for elimination after any fluid has been recovered.

© Getty

The importance of fibre

Dietary fibre is composed of food matter that our cells are unable to digest and subsequently absorb. You could be forgiven for thinking that fibre is a useless thing for us to ingest, but in reality a healthy intake of fibre can be massively important to gut health. Soluble fibre, which dissolves in water, forms a gel-like substance as it migrates through the gut, whereas insoluble fibre is broken down only by mechanical digestion. Fibre helps to keep food matter moving through the digestive system and aids when passing bowel movements. It also helps to control blood sugar and cholesterol levels, and also feeds gut microorganisms – which help to keep your intestines healthy as well as producing vitamin K and short-chain fatty acids as useful by-products.

The long path to absorption

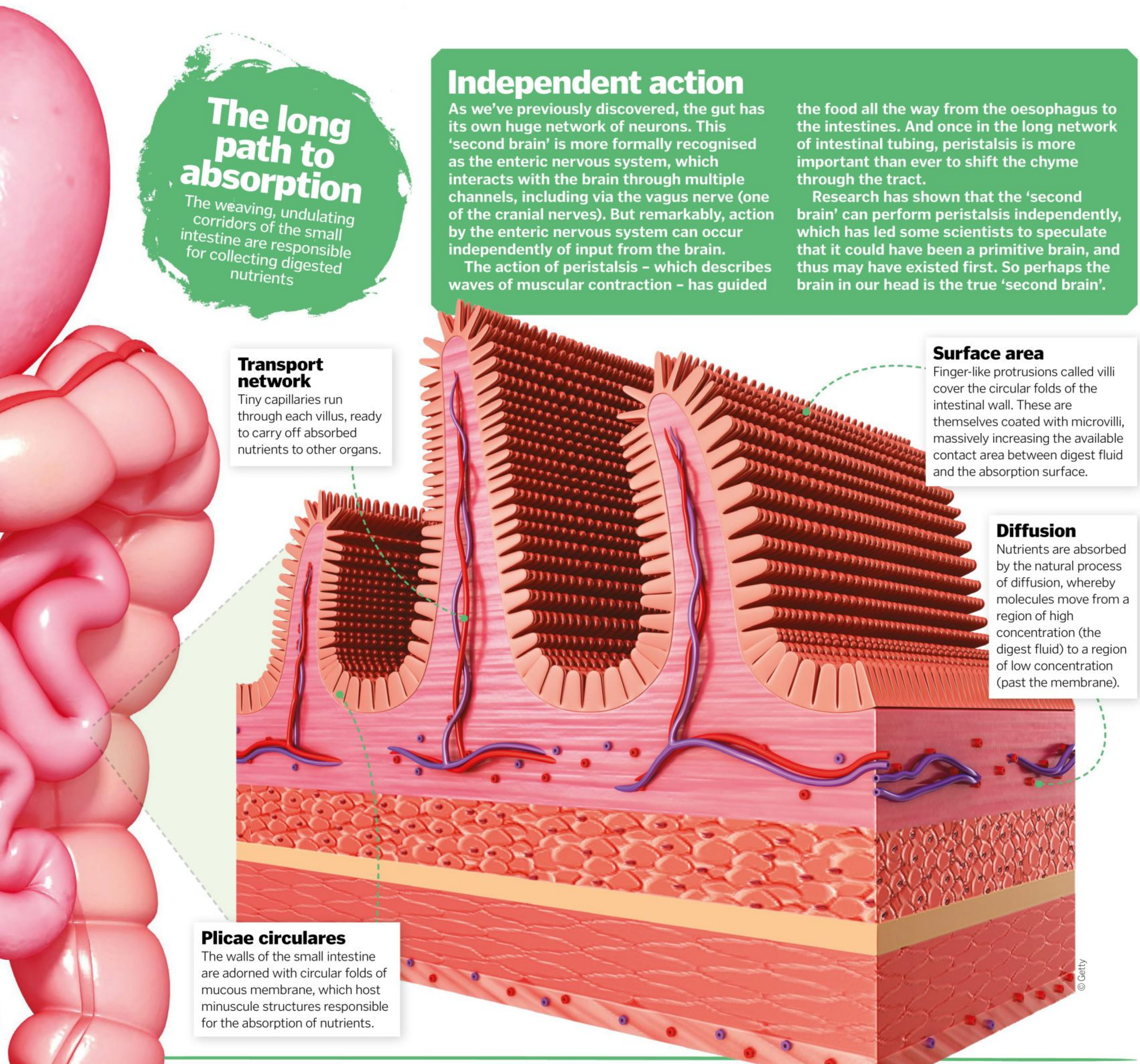
The weaving, undulating corridors of the small intestine are responsible for collecting digested nutrients

Independent action

As we've previously discovered, the gut has its own huge network of neurons. This 'second brain' is more formally recognised as the enteric nervous system, which interacts with the brain through multiple channels, including via the vagus nerve (one of the cranial nerves). But remarkably, action by the enteric nervous system can occur independently of input from the brain.

The action of peristalsis – which describes waves of muscular contraction – has guided the food all the way from the oesophagus to the intestines. And once in the long network of intestinal tubing, peristalsis is more important than ever to shift the chyme through the tract.

Research has shown that the 'second brain' can perform peristalsis independently, which has led some scientists to speculate that it could have been a primitive brain, and thus may have existed first. So perhaps the brain in our head is the true 'second brain'.



Transport network

Tiny capillaries run through each villus, ready to carry off absorbed nutrients to other organs.

Surface area

Finger-like protrusions called villi cover the circular folds of the intestinal wall. These are themselves coated with microvilli, massively increasing the available contact area between digest fluid and the absorption surface.

Diffusion

Nutrients are absorbed by the natural process of diffusion, whereby molecules move from a region of high concentration (the digest fluid) to a region of low concentration (past the membrane).

Plicae circulares

The walls of the small intestine are adorned with circular folds of mucous membrane, which host minuscule structures responsible for the absorption of nutrients.

The five essential nutrients

Learn the molecular groups that are vital to building your world

Proteins

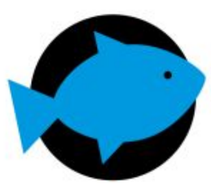
Proteins are the workhorses powering chemical reactions inside every cell in the human body. Not only are proteins required to build each muscle and get us moving, they also perform the roles of hormones, enzymes, antibodies and more.

Fats

Fats are often maligned as being unhealthy, but in fact they're an important macronutrient involved in an array of integral processes. They aid in mineral absorption, muscle movement, forming anti-inflammatories, blood clotting and building cells.

Carbohydrates

Carbohydrates are an important resource for energy. The brain operates solely on energy provided by glucose – a basic sugar building block of complex carbohydrates. Carbohydrates are stored as long chains and are harvested for energy during periods of fasting.



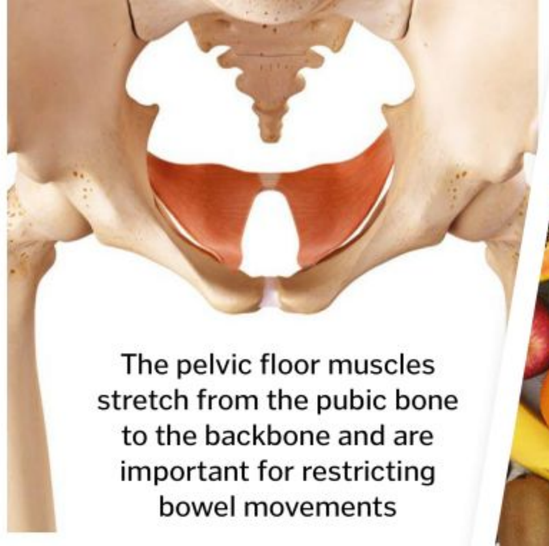
Vitamins

Vitamins are micronutrients that play important supporting roles in many bodily processes. For example, they help store and release energy from food, keep our organs and nervous systems in good working condition and power the immune system.

Minerals

In a similar role to vitamins, minerals are also micronutrients that bolster many of the key processes in the body. For example, they aid in building and keeping our bones strong, regulating metabolic activity and maintaining proper hydration.

RECTUM, SPHINCTER & WASTE

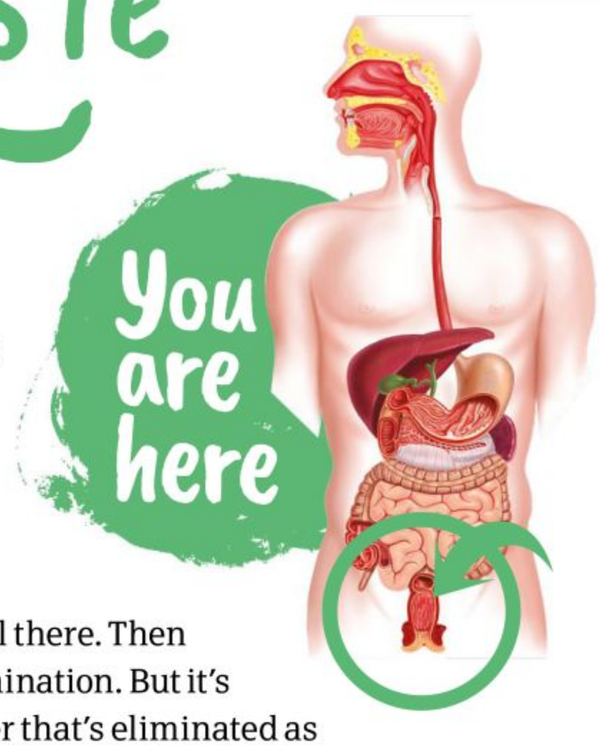


The pelvic floor muscles stretch from the pubic bone to the backbone and are important for restricting bowel movements

Wholegrains, vegetables, nuts, seeds, beans, peas and pulses are rich in dietary fibre

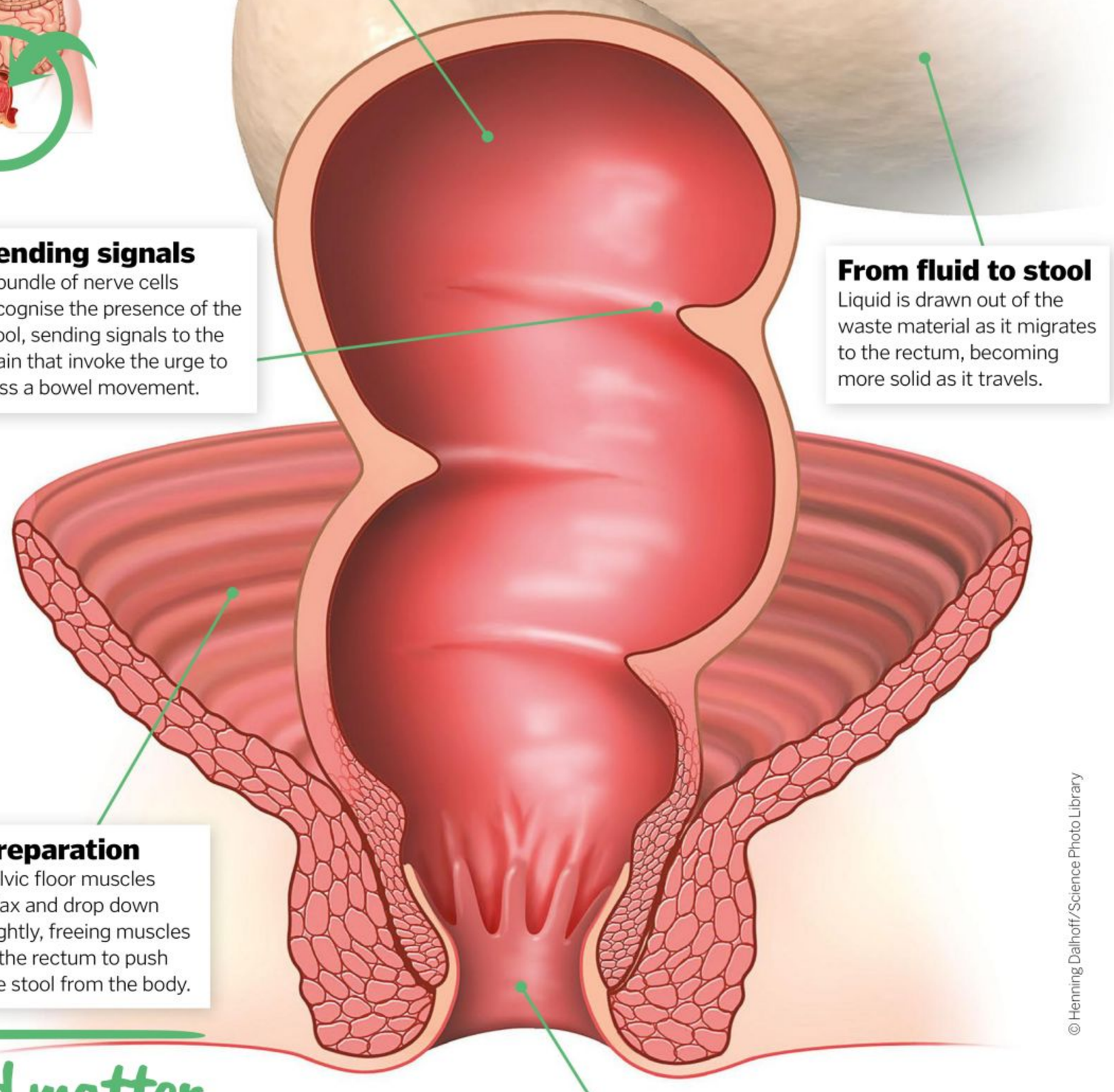
Leaving the body

Indigestible and unneeded nutrients, cellular debris and microorganisms are eliminated in stools



For a large portion of ingested food matter, it's time for a new start as part of your body. But for the rest waits the long, winding path through the large intestine and the huge number of microorganisms that dwell there. Then it's into the rectum for elimination. But it's not just leftover food matter that's eliminated as stool. On the contrary, alongside food remnants are cellular debris from dead cells that lined the intestinal wall; fibrous materials that have migrated through your entire system largely unscathed; and many members from the gut microorganism community. This diverse ensemble includes bacteria, viruses, fungi and archaea. Together they form a waste product that will provide energy to a suite of new organisms outside of the body.

The final stage of the gastrointestinal tract is of huge importance, primarily because bowel movements ensure the release of toxins from the body. Humans are imperfect creatures with imperfect diets, and it is inevitable that we will not uptake every iota of energy we ingest, so it's integral we maintain healthy organs for elimination. As with the beginning of our food journey, the end is one of the few areas over which we have voluntary control. And just as we take care over what we ingest, we should be careful to ensure our eliminations are regular and comfortable.



Entering the rectum
The stool automatically moves into the upper anal canal through an internal sphincter.

Sending signals
A bundle of nerve cells recognise the presence of the stool, sending signals to the brain that invoke the urge to pass a bowel movement.

From fluid to stool
Liquid is drawn out of the waste material as it migrates to the rectum, becoming more solid as it travels.

Preparation
Pelvic floor muscles relax and drop down slightly, freeing muscles in the rectum to push the stool from the body.

Elimination
The external sphincter is under voluntary control, and when consciously decided upon can be opened, allowing the stool to pass from the body.

> "It's not just leftover food matter that's eliminated as stool"

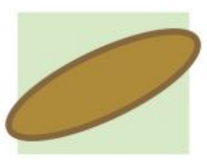
What your poo says about you

Doctors use the Bristol Stool Chart to grade their patients' poos

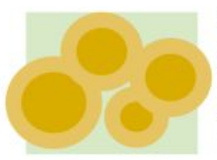
Type 1
Separate hard lumps
SEVERE CONSTIPATION

Type 2
Lumpy and sausage-like
MILD CONSTIPATION

Type 3
A sausage shape with cracks in the surface
NORMAL



Type 4
Like a smooth, soft sausage or snake
NORMAL



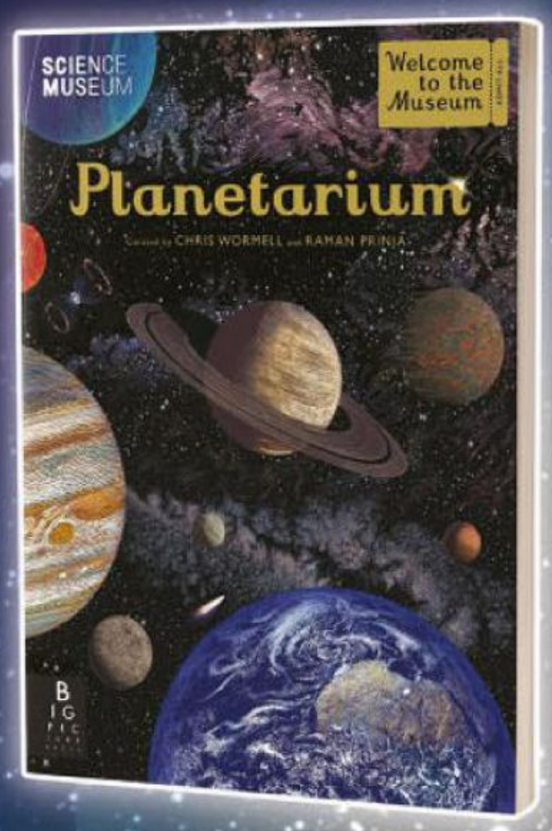
Type 5
Soft blobs with clear-cut edges
LACKING FIBRE

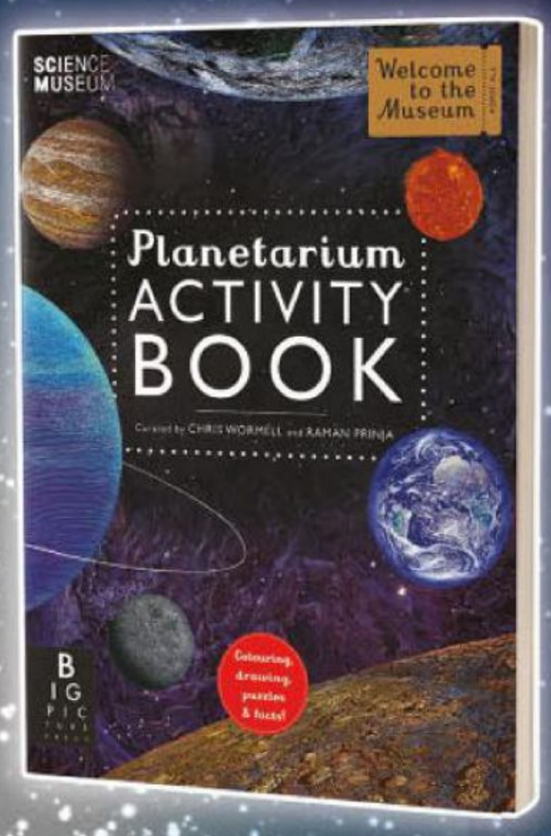
Type 6
Mushy consistency with ragged edges
MILD DIARRHOEA

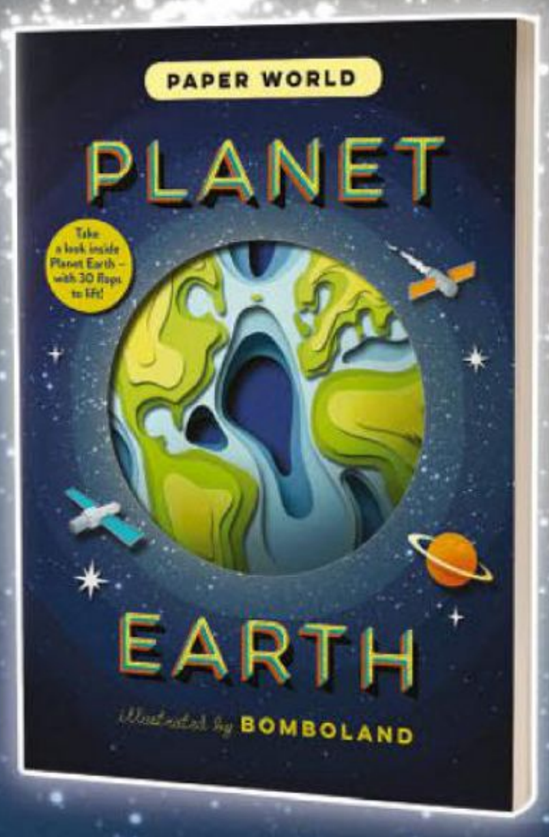
Type 7
Liquid consistency with no solid pieces
SEVERE DIARRHOEA

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*

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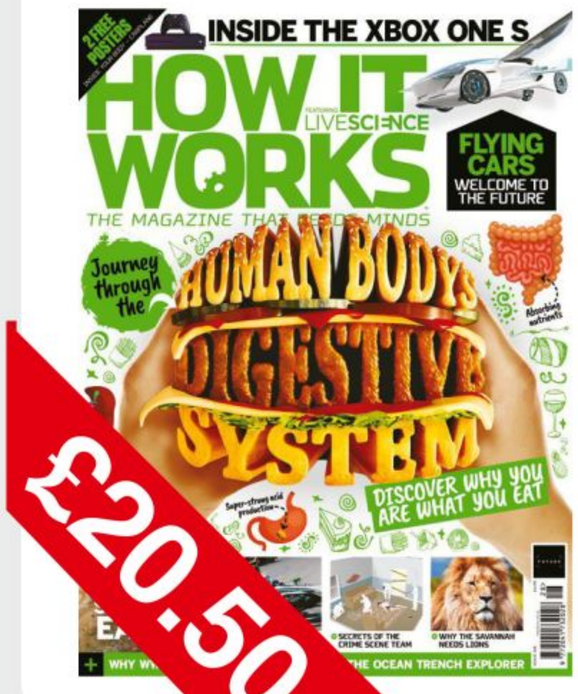

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How to catch a criminal

Words by **Joanna Elphick**

Forensic scientists are continually inventing ingenious ways to gather evidence and catch the bad guys

Every time you walk into a room, take a sip of water from a glass or sit in a chair, you are leaving tiny traces of yourself behind. It's these minuscule clues that forensic scientists attempt to find at a crime scene. Identifying a suspect's fingerprint at the site of a crime clearly shows that he or she was there, no matter how strongly they deny it. This concept is known as Locard's exchange principle, named after the French scientist Edmond Locard, who initially realised the importance of this fact when hunting down criminals.

It is during the last 100 years, however, that crime scene investigation has really taken off. Criminals have invented ingenious methods of avoiding capture, but forensic scientists have matched them, devising new ways to gather, analyse and identify evidence in order to secure a conviction in the courtroom.

When Arthur Conan Doyle created Sherlock Holmes, his powers of deduction were science fiction – Holmes's ability to know what the killer was wearing by listening to the sound of his footfall, or knowing which particular shop he had bought his tobacco from based on the flecks of ash caught in his beard. The idea that someone could know so much from such minute details seemed ridiculous, but today science fiction has become science fact, and this is exactly what crime scene investigators do.

But how realistic are the crime TV shows we watch? Can specialists really tell the exact pen used to write a ransom note, or whether fibres found at the scene of a crime came from a particular item of clothing? The answer is yes, thanks to the painstaking work of the forensic investigators at the scene, as well as the brilliant scientists and inventors who constantly come up with new and improved methods of analysing evidence.

Police tape helps preserve the crime scene and stops it from becoming contaminated by the general public

The hidden world of micro-clues

In the world of the crime scene investigator, minuscule samples can be massive clues

PAINT

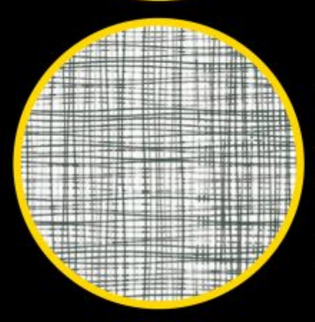
Flakes of paint can be examined under a microscope to establish the make, age and usage. This can be used to prove a particular car was involved in a crash.

GLASS

Glass shards can show whether a window was broken from the inside or the outside. Any cracks in the window can help to establish how fast an object was travelling when it hit the glass.

HAIR

Hairs, seen with the naked eye and gathered using tweezers, can be used to prove the presence of a suspect and their movements during a crime.



FIBRES

Fibres can be used to prove a suspect or an object was present at the scene. This is known as evidence of association and is gathered using sticky tape.

DNA

Both the victim and the perpetrator of a crime are likely to leave behind biological traces from their sweat, saliva, hair, blood or even dandruff. These can link criminals and victims to a crime scene.

DIGITAL FOOTPRINT

Digital forensics looks at the recovery and analysis of material stored in devices, such as computers and mobile phones, in order to gather evidence or confirm alibis, using equipment like WindowsSCOPE and XRY.

"Criminals have invented ingenious methods of avoiding capture, but forensic scientists have matched them"

CRIME SCENE DO NOT CROSS

Walking the crime scene

Processing the scene and gathering all the forensic evidence is a vital role in today's police investigations

Photographers
CSI photographers take pictures of all the evidence at the crime scene, before it is taken away for further analysis.

The victim
Officers take note of the victim's position, and any fibres, fingerprints or DNA evidence is carefully removed.

Crime scene tape
Yellow tape is placed across the door, in order to secure the entrance and preserve the scene while evidence is being collected.

Broken window
Cracks in glass show whether the gun was fired from inside or outside the room.

Glass fragments
Each glass shard creates a unique shape, which is used to prove what was broken and where it came from.

Bloodstains
Bloodstains show the movements of the killer and the victim as they moved around the room, touching furniture, walls and the floor.

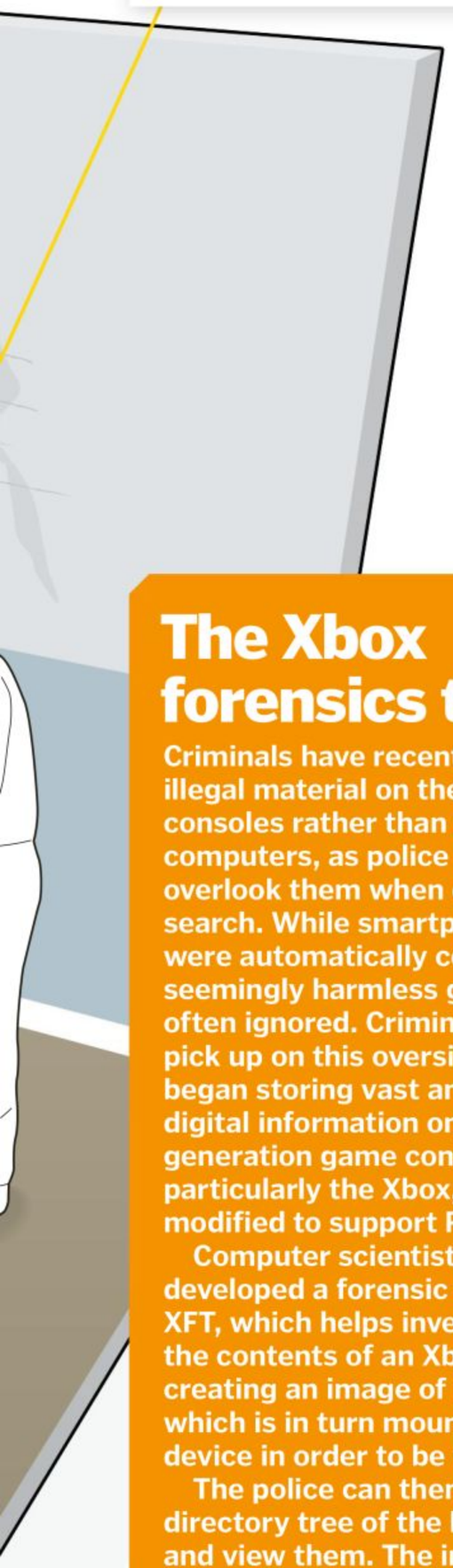
The weapon
The weapon is dusted for fingerprints and examined, to check for any distinguishing marks, such as make or serial number.

Spent cartridges
Bullets and spent cartridges are examined by the ballistics specialists, who identify the gun used.

Crime scene investigators catalogue bags of evidence, before they are removed for further analysis

Investigators dust for fingerprints on a spent bullet casing

Trigonometric calculations
Officers identify the trajectory and angle of impact by recreating the path of the bullets with string. The position of the killer is also established.



The silent witness

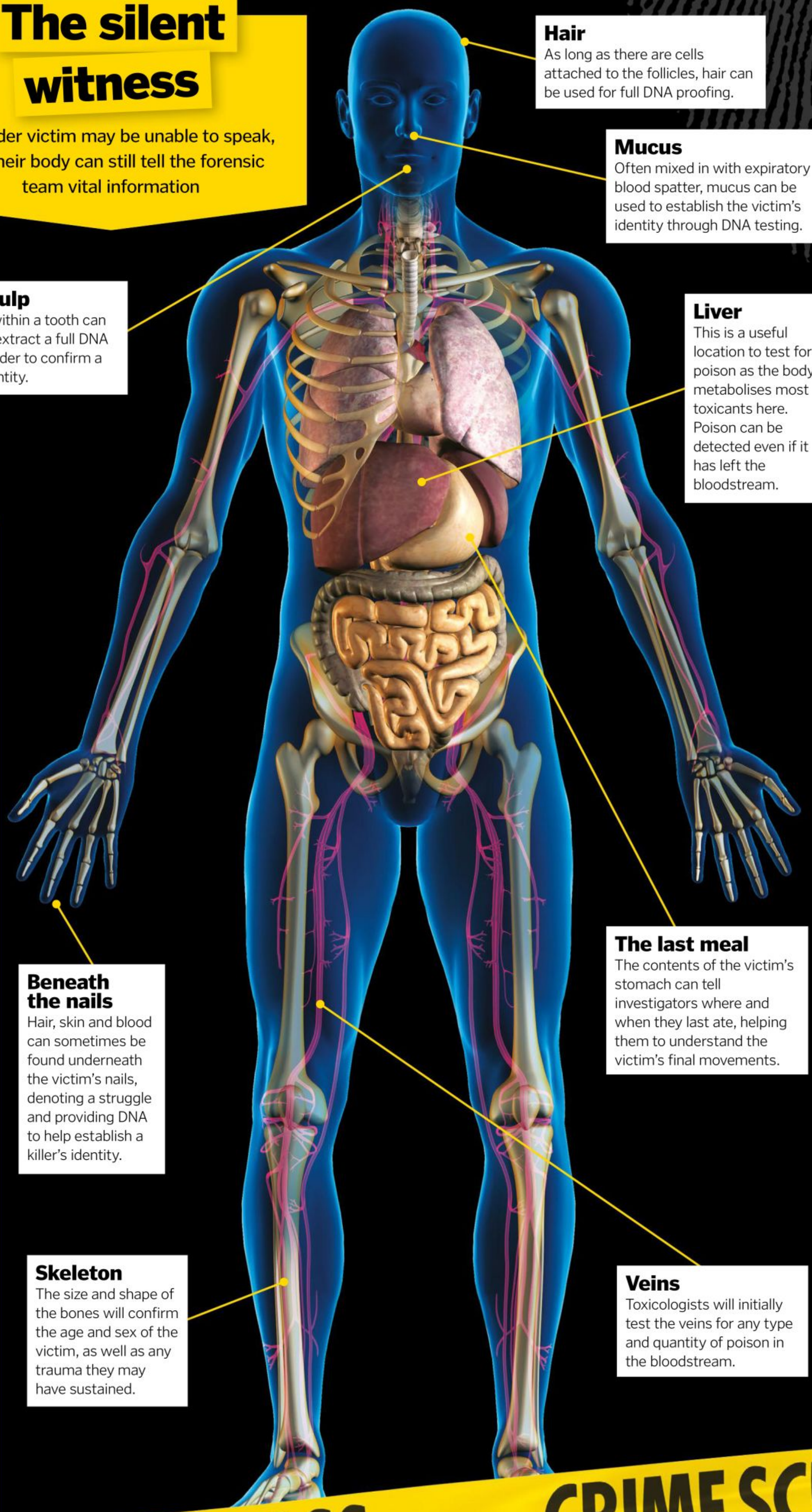
A murder victim may be unable to speak, but their body can still tell the forensic team vital information

Hair
As long as there are cells attached to the follicles, hair can be used for full DNA proofing.

Mucus
Often mixed in with expiratory blood spatter, mucus can be used to establish the victim's identity through DNA testing.

Tooth pulp
Pulp from within a tooth can be used to extract a full DNA profile, in order to confirm a victim's identity.

Liver
This is a useful location to test for poison as the body metabolises most toxicants here. Poison can be detected even if it has left the bloodstream.



Beneath the nails
Hair, skin and blood can sometimes be found underneath the victim's nails, denoting a struggle and providing DNA to help establish a killer's identity.

The last meal
The contents of the victim's stomach can tell investigators where and when they last ate, helping them to understand the victim's final movements.

Skeleton
The size and shape of the bones will confirm the age and sex of the victim, as well as any trauma they may have sustained.

Veins
Toxicologists will initially test the veins for any type and quantity of poison in the bloodstream.

© Getty

The Xbox forensics toolkit

Criminals have recently started hiding illegal material on their Xbox gaming consoles rather than on their laptops and computers, as police previously tended to overlook them when carrying out a search. While smartphones and PDAs were automatically confiscated, the seemingly harmless gaming devices were often ignored. Criminals were quick to pick up on this oversight, and many began storing vast amounts of illegal digital information on any sixth-generation game console or later – particularly the Xbox, which can be easily modified to support PC-like functions.

Computer scientist David Collins developed a forensic toolkit, known as XFT, which helps investigators to reveal the contents of an Xbox hard drive by creating an image of its FATX file system, which is in turn mounted onto another device in order to be viewed.

The police can then look through the directory tree of the hard drive, open files and view them. The investigation can be recorded onto XFT so that it can be shown during a trial, thereby limiting the chance of evidence-tampering and falsifying. It also makes things easier for a non-scientific jury to understand.

© Getty

Fun and video games or a hiding place for criminal data?

CRIME SCENE DO NOT CROSS CRIME SCENE

CRIME SCENE DO NOT CROSS

Call in the handwriting experts

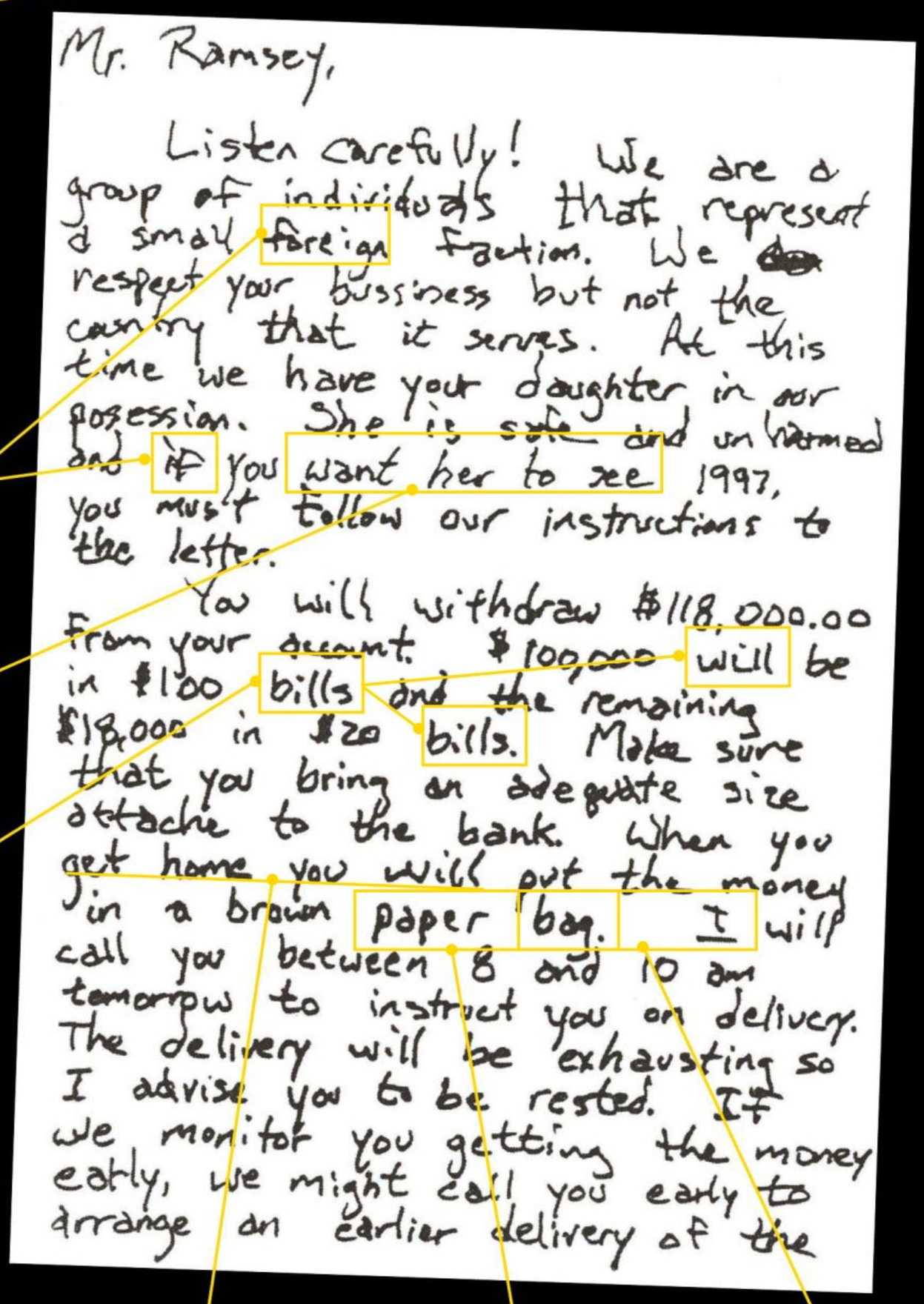
Was this infamous letter penned by a little girl's alleged kidnapper, or her own mother?

Handwriting experts will be called in if investigators wish to know whether two pieces of writing have been written by the same person. There are three distinct types of writing: block capitals, cursive (where the letters are joined up) or script (where letters are unjoined).

The expert will compare similar writing types in order to establish whether the same person wrote both pieces, but attempting to compare different writing types is almost impossible and makes for unreliable evidence during a trial.

The longer the piece of writing, the easier it is for the expert to make a confident match and to ascertain whether the creator of the letter is left or right-handed. In some cases, the expert may wish to use a low-power stereoscopic microscope in order to analyse the characteristics of each individual letter and the direction of the pen strokes.

"There are three distinct types of writing"



Mr. Ramsey,

Listen carefully! We are a group of individuals that represent a small foreign faction. We respect your bussiness but not the country that it serves. At this time we have your daughter in our posession. She is safe and unharmed and if you want her to see 1997, you must follow our instructions to the letter.

You will withdraw $118,000.00 From your account. $100,000 will be in $100 bills and the remaining $18,000 in $20 bills. Make sure that you bring an adequate size attache to the bank. When you get home you will put the money in a brown paper bag. I will call you between 8 and 10 am tomorrow to instruct you on delivery. The delivery will be exhausting so I advise you to be rested. If we monitor you getting the money early, we might call you early to arrange an earlier delivery of the

Letter formation: f
The f is distinctive, as the top often curves down, almost touching the cross.

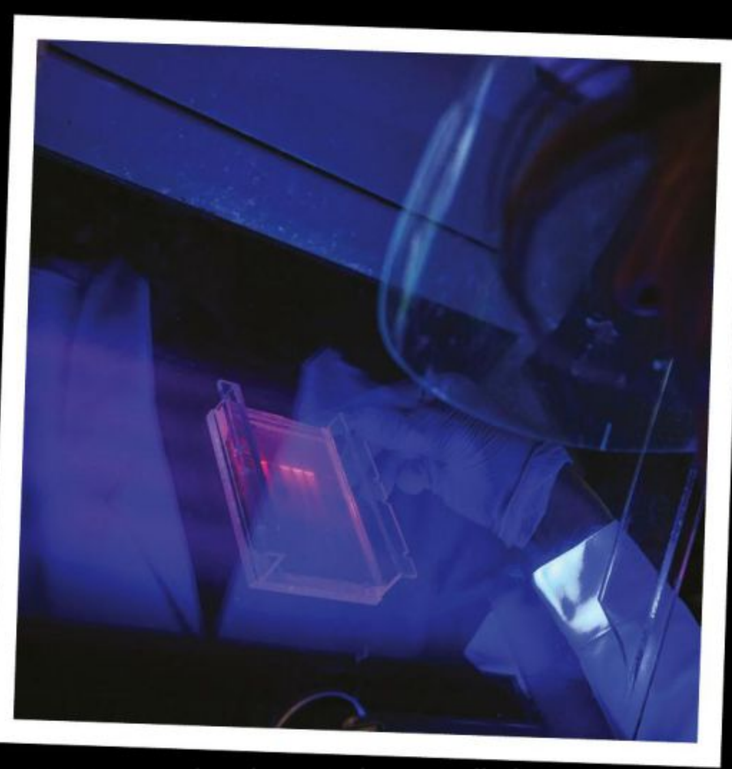
Slant of letters
Most letters slant forward, veering towards the right.

Letter formation: ll
Double l's are distinctly bent in the middle. Such a stylised form of writing is useful when establishing the author.

Baseline
Baseline looks at the shape of the sentence. It is very unusual to have such a straight sentence line this far into a letter.

Script writing
The majority of the letter is written in script, or 'unjoined' letters, suggesting that it has been carefully printed rather than scribbled.

Word spacing
Note the extended gap after a full stop before the following sentence begins. This is unusually long.



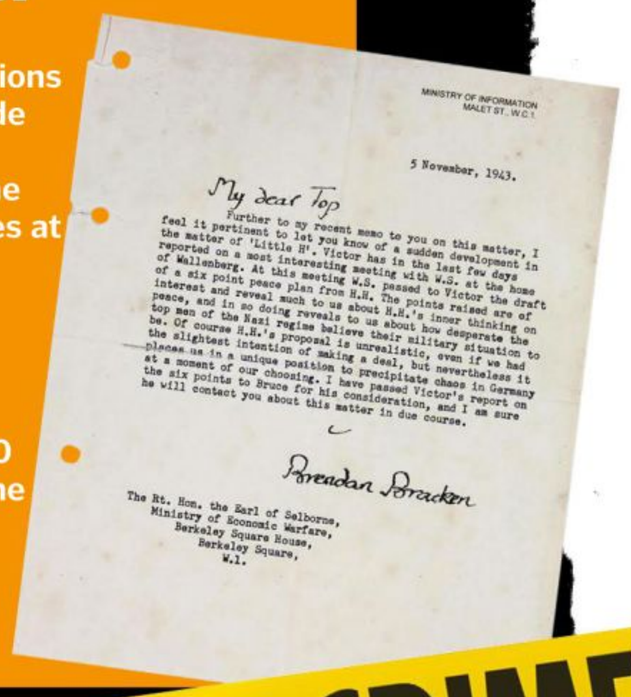
© Getty

DNA is tested under strictly controlled conditions, including specialist lighting

Himmler's 'murder' hoax letter

In 2005, a book was published entitled *Himmler's Secret War,* written by the historian Martin Allen. Within its pages, allegations were raised that Himmler, the SS leader, did not commit suicide and was in fact murdered with the knowledge of Winston Churchill and his ministers. What made it so believable was the reference to various documents stored in the National Archives at Kew. Surely the Public Records Office guaranteed validity?

Suspicions were quickly raised. The letters were gathered together and put in the capable hands of Dr Audrey Giles, a forensic documents specialist, who quickly discovered some serious flaws. The letterheads had been created on a high-resolution laser printer, which had not been developed until 50 years after the date written on the document. Signatures of the minister Brendan Bracken had also been traced over pencil marks. Finally, two letters from separate government offices had been written using the same typewriter. The documents were proven to be forgeries.



MINISTRY OF INFORMATION
MALET ST., W.C.1.

5 November, 1943.

My dear Top

Further to my recent memo to you on this matter, I feel it pertinent to let you know of a sudden development in the matter of 'Little H'. Victor has in the last few days reported on a most interesting meeting with W.S. at the home of Wallenberg. At this meeting W.S. passed to Victor the draft of a six point peace plan from H.H. The points raised are of interest and reveal much to us about how desperate the peace, and in so doing reveals to us about H.H.'s inner thinking on top men of the Nazi regime believe their military situation to be. Of course H.H.'s proposal is unrealistic, even if we had the slightest intention of making a deal, but nevertheless it places us in a unique position to precipitate chaos in Germany at a moment of our choosing. I have passed Victor's report on the six points to Bruce for his consideration, and I am sure he will contact you about this matter in due course.

Brendan Bracken

The Rt. Hon. the Earl of Selborne,
Ministry of Economic Warfare,
Berkeley Square House,
Berkeley Square,
W.1.

CRIME SCENE DO NOT CROSS

How bullet holes are investigated

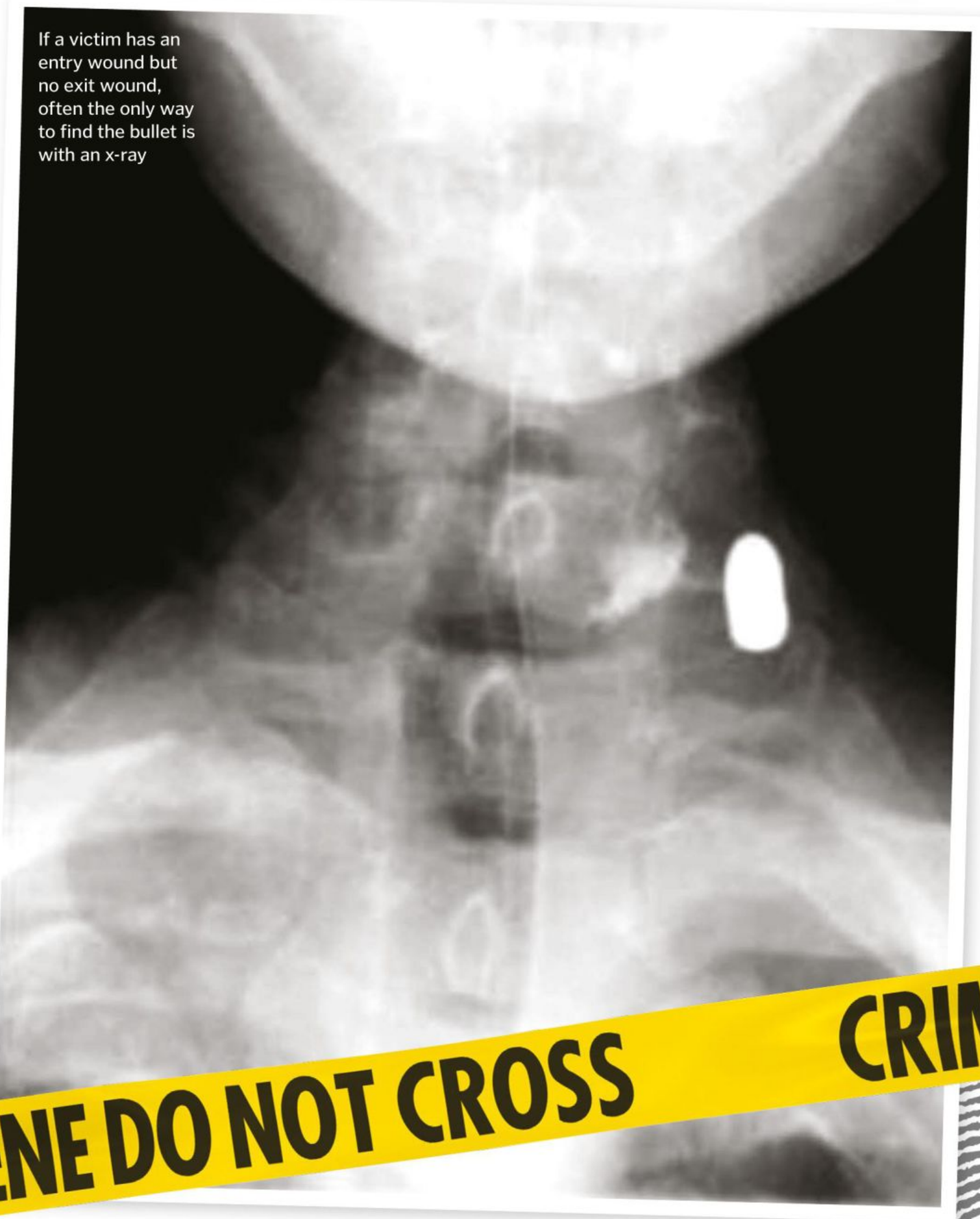
Processing the scene and gathering all the forensic evidence is a vital role in today's police investigations

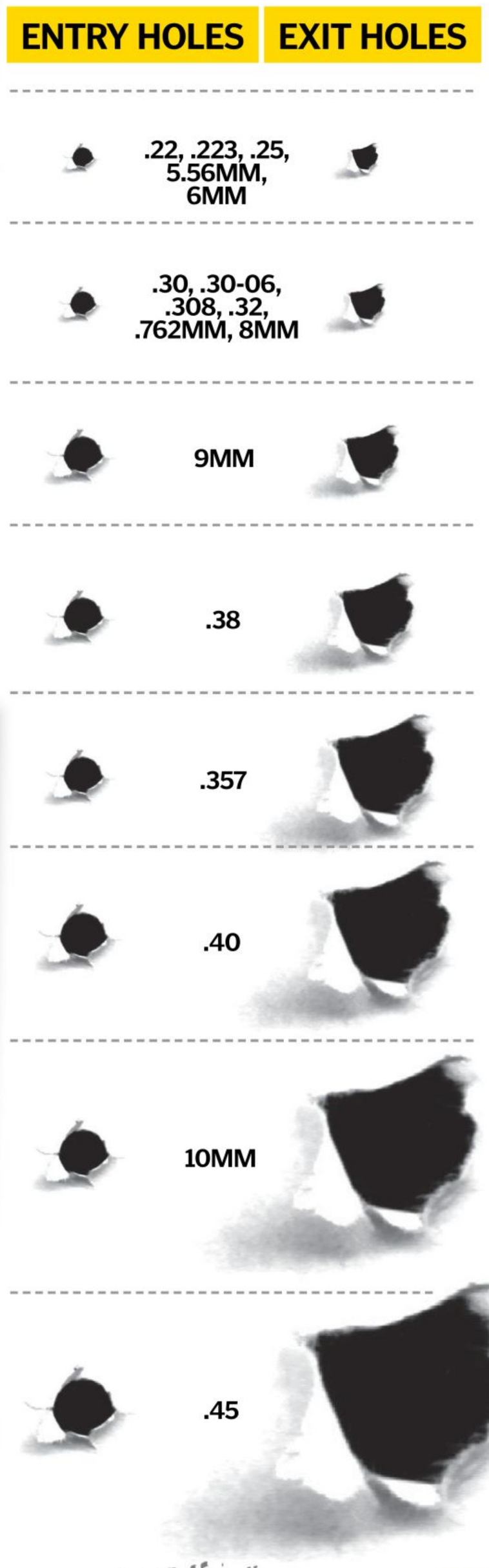
© Getty

Evidence regarding a bullet casing is given by a ballistics expert during a court trial

The study of bullets is called ballistics, and it is amazing how much information one bullet can offer. Internal ballistics looks at what happens to the projectile as it leaves the gun. Grooves inside the barrel scratch the bullet, leaving marks known as striations, enabling the specialist to identify the exact gun used during the crime. If the bullet is never recovered, the investigator can obtain the make and number of the weapon from any shell casings discovered at the scene, as marks are also made on casings when they are forced back against the gun breech.

Terminal ballistics is the study of what happens when the bullet makes contact with its target. Entry holes tend to be neat and relatively small compared to the larger exit holes, which are often ragged and untidy. The size and shape of the wound can tell the investigator vital clues about the position of the gunman.


If a victim has an entry wound but no exit wound, often the only way to find the bullet is with an x-ray



Learn more

Go to page 95 to discover how to dust for fingerprints in your own home.

HOW FLYING CARS WORK

Airborne automobiles are finally starting to arrive – and they're soaring higher than ever

Words by **Mike Jennings**

We've all been promised loads of cool stuff when it comes to the future of technology, but it's not often that they actually live up to the hype. When it comes to flying cars, though, it's looking like the future really will arrive sooner than anyone thinks. Exciting companies are working on real flying cars – and some are planning entire racing leagues, using vehicles with power-to-weight ratios that match jet fighters and beat F1 cars.

Toyota and Airbus are investigating flying cars, Google's co-founders have already invested, and Uber is preparing its own fleet of flying taxis. In total, there are more than 100 flying car projects in development that we know about.

The world of airborne automobiles has come a long way recently – from ambitious, vague prototypes to vehicles that can be pre-ordered, delivered and driven. So, what's changed? Well, for starters, money talks. More people have invested more cash in order to get these things off the ground – quite literally. Beyond that, technology talks too. Electric batteries are developing at speed, which means the power packs inside flying cars can last for longer. In addition, lighter metal alloys and more powerful engines mean that flying cars aren't just getting off the ground, they're doing it with more speed and agility than ever.

There's another benefit these vehicles offer: comfort. Many of today's most exciting flying cars aren't just impressive machines, they're luxurious too. Take AeroMobil, which is a Slovakian company working on its fourth generation of flying vehicle. The AeroMobil's cockpit looks like something from the bleeding edge of conventional motoring, featuring sleek seats, next-generation controls and touchscreens everywhere. It's apt that AeroMobil showed off its fourth-generation flying car at the Goodwood Festival of Speed's Future Lab, alongside the Alauda Airspeeder flying racer and loads of other incredible hardware.

So with this much investment and drive to develop these futuristic machines, will flying cars really be the next big thing, or are they going to struggle to get off the ground?

The AeroMobil 5.0 VTOL looks futuristic and is packed with technology to make flying and driving easier

The Airspeeder will form the basis of an airborne racing league in exotic locations

A formula for the future?

Not every company is building flying cars for consumers – some want to race instead. The leading light here is an Australian company called Alauda Racing. Its Airspeeder machine could revolutionise racing in the same way that aerodynamics did in F1. The company is building its fourth generation of Airspeeder craft. It hopes to start racing by 2020 and is already using its second-generation device for demonstrations.

So what will an Airspeeder race look like? Let's start with the craft itself. It looks like a sleeker version of an F1 cockpit, but instead of wheels on each corner it has a 150-centimetre propeller. Each machine has a ferocious top speed of 200kph.

Alauda aims to race its crafts at existing, historically important circuits, as well as in more exotic locations, like deserts and tropical seascapes. If the company can pull it off, Alauda's Airspeeder series could compete with F1 and Formula E. But it's a big ask.

5 FACTS ABOUT THE NEXT-GEN AEROMOBIL

1 VTOL
VTOL is an acronym of vertical take-off and landing, and it means that vehicles launch straight upwards. The AeroMobil 4.0 doesn't do this, but it's coming to AeroMobil 5.0.

2 Sitting comfortably?
The AeroMobil 4.0 has enough room for two people – so, like many sports cars, it's not practical. The 5.0 craft is going to seat four people, so it's far more versatile and practical.

3 Future of flight
The wings will be improved on the AeroMobil 5.0 – they'll be safer, more efficient and will make the flight experience smoother and more comfortable.

4 Get suspended
The rest of the technology will be improved too: AeroMobil 5.0 will have adaptive suspension for smooth landings, and a bigger battery, which means a greater range for travelling.

5 A personal experience
The AeroMobil 5.0's four occupants will have a personalised experience, with advanced communications and media throughout the cockpit – similar to the entertainment you get on a plane, but better.

Flying into the future

The AeroMobil 4.0 STOL is a flying car that'll be available in 2020. What makes it tick?

It may be a plane, but AeroMobil's interiors are comfortable, familiar and easy to navigate

Spread your wings
The AeroMobil has a huge 8.8-metre wingspan. But if you want to drive, the wings fold neatly into the fuselage.

Suspended animation
The rear combines car suspension and aircraft technology to deliver control in road and air modes, and the propeller folds away when not needed.

Interior design
Two comfy seats, loads of touchscreens and stylish carbon fibre make for a cockpit that's great on the road or in the air.

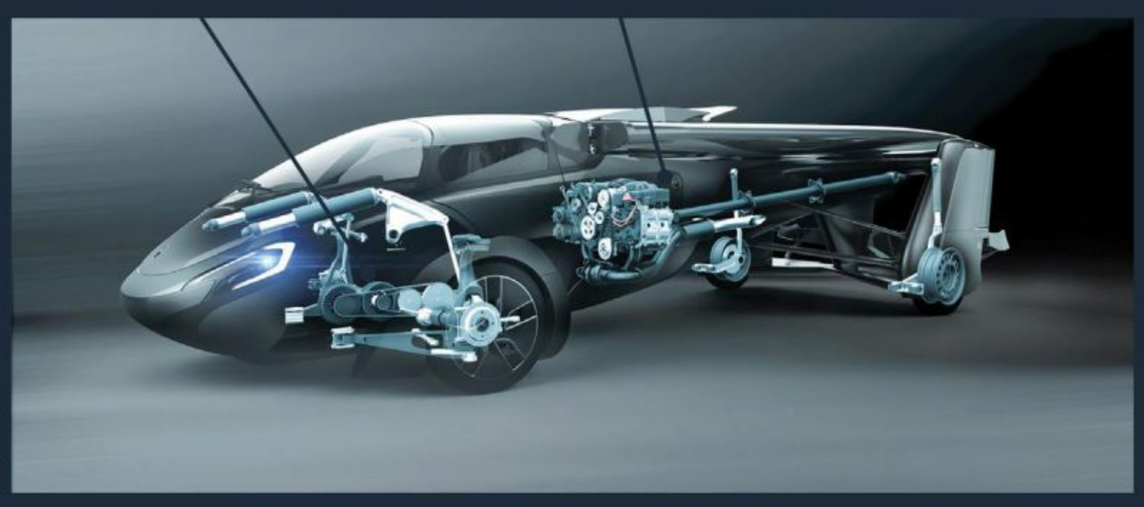
Wheely good
The AeroMobil has lightweight wheels that are strong enough to handle road use, as well as landings on tarmac, concrete or grass.

Feel the power
On the road, the AeroMobil uses a hybrid system – an engine at the back and two electric motors at the front axle.

To infinity and beyond
Turbocharging helps the AeroMobil's lightweight engine to deliver 300bhp when flying, and 110bhp on the road.

Carbon strength
This vehicle is full of carbon fibre – perfect for weight reduction. Despite that, the cockpit is surrounded with a stable structure to keep pilots safe.

Flying ahead
The rear section is made entirely from carbon fibre. It's strong enough for the rear suspension and propeller assembly, while remaining lightweight.



© Aeromobil

Falling gracefully?

There was a live demonstration of Alauda's Airspeeder at the Goodwood Festival of Speed Future Lab. The Airspeeder was immediately impressive: it rose sharply, quickly gained speed and proved manoeuvrable and acrobatic as it soared through the air. It's certainly exciting enough to be used for racing, and this was the older Mk2 craft – so the Mk4 will doubtless be faster and more agile.

The Airspeeder Mk2 we saw was flown by remote control. That's probably a good thing, because it malfunctioned, crashing into a nearby field. Alauda's engineers ensured us that the crash wouldn't have happened if the Mk2 was piloted and were quick to remind us that the Mk2 is an older, prototype craft.

So there's reason to be cautiously optimistic. The Mk4 has been through a lot more development, and having pilots on-board will always deliver better control.

The Airspeeder Mk2 is fast, nimble and loud – but not always stable

© Mike Jennings

Q&A Matt Pearson: Alauda Racing CEO and founder

Matt Pearson is the South African-born entrepreneur behind the stunning, ambitious Airspeeder project

Why did you choose to develop flying cars? And why do you want to race them?
Since I was 15 I've wanted to build a flying car. It's only in the last few years that the technology has got to the point where it's possible. We decided on racing because we needed a catalyst. We looked at the early days of aviation and [motor-powered cars] and realised that racing turbo-charged those industries – it was Henry Ford who said that "auto racing began five minutes after the second car was built"! We could have made a flying taxi, but racing moves technology forward.

What will your racing series look like when it launches in 2020?
In terms of environments, we fly in the air, so we don't need circuits. We're looking at more exotic locations, with a small audience but with everything streamed online. At first we'll have showcase events at racing circuits, head-to-head races, but we want to have at least five teams with two pilots each. We'll be using our Mk4 Airspeeder to race.

It's going to be an iterative platform – we can improve it and build on it. We can also develop it for customers. It'll start out like a hypercar and eventually become a more affordable 'run of the mill flying car', whatever that will mean!

At Goodwood your Mk2 Airspeeder had a somewhat bumpy landing. Were you worried?
That's the nature of testing, and it wouldn't have happened if the craft had a pilot. But we're aware of this and we have loads of redundancies in hardware and software to reduce the chances of similar incidents. We've done several demonstrations, and they're always a learning experience!

What are the biggest challenges and successes you've faced with the Airspeeder project?
One of the biggest successes is our team. It's full of people who are willing to sleep for an hour a night in order to create something that will change the world. But we also need more people, and finding them is a challenge. In terms of challenges for the Airspeeder, it's technology. The chemistry inside batteries is getting better, so we need to stay on top of that.


© Matt Pearson's twitter

Matt Pearson is the founder and CEO of Alauda Racing, and also works with startups and space rockets

© Mike Jennings

The gleaming Alauda Airspeeder Mk4 should start to race in 2020 – with real pilots

JOURNEY TO THE BOTTOM OF THE OCEAN

Engineer John Ramsay talks us through designing and piloting the submersible that recently dived nearly 11,000 metres into the world's deepest oceanic trench

The Five Deeps Expedition is an ambitious project that aims to visit the deepest sites in each of the world's five oceans, with the goal of developing new technologies (including the high-tech submersible Limiting Factor), exploring and mapping the ocean floor and discovering new deep-sea species and ecosystems. It's the brainchild of multimillionaire explorer Victor Vescovo – and it's been a wildly successful expedition so far, having dived to four of these five trenches. The final trench, the Arctic Ocean's Molloy Deep, is in the team's sights for a September dive.

John Ramsay is the engineer who led the design team for Limiting Factor, a submersible rated to survive ocean pressure when as deep as 14 kilometres, and whose extreme capabilities meant that everything had to be designed and built from scratch.

You've never been that deep before – what was is like?

No. That's the thing: Victor's [explorer and sub pilot Victor Vescovo] dive was the third time it's ever been done in history. It's a very surreal experience because you spend 3.5 hours just descending. The descent is so fast that you're into pitch black extremely quickly, after a couple of minutes really. Then when the bottom emerges the lights on the sub are so powerful that it's really quite striking as it appears. What we were looking at was hard-packed sediment, I would describe it as.

What kind of technology did you need for Limiting Factor to survive these depths?

Everything was completely custom-made for it. The problem with diving to 11,000 metres is that there's no off-the-shelf technology that you can buy... [there's nothing beyond] 6,000 metre-rated equipment, and even that's getting quite rare. So everything was developed [from scratch] – from lighting and batteries to the pressure hull. The buoyancy foam was all custom-made. The whole vehicle was full of one-off pieces of equipment that we had to develop, test, make, certify and approve for use on the vehicle.

How much testing was there prior to the Challenger Deep dive?

Every bit of kit was tested. The pressure hull went to Russia to be tested at the Krylov State Research Centre, to 14,000 metres. We built our own giant pressure test – two different chambers capable of running to 14,000 metres. So any component on the vehicle was pre-tested. All of the electrical systems we pressurised to 14,000 metres, and then we made sure the components were behaving in exactly the same way as we predicted they should.

So we knew we had the safety aspect covered, but really the only way we could do the final testing is to take the vehicle progressively deeper on the first few missions, to sort out all the things like how we get it in and out of the water, which is really difficult.

There was special technology on the research ship and host platform, the DSSV Pressure Drop, too.

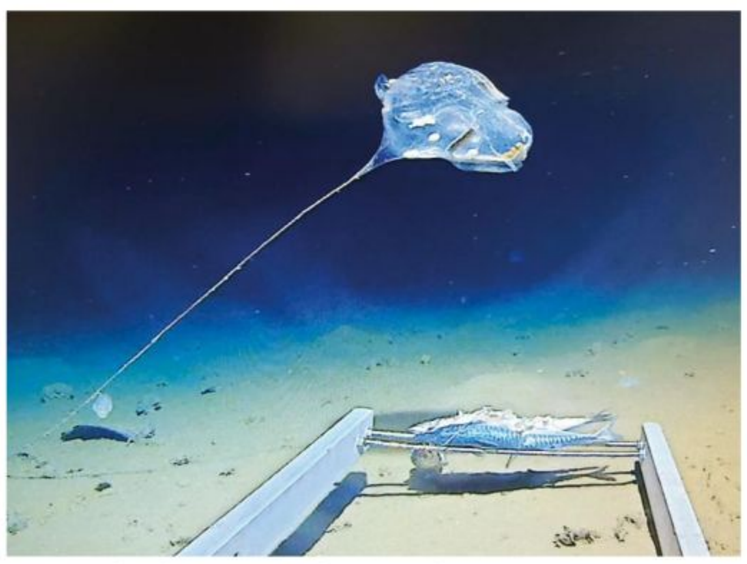
There was exceptional sonar – the most capable and accurate multi-beam sonar ever put onto a privately owned vessel. That's what allows us to go and scan the sea bed and map it, to get these incredibly accurate locations where we can dive with the sub. Then of course there's cradles and various bits of launch and recovery equipment that get the sub in and out of the water. So it's not just the sub, we've got retracting hangars and all sorts of things like that.

As chief designer, was it a bit nerve-wracking when Limiting Factor made its first descent?

Well... not really. I was more worried that something annoying was going to happen and we would have to abort the dive. It's so covered in safety systems and so tested that you don't really have much concern that all of a sudden something's going to happen that could jeopardise anyone's safety. You're sat there hoping that all the systems are going to work as they're supposed to at each increasing depth. That's it... the safety systems on it are just unbelievable really, how many layers of contingency we've got: from ejectable weights, thrusters that can eject if they get snagged, batteries that can be released, self-releasing systems if the pilot doesn't input anything... all sorts of stuff like that.

So nothing like an Apollo 13 moment, an oxygen tank exploding or anything like that is likely to occur then?

[Laughs] I think on Apollo 13 they purge the entire cabin of oxygen, and that's something we specifically don't do!



During the dives, several new and curious species were discovered, including this alien-looking jellyfish

Inside the submersible

One of the heroes in this story is Triton Submarines' DSV Limiting Factor, the world's deepest-diving operational submarine, which took pilot Victor Vescovo to a depth of 10,928 metres – the deepest dive ever and much deeper than mount Everest is high. It is packed with safety features that keep its two-crew capacity safe, including a 90mm-thick titanium pressure hull and 96 hours of emergency life support on top of the 16-hour standard dive-time. Three acrylic viewports give the pilot unobstructed forward and downward views of the ocean floor, and 4K digital cameras allow high-resolution imaging of interesting deep-sea life and geological features.

© Triton Subs

Limiting Factor is tested to operate in depths of up to 14,000 metres

John Ramsay is lead designer on the Five Deeps Expedition, responsible for the concept behind the submersible Limiting Factor, and much of the on-board technology

© Nick Verola

John Ramsay prepares to take a dive nearly 11,000 metres into the Challenger Deep, after Victor Vescovo completed his record-breaking dive

© Nick Verola

Is this expedition analogous to the Moon missions in terms of the dangers?
I'm not sure I'd put the risks at that level. There's never been an incident with loss of life or serious injury in a submersible – certainly not in this class of submersible… One great thing about a submersible is that it tends to want to float back to the surface, rather than slam down into the land. Which is a reassuring feature!

The five deeps include trenches in the Arctic and Indian oceans. Are these different environments that require different equipment?
To be honest, not really. There's such a tiny difference in water temperatures and that's pretty much the only factor that changes with these depths. Everything else is much the same, it's just the depth and how much ballast you put on the sub to get down there.

"One great thing about a submersible is that it tends to want to float back to the surface"

What have the highlights been for you so far with each of the dives?
That each of the dives, really, has been a complete success. While we haven't had the optimum weather for all of them, getting to Challenger Deep and having fantastic conditions, diving four times there then moving to Sirena Deep and doing the fifth dive… it was just incredible to see the sub going down, being lifted up, put on charge, then ready to go again. That's an amazing achievement for everyone and proved how capable Limiting Factor was – considering the two other vehicles went down once, came back and were then shelved.

Were you on the design team for the expedition from day one?
Yes. I don't go out on all of the expeditions, but I've been heavily involved in the design of the vehicle from the very start: from producing the concept through to developing the hull; doing the ergonomics and working out whether it's going to float; whether it will go down and dive and manoeuvre the way it's supposed to; and all of the deck-side handling equipment, working with Triton's engineers to make sure all of that's going to work. It's been a massive undertaking for what's quite a small company, and it's been quite a challenge. Some things were a lot harder than we expected, but the involvement is massive – a huge commitment from everyone.

How long in the making has Limiting Factor been?
I think it's been three years from meeting with Victor to having the sub on the vessel for its first dives… so not really that long. It was an initial design study that took six months, where we went through the process of making sure everything we thought we could do, we could do, making sure it's feasible and we weren't kidding ourselves about anything. I think it might have been just over two years, in fact.

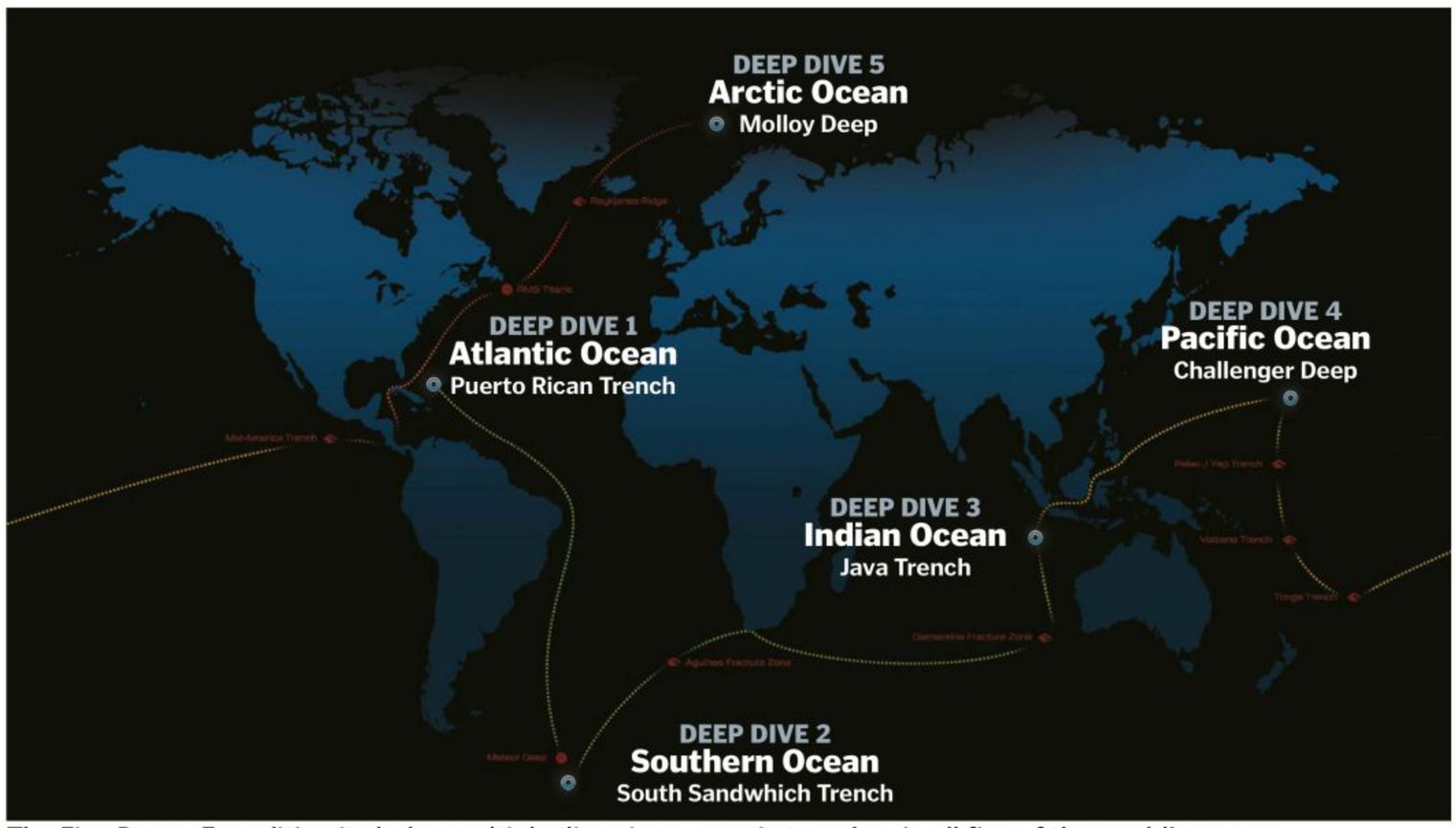
Going to the bottom of any ocean must be a dream job for you.
Yeah, it was an amazing thing. To have designed the vehicle and then to climb into it… during the dive I was not just taking in the experience but was constantly analysing whether everything that I did and every decision I'd made was panning out in the way the vehicle's being used, whether it was as comfortable as I'd hoped it would be, as stable, fast, manoeuvrable – that was an exciting part of the mission: not just going down to the bottom of the ocean but doing all that stuff as we went. It's an extra element of excitement for the engineer.

Molloy Deep is the final trench you're visiting in September. What challenges are you anticipating there?
Weather. I'm assuming it's going to be cold and shocking conditions, so getting the sub in and out of the water safely is going to be the fun part. That's why it's timed for September, when the sea is calmest. But it's a baby compared to the others! It's about half the depth of the Challenger Deep. Depth is never the issue though, it's always getting the thing in and out of the water. It's quite funny actually: we cycle the acrylic viewports in a pressure chamber in Barcelona… but it's such a deep-diving sub that it's not considered a pressure cycle until the dive exceeds 5,000 metres. So the Molloy deep is only just going to be considered a dive for this sub – pretty impressive considering this is almost as deep as the limit of the next deepest-diving submersible.

Where do you go, once you've explored the deepest points in the world's oceans?
Oh, there's plenty more. One thing's for sure, when we've been out with the scientists there's no shortage of places to explore. The number of suggested dives is immense. We've explored such a tiny fraction of an unknown world, and each time you go down you see only a tiny speck of a tiny point. It's so difficult to fully explore the ocean, there are going to be an huge number of geological things, bacteria, different creatures that we know so little about. The hope is that this vehicle can help the science community get a better understanding of what's going on.

What did they find during the dives?

Before Ramsay took controls of Limiting Factor, pilot Victor Vescovo made the record-breaking descent to the deepest parts of four oceanic trenches. Exploring the bottom, they discovered some amazing and surprising things. Among the many species Vescovo encountered, he saw a spoon worm at 7,000 metres and a pink snailfish at 8,000 metres. The Five Deeps Expedition team also think they discovered four new species of amphipods, a kind of prawn. To the team's dismay, though, they also discovered a plastic bag and sweet wrappers on the sea bed, evidence that even the most extreme places on the planet are susceptible to plastic pollution.



The Five Deeps Expedition includes multiple dives into oceanic trenches in all five of the world's oceans

FIVE DEEPS EXPEDITION

How far down did each dive in Limiting Factor go?

0m
1,000m
2,000m
3,000m
4,000m
5,000m
6,000m
7,000m
8,000m
9,000m
10,000m
11,000m

Puerto Rico Trench
Location:
Atlantic Ocean
Depth:
8,376m
Date:
21 Dec 2018

South Sandwich Trench
Location:
Southern Ocean
Depth:
7,434m
Date:
4 Feb 2019

Java Trench
Location:
Indian Ocean
Depth:
7,192m
Date:
16 Apr 2019

Challenger Deep
Location:
Pacific Ocean
Depth:
10,928m
Date:
28 Apr 2019

Molloy Deep
Location:
Arctic Ocean
Depth:
5,669m
Date:
Sep 2019

Mount Everest
Height:
8,848m

The French submersible Archimede explored this trench to a depth of 8,300 metres in 1964. The Five Deeps Expedition ship, DSSV Pressure Drop, used its high-tech sonar system to pinpoint the deepest part of the trench, allowing Victor to beat this record by 76 metres. The trench lies north of Puerto Rico and marks the divide between the North American and Caribbean tectonic plates.

The South Sandwich Trench lies around 100 kilometres east of the South Sandwich Islands, not far from Antarctica in the chilly Southern Ocean. It is the only place on Earth with a hadal zone (deepest region of the ocean) that has sub-zero temperatures. As a result of DSSV Pressure Drop's sonar survey, the location of Meteor Deep, previously thought to be the deepest part of the trench, was moved.

This 3,200-kilometre trench marks a subduction point where the Australian-Capricorn plates slip underneath the Eurasian plate. The Five Deeps Expedition was the first to visit the bottom, where they discovered new species including a sea squirt unlike anything observed before.

The submersible Trieste visited Challenger Deep's Western Pool in 1960 for its record-breaking dive. Deepsea Challenger made the dive to Eastern Pool in 2012, and Limiting Factor made its four dives, breaking the previous records, in April and May. The expedition also skipped across the Pacific to dive 10,823 metres into the planet's second deepest point, in the Tonga Trench.

The expedition's final dive location is in the cold and stormy – but relatively shallow – waters of the Arctic. Molloy Deep is found between the island of Svalbard and Greenland, in the Fram Strait. While the dive itself isn't expected to be more challenging than the previous dives, the inclement weather could cause launch and recovery problems.

THE LION KING

Why does Africa need the king of the jungle, and how has his kingdom changed over time?

Words by **Scott Dutfield**

Prowling across the African savannah, the 'king of the jungle' has gained a reputation as a fierce, formidable predator, not to be trifled with. As keen killers, lions have evolved to form social hunting packs called a pride. This feline squad is typically comprised of 14 members, but prides as large as 40 individuals have been reported.

This social structure is made up predominantly of females, with one of two males for reproduction and protection from other wandering males. Lionesses in a pride are typically related and spend their entire lives with their family, but for males reaching the age of three, the time comes to leave the pride and search for a new home.

Female members of a pride will remain with the same group for their entire lives

© Getty

As unrivalled predators, these food-chain-toppers work as a team to take down prey across the African plains. From agile antelopes to thunderous elephants, lions and lionesses bide their time, stalking within the savannah's tall grass before pouncing on their prey.

Lions play a vital role in the ecology of Africa's wildlife. Much more than charismatic attractions for onlooking tourists, lions help maintain the environment by managing those that cause it damage. Similar to any large carnivore, lions help to control the populations of many herbivore species, such as antelopes and zebras. These grass-grazing species have the potential to disturb the natural balance of an ecosystem by overgrazing. Therefore, apex predators – those at the top of the food chain – keep populations from growing too big by using them as a food source.

Lions tend to prey on the weakest and slowest in the herbivorous herd. The individuals falling behind are often suffering from natural disease. By removing these infected individuals, the herd is spared from the disease spreading, so lions can act as a defence against disease.

A world without large carnivores like the lion would also see the rise of a new food chain in which medium-sized predators take centre stage. Lions not only feed on these predators but also compete with them for food resources and territories. Should lions be removed from Africa then these predators, such as the wild dog, would be free to grow in numbers, and their prey species would decline. Unable to tackle African giants like buffalo and giraffes, the dynamics of the African ecosystem would completely change. This is known as 'mesopredator release' and can have a devastating effect on biodiversity.

As the linchpin of African wildlife, lions are often referred to as a keystone species, where without them some ecosystems would unravel. Unfortunately, over the past few decades these majestic mammals have become vulnerable to eradication in Africa. Having once stretched their paws across the entire continent, lions are now restricted to small pockets of territory across central and southern Africa. It is estimated that there are 23,000 to 39,000 individuals left in the wild.

The main threat to a lion pride is the use of land in their territories for farming and

Last of the lions

Although the majority of lions in the world live on the African continent, there is a small population clinging to the Asian continent. Once roaming across India, the Asiatic lion population is down to about 500 individuals, all of which inhabit the Gir National Park in Gujarat, western India. Having fluctuated in population size over recent decades, this group of lions has now begun to roam outside the park's borders.

After increasing numbers of lions have been found killed by humans, and fearing that this isolated population could be wiped out by a disease epidemic, a plan to translocate a few members to another park has been in the works since the 1990s. Their new home will be Kuno National Park in Madhya Pradesh, India – an area with around 750 square kilometres of space to repopulate. But that plan is still without a date for completion due to political differences between the Gujarat and Madhya Pradesh governments.

Male lion cubs will remain with the pride until they reach three years old

© Getty

urbanisation. Also, due to the overhunting of prey species, some lion prides have been starved into extinction or forced to migrate to other areas, where they might come across farmers who are trying to protect their livestock – their entire livelihood – and meet their demise at the end of a gun.

Alongside conflict with humans, use of industrial poisons across African countries has also been the cause of many lion deaths.

Although the lion has faced hardships over the years, there are ways in which the species can be kept from the brink of extinction. In order for lions to thrive in the wild they require a great deal of space to hunt. The typical territory of a pride is around 260 square kilometres. Therefore, in order to keep these big cats safe, national parks and sanctuaries have been set up across Africa to prevent illegal poaching. The areas are often solely protected by legal designation, but some countries actively secure borders with fencing or human patrols. Ruaha National Park in Tanzania holds around ten per cent of the world's remaining lion population. Working with local communities, the park's representatives have been developing lion-proof enclosures to house livestock, in order to reduce the retaliative killings of lions by farmers.

"To keep these big cats safe, national parks and sanctuaries have been set up across Africa"

Why do lions have manes?

It seems counterproductive to grow a thick patch of hair around your face when living beneath the scorching African sun. So why have male lions evolved to have these luscious locks, and do they even serve a purpose? It had previously been believed that the role of the lion's mane was to offer protection during a battle with another male. However, during a catfight, lions tend to strike the back of their opponent, which would make the mane redundant.

It wasn't until scientists turned their attention to the mane's powers of attraction that the truth was revealed. It turns out that female lions have a type, and that type is a male with a long, thick and dark mane. Much like the plumage of peacocks, a strong mane is a sign of strong genes that will be passed on to offspring.

A lion's mane typically starts to grow at the age of one

In pursuit of their prey, lions can reach speeds up to 80 kilometres per hour

5 FACTS ABOUT WHAT'S ON THE MENU

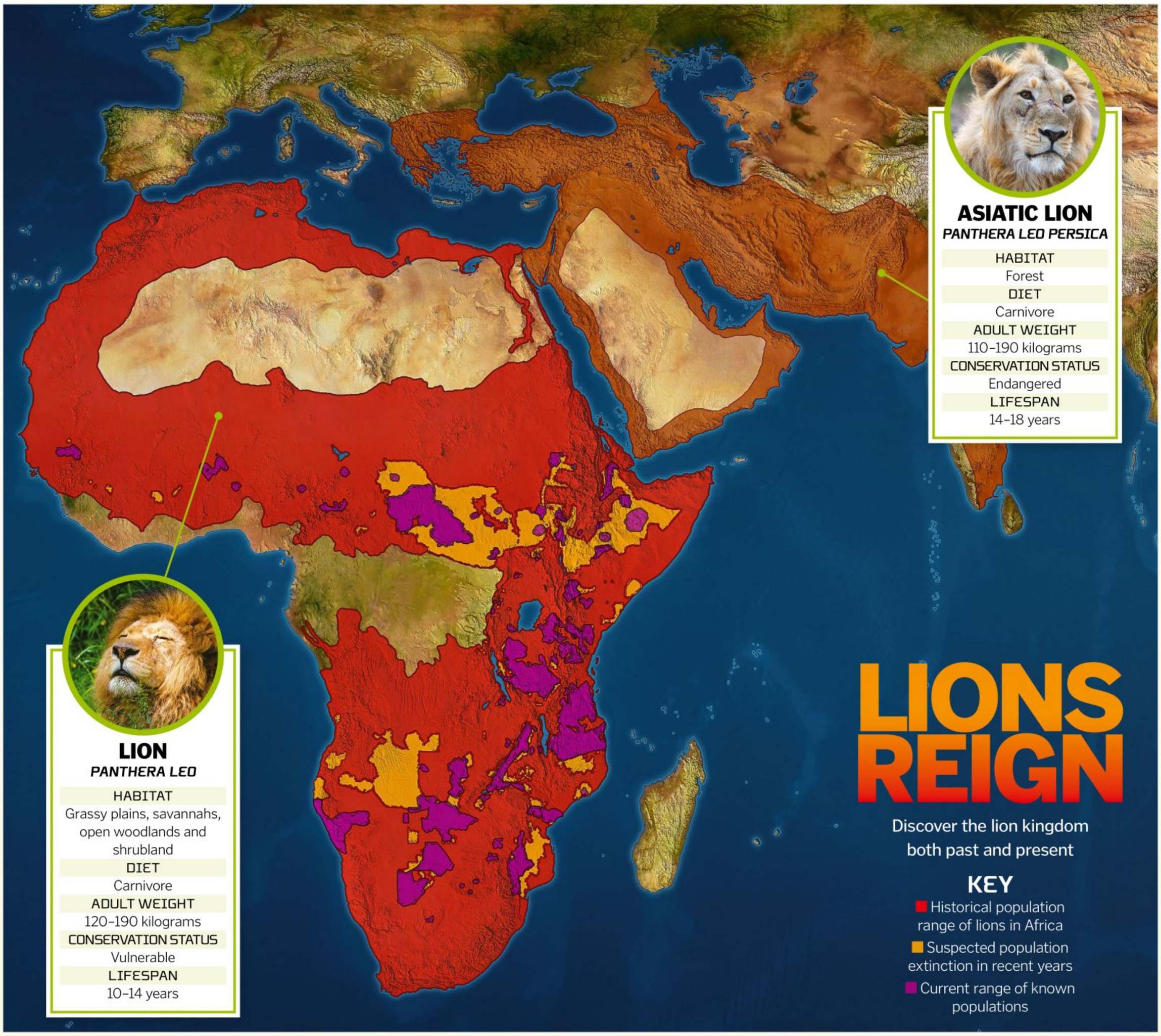
1 Wildebeest
Migrating around 1,600 kilometres every year, wildebeest cross through a lot of lion territories en route. Preferring open woodlands and grassy plains, these dark mammals are an easy spot for hunting lions.

2 Zebra
Although a tasty treat for a lion on the hunt, zebras travel in herds that when accosted by predators will often gang together to warn them away.

3 Antelope
Lions prey on many different species of antelope, such as the kudu. These nimble mammals require a quick sprint and precise strike to take down.

4 Hippopotamus
Trying to take down a hippopotamus is a team effort, with multiple members of a pride joining in the hunt. These powerful mammals can weigh up to four tons – more than enough to feed a whole family of lions.

5 Giraffe
These six-metre-tall giants are not a common meal for lions, but in the event an injured or juvenile giraffe crosses their path, the pride will quickly pounce.



SOUTHERN AFRICA (SOUTH OF THE ZAMBEZI RIVER)

▲ 417

CENTRAL AFRICA

▼ 102

EAST AFRICA

▼ 1,846

*Stats from a 2017 report by WildAid and Panthera for the #LetLionsLive campaign

WEST AFRICA

▼ 763

*Population change between 1993–2014

SOUTHERN AFRICA (NORTH OF THE ZAMBEZI RIVER)

▲ 857

Lions are not solely hunters and will often scavenge the remains of another's kill

Q&A Dr Claudio Sillero

How It Works speaks to the chief scientist at the Born Free Foundation and deputy director of the Wildlife Conservation Research Unit, about lion conservation and the future of these vital big cats

©Born Free

What are the biggest threats lions face? And how has the African population changed over the last few decades?

In the 1970s and 1980s, we were all talking about tigers going extinct and what we were going to do about it, and everyone assumed that African lions were relatively common and they were doing well. It wasn't until we started looking at the numbers, around 10-12 years ago, when the continent-wide estimate was produced and returned a figure of 22-23,000 lions, when we kind of assumed that there may be as many as 100,000 lions on the continent. So that was a really sobering find.

The main explanation across Africa is a change in land use, more of which has been set aside for agriculture. Clearly when you have a large human population and farmers there's no real room for dangerous animals, so they tend to get pushed away. There is also an increasing presence of livestock. With large herds of cattle being moved across Africa, mostly northern Africa, you're bound to have conflict. Cattle are readily available and quite stupid and easy to pick off by large carnivores. When lions start eating cattle people have an objection to that, and they might retaliate and kill the lions. So all-in-all we have less space for them and we have more antagonistic responses.

I think it's a combination of factors that resulted in them being less common than they once were. There is an additional concern of protected areas. Many of these parks are ill-staffed, lack proper financial support and basic management processes. They become known as paper parks – protected areas only in name. Without the necessary protection for wildlife living in them, people might come in and kill the prey species, such as antelope, that lions need to survive. That leads to large expanses of land with little food in them. So it gets hard for lions to occur at high densities.

Why should lions across the African continent be conserved?

Large carnivores, not just lions, play a very important role in ecosystems as a top predator, and in some cases become keystone species crucial to the function of the ecosystem, and if you were to remove them things would collapse or deteriorate.

A good example of this is with grey wolves in North America. In some landscapes where they go extinct, some herbivores such as deer become increasingly common, and that affects the dynamics of vegetation and forests, and the landscapes become more open and lose vegetation cover. When the wolves came back to a place such as Yellowstone, slowly some of those processes reverted to a more pristine state. You have a richer ecosystem when it's diverse in species and when there are large carnivores such as lions at the top.

Also, lions are beautiful and we care for them. They have an aesthetic and an ethical value. We should think that we want to live in a richer world that includes all animals, large and small.

One method used in lion conservation is translocating them from one area to another. Do you think it's an effective way to conserve populations?

Conservation translocation is one of the tools in our toolkit that could help – but only in certain circumstances, under certain conditions. So there might be situations in which there is an area where a particular species is no longer found, but the conditions are improved for them to come back. If the threats that initially resulted in the disappearance of lions have been addressed and there is protection and a good prey base, only then do we find ourselves in a position where we could put lions back.

There is one lion in Gabon, central Africa, who happens to be a male, and he's quite lonely. He lives in this fantastic place of grassland and forest in the southeastern corner of Gabon, on the border with the Congo. There is now a proposal for two lionesses to be brought over from southern Africa, which is the closest genetic type of lion, to hopefully then meet with this lone chap and reestablish a small lion population in Gabon.

So there's a valid case to be made for conservation translocation. All of this involves wild-caught lions. We're not taking a lion from a zoo and taking it out and back to Africa and releasing them, that is bound to fail. We can't just put animals that were born or raised in captivity back into the wild. So successful interventions would always have to involve wild-caught animals.

How do you see the future of lion populations in the current climate, and do you see a chance of population growth?

As for the future, I'm in the business of conservation biology because I'm an optimist. I can see lion numbers increasing in some areas, but will continue to disappear from some other areas. What we're going to see is a different map going forward. Lions will continue to exist for generations, and certainly throughout my lifetime. There is a global consensus that something needs to be done, and there is certainly more interest in protecting lions than ever before. So I remain positive that things are going to improve.

The key would be for African governments to pay more than just lip service to wildlife conservation. You'll see different governments behave differently – some have very good conservation practices while there are some others where wildlife is certainly not a topic for debate or interest.

So it would be too simplistic to come up with an assessment for the whole continent or a solution for the whole continent.

I think it helps to think of lions as occupying 'lionscapes', for example the Mara Serengeti ecosystem, or Amboseli in Kenya, south Sudan and western Africa – large landscapes that quite often struggle with international borders, with regards to lions. I like the idea of conservation areas across national borders, because it brings recognition to these countries, and also brings prestige for engaging in international conservation practices.

And there is a lot of potential to continue to do so. International landscapes such as these are also more resilient to local political change. Maybe the future needs to involve more of these regional approaches to conservation as opposed to national efforts.

Learn more

Discover more about lion conservation programmes at **bornfree.org.uk** and learn how you can help support the king of the jungle in the wild. #KeepWildlifeInTheWild

Rubbish removal

How we deal with mountains of household waste at landfills

Hills of household rubbish can be found in every country on our planet, along with flocks of gulls scavenging from them. Landfills are a common method of ditching our rubbish – something humans have been doing since 3000 BCE. However, it didn't catch on in the UK until the 1800s. Before then, waste was left in the streets, which led to the spread of disease and poor environmental conditions.

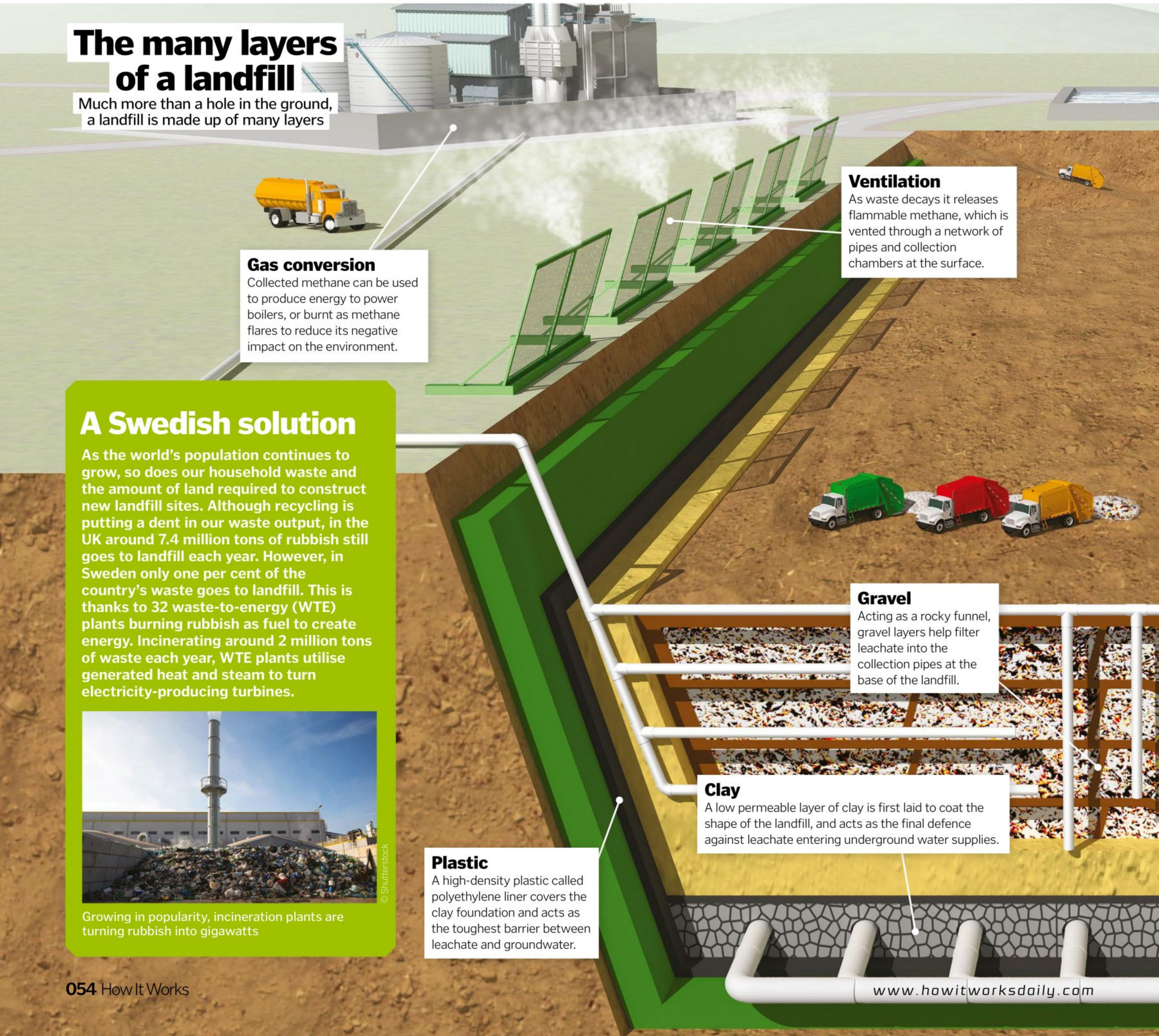
Now known as 'historic landfill sites', waste-filled holes were first constructed without any consideration for the disastrous consequences to the surrounding environment. Over time some materials break down in mounds of rubbish, releasing a rotten stew called leachate. This gathering bin juice at the base of the landfill seeped through rock and entered natural underground water systems, known as aquifers. Carrying harmful chemicals and metal ions, the leachate was an environmental nightmare for wildlife and humans.

Having recognised the environmental threat leachate posed, 'sanitary landfills' were introduced in the early 1900s. They contain the toxic leachate by lining landfills with a series of protective layers. In order to stop the liquid from building up, collection pipes are installed to pump leachate from the landfill to tanks on the surface. The leachate is then sent to a water treatment facility.

These modern-day sanitary landfills are capable of holding a great deal of household waste. Spanning hundreds of thousands of

The many layers of a landfill

Much more than a hole in the ground, a landfill is made up of many layers



Gas conversion
Collected methane can be used to produce energy to power boilers, or burnt as methane flares to reduce its negative impact on the environment.

Ventilation
As waste decays it releases flammable methane, which is vented through a network of pipes and collection chambers at the surface.

Gravel
Acting as a rocky funnel, gravel layers help filter leachate into the collection pipes at the base of the landfill.

Clay
A low permeable layer of clay is first laid to coat the shape of the landfill, and acts as the final defence against leachate entering underground water supplies.

Plastic
A high-density plastic called polyethylene liner covers the clay foundation and acts as the toughest barrier between leachate and groundwater.

A Swedish solution

As the world's population continues to grow, so does our household waste and the amount of land required to construct new landfill sites. Although recycling is putting a dent in our waste output, in the UK around 7.4 million tons of rubbish still goes to landfill each year. However, in Sweden only one per cent of the country's waste goes to landfill. This is thanks to 32 waste-to-energy (WTE) plants burning rubbish as fuel to create energy. Incinerating around 2 million tons of waste each year, WTE plants utilise generated heat and steam to turn electricity-producing turbines.

© Shutterstock

Growing in popularity, incineration plants are turning rubbish into gigawatts

square metres, some sites receive thousands of tons of material daily. In the UK one of the largest landfills, Packington, outside Birmingham, covered 1.5 square kilometres and had a 35 million ton capacity before its closure in 2015.

Landfills can take decades to fill, and once closed for business the sites are monitored for a further 30 years to ensure accumulating gas and leachate are being removed safety.

Around 200 waste-filled lorries may visit a household landfill site in a single day

© Getty

Bring in the bacteria

Bacteria plays a principal role in breaking down the contents of a landfill. Packed in layers, much of our waste, such as the many pieces of plastic we throw away, will sit underground for thousands of years without decomposing. However, a great deal of rubbish has the potential to biodegrade, such as food, but won't get the opportunity if the landfill is too tightly packed. Within a landfill, there is little soil, water, oxygen and bacteria – all things needed to breakdown possible materials.

Countries such as the US, India and China are now using bioreactor landfill sites, where air and bacteria-rich liquids such as sewage sludge are pumped into a landfill to promote more degradation.

To utilise the flammable gases produced from landfills and turn it into a source of energy production, anaerobic bioreactors don't add air, instead inserting vents to collect the valuable methane.

Digestive microbes release digestive enzymes to break down organic waste

© Getty

Capping
At the end of each day of dumping waste, all of the compacted cells are covered in around 15cm of soil.

Closing off
Once a landfill is filled (which, depending on its size, can take more than 30 years), layers of clay, geotextiles, plastic and a final 60cm of soil covers the area.

Waste cells
Layers of separated waste are dumped into the landfill and compressed to form compact waste cells.

Fabric
A strong geotextile fabric is placed beneath the layer of gravel to prevent the jagged rocks from damaging collection pipes and plastic layers.

Drainage
As leachate collects in the landfill it flows into the collection pipes, which pump the liquid into storage tanks for future treatment.

Ground rock
Surrounding bedrock offers stability for the landfill excavation and supports leachate pipes inserted throughout the landfill.

© Illustration by Adrian Mann

Anatomy of a spider

How this clever eight-legged predator spins silk stronger than steel

Spiders' intricate bodies have been in the making for 400 million years. They were some of the first animals to live on land after emerging from the ocean and have survived every extinction event – they even lived alongside the dinosaurs. Amber fossils reveal that spiders that existed 30 million years ago were more or less the same as they are today.

These arachnids utilise complex hunting behaviour, from lurking under hidden trapdoors to lassoing prey from an aerial trapeze line. Some weave elaborate webs, while others cut to the chase and tackle prey out in the open.

Spider reproduction is a complicated and dangerous process. Females are much bigger than their male counterparts and are famous for their tendency to kill their partners after mating. The male 'gift-giving' spider tricks females with a juicy piece of prey wrapped up in silk. 70 per cent of these 'presents' are worthless leftovers, but they distract the female long enough for the male to get away safely.

The silk spiders produce has mystified scientists for centuries. Pound for pound it's five times stronger than steel, and we still don't fully understand how they do it. The thread emerges as a liquid and solidifies quickly when it passes through the acidic silk duct. Glands make seven different varieties of thread. Some strands are wrapped around prey, while others are ideal for constructing webs. The strongest silk forms safety lines in case the spider falls. Every part of the body is an important tool to help the animal survive.

The Antilles pinktoe tarantula is covered with hairs that embed themselves in enemies that get too close

Inside a spider

The internal workings of spiders are fine-tuned to transport oxygen, break down food and help with locomotion

Sucking stomach
Muscles around the stomach tighten like elastic bands to pump food into the body.

Eye
These aren't compound insect eyes but give the spider near 360-degree vision. Each eye has one lens, and spiders must tilt their heads to get the image in focus.

Brain
This organ is so big that it spills over into other body cavities. The smallest spiders dedicate 80 per cent of their space to the central nervous system.

Caecal ring
Partially processed food is stored in this series of canals between the stomach and intestine.

© Getty

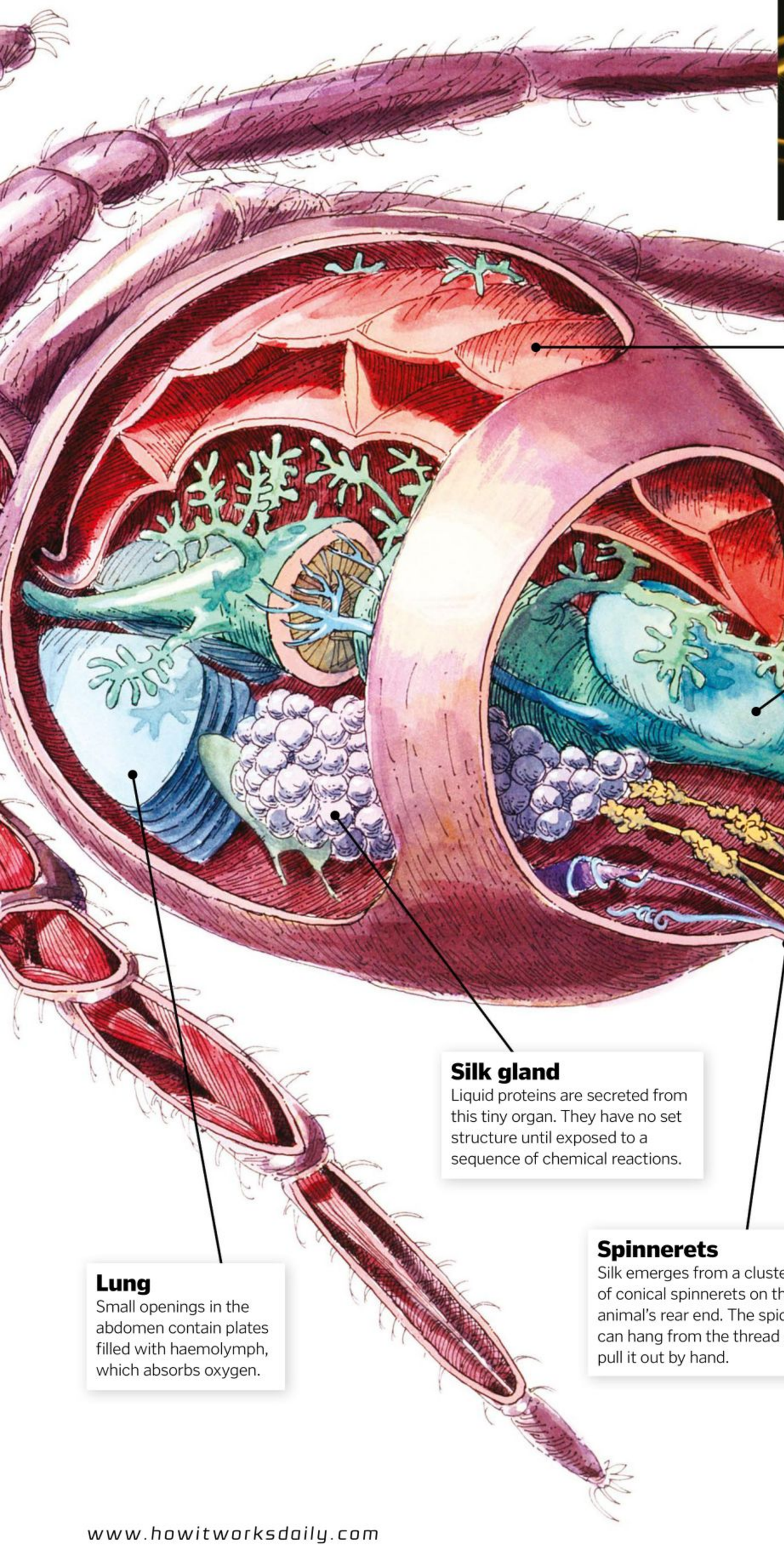
Harvestmen congregate in large groups in the autumn to stay safe from predators

100,000 arachnids

Spiders represent just one of 11 orders of the class Arachnida. This group of animals includes small arachnids like fleas, as well as big predators like camel spiders and whip scorpions. All arachnids have an exoskeleton and four pairs of legs, but they differ from one another in a lot of other ways. Scorpions have chunky claws and a curled stinger, while ticks have engorged abdomens to stockpile a mass of blood.

Some arachnids live underwater. The diving bell spider creates a spherical net from silk and sticky protein at the surface. It inflates the diving bell and spends most of its time submerged. It only returns to the surface briefly to replenish the oxygen in its subaquatic home. There are also 5,000 species of water mites. They start out in life as parasites but grow up to become free-swimming hunters of small crustaceans.

"Spiders that existed 30 million years ago are more or less the same as they are today"



Heart
Spiders have an open circulatory system full of blood-like fluid called haemolymph. The heart forces blood through the arteries.

Stercoral pocket
Faeces and other waste accumulates in a space in the hindgut before it is expelled.

Silk gland
Liquid proteins are secreted from this tiny organ. They have no set structure until exposed to a sequence of chemical reactions.

Lung
Small openings in the abdomen contain plates filled with haemolymph, which absorbs oxygen.

Spinnerets
Silk emerges from a cluster of conical spinnerets on the animal's rear end. The spider can hang from the thread or pull it out by hand.

The spider swings a silk lure to trap moths attracted by pheromones the spider produces

Bird dropping spiders mimic the size and shape of avian excrement and hunt at night to avoid predators

Miracle material

Medical science has been working on creating synthetic spider silk for decades. It could be used to repair damaged tissues, deliver drugs into the body or protect against harmful bacteria. Researchers have found a way to draw organic protein into threads and sheets. One day these could be used as scaffolding within cells and could be introduced into cancer therapy in the future. This technique is still in its infancy, and we're yet to perfect creating silk proteins that hold their shape. Evolution has crafted a material so complex that it's almost impossible for even the brightest minds to recreate.

Spiders avoid sticking to their webs like their unfortunate prey by gripping strands with miniature claws

FORM RACE TO THE

Words by **Beth Lily Georgiou**

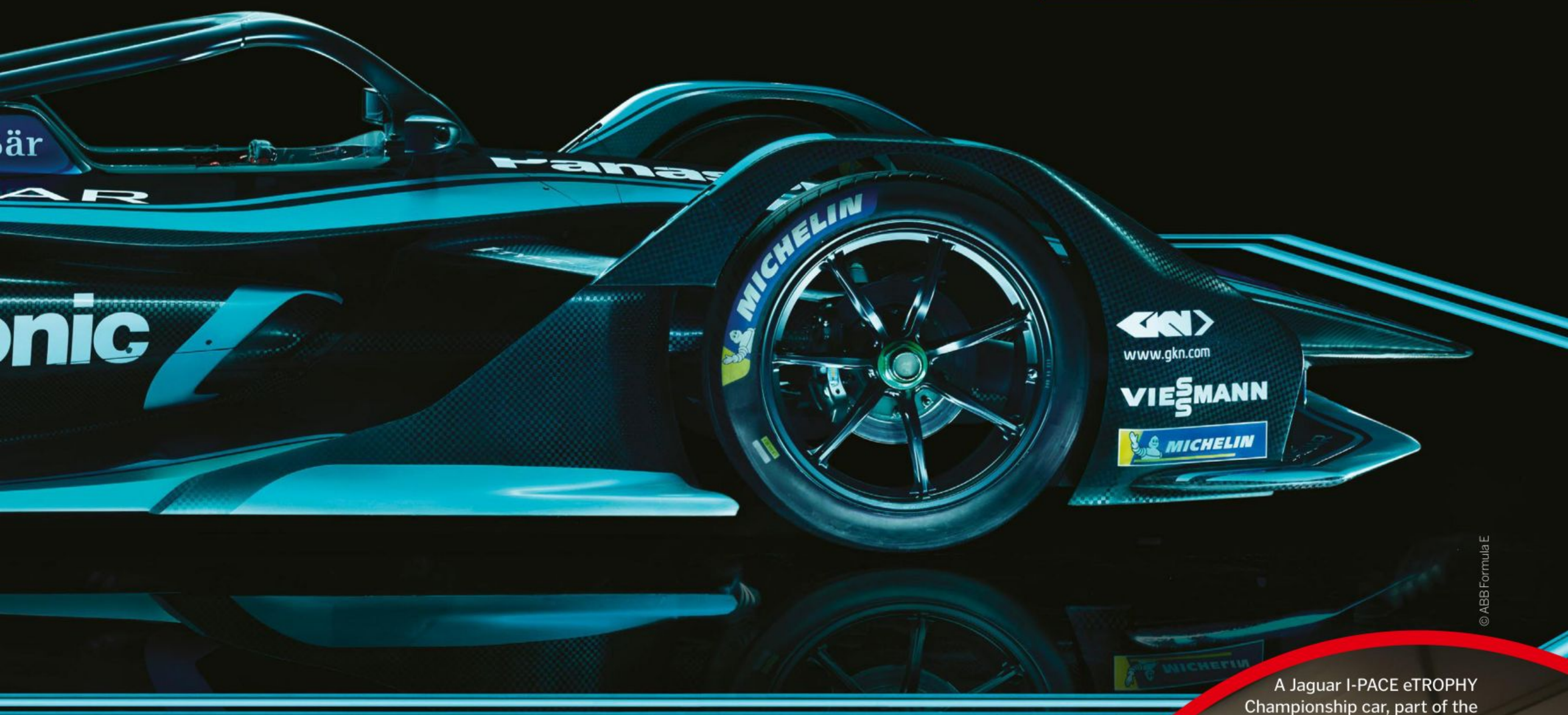
Discover the new series of race cars electrifying the streets of the world's most iconic cities

With exhilarating wheel-to-wheel battles along tight street circuits around the world, the ABB FIA Formula E Championship is at the forefront of a new electric era in motorsport. 11 teams and 22 drivers race for their respective championship titles in 12 cities across five continents, with all-electric single-seater race cars that are designed to put the focus on team tactics and driver's skills. Each 'ePrix' race is 45 minutes long, with points awarded to the top ten finishers, and additional points available for securing pole position or the fastest lap. The urban race locations give fans the chance to get closer to the action than ever before, and gamification brings uniquely fun elements to the championship, with 'FANBOOST' enabling fans to vote and boost the performance of their favourite driver – as well as a new 'ATTACK MODE' .

This is more than just a race, though. Formula E manufacturers are flocking to research and develop the latest battery and powertrain (the parts that make the car

DID YOU KNOW? *Michelin supplies bespoke all-weather tyres to avoid teams having to ship many sets around the world*

FORMULA E: THE ELECTRIC FUTURE



© ABB Formula E

move, including the motor) technology for electric vehicles, in order to accelerate the transition from dirty fossil fuels to cleaner transportation on a global scale. Incredibly, more manufacturers are represented in Formula E than in any other comparable series in the world, as the first ever all-electric championship sparks innovation in production vehicle technology.

Season 5 has seen the second-generation (Gen2) vehicles compete for the first time, with substantial performance enhancements compared to previous seasons. The futuristic appearance of the carbon fibre chassis and covered front wheels, combined with an upgraded battery and power output, makes Formula E an even faster, more exciting racing format. These developments have enabled season 5 to be the first with only one car per driver, where previously swapping to a vehicle with a fully charged battery halfway through a race was necessary.

A Jaguar I-PACE eTROPHY Championship car, part of the Formula E Championship support series, topping up on electricity

How a Formula E car works

The second generation of Formula E electric racing vehicles are futuristic and packed full of the very latest technology

Cooling system
This crucial system ensures that the battery and motor maintain optimum performance and do not overhead during the race.

Safety
A new 'halo' head protection incorporates LED lights to show when the new ATTACK MODE and FANBOOST are active.

Motor
Peak power has increased in Gen2 to 250kW, with a top speed of 280kph.

Tyres
All-weather tyres last the full race: in season 5 there is no longer a car swap.

Chassis
The carbon fibre chassis has covered front wheels and spoilers above the rear wheels.

Battery
At 54kW/h capacity, the Gen2 battery gains 95 per cent more energy for just 20 per cent more weight.

"Formula E cars are optimised for narrow streets"

DRIVING FORWARD

2011
A concept for an international electric single-seater racing series is developed by FIA president Jean Todt. Formula E founder and CEO Alejandro Agag creates Formula E.

2014
Season 1 of Formula E begins in September with a race in Beijing, China, featuring ten participating teams using identical single-seater cars.

2015
Nelson Piquet Jr wins the Driver's Championship and Renault e.dams wins the Team Championship, in an exciting season 1 finale in June at Battersea Park, London.

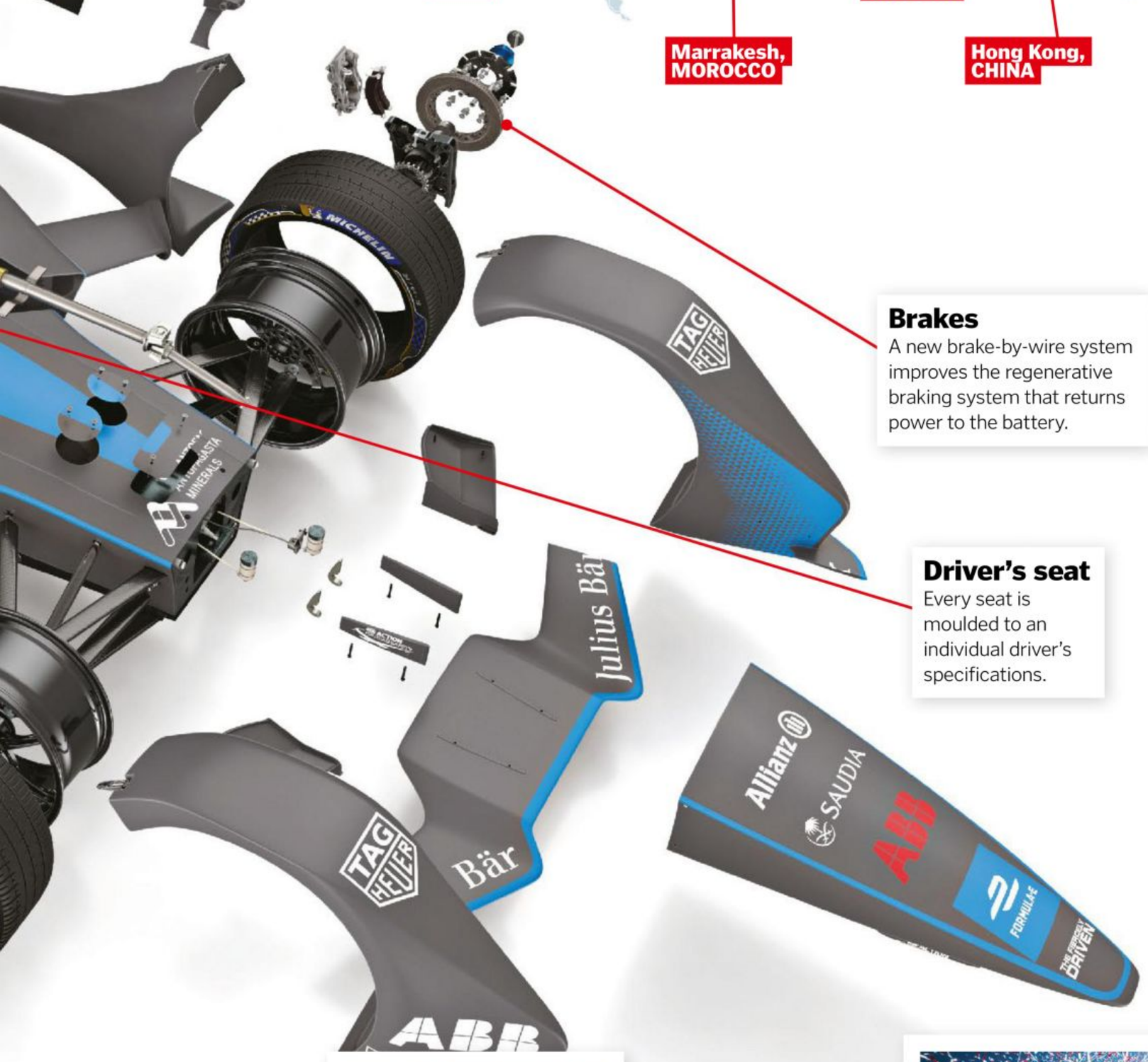
2015
Season 2 begins in October with a race in Beijing, China, and the championship becomes open, allowing teams to develop new powertrain solutions.

2016
The final race takes place again in Battersea, London, in July, with the Driver's Championship going to Sébastien Buemi, while Renault e.dams takes its second team title.

2016
A double-header in Hong Kong kicks off season 3 in December, and the cars gain a new front wing. Energy regeneration is increased, enabling greater variation in race strategies, and a new version of the 28kW/h battery is introduced by Williams Advanced Engineering.

Acceleration (0-100kph)
Gen1: 3 seconds
Gen2: 2.8 seconds
Maximum speed
Gen1: 225kph
Gen2: 280kph
Maximum power/ Maximum race power
Gen1: 200kW (268bhp)/180kW
Gen2: 250kW (335bhp)/200kW
Minimum weight (incl. driver)
Gen1: 880kg
Gen2: 900kg
Battery make + capacity
Gen1: Williams Advanced Engineering 28kW/h
Gen2: McLaren Applied Technologies 54kW/h

Electric racing in the world's greatest cities



Brakes
A new brake-by-wire system improves the regenerative braking system that returns power to the battery.

Driver's seat
Every seat is moulded to an individual driver's specifications.

© ABB Formula E

Piquet Jr on track in Santiago. Formula E takes place in cities across the globe

Formula E vs Formula 1

Although on the surface Formula E and Formula 1 cars may appear similar, they couldn't be more different under the bodywork. The fully electric cars in Formula E use only electricity to power the motor that turns the wheels, unlike the 1.6 litre fuel/hybrid engine found in a Formula 1 car. The electricity in a Formula E car is stored in a large battery pack, which needs to be charged up via an external power supply.

Formula 1 cars are intended to race on circuits, whereas Formula E cars are optimised for narrow streets with tight turns, resulting in dramatically contrasting designs and specifications. Although both cars accelerate eye-wateringly quickly, Formula 1 requires much higher top speeds. The difference in racing environments also means that Formula E requires one type of tyre, whereas Formula 1 teams have a range of choices of tyre type, as well as different pit stop strategies.

© ABB Formula E

Formula E cars work very differently to Formula 1 cars under the bodywork

© ABB PRESS PACK

2017

Lucas di Grassi wins the Driver's Championship and Renault e.dams once again takes the Team Championship at the double-header finale in Montreal, Canada.

2017

The cars are given 10kW more power during races for season 4, increasing the output to 180kW and enabling the cars to accelerate from 0–100kph in three seconds, with a top speed of 225kph.

2018

The season 4 finale in New York sees Audi Sport ABT Schaeffler beat TECHEETAH to the Team Championship by just two points, and Jean-Éric Vergne secures the Driver's Championship.

© ABB PRESS PACK

2018

A new era of Formula E begins with the introduction of the Gen2 car in its first race in Ad Diriyah, Saudi Arabia. Going forward, only one car will be required per driver during the race due to increased battery capacity.

© ABB PRESS PACK

2019 and beyond

With a global focus on electric vehicles, the Formula E grid is set to represent even more manufacturers in season 6, with Porsche and Mercedes joining Audi, Jaguar, BMW, Mahindra and Nissan on the grid.

What is the new ATTACK MODE?

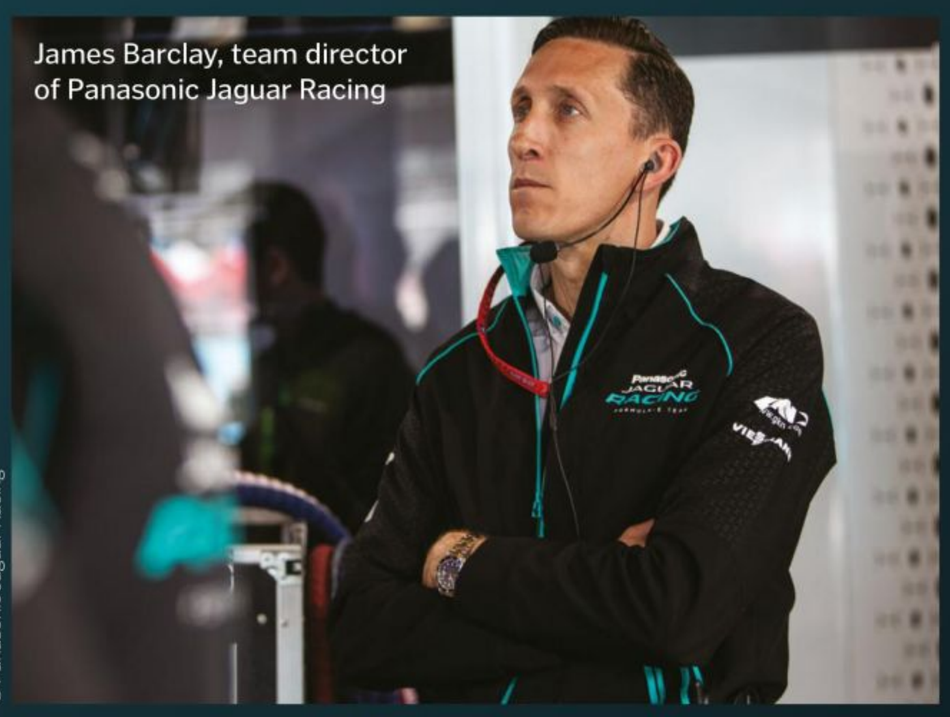
New for season 5, ATTACK MODE increases overtaking and adds an interesting twist to energy conservation strategy. To ensure that teams have a variety of strategic options during a race where no pit stops are required, drivers must use two different modes of power during a race. This gives them access to 225kW of power in the higher mode, as opposed to the standard 200kW used throughout the race. In order to attain the higher power mode, drivers pass through a special activation zone marked out on the circuit. Drivers with the higher power mode engaged can be spotted by the change of coloured LEDs on their halo head protection.

© ABB Formula E

Formula E long-timer Sébastien Buemi racing on the streets of Rome for Nissan e.dams

Overhead view of the Jaguar I-TYPE 3 as Mitch Evans prepares for an out lap

© Panasonic Jaguar Racing



James Barclay, team director of Panasonic Jaguar Racing

© Panasonic Jaguar Racing

Formula E's support race – Jaguar I-PACE eTROPHY

© Panasonic Jaguar Racing

© ABB Formula E

Formula E cars are specially designed for street circuits, such as this one in Hong Kong

The Gen2 cars are a significant step up from G1 in terms of performance and battery life

Mitch Evans races a Gen1 car for Panasonic Jaguar Racing on the streets of Santiago

Formula E features several ex-Formula 1 drivers, such as Nick Heidfeld

Q&A

James Barclay, team director – Panasonic Jaguar Racing

Jaguar: how a legendary name in motorsport is gearing up for the future

Since 2015, James Barclay has been responsible for managing Jaguar's return to motorsport in the ABB FIA Formula E Championship, while also playing an instrumental role in the launch of Formula E's main support series, the Jaguar I-PACE eTROPHY.

Why does Panasonic Jaguar Racing choose to compete in Formula E, and how do you see the sport evolving in the next few years?

Jaguar is committed to ABB FIA Formula E as it is a great real-world test bed for electrification technology, and a platform to highlight and grow our world-class expertise in electric vehicles. Our commitment to the series long-term has strengthened and evolved with the introduction of the Jaguar I-PACE eTROPHY, which debuted in December – the world's first international championship for production-based electric cars. Jaguar was the first premium manufacturer to join the series in season 3, and we have a mission called 'Race To Innovate'. This season (season 5) with the Jaguar I-TYPE 3, we've seen improved battery technology, which has allowed Jaguar and all the other teams in Formula E to drop the mandatory mid-race car swap. This development rate will only continue, and it will be exciting to see how the cars become more efficient in the future.

What differences do drivers face racing in Formula E, compared to racing in a combustion-engine series such as Formula 1?

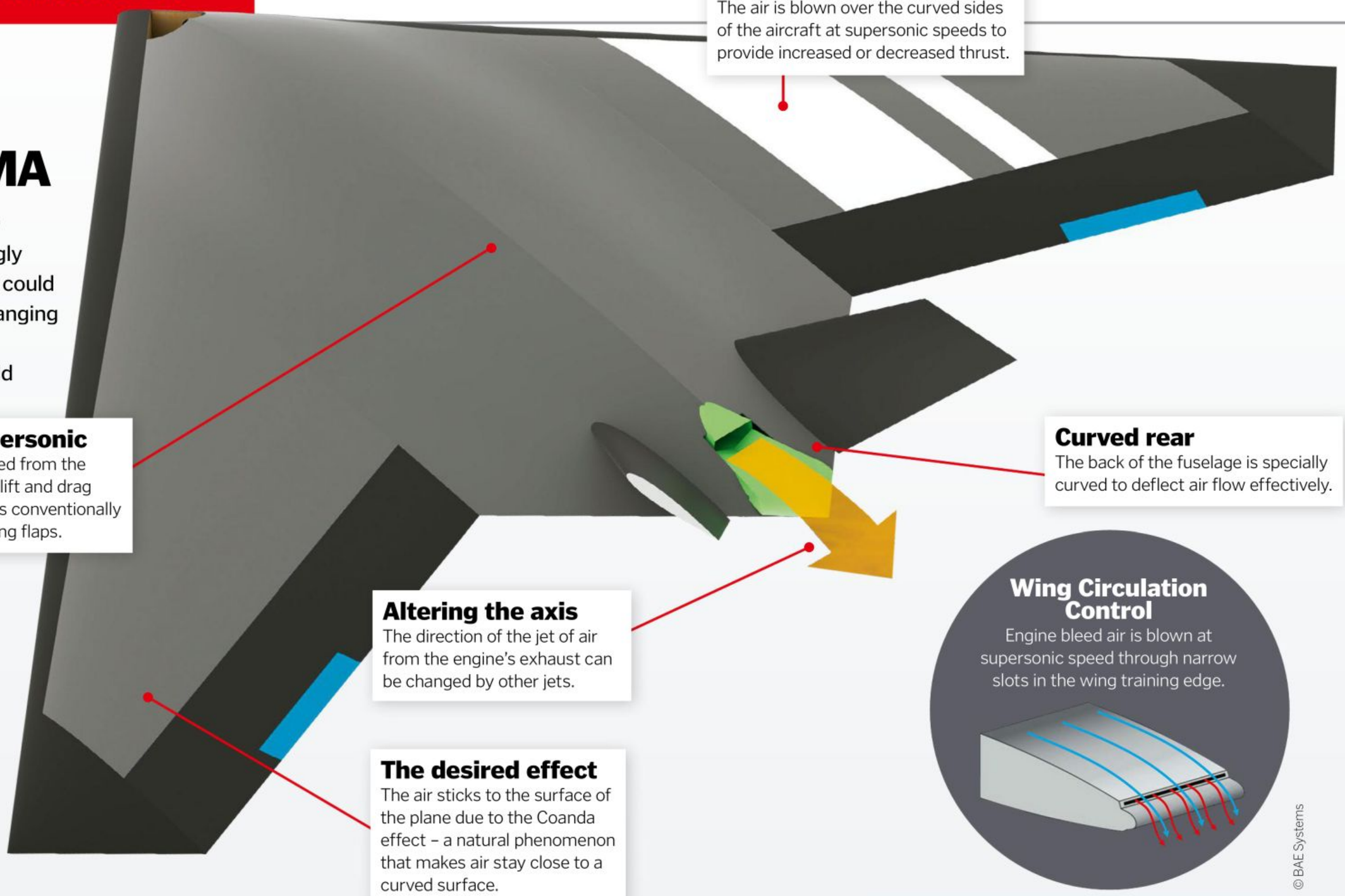
The feedback from the drivers is that the cars are similar apart from the distinct lack of noise. One of the interesting elements of Formula E is energy-saving. The drivers have to adapt their driving style to be efficient and quick, with regeneration from the brakes, and sometimes have to be able to lift and coast while racing. But like most race cars they have an accelerator and brake, so there's a lot of carry-over.

How has the switch from Gen1 to Gen2 vehicles made a difference to team and driver tactics?

With the Jaguar I-TYPE 3 (Gen 2) we have to concentrate on making the most efficient powertrain to optimise the energy from the battery. The cars are faster now, and we also have the introduction of ATTACK MODE, which increases the power of the car for eight minutes during the race. There is also a lot of importance in qualifying sessions in Formula E because it is critical to get a good starting position – overtaking on the street tracks can prove difficult.

How MAGMA works

How a seemingly simple system could yield game-changing results on the aerial battlefield



Give me wings
The air is blown over the curved sides of the aircraft at supersonic speeds to provide increased or decreased thrust.

Feeling supersonic
The air is generated from the engine and alters lift and drag – something that's conventionally achieved by moving flaps.

Curved rear
The back of the fuselage is specially curved to deflect air flow effectively.

Altering the axis
The direction of the jet of air from the engine's exhaust can be changed by other jets.

The desired effect
The air sticks to the surface of the plane due to the Coanda effect – a natural phenomenon that makes air stay close to a curved surface.

Wing Circulation Control
Engine bleed air is blown at supersonic speed through narrow slots in the wing training edge.

© BAE Systems

Supersonic stealth drones

New flow control technology could make new military drones of the future lighter, faster and harder to detect

Unmanned aerial vehicles (UAVs) are designed to be both covert and agile, but new 'flap free' technology could boost their capabilities even further. Hinges, rudders and flaps are used on aircraft to change the curvature of a wing. They move to different angles, which helps achieve increased lift or drag and allows aircraft to perform sharper turns and more rapid stops.

New technology has been developed to replace this system with one that will provide better performance and efficiency. Flow control or 'flap-free' technology sends air at supersonic speeds from the aircraft's engine into narrow slots on the wings and tail. The air moves over specially curved surfaces, instead of flaps and hinges, to give added lift or drag. This air flow can also be diverted by 'fluidic thrust vectoring', where more jets of air alter the direction of travel from the engine to help an aircraft to turn.

This technology could make UAVs and other aircraft lighter, faster and cheaper to produce.

An example of this flow control innovation in action is on MAGMA. Created by technology company BAE Systems, it is the first aircraft to utilise this technology with supersonic jets. MAGMA had its maiden flight earlier this year, and testing is ongoing. It's hoped that it can be the first aircraft to fly without the aid of moving parts on the surface.

© BAE Systems

MAGMA was designed with assistance from the University of Manchester

Drones to fighters

BAE Systems isn't just earmarking this new technology for drones; the company is planning on incorporating flow control into a next-generation fighter. The Tempest is a modern fighter that was first revealed as a concept model in 2018 and is part of Britain's Future Combat Air System project. The Tempest and other fighters are being designed to work in unison with UAVs. They are planned to be customisable, with different types of fuel, cameras and weapons systems fitted depending on the mission type.

The Tempest will also be fully upgradable, so new technology can be incorporated into its design, ensuring that it will stay at the forefront of air combat for the foreseeable future. It is expected to enter service by 2035, eventually replacing the Eurofighter Typhoon, which has been in service in several countries since 2003.

© Getty

The project is being partly funded by a £2 billion grant from the UK government

AIRFIX®

STARTER SETS: WHAT'S ON THE BOX?

Every Airfix Starter Set box contains a wealth of information to help you choose the best kit and achieve the best finish.

1. History
A small piece of history is included on the top of each Airfix kit box. This gives some background information of the product, including actions the real item was involved in. The area also shows the dimensions of the finished model and the number of pieces.

2. Flying hours
Become a member of the Airfix Club and you can collect the Flying Hours to receive FREE model kits. The bigger the kit, the more Flying Hours are available to accumulate.

3. Skill level
The skill level, from 1 to 4, explains how difficult the model will be. A higher skill level kit often has more parts and is more challenging to build.

4. Paints, Cement and brushs
Everyting to build a finished model is included, including model cement, paint brushes and acrylic paints. The Humbrol™ products will enable you to create the best finish for your model.

5. Scheme
The scheme is outlined on the top of the box with the markings and descriptions.

6. Decals
The side profile on the front shows the position of the decals to give you a clear idea what the final model will look like.

7. Product code
The product code is unique to each kit. It helps you to identify your kit of choice easily, assists with navigating through the catalogue or Airfix website accurately, determines the size of the kit and gives guidance to the number of parts.

8. Model scales
The scale of the kit indicates how large the model will be in relation to the full size vehicle. All of the aviation Starter Sets are 1:72 scale, therefore the model is 72x smaller than the original (1:32 = 32x smaller). The smaller the scale number – e.g. 1:24 = the larger the kit compared to the original. All of the automotive Starter Sets are 1:32 and the tanks are 1:76.

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Inside the Xbox One S Digital

Just how different is this disc-free console to its twin?

When Microsoft announced its first ever disc-free Xbox console earlier this year, the world wasn't too surprised. Early in 2019, The Entertainment Retailers Association released figures showing that 80 per cent of UK video games sales are now digital, with physical sales making up the other 20 per cent. With so many players choosing to download their games rather than pop a disc in, it was an obvious step to create a console without the added cost of a disc drive.

The Xbox One S All-Digital Edition looks familiar from the outside. It matches the white, rectangular design of the standard Xbox One S in every way – except for the solid plastic face where the disc slot would otherwise be. It offers the same features, from HDR support that deepens colours and makes games more intense, to the 1TB hard drive that stores all your downloaded titles.

The plan here wasn't to create a new, smaller Xbox. Microsoft knew that by using similar designs and technology, it could save money and pass that saving onto its players. And with three games bundled with the console for free, it makes for a pretty alluring package for those after a cheaper console.

So does this give us a vision of the future for gaming? Perhaps. Several games companies (including Microsoft) are now pushing their digital subscriptions that let you download and play specific games, and cloud gaming might be the next big thing. Soon, games on disc might seem as outdated as VHS tapes.

Discless Xbox exploded

We go under the hood to see how different this all-digital console is

Ports
These ports normally stick out the back of the console so you can connect it to your TV, speaker and external hard drives.

Power supply
This Xbox doesn't have a big power brick hanging from its cable. Instead, it packs its fanless power supply into the case.

Wireless board
This small board handles your console's Wi-Fi connection – essential because you'll be downloading all your games.

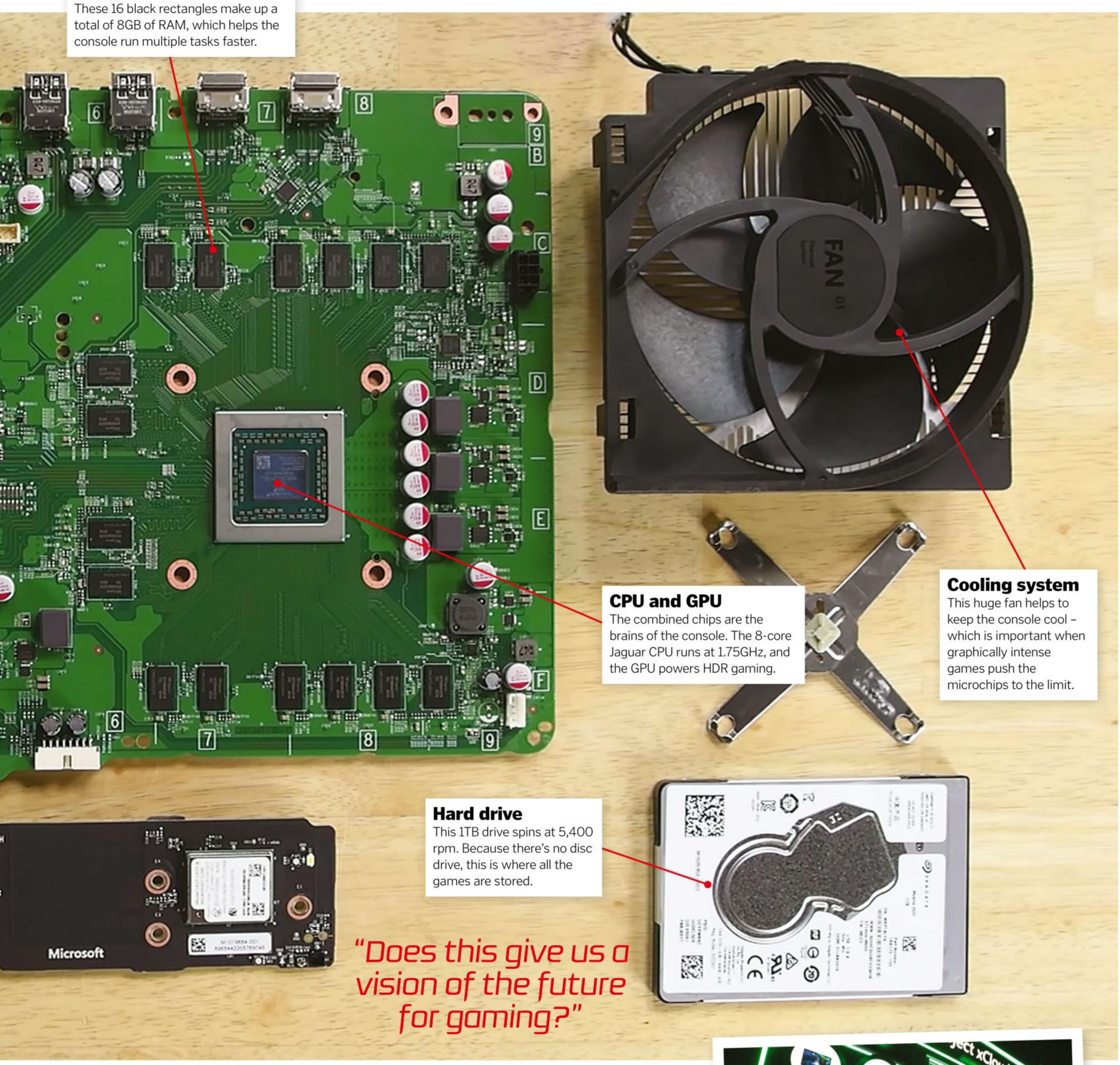
Front panel
This board holds the power switch, along with a Bluetooth module that connects with wireless controllers, and an IR blaster.

The new console looks almost identical to the previous Xbox One S, but without the disc drive slot

© Microsoft

The team at Microsoft work hard to pack all the components into a small, neat casing

© iFixit



Memory
These 16 black rectangles make up a total of 8GB of RAM, which helps the console run multiple tasks faster.

CPU and GPU
The combined chips are the brains of the console. The 8-core Jaguar CPU runs at 1.75GHz, and the GPU powers HDR gaming.

Cooling system
This huge fan helps to keep the console cool – which is important when graphically intense games push the microchips to the limit.

Hard drive
This 1TB drive spins at 5,400 rpm. Because there's no disc drive, this is where all the games are stored.

"Does this give us a vision of the future for gaming?"

© iFixit

Project xCloud

Microsoft recently announced a new game-streaming service, currently dubbed Project xCloud. The system lets players stream their games to any device, wherever they are in the world, as long as they have a good enough internet connection. When it launches, Project xCloud will allow players to use their own Xbox One consoles at home as a streaming box. All you'll need is an Xbox controller connected to your phone, your laptop or your tablet, and you'll be able to play the games you own over the internet.

Microsoft will also be installing hundreds of Xbox Ones in server farms (large rooms full of interconnected units) around the globe, so if you don't want to use your own console, or your internet connection isn't up to scratch, you can still play the games you love. This could be the future of gaming.

© Microsoft

HOW JUPITER SAVED THE EARTH

Even before the Earth formed, its destiny was being carved out by the giant planet

Words by **Andrew May**

5.2
Jupiter's average distance (in astronomical units) from the Sun – 780 million km

10
Typical mass of a super-earth, relative to Earth

0.02%
Amount of water on Earth, relative to its total mass

0
Number of super-earths in the Solar System

It's been known for a long time that the planets of the Solar System condensed out of a swirling mass of gas and dust – the protoplanetary disc – revolving around the newly formed Sun. But the picture has become much clearer in recent years thanks to a combination of detailed computer simulations and a revolution in observational astronomy, which means we can now see planetary systems – and protoplanetary discs – around other stars.

One outcome is the so-called 'Grand Tack' model – originally developed by a NASA-led team of scientists in 2011 but recently opened up to a wider audience by Professor Brian Cox in his TV series *The Planets*.

Jupiter, the largest of the eight planets, was the first to form, around 4.6 billion years ago. At that time it was closer to the Sun than it is today – about two-thirds of its present distance. But it didn't stay put. The surrounding circumstellar disc, still filled with gas and dust, began to sap energy from the newly created planet through a process analogous to aerodynamic drag. This caused Jupiter to spiral into an even smaller orbit – only halting after the second planet in the Solar System, Saturn, arrived on the scene. Orbiting further out than Jupiter, Saturn pulled it back outwards until the two planets ended up close to their present positions.

"All this happened extremely rapidly by astronomical standards"

All this happened extremely rapidly by astronomical standards – in around half a million years, rather than the billions astronomers usually talk about. The Grand Tack was over before Earth and the other rocky inner planets had even begun to form. But their destinies had been sealed. Jupiter's inward plunge pushed large quantities of rocky debris, which might otherwise have coalesced into a massive inner planet, into the Sun. This left just enough material to make Mercury, Venus, Mars and Earth – the latter at just the right distance from the Sun to provide surface temperatures in the narrow range where the development of life was possible.

A whimsical tourist poster NASA produced for the inhospitable super-earth 55 Cancri e

Where are the super-Earths?

Looking beyond our Solar System to the many other planetary systems that have been discovered in recent years, it's clear that 'super-Earths' are commonplace in the galaxy. These are rocky worlds similar to Earth in composition but significantly larger – up to twice the radius and ten times the mass. Super-Earths are often found very close to their parent star – for example 55 Cancri e is six times closer to its star than we are to the Sun.

But if super-Earths are so common, why doesn't our Solar System have one? It's possible that one did start to form and was then pulled apart by Jupiter's gravity during the Grand Tack, causing most of the pieces to fall into the Sun.

Earth vs super-Earth

How does our planet compare to one of the galaxy's super-Earths?

Earth

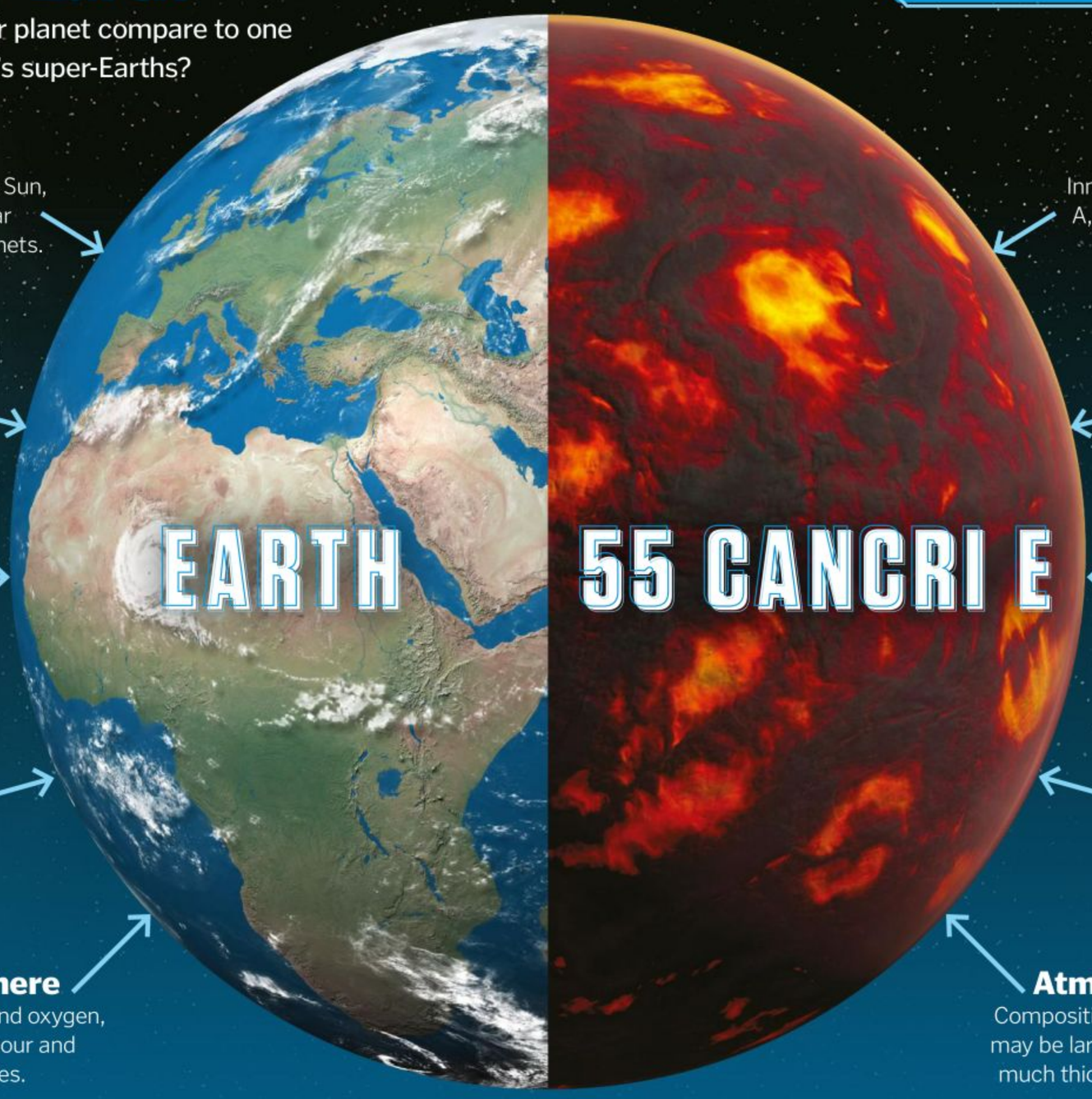
The third planet from the Sun, the largest of the Solar System's rocky inner planets.

Vital statistics
Diameter 12,700km; mass 6 septillion kg; year 365 days.

Internal composition
Well understood – a dense metallic core surrounded by concentric layers of rock.

Surface conditions
Average surface temperature 15 degrees Celsius; plenty of liquid water.

Atmosphere
Mainly nitrogen and oxygen, plus water vapour and other gases.



55 Cancri e

Innermost planet of 55 Cancri A, a slightly smaller star than the Sun.

Vital statistics
Diameter 23,800km; mass 48 septillion kg; year 0.7 days.

Internal composition
Unknown, but probably high in carbon – possibly in the form of solid diamond.

Surface conditions
Average surface temperature 2,300 degrees Celsius; vast lakes of lava rather than water.

Atmosphere
Composition unknown, but may be largely nitrogen and much thicker than Earth's.

THE GRAND TACK

Jupiter's zigzagging path through the fledgling Solar System

APPROX 4.6 BILLION YEARS AGO: T=0

Jupiter forms near the 'ice line' in the protoplanetary disc, between its rocky inner parts and icy outer parts. The other large planets are also beginning to condense out.

T = 70,000 YEARS

The 'drag' of the protoplanetary material causes Jupiter to migrate inwards, pushing much of the rocky material into the Sun.

T = 100,000 YEARS

Saturn follows Jupiter inwards, almost catching up with it and halting their inward movement. In the process, some icy asteroids are dragged into the inner Solar System.

T = 300,000 YEARS

Jupiter and Saturn migrate back outwards, leaving behind a mixture of rocky and icy debris from which the inner planets will form.

T = 500,000 YEARS

At the end of the Grand Tack, Jupiter is near its present position – but the outer planets are still much closer to the Sun than they are today.

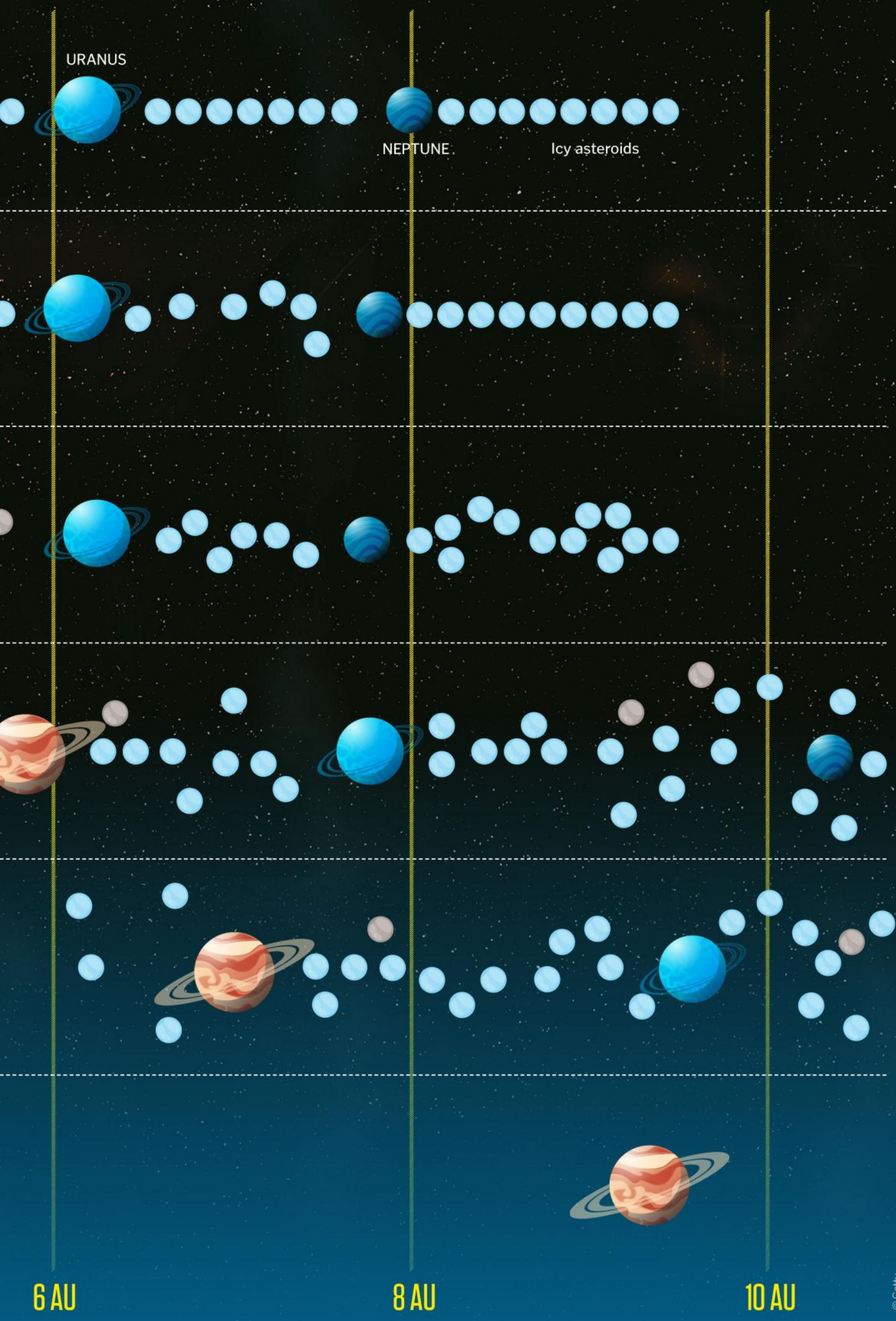
APPROX 4.5 BILLION YEARS AGO

Now the inner planets have formed too, close to their present positions. After another half a billion years, Uranus and Neptune will migrate outwards to their final positions.

1,364
Number of super-earths discovered by Kepler space telescope

22,000
Number of asteroids hitting Earth in the Late Heavy Bombardment

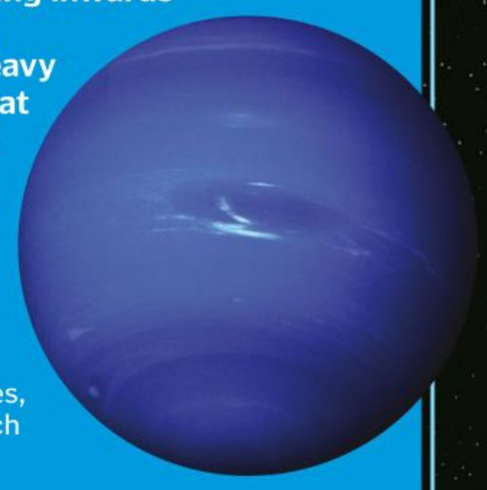
3.5
Ratio of Jupiter's furthest and closest distances to the Sun



What happened next in the Solar System?

Around half a billion years after the Grand Tack – and after all eight planets had formed – the Solar System saw a second dramatic episode of planetary migration. It started when the orbits of the two largest planets became locked together, with Saturn completing one revolution for every two of Jupiter. Called a 'resonance', this produced a gravitational instability that threw the outer Solar System into near-chaos. In the course of a few million years, the two outermost planets, Uranus and Neptune – which originally formed not far beyond the orbit of Saturn – were flung into the much more distant regions where we see them today.

The inner planets didn't emerge unscathed either. While their orbits weren't greatly affected, the massive disruption further out sent a huge swarm of asteroids hurtling inwards – resulting in the so-called 'Late Heavy Bombardment' that saw thousands of space rocks hitting Earth and its neighbours.



Now on the Solar System's outer fringes, Neptune formed much closer to the Sun

How Earth got its water

When the Earth first formed, it was so hot that any water would have boiled off very quickly. Yet today it's covered with oceans – and water is essential for the life that thrives on its surface. Scientists believe most of that water was delivered by icy asteroids that crashed into Earth in its youth, when the Solar System was far more cluttered than it is now. Here too, Jupiter played a crucial role in creating the Earth we see today. It was the gravity of that giant planet that, by destabilising orbits in the outer Solar System, produced the Late Heavy Bombardment, which is probably when most of our water arrived.

The young Earth was bombarded by asteroids, which may have delivered much of its water

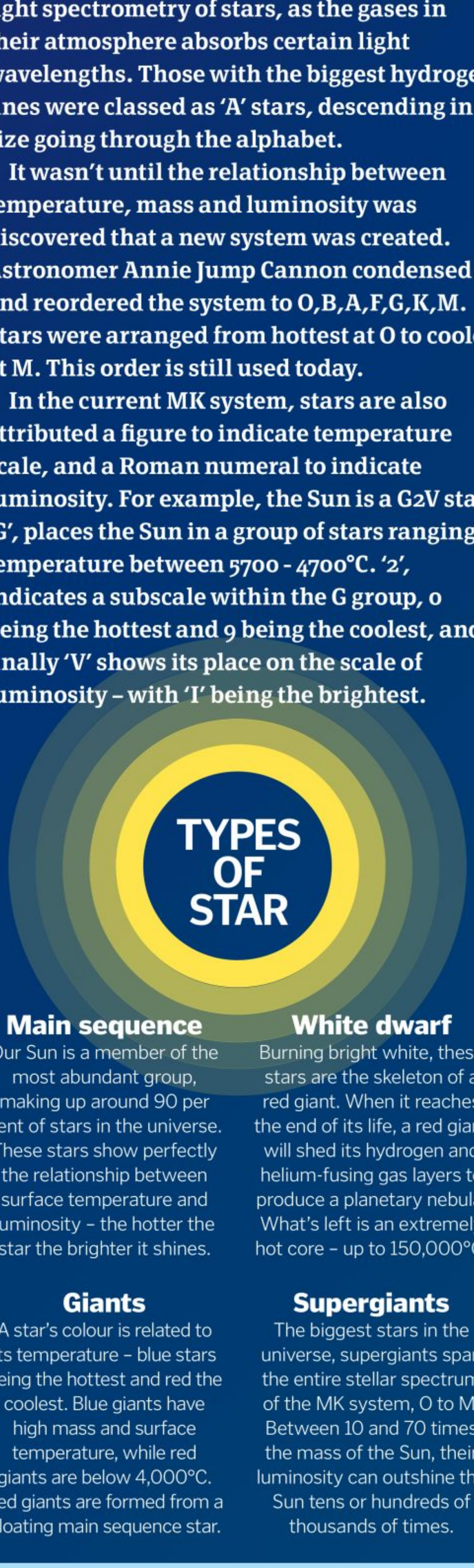
How stars are classified

From white dwarfs to red giants, discover how astronomers have categorised the cosmos

Within our galaxy alone there are over 100 billion stars, so how do astronomers keep track of what's what in the universe? From the late 19th century stars were classified based on 'hydrogen lines'. These lines are gaps in the light spectrometry of stars, as the gases in their atmosphere absorbs certain light wavelengths. Those with the biggest hydrogen lines were classed as 'A' stars, descending in size going through the alphabet.

It wasn't until the relationship between temperature, mass and luminosity was discovered that a new system was created. Astronomer Annie Jump Cannon condensed and reordered the system to O,B,A,F,G,K,M. Stars were arranged from hottest at O to coolest at M. This order is still used today.

In the current MK system, stars are also attributed a figure to indicate temperature scale, and a Roman numeral to indicate luminosity. For example, the Sun is a G2V star. 'G', places the Sun in a group of stars ranging in temperature between 5700 - 4700°C. '2', indicates a subscale within the G group, 0 being the hottest and 9 being the coolest, and finally 'V' shows its place on the scale of luminosity – with 'I' being the brightest.



Main sequence

Our Sun is a member of the most abundant group, making up around 90 per cent of stars in the universe. These stars show perfectly the relationship between surface temperature and luminosity – the hotter the star the brighter it shines.

White dwarf

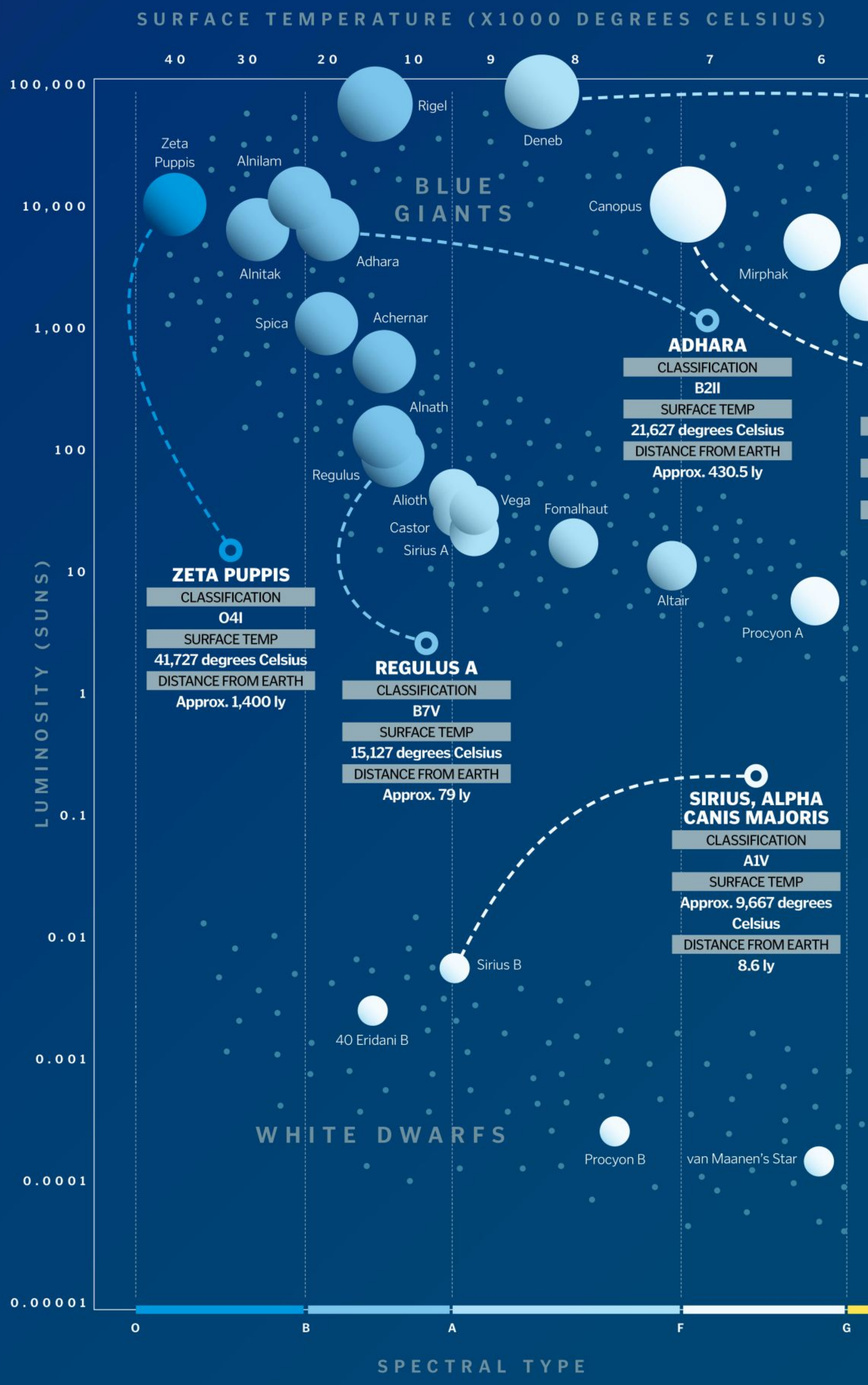
Burning bright white, these stars are the skeleton of a red giant. When it reaches the end of its life, a red giant will shed its hydrogen and helium-fusing gas layers to produce a planetary nebula. What's left is an extremely hot core – up to 150,000°C.

Giants

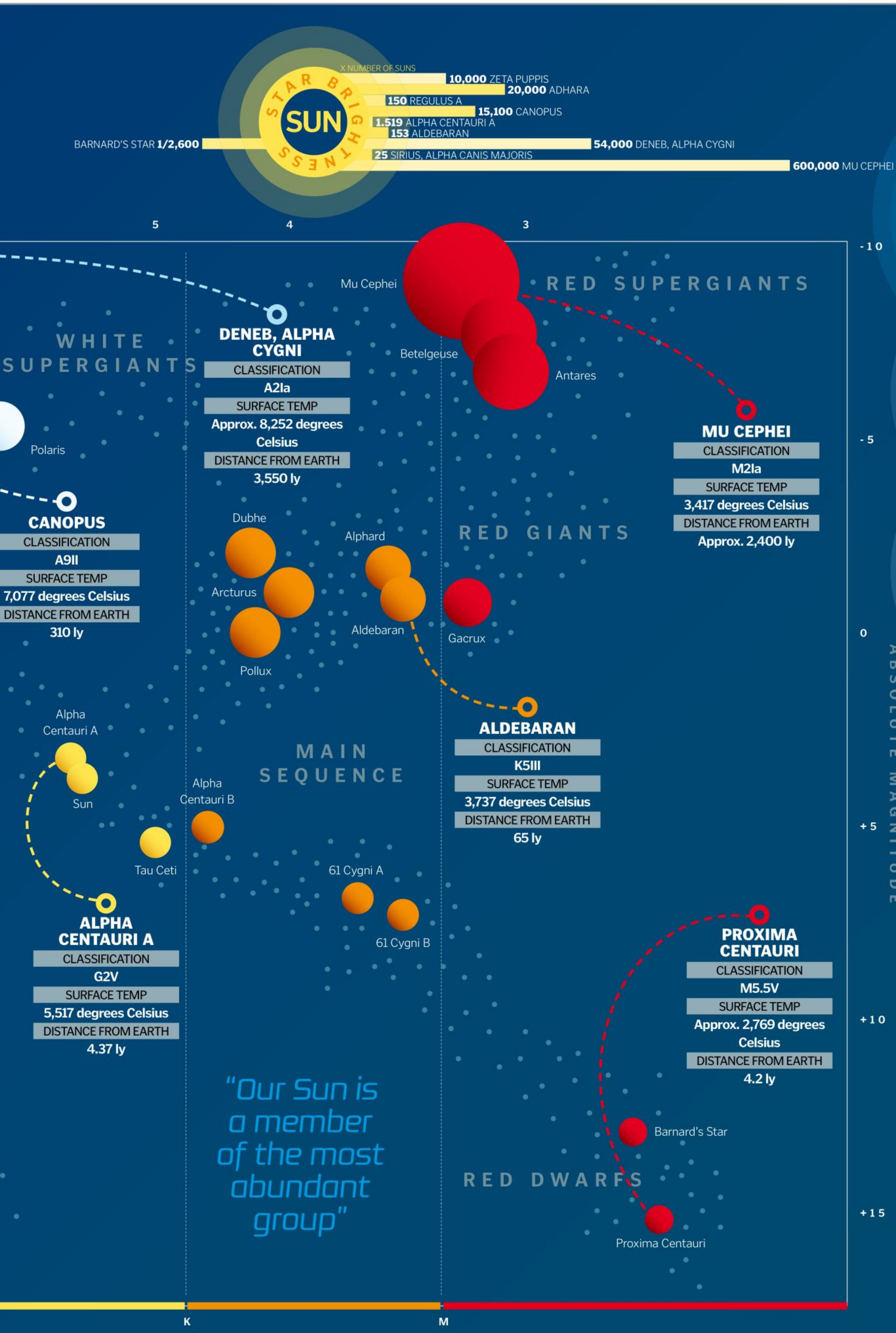
A star's colour is related to its temperature – blue stars being the hottest and red the coolest. Blue giants have high mass and surface temperature, while red giants are below 4,000°C. Red giants are formed from a bloating main sequence star.

Supergiants

The biggest stars in the universe, supergiants span the entire stellar spectrum of the MK system, O to M. Between 10 and 70 times the mass of the Sun, their luminosity can outshine the Sun tens or hundreds of thousands of times.



DID YOU KNOW? *In our galaxy there are around 10,000 stars that can be seen with the naked eye*



SPECTRAL CLASSIFICATION OF STARS

O
Av. surface temp.
> 30,000°C

B
Av. surface temp.
20,000°C

A
Av. surface temp.
8,500°C

F
Av. surface temp.
6,500°C

G
Av. surface temp.
5,300°C

K
Av. surface temp.
4,000°C

M
Av. surface temp.
3,000°C

HOW THE BLACK DEATH SPREAD

Fleas, rats and puss-filled boils – find out how the bubonic plague killed millions

Words by **Jodie Tyley**

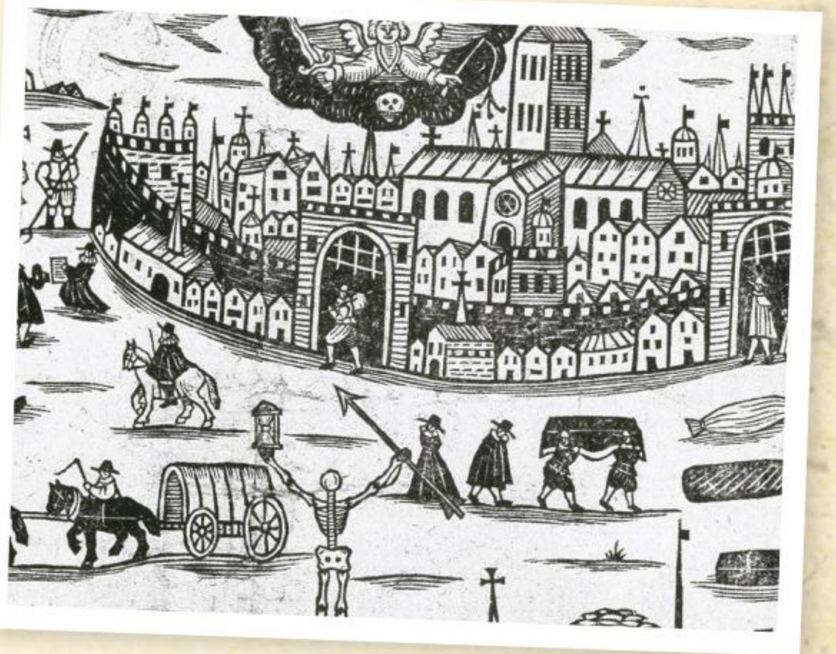
History has seen many pandemics, but the bubonic plague, better known as the Black Death, was one of the most devastating. This infectious bacteria is believed to have originated in China in the 1330s and was most likely spread via rat fleas on merchant ships, arriving in Europe in 1347. Tens of millions of people died, and records show that victims were from both poor and very wealthy backgrounds – the plague did not discriminate.

It became known as the 'pestilence' or 'great mortality' because of the high death rate. Coffins couldn't be made fast enough to match demand, so mass graves or 'plague pits' were built. One observer noted, "There were hardly enough living to care for the sick and bury the dead."

No one knew what caused the plague, meaning people often invented wild and even prejudicial theories – from exposure to bad air to the movements of the planets, or even Jews poisoning wells. The death and destruction led many to believe it was the end of the world, driving some people into madness.

Once the plague subsided in the early 1350s, those who survived demanded change. It's been argued that this resulted in the collapse of feudalism, the medieval system of power at the time. Laws were introduced in a bid to prevent labourers commanding higher wages and even dictating what clothes they wore, but the plague had caused a permanent change to society throughout Europe.

As many as 50 million people had died across the continent, but the nightmare was not over, and the disease reappeared over several centuries until the bacterium was uncovered. In fact, the bubonic plague still exists today, but thanks to modern medicine we now have a way to fight back.

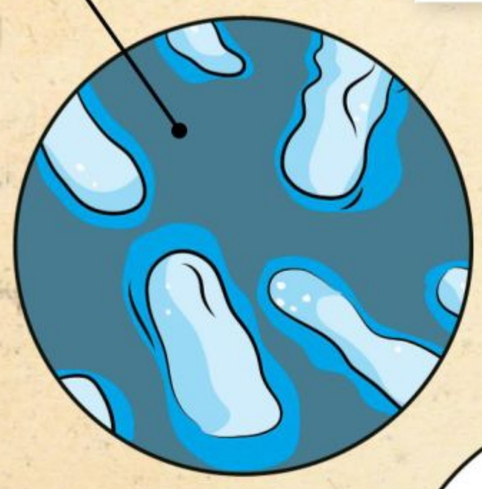


© Alamy

A woodcut of the plague printed above a "lamentable list of Death's triumphs in the weekly burials of the city of London"

Deadly signs and symptoms

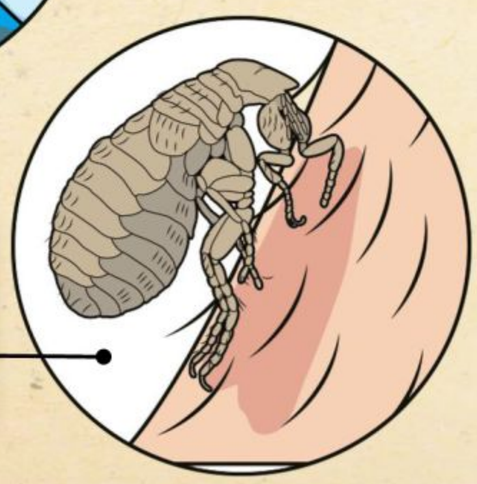
Infection
The plague is caused by the bacteria *Yersinia pestis* and can take one of three forms. Bubonic is the most common.



Fever
Early signs also include headaches, chills, weakness and vomiting.

The Black Death
Skin may turn black and die. This is known as septicemic plague and can develop from untreated bubonic plague.

Pneumonic plague
This lung-based plague can develop by inhaling infectious droplets from other humans. It's the most serious form of plague and can cause respiratory failure.



The cause
Fleas from rats can carry the bacteria in their digestive system, infecting humans through bites.

Swelling
Victims will suffer from fever and swollen, painful, egg-sized swellings called buboes form near where the person has been bitten.

© Getty; Illustration by Ed Crooks

The different forms of plague

Bubonic plague is the most common form, caused by a bite from an infected flea. The bacteria invades the nearest lymph node – infection-fighting glands found throughout the body – and cause it to swell. This inflammation is known as a bubo, hence bubonic plague, which is one of three types of plague caused by the bacterium *Yersinia pestis*.

Another form is septicemic plague, which can cause the sufferer's skin to turn black and die, particularly on the nose, fingers and toes, and gave rise to the name 'Black Death'. This is caused by a flea bite, handling an infected animal or from untreated bubonic plague.

Finally, the least common but deadliest type is pneumonic plague. It's passed from person to person by inhaling infectious droplets, such as phlegm, and can also develop from the other types of plague if they spread to the lungs. This particularly nasty form of the disease causes respiratory failure and shock.

© Alamy

An oriental rat flea carrying the *Yersinia pestis* bacteria in its abdomen

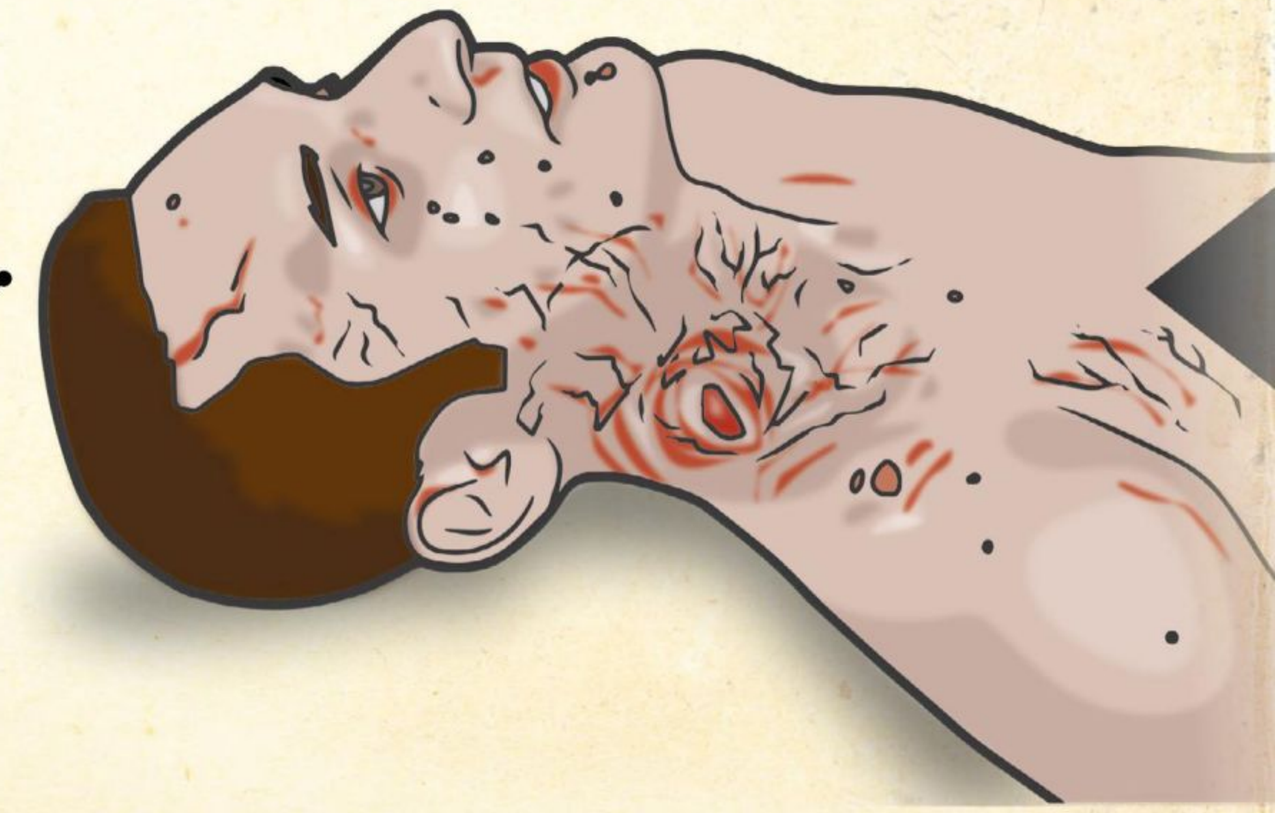
A miniature from Switzerland, 1411, generally believed to be depicting the plague

Outbreak

How the deadly plague is thought to have spread, via black rats and fleas

© Alamy

Rat infestations
In urban areas where rodents tend to live in large numbers, the plague bacteria passes between rats and their fleas.



Infected
The plague enters the human's bloodstream, and symptoms manifest within three to seven days.

50%

Estimated percentage of the population in Europe that died from the Black Death between 1347–1351

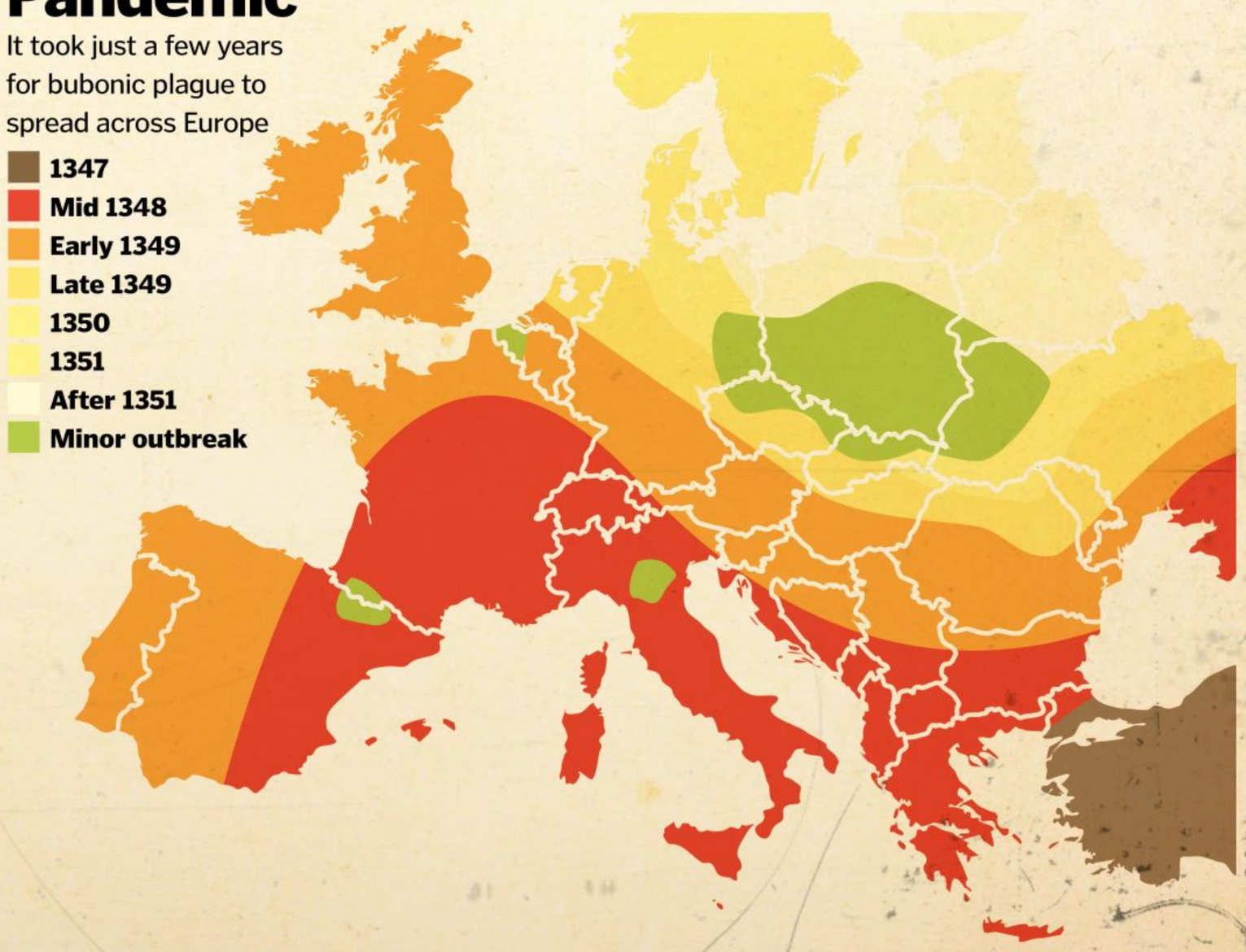
Mass burial pits were made as there were not enough coffins

30–100%

The case-fatality rate if left untreated

Pandemic

It took just a few years for bubonic plague to spread across Europe



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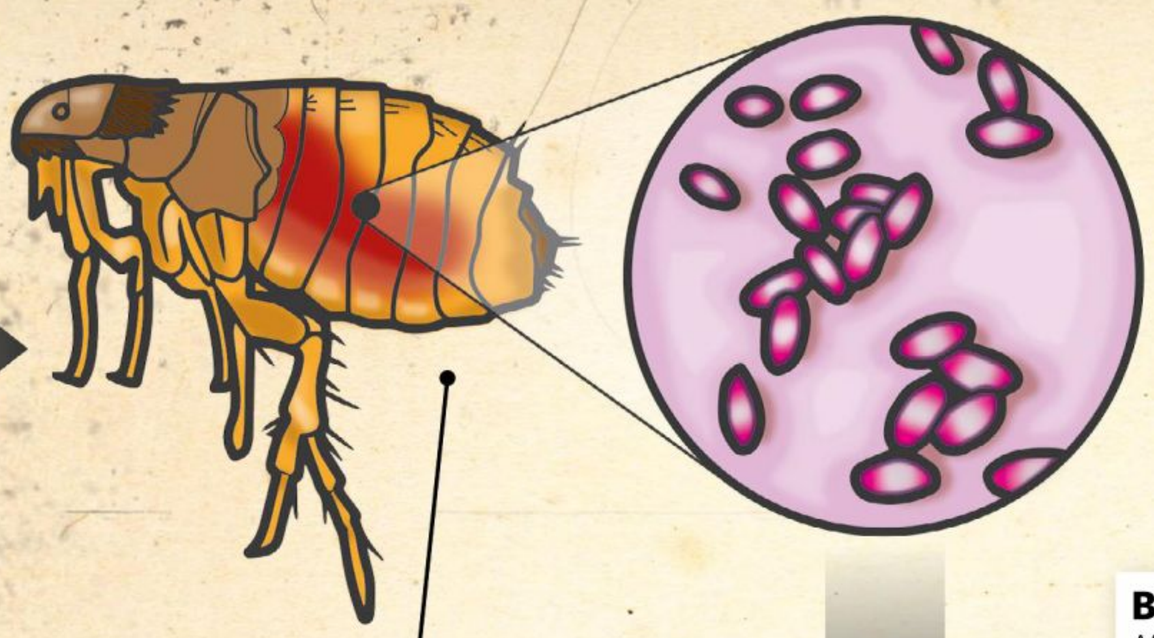
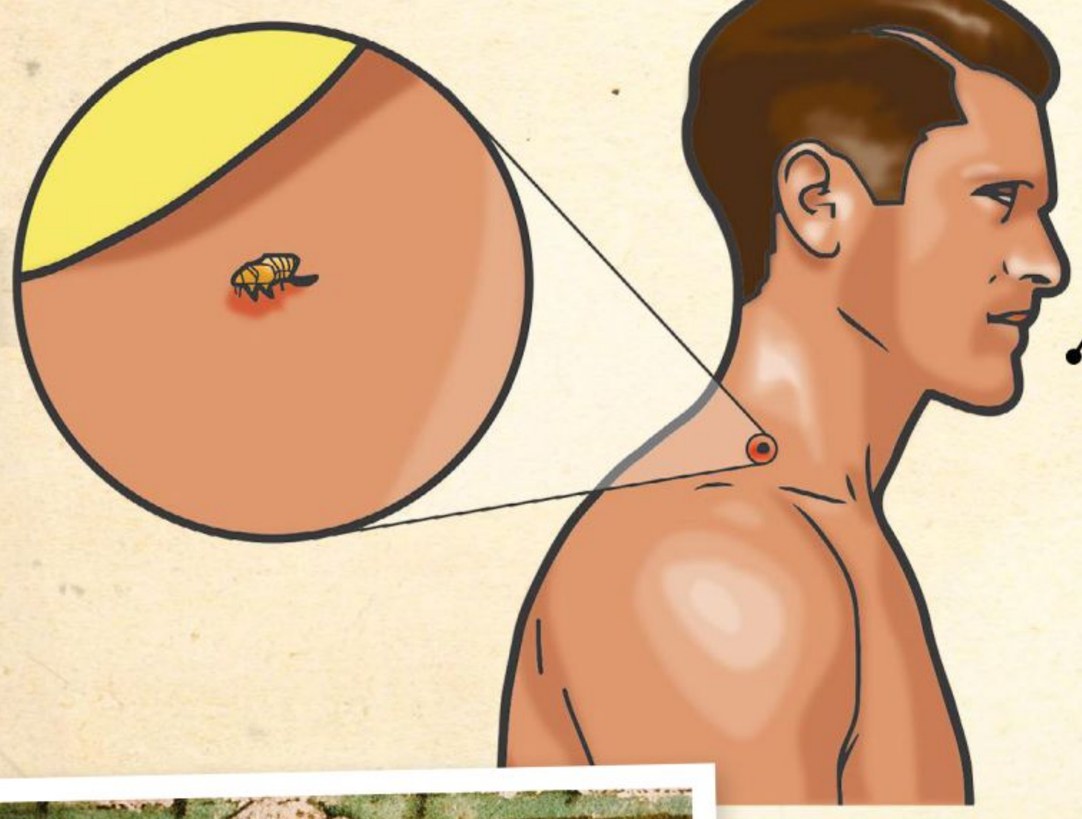


Bacterial growth
The plague bacteria multiply in the flea's stomach and cause a blockage.

Bad blood
After 10–14 days the infected rat colony dies, and the fleas turn on humans in search of fresh food.



Flea bite
The hungry flea bites a human and regurgitates the bacteria in its stomach during feeding.

© Illustration by The Art Agency/Nick Sellers

3.2 million

Estimated death toll for Britain and Ireland

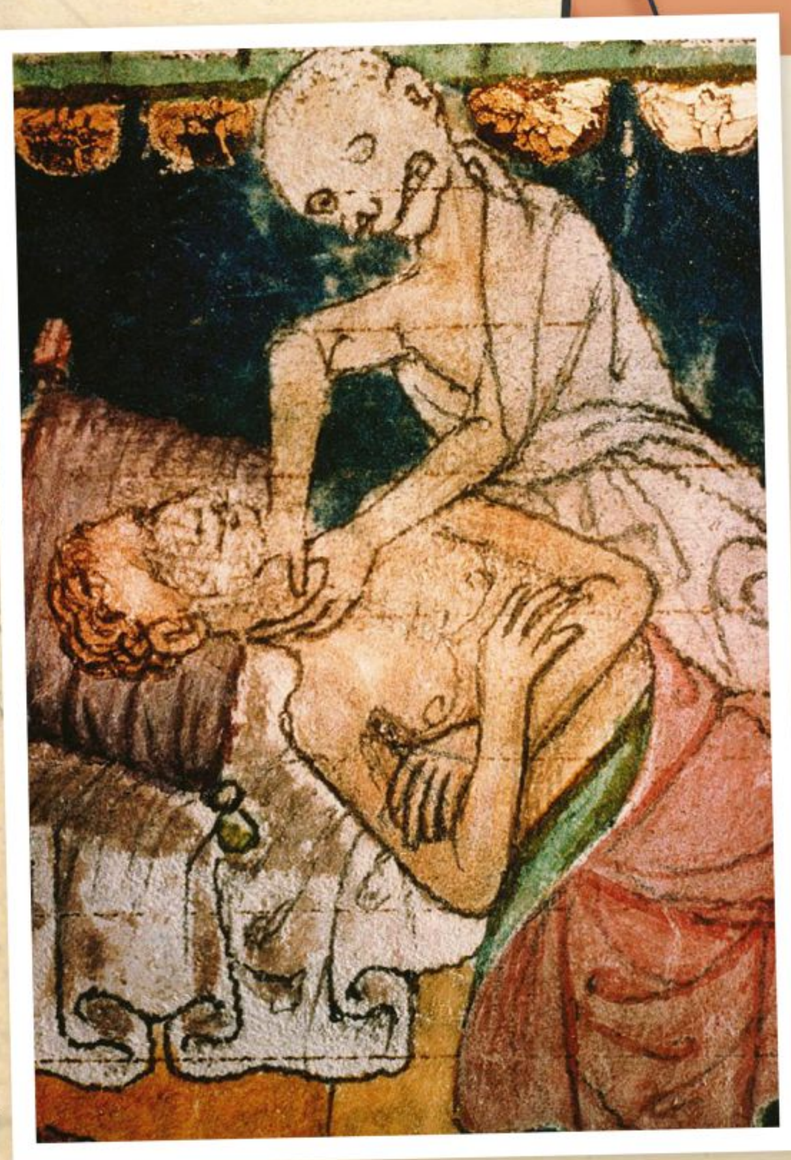
The term Black Death wasn't introduced until the 1800s

3,248

People infected with plague worldwide between 2010 and 2015

© Getty

The Black Death spread via the bite of infected rat fleas



© Alamy

Death strangling a plague victim, 1376

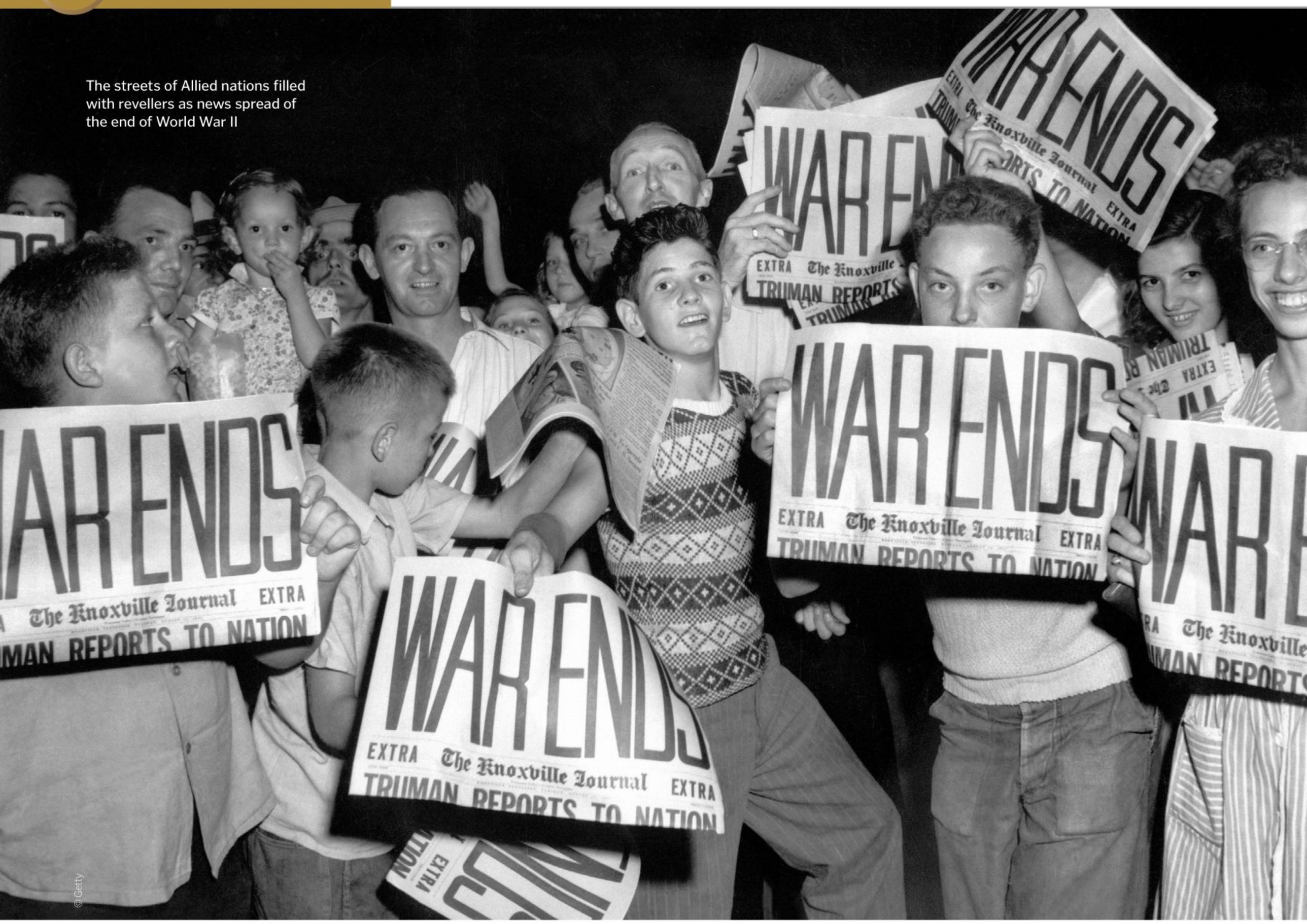
Quack cures

Today plague can be treated with antibiotics, but back in medieval times doctors had no idea what they were up against. With no knowledge of germs or how diseases spread, they turned to the ancient Greek idea of 'humours'. This referred to any type of fluid, such as phlegm or blood, and they believed an imbalance could lead to illness.

Bloodletting was one toe-curling 'cure', and drilling a hole in your head (trepanning) was another. Some doctors recommended rubbing a frog over your diseased body, drinking arsenic or vinegar and filling the house with herbs to purify the air. This belief that the plague was airborne led to doctors of the 17th century wearing beak-like masks filled with aromatic substances for protection. The plague remained a mystery for several centuries, and although treatments varied, the result was usually the same – death within days.

© Alamy

Some believed the plague was a punishment from God and whipped themselves in the streets



The streets of Allied nations filled with revellers as news spread of the end of World War II

How did WWII end?

After six years of conflict, the Allies clinched a dramatic and destructive victory in Japan

World War II raged from 1939–1945, leaving millions dead in its wake. It consumed the world in gunfire and destruction, as the Allies faced off against the Nazis and the other Axis nations. Claiming around 80 million lives, it is the deadliest war the world has ever faced. But what made the last nations finally lay their guns down?

Following the fall of Berlin in May 1945 and the surrender of two of the three Axis nations – Italy and Germany – war in the European theatre ended. However, Japan still remained at war with the Allies.

Gathered in Potsdam, Germany, in July 1945, Allied leaders including the US President Harry S. Truman, British Prime Minister Winston Churchill and Chinese Nationalist leader Chiang Kai-shek outlined terms for a Japanese surrender, known as the Potsdam Declaration. This proposal, however, came with a dire warning. Should the Japanese refuse to unconditionally surrender, they would face "prompt and utter destruction." These calls for a final resolution to the war were ignored by the Japanese government, and the threat of destruction soon became a reality.

> "The enemy has begun to employ a new and most cruel bomb"

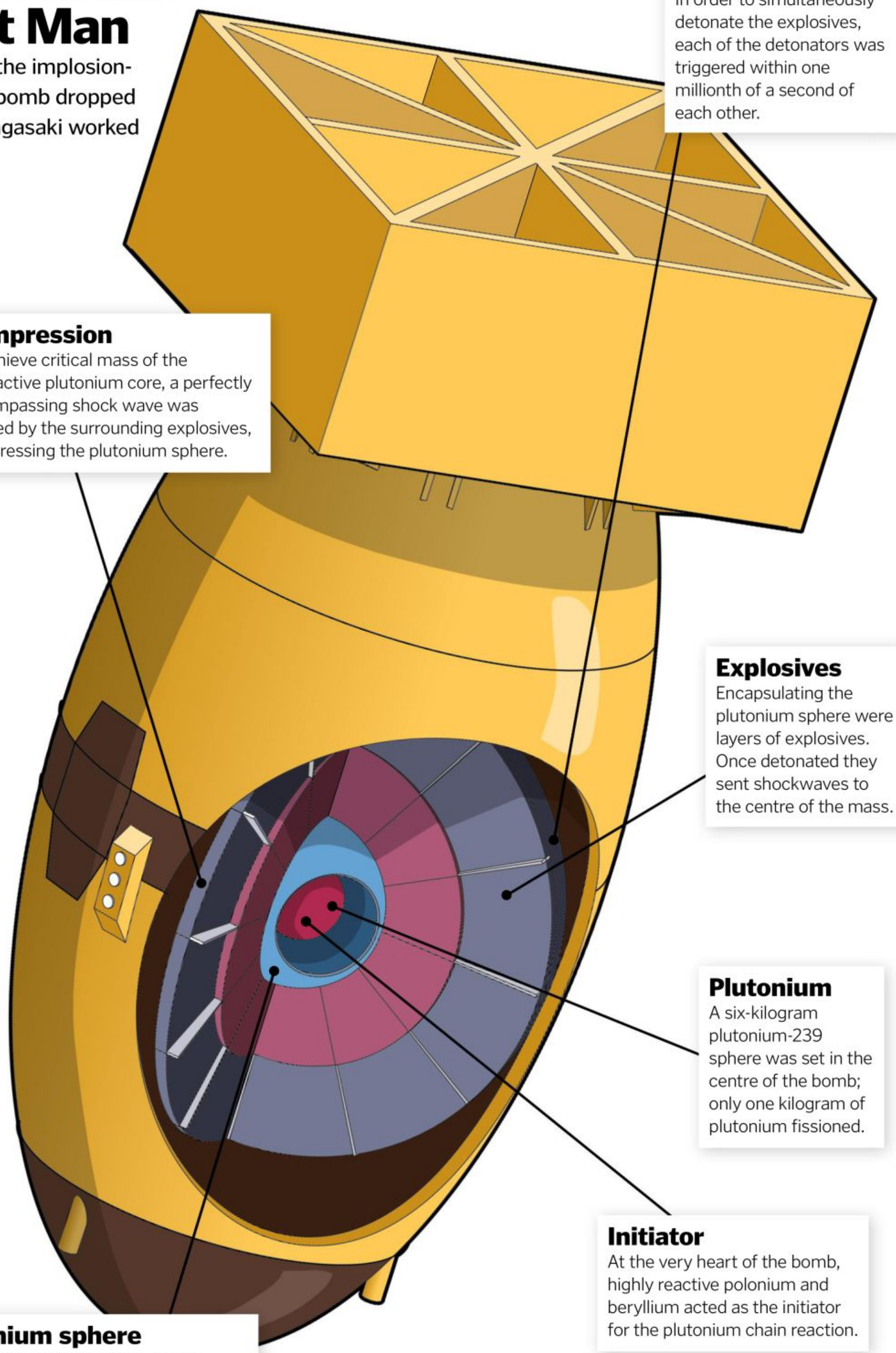
The US prepared to end the war by unleashing a type of bomb the world had never seen before. During the war nuclear physics was still in its infancy, but teams of scientists led by physicist and engineer J. Robert Oppenheimer utilised the recent discovery of nuclear fission – where a large amount of energy can be produced from a nuclear chain reaction – to create two nuclear bombs with huge destructive force.

The Japanese cities of Hiroshima and Nagasaki were hit with nuclear strikes by US forces on 6 and 9 August 1945 respectively, causing widespread devastation and fatalities. Fearing complete destruction, Japan surrendered on 15 August, with Emperor Hirohito announcing, "the war situation has developed not necessarily to Japan's advantage... the enemy has begun to employ a new and most cruel bomb".

It's now known as VJ Day (Victory over Japan), but it wasn't until 2 September that Japanese officials formally signed the unconditional surrender, marking the end of World War II.

Inside the Fat Man

How the implosion-type bomb dropped on Nagasaki worked



Detonators
In order to simultaneously detonate the explosives, each of the detonators was triggered within one millionth of a second of each other.

Compression
To achieve critical mass of the radioactive plutonium core, a perfectly encompassing shock wave was created by the surrounding explosives, compressing the plutonium sphere.

Explosives
Encapsulating the plutonium sphere were layers of explosives. Once detonated they sent shockwaves to the centre of the mass.

Plutonium
A six-kilogram plutonium-239 sphere was set in the centre of the bomb; only one kilogram of plutonium fissioned.

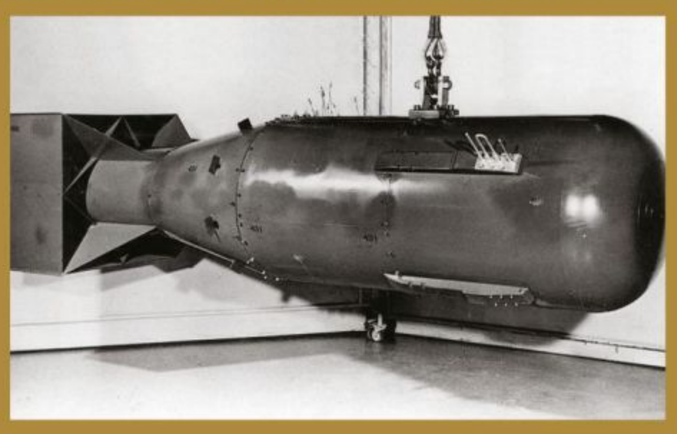
Initiator
At the very heart of the bomb, highly reactive polonium and beryllium acted as the initiator for the plutonium chain reaction.

Uranium sphere
During the chain reaction, excess neutrons were reflected back into the core by the uranium sphere to increase the plutonium's critical mass.

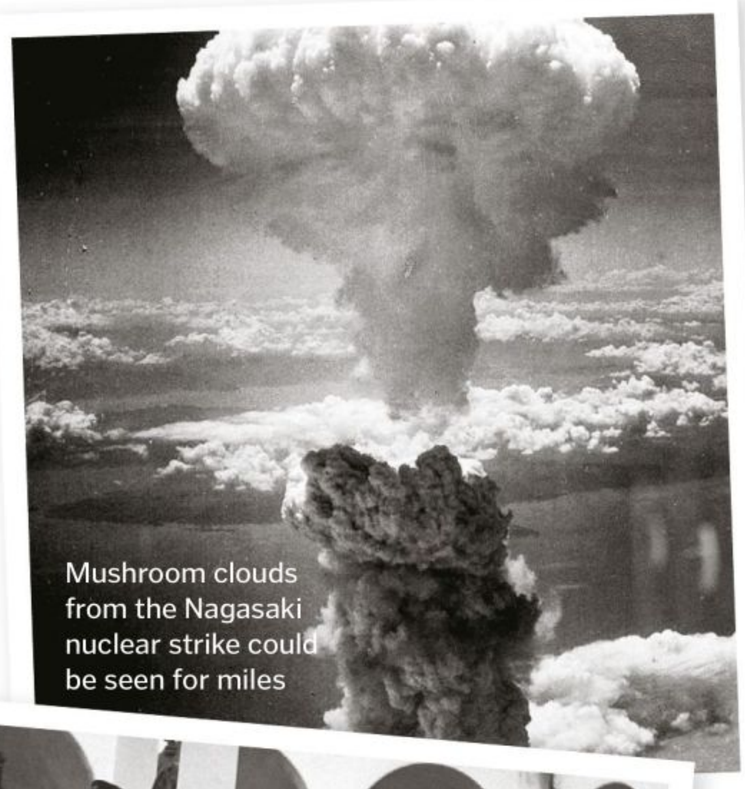
The first nuclear strike

The first attempt to force the Japanese to surrender fell in the form of an atomic bomb nicknamed 'Little Boy'. Within this 'gun-type' bomb a radioactive uranium-235 bullet would fire into a uranium core and trigger a nuclear chain reaction, creating an explosion with the same energy as 15,000 tons of TNT.

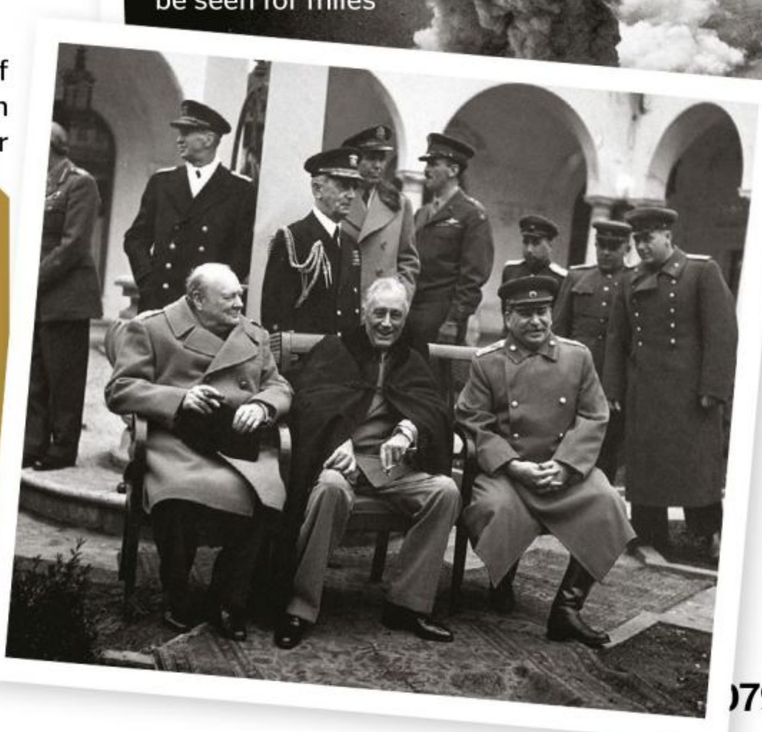
On 6 August 1945 an American B-29 bomber nicknamed 'Enola Gay' carried the Little Boy bomb over the Japanese city of Hiroshima – a hub for manufacturing and the military and occupied by 350,000 people. Little Boy was released from the aircraft and exploded 580 metres over the city, claiming the lives of around 80,000 people, both civilian and military, with countless more perishing from radiation poisoning later. But this wasn't the bomb that forced the Japanese to surrender.



Little Boy was the first nuclear bomb ever used in war



Mushroom clouds from the Nagasaki nuclear strike could be seen for miles



Following the fall of Berlin the leaders of the three dominant Allied nations met in Potsdam to discuss Japan's surrender

The final nuclear strike

In a second attempt to end World War II, a mere three days after the attack on Hiroshima, another American B-29 aircraft nicknamed 'Bockscar' headed for the densely populated Japanese city of Kokura. Onboard was a five-ton plutonium bomb called 'Fat Man'. Dense cloud coverage, however, prevented the bomb's release, and so Kokura was spared, forcing the American bomber to fly to the seaport city of Nagasaki. Finding a break in the clouds, Fat Man was dropped on the city and detonated, delivering an explosion equivalent to 21,000 tons of TNT, killing around 40,000 people and leaving the city in ruins.

© Alamy

Çatalhöyük settlement on the Konya Plain in Turkey

The first human settlements

More than 10,000 years ago, nomadic tribes put down their roots to establish the very first towns

Early humans led a nomadic life, constantly travelling in search of food and water. Small tribes would create basic shelters in caves or other rock formations, and then leave to follow the seasonal changes and migration of the animals on which they depended. This way of life continued for hundreds of thousands of years, until the first farms marked the dawn of a new era – the Neolithic period (or New Stone Age), around 12,000 years ago. By discovering that crops could be grown and animals could be tamed, the hunter-gatherers began to settle down and build permanent dwellings.

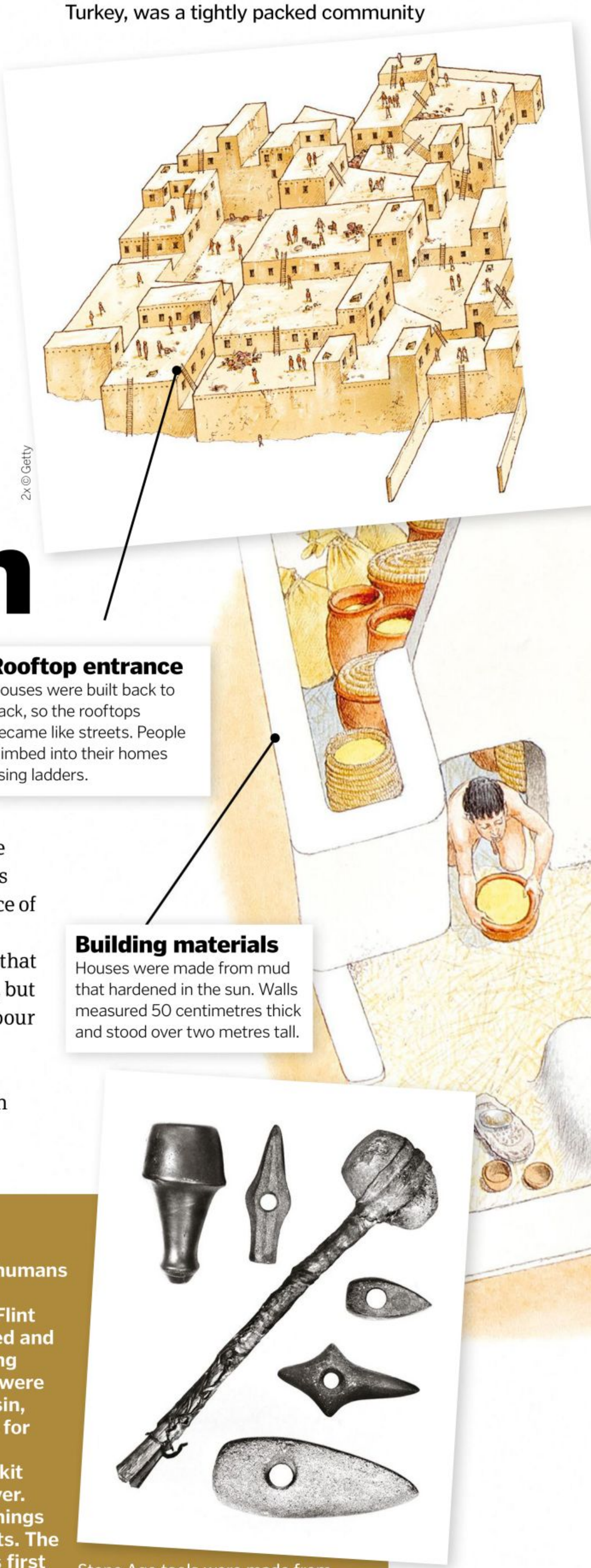
Neolithic towns were constructed from any natural materials that could be found nearby, but most houses were made using the wattle and daub technique. The wattle was made by weaving branches between wooden frames, and the daub – a mixture of manure, mud, hay and water – was smeared over the top, helping to strengthen the structure and keep the inhabitants warm and dry. However, when wood was not available, as on Scotland's Orkney Islands, Neolithic people used stone to build their houses, and even used it for their furniture.

In the settlement of Çatalhöyük in Turkey, the residents used mud bricks that hardened in the hot sun. This is one of the largest settlements to have been discovered, and is thought to have housed as many as 8,000 people. The site was built near marshy swamps – a valuable source of water and building materials. However, archaeologists think it wasn't just resources that drew such large numbers of people together, but also security against enemies, division of labour and community rituals.

Life was still pretty primitive for Neolithic settlers, but they thrived in these early urban environments and would pave the way for civilisation as we know it.

Ancient urban living

9,000 years ago this settlement in Çatalhöyük, Turkey, was a tightly packed community



2x © Getty

Rooftop entrance
Houses were built back to back, so the rooftops became like streets. People climbed into their homes using ladders.

Building materials
Houses were made from mud that hardened in the sun. Walls measured 50 centimetres thick and stood over two metres tall.

Tools of the trade

The Stone Age was a period when early humans used tools and weapons made of stone, beginning around 3.4 million years ago. Flint and obsidian (volcanic glass) were shaped and sharpened using a hammerstone, creating arrow heads, knives and hand axes, and were stuck onto pieces of wood using pine resin, beeswax and charcoal. These were used for hunting and preparing food.

The simple but effective Neolithic toolkit wasn't exclusively made of stone, however. Bones and antlers were used to create things like needles, combs and even instruments. The Stone Age came to an end when humans first started using metal around 5,000 years ago.

Stone Age tools were made from flint, obsidian, antlers and bones

© Alamy

"Neolithic towns were constructed from any natural materials they could find"

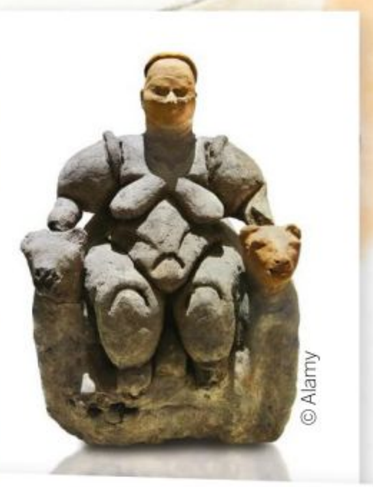
Crafts
Cloth was woven on looms to create clothing and blankets, while reeds were woven into mats.

Home burials
People buried their relatives under the floors of their homes.

Early farmers
They spent most of their time farming the land but also went hunting and gathered fruit to eat.

Cooking
A fire was positioned near the rooftop entrance so smoke could escape. This 'dirty' area was separate from the 'clean' zone of the house.

Meat
Sheep, goats and eventually wild oxen were tamed, providing meat, as well as wool and milk for the people.



A terracotta figure from 5750 BCE, believed to be associated with agriculture and fertility

Skeletal remains found in Çatalhöyük

Neighbours from hell

Çatalhöyük may be a model of early urban living, but its residents were far from model citizens. A recent study suggests that when the population was at its largest, overcrowding led to violence. Excavated skulls show signs of healed fractures, and others had been hit with round, hard objects.

Many of the victims were women. Clay balls unearthed at the site seem to fit the size of the weapon and may have been used as projectiles flung by a slingshot.

People and animals living in such close quarters could have increased the spread of disease, adding to stress in the community.

Professor Clark Spencer Larsen, who led the study, said, "Çatalhöyuk was one of the first proto-urban communities in the world, and the residents experienced what happens when you put many people together in a small area for an extended time. It set the stage for where we are today."

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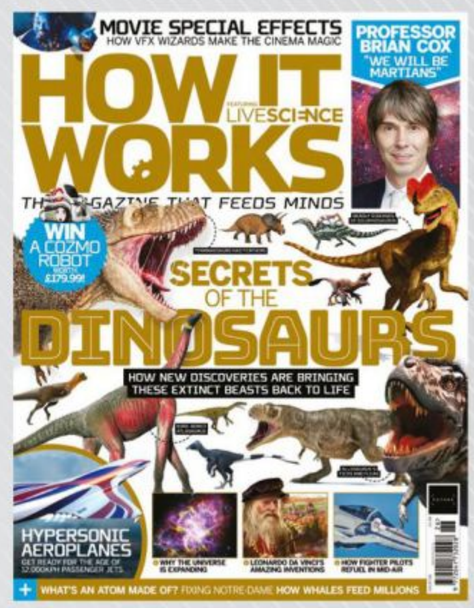

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What if Earth was twice its mass?

Felipe Jacobs

The surface gravity of a planet depends on its mass and its radius. You calculate it using the formula $g = GM/r^2$, where G is the gravitational constant, M is the mass and r is the radius. Increasing Earth's mass would make surface gravity go up, but increasing its radius would make surface gravity go down. The effect of doubling Earth's mass would depend on how you did it. If the mass of Earth doubled but the radius didn't increase, surface gravity would double. But if Earth's radius did increase, the effect on surface gravity wouldn't be so extreme. If the radius increased far enough, surface gravity would actually decrease. **LM**

Size isn't everything: the mass of a planet also dictates its gravity

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What powers the world's trains?

Clara Harrison

Many of the world's trains run on electricity from cables that run above the tracks. However, less than 50 per cent of rail lines have these cables, so some trains still use diesel. **JS**

© Getty

Could we make a holodeck, like in *Star Trek*?

Tina Walters

Our best bet for making a life-like virtual reality space probably lies with VR headsets used alongside haptic gloves (and eventually full haptic suits). Together, these technologies can fool our sight, hearing and sense of touch to build an immersive virtual playground. **JH**

Why is nuclear power considered 'clean'?

Myra Gibson

Nuclear reactors are considered 'clean' in contrast to coal, oil and gas because they don't directly make carbon dioxide or pollute the air. However, they're not environmentally innocent. The energy-intensive process of making nuclear fuel is sometimes powered by burning fossil fuels. And nuclear reactors produce radioactive waste. **LM**

© Getty

Can snowstorms produce thunder and lightning too?

Yvonne Hoffman

For thunder and lightning to form, warm air in the lower atmosphere needs to rise up into colder air above it. The water vapour carried by the warmer air then collides with ice crystals in the cold air, creating friction, which forms an electric field within storm clouds. The bottom of the cloud then becomes negatively charged, and the difference between this and the positively charged ground creates a bolt of lightning. In snowy weather, the atmosphere is too cold and dry to create the updraft of warm, wet air needed to generate any friction. **JS**

© Pixabay

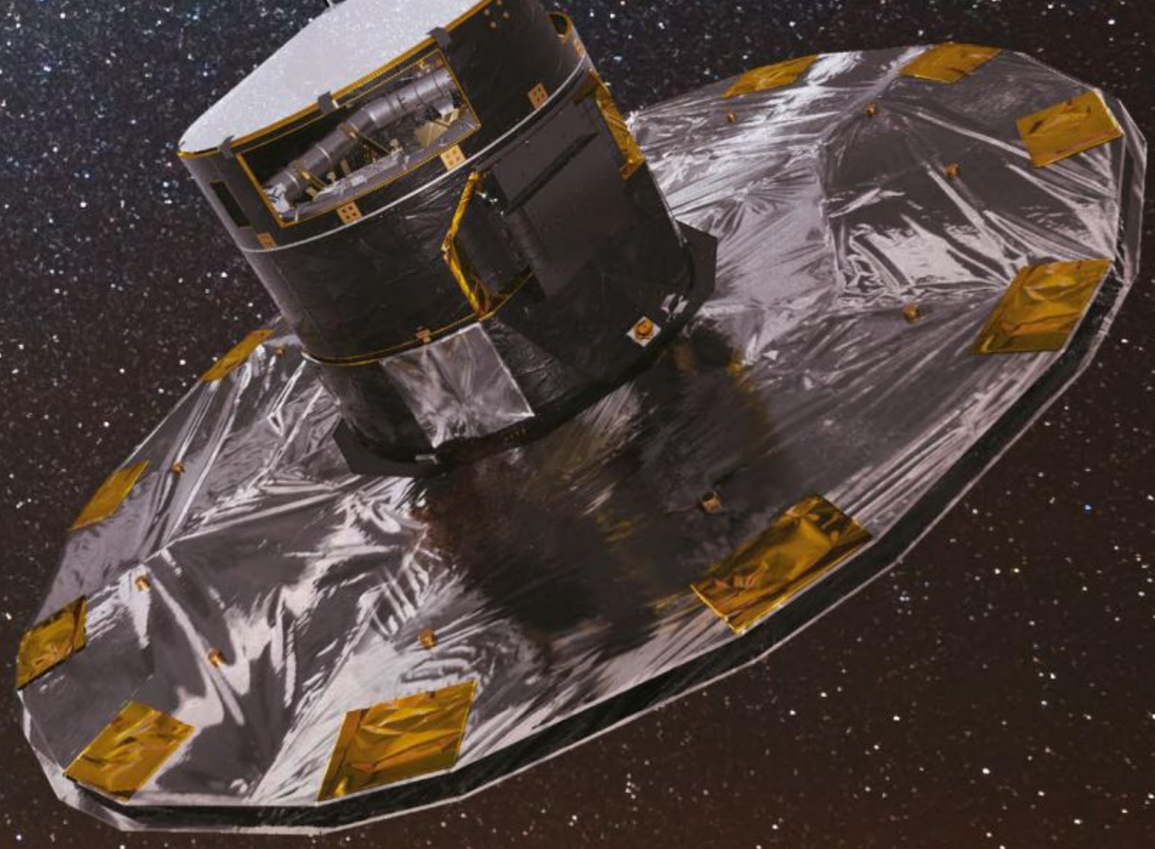
Snowstorms don't provide the right conditions for thunder and lightning to form

BRAIN DUMP

Are there places in space we can leave spacecraft without them drifting off?

Phil Jensen

A Lagrangian point is essentially a 'parking space' for spacecraft, where the forces of gravity balance out to allow a probe to stay in one place with minimal fuel consumption. There are five of these points in the Earth-Sun system, but only two are currently occupied by a total of five spacecraft. **JS**



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Why is public Wi-Fi more risky?

Gretchen Schneider

Public Wi-Fi hotspots, such as those offered by cafes and hotels, don't require any authentication when you connect to them. This makes it relatively easy for anyone with the right technological know-how to access the data stored on your connected device. For example, they could intercept the connection and gain access to anything you send via the internet, including emails and money transactions, or they could use the network to plant infected software, called malware, onto your device. **JS**

Does more body fat make you more cold resistant?

Theodore Alexander

Body fat is a good insulating material because it's a poor conductor of heat. This means that warmth generated in the body will be lost to the outside environment more slowly in people with higher body fat. However, people with high body fat may sometimes feel colder than individuals with lower body fat, as their skin receives less heat from their core. **JH**

Why did sailors eat wormy biscuits on long voyages?

Lily Fitch

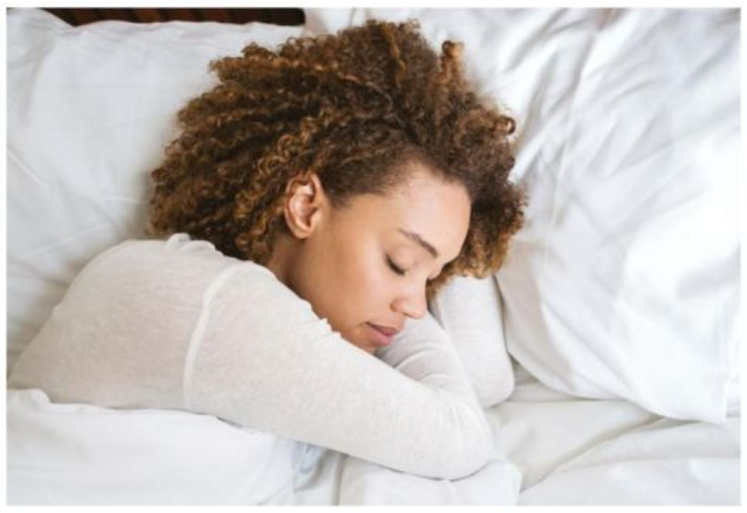
Keeping food fresh on long voyages was difficult, but dry biscuits made from flour and water could last for years. They often became infested with weevils, but the sailors didn't have any other option. **LM**

© Getty

What's the most expensive car in the world?

Rafael Riley

■ In March 2019, Bugatti sold the one-off La Voiture Noire for £14.4 million ($18.7 million). It was bought by an unnamed customer who didn't even ask about the price. **TL**



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How many hours of sleep do we really need?

Jack Day

■ It depends on your age. That's according to the National Sleep Foundation, which reviewed 320 studies. Adults need between seven and nine hours of sleep, while a teenager should have between eight and ten. The amount of zzz's you need increases the younger you are, with newborns needing 14-17 hours. **JT**

© Pixabay

How many trees have to die before we're in trouble?

Roy Murphy

■ Each person on Earth needs the amount of oxygen produced by around eight trees every year. If there are 7.7 billion people, that means we need 61.6 billion trees to keep everyone alive. There are currently around 3 trillion trees, so around 2.9 trillion would have to die before we're in trouble. **TL**

Gravity Industries' jet suit uses turbine engines mounted on the wearer's back and arms to achieve flight

© Gravity Industries

Has anyone perfected the jetpack yet?

Leon Mclaughlin

■ Jetpack technology has come along leaps and bounds in the last few years, but its origins are found in the 1960s. The first set of jetpacks weren't actually powered by jets at all, but instead were fuelled by rockets. Known as 'Rocket Belts', they were able to shoot into the sky at impressive speeds – but only for brief periods. This was because they burned through their fuel tanks amazingly quickly, as the only source of thrust came from the gas released from the rocket pack. But true mastery of the field arrived in 2017 with Gravity Industries' Jet Suit, which uses a three-component jet engine-powered suit. The use of jet engines – mounted on both the wearers' back and arms – grant unrivalled control in the air. **JH**

Why are there so many different fuels made from oil?

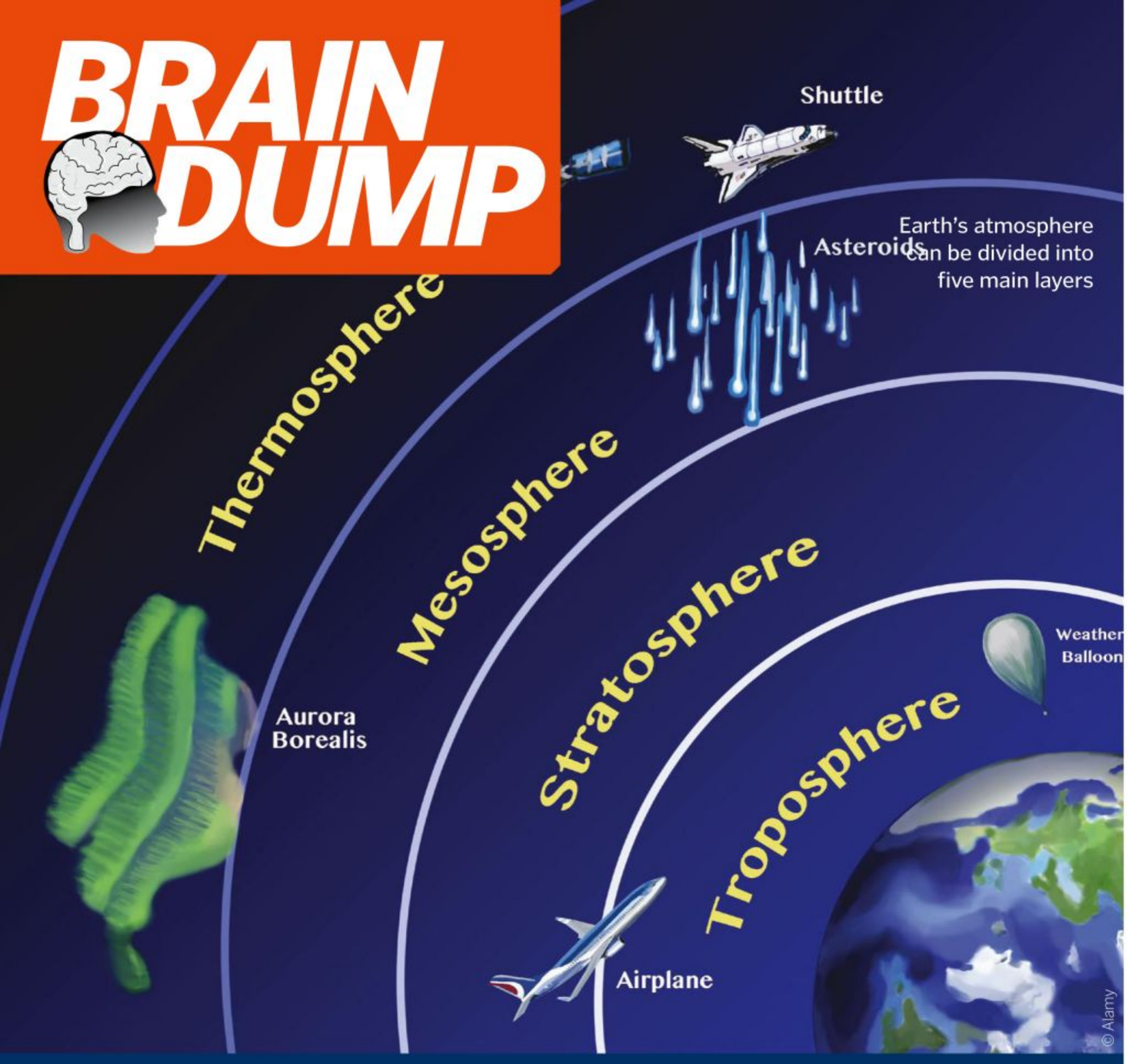
Rogelio Walsh

■ Oil contains a mixture of chemicals with different sizes, shapes and properties. The smaller they are, the more easily they flow, evaporate and ignite. We separate oil into fractions to make fuels with different properties. Liquefied petroleum gases are the smallest, with up to four carbons per molecule. Then there's petrol, followed by kerosene, diesel and heavy fuel oil. Bitumen, with more than 35 carbons per molecule, is too sludgy to use as fuel but is useful for covering roads. **LM**

Refineries heat crude oil to separate it into fractions with different chemical properties

© Getty

BRAIN DUMP



Is there any life high up in Earth's atmosphere?

Jared Welch

The atmosphere is a mixture of gases that protects our planet and makes life possible, but whether life can exist high above the Earth's surface is up for debate. While microscopic organisms have been reported as high up as 77 kilometres, there is doubt over how they got there and whether they can grow or divide in such dry and cold conditions. These microorganisms could have been carried into the atmosphere by storms and hurricanes, for instance. As many experiments date back to the 1930s, the results need verifying. **JT**

Does China really have 5,000 years of history?

Sue Jennings

This claim is based on the supposed existence of the Yellow Emperor, said to be the common ancestor for all Chinese people and the founder of Chinese society, ruling from 2697 BCE. However, there is no evidence that he ever existed, and archaeological evidence only stretches back to the Shang dynasty, founded around 1600 BCE. Other civilisations predate China – the world's first city dates back 7,000 years, and writing systems in Egypt and Mesopotamia existed 1,000 years before Chinese writing. **JT**

How do I stop my laptop battery dying?

Sherman Barnett

The biggest drain on your laptop's battery is the display, so if you need to squeeze some extra power out of your device then the first step is to turn down the screen brightness. Next you should turn off any unnecessary applications running in the background, and if you're not using them, switch off Wi-Fi and Bluetooth too. Some laptops will even have a power-saving mode to do all of this for you to make it easier. **TL**

Can microwaves make food cold?

Yasuko Ito

Microwaves heat food by creating high-frequency electromagnetic waves. The energy from these waves is absorbed by the food inside, causing its molecules to move around and generate heat. This process can't be easily reversed – to slow down the movement of molecules quickly you need specialist equipment such as liquid nitrogen or lasers. **TL**

Why are the Mars rovers so slow?

Maggie Waters

There are several reasons for this. Firstly, using solar power limits the energy available. Rovers are also reliant on controllers on Earth, who need time to issue commands. And there's the suspension. Rovers, with their rocker-bogie suspension, can climb over rocks larger than their wheels. But this can generate a lot of stress, which is amplified by speed, so going slowly avoids damage. **JH**

Why don't humans grow to be ten feet tall?

Juan Gutierrez

Humans have evolved over millions of years, and natural selection has determined our genetic makeup. In fact, between 60 and 80 per cent of our height is down to genes, and the rest is influenced by environmental factors, such as nutrition. **JT**

Want answers?

Send your questions to...

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BOOK REVIEWS

The latest releases for curious minds

Invasive Aliens

The foreign animals you take for granted

- Author: **Dan Eatherley**
- Publisher: **William Collins**
- Price: **£16.99 / $25.99**
- Release: **Out now (UK) / 27 August (US)**

If you look out of your window or go for a stroll through your local park, it's almost certain that you'll encounter an alien species. No, we're not talking about little green men – we mean animals and plants from foreign countries that didn't originate in the UK. And it could be anything from a grey squirrel to a rhododendron. These flora and fauna species make up a large percentage of British wildlife, and in most cases you might not even notice. When was the last time you commented on a sycamore tree being out of place in this country, or wondered why Canada geese were feeding at your local pond?

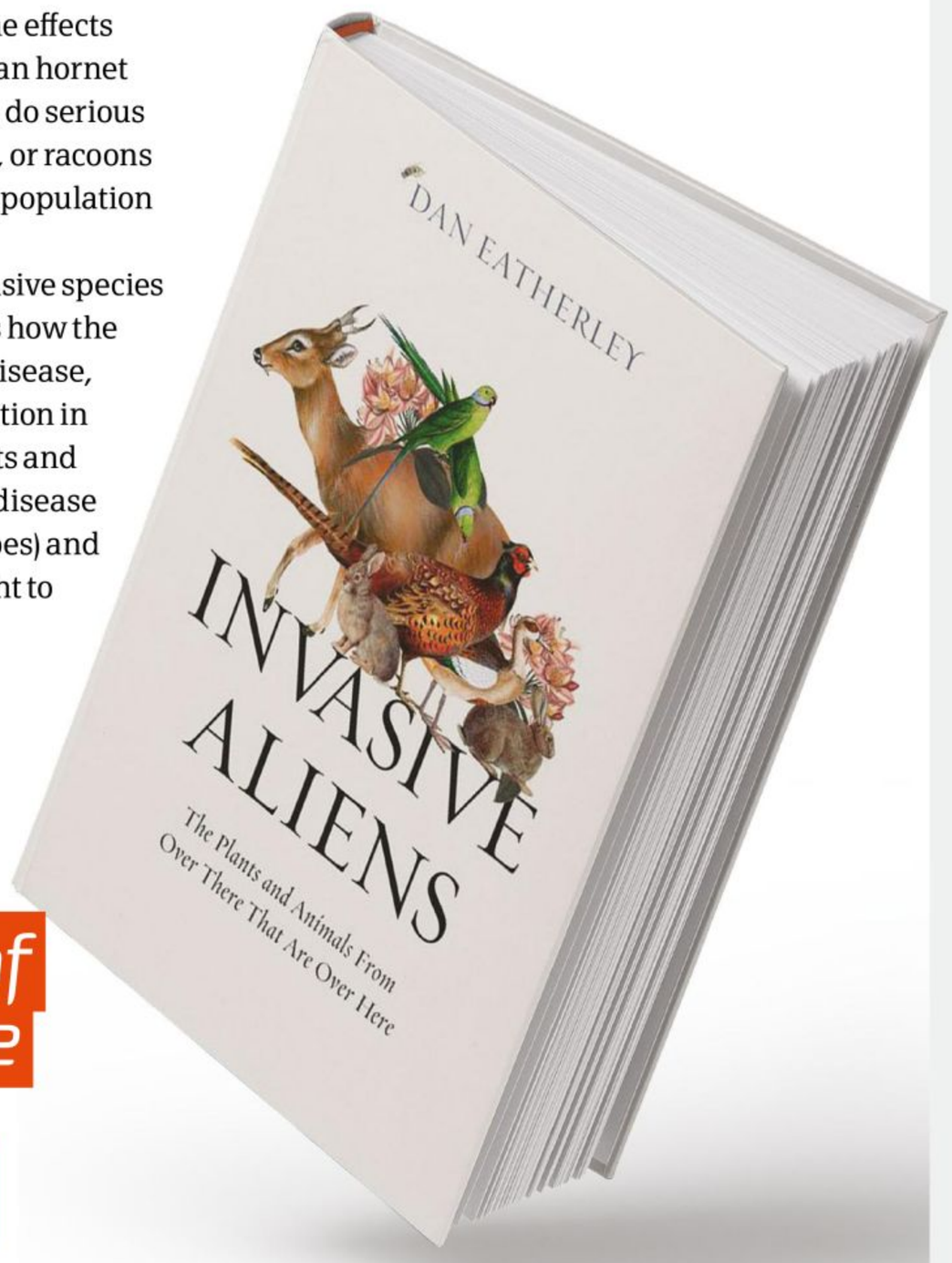
This is the central idea behind *Invasive Aliens*, which shines a light on the species that have hitched a ride over to the UK, and the effects they're having. Whether it's the Asian hornet that has recently arrived and might do serious damage to Britain's bee population, or racoons that haven't yet managed to build a population base in the UK.

Early on, the threats of these invasive species are made clear. Eatherley discusses how the arrival of a new species can cause disease, population decline and even extinction in others. And that's just to other plants and animals – for humans, it can mean disease transfer (from insects like mosquitoes) and even costs to the economy as we fight to maintain the country's carefully balanced ecosystem.

The book shifts between first-person accounts from Eatherley, which help set scenes and provide context for studies and topics, and more general writing that covers the science behind those topics. For the most part this works well and the balance is good, but at times we felt things were getting just a little dry, and we wanted Eatherley to inject more of his personality into the prose.

Still, for science lovers it's a treat. *Invasive Aliens* raises big and interesting questions. For example, can you define a species as 'invasive' if it moves to the UK due to the rising temperatures caused by climate change? As is often the case, that can't be answered yet – but there's much to be learned by simply asking these questions.

★★★★☆



> "The threats of these invasive species are made clear"

Math Games Lab for Kids

The magic number

- Authors: **Rebecca Rapoport, J.A. Yoder**
- Publisher: **Quarry Books**
- Price: **£16.99 / $24.99**
- Release: **Out now**

It's an age-old conundrum faced by teachers the world over: how do you make mathematics fun for those who don't enjoy times tables, trigonometry and the like?

Happily, this book has an answer: keep things practical and make it clear to the young audience that their efforts will have an end product. What's more, some of the things included in this book can be created with the most innocuous of items. There are antiprisms made from cocktail sticks and fruit pastilles; Möbius strips from paper, tape and markers; toothpick puzzles, and many more besides. Included within are a variety of shapes, maps and more that serve as props for some of the instructional guides – and to be coloured in, of course.

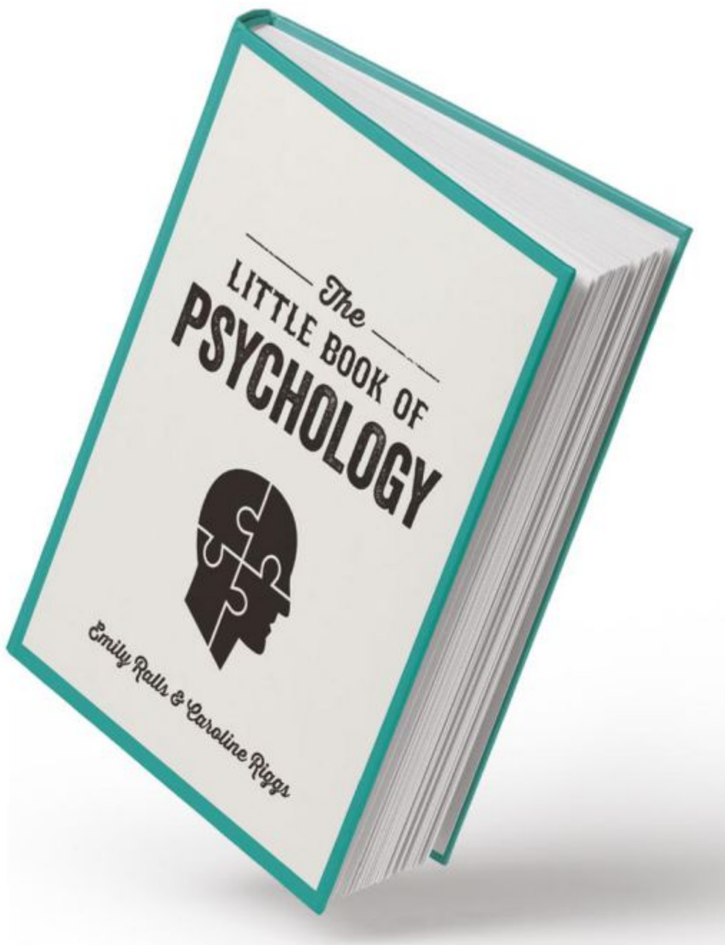
A lot of it falls squarely outside the curriculum, but then again broadening the audience's knowledge of the subject matter is no bad thing. Making mathematics a more interactive field of study could go a long way to encouraging more independence in students, and it's these kind of fun puzzles that make this a real possibility. Maths never quite gets the credit it is due, so hopefully the book can redress the balance.

★★★☆☆

The Little Book of Psychology

Mind games

- Authors: **Emily Ralls, Caroline Riggs**
- Publisher: **Summersdale**
- Price: **£6.99 (approx $10)**
- Release: **Out now**



Nowadays, everyone seems to be an amateur psychologist (just take a look at what passes for 'mind games' in your average Premier League game). They could probably do with a little book like this in their front pocket.

For such a small volume, a lot is packed in. After giving an overview of psychology and the history of its study, it breaks off into a lowdown on the various approaches that can be applied to it: biological, psychodynamic, behaviourist, cognitive and humanistic, plus a few more. It's far from a complete picture, but it's perfect if you want to separate the self from the shadow, and the animus from the persona.

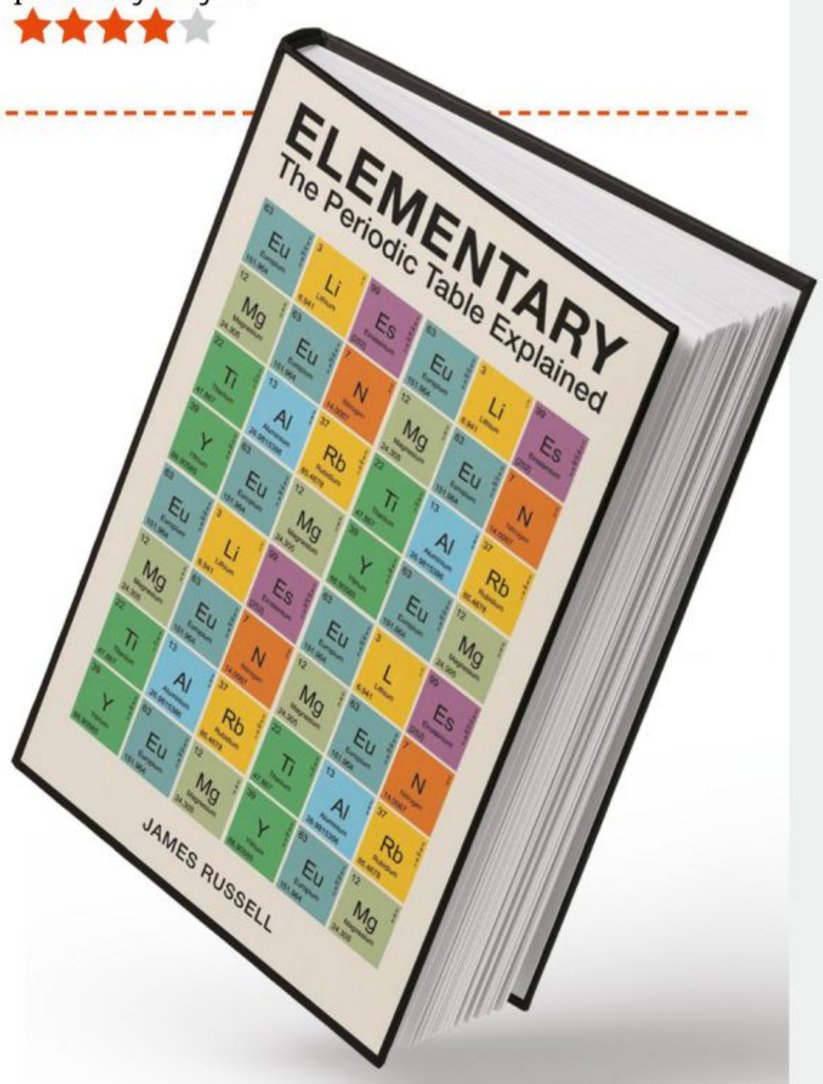
Rather than an implement of further study, think of this instead as a bite-sized introduction to the subject matter, aimed at discerning whether it's something that warrants further study from you. And considering how well written this is, we suspect the answer will probably be yes.

★★★★☆

Elementary: The Periodic Table Explained

The chemical brothers

- Author: **James M. Russell**
- Publisher: **Michael O'Mara Books**
- Price: **£9.99 (approx $15)**
- Release: **Out now**



Think you learned everything meaningful there is to know about the periodic table during those long chemistry lessons at school? After you've read this book, you'll realise that you weren't even close.

Still, for a number of you there's a good chance it's been a long time since you were last in a classroom so could probably do with a refresher, which this book more than ably provides. Beginning with the story of how the idea to organise the elements into a presentable format first formed in Dmitri Mendeleev's mind, writer James M. Russell proceeds to detail each element's properties and usage. From hydrogen to lawrencium, and possibly even beyond (yes, we're referring to the elusive element 119), there's a lot to learn and re-learn about the building blocks of the world around us.

Inevitably, with such a perfunctory format, it's difficult to consume in one sitting. In truth, it's probably the kind of book that's easier to come back to every now and then while you're doing other things. Russell does an efficient job of adding character to each description, though, meaning that this ultimately transcends what it was designed to be. One for the bookshelf of every budding chemist.

★★★★☆

Owling: Enter the World of the Mysterious Birds of yhe Night

Why the round face?

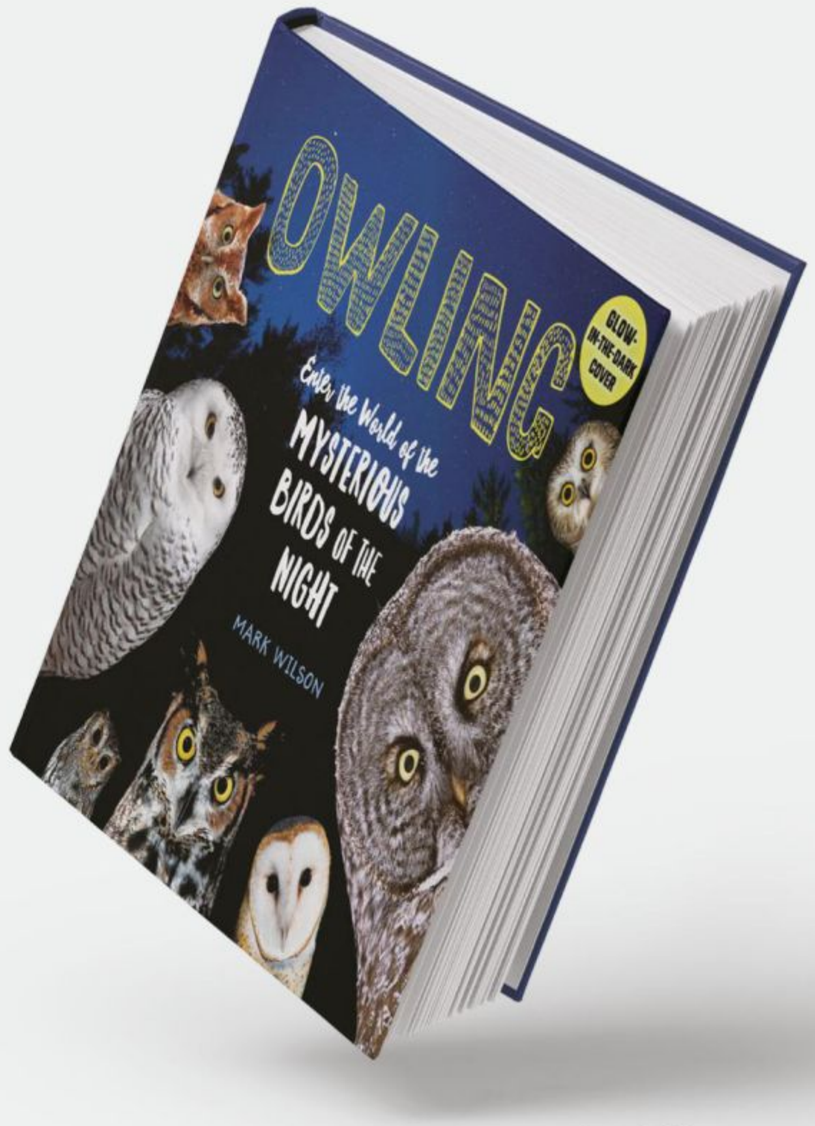
- Author: **Mark Wilson**
- Publisher: **Storey Publishing**
- Price: **£14.99 / $18.95**
- Release: **Out now**

There's a lot to be said for owls: with their striking eyes and sharp beaks, they're undoubtedly one of the most evocative birds in the world. With this in mind, we're happy that this book landed on our desk.

Running through the lifecycles of the various 19 species of owl that inhabit North America, from hatching to first flight, there are also a number of pages of trivia and information about their habits, aided by a series of colourful photographs of the birds themselves. Admittedly it's nothing groundbreaking, but it will more than likely be the most you've read about these round-faced sky predators in one sitting.

At £14.99, it's quite a lot of money for what is quite a small volume (just over 100 pages). Even so, it's competently done and could make a decent enough gift for the budding twitcher in the family.

★★★☆☆



BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

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

FIND THE FOLLOWING WORDS...

INTESTINES
FORENSIC
FLYING
CHALLENGER
LIONS
LANDFILL
SPIDER
ELECTRIC
DRONE
XBOX
JUPITER
PLAGUE

Quickfire questions

Q1 What is the approximate pH of human stomach acid?

- 2
- 4
- 6
- 8

Q2 Where is *Panthera leo* typically found?

- Asia
- Africa
- Antarctica
- Australia

Q3 Jupiter has the mass of ___ Earths.

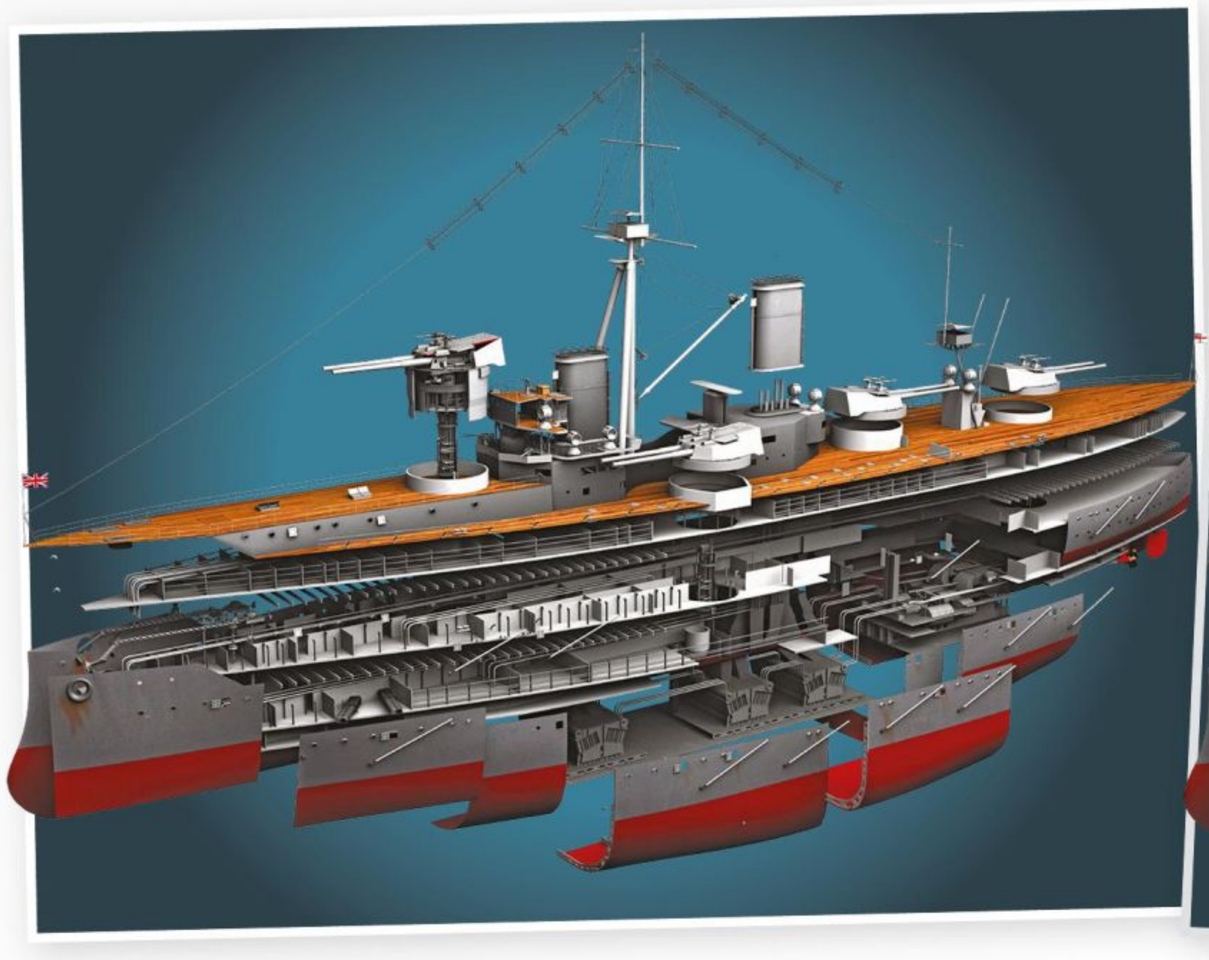
- 11
- 318
- 118
- 93

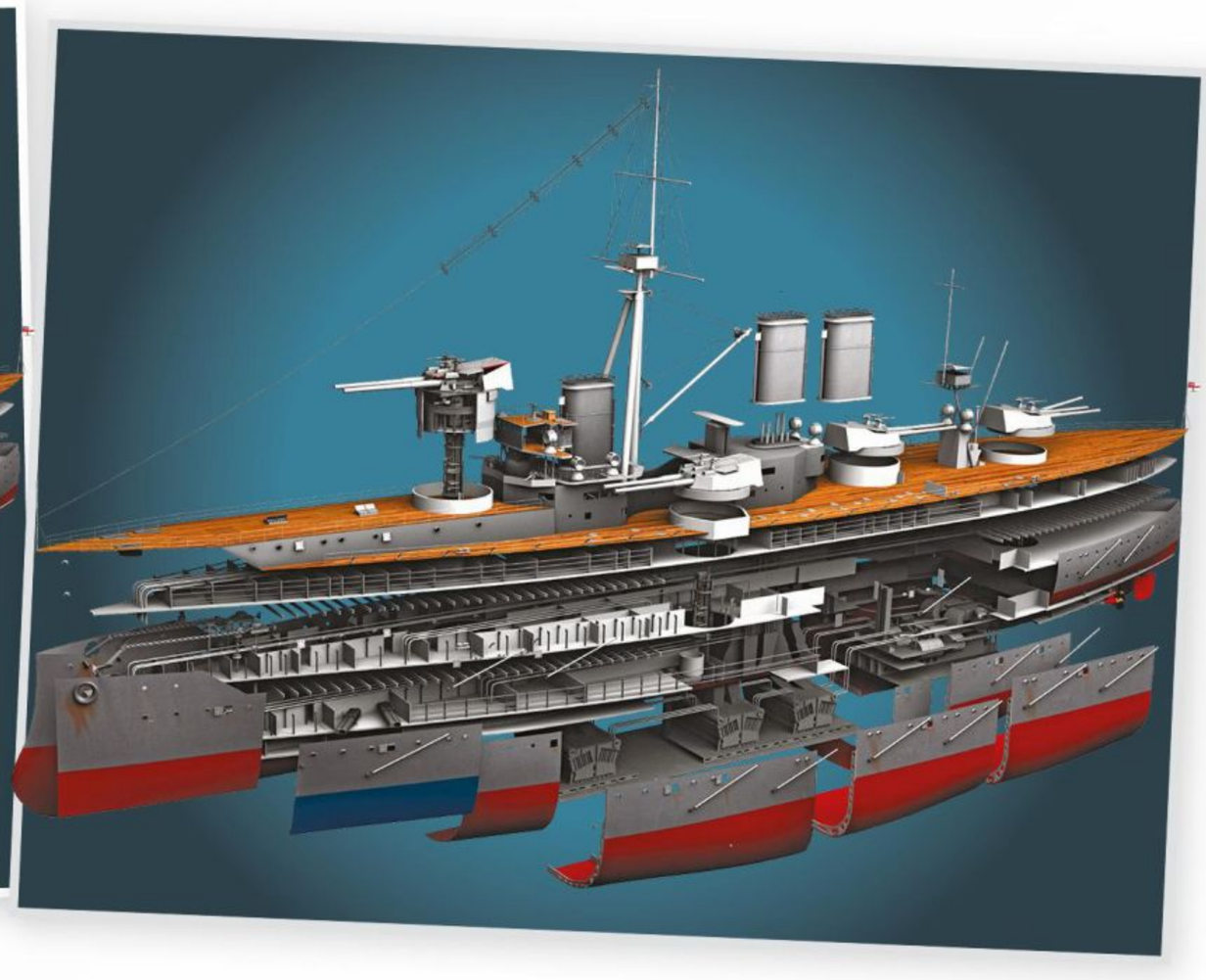
Q4 What year did the Black Death begin to spread across Europe?

- 1347
- 1247
- 1147
- 1747

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

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

DIFFICULT

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

What is it?

Hint: It's got its eyes on you. All four pairs of them.

A .....

Spot the difference

Check your answers

Find the solutions to last issue's puzzle pages

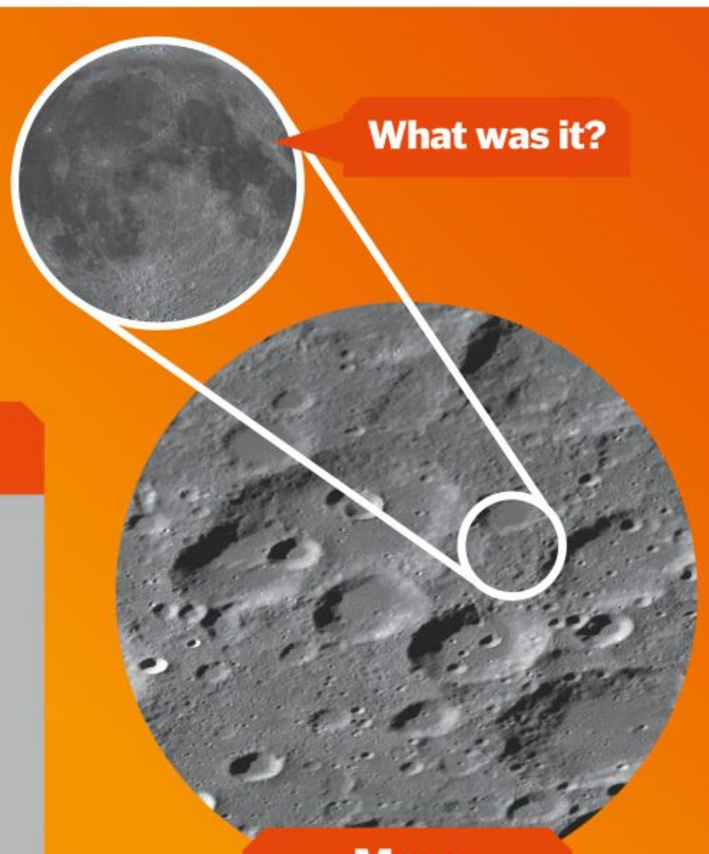
Quickfire questions

Q1 86 billion

Q2 Michael Collins

Q3 Greenland

Q4 Galley ship



What was it?

Moon

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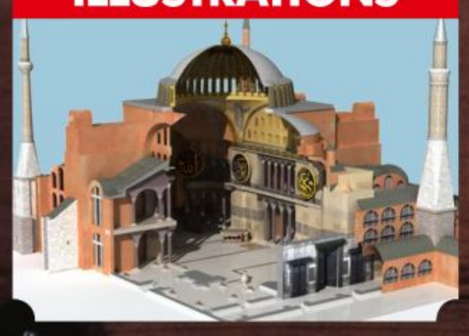

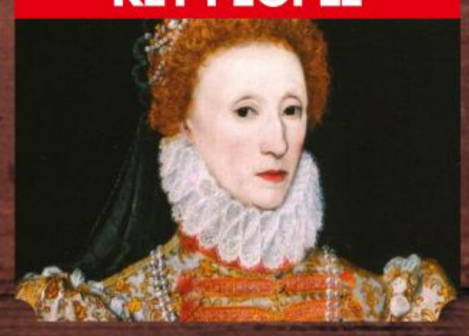

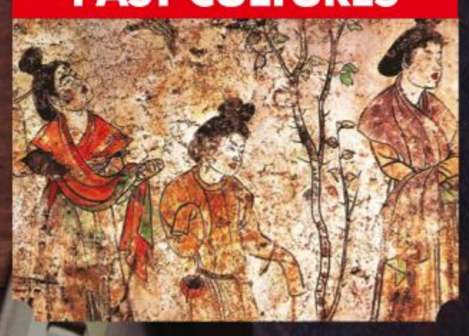

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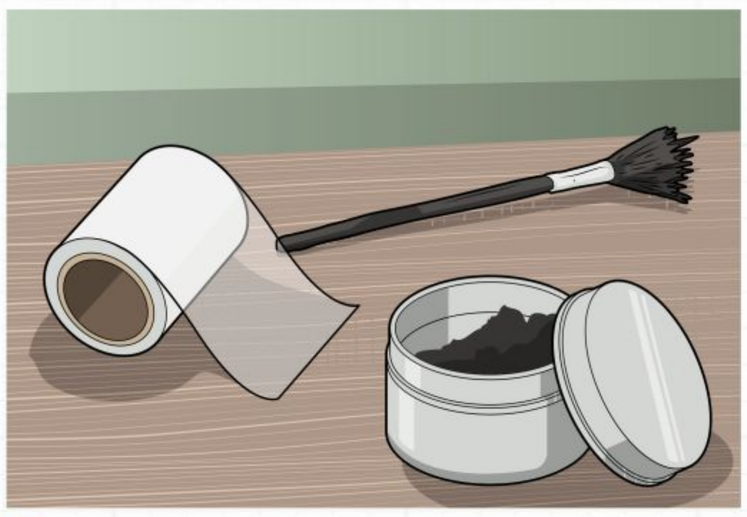
How to dust for fingerprints

Find out how detectives gather evidence, and see for yourself who's been touching your stuff



1 Find your tools

First, you'll need tools. Find some fine powder, such as cornflour or cocoa powder, clear tape and a soft brush. A makeup brush or small paintbrush will be fine as long as the bristles aren't stiff.

2 Make some fingerprints

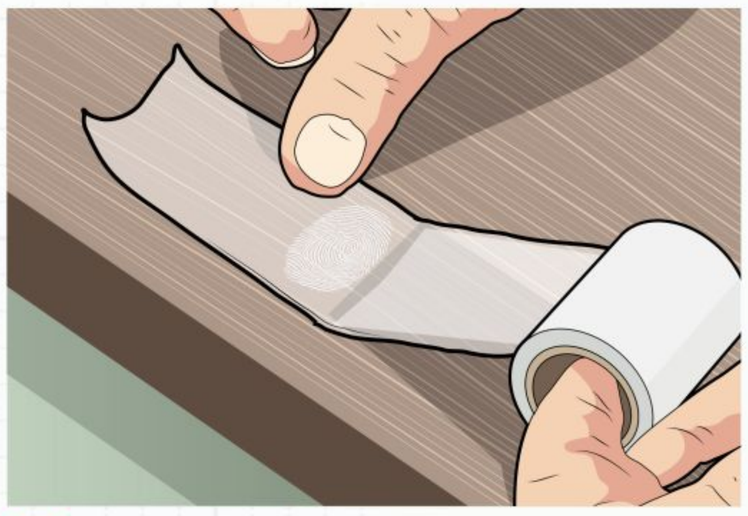
Find a smooth, flat surface like a tap, a mug or even a table or chair. Press your finger down hard to leave a slight trace of your skin's natural oils on the surface.

3 Dust the area

Take some of your powder and sprinkle it carefully over the area where you placed your finger. Make sure it's covered evenly – you can blow it gently to spread it if you need to.

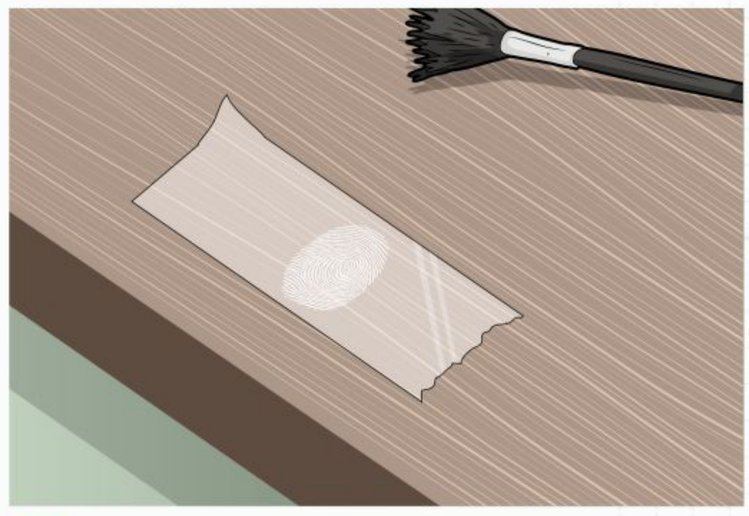
4 Brush it off

The fine powder should stick to the tiny traces of oil you left on the surface with your finger. Use the brush to carefully remove excess powder and only leave the powder that's stuck.



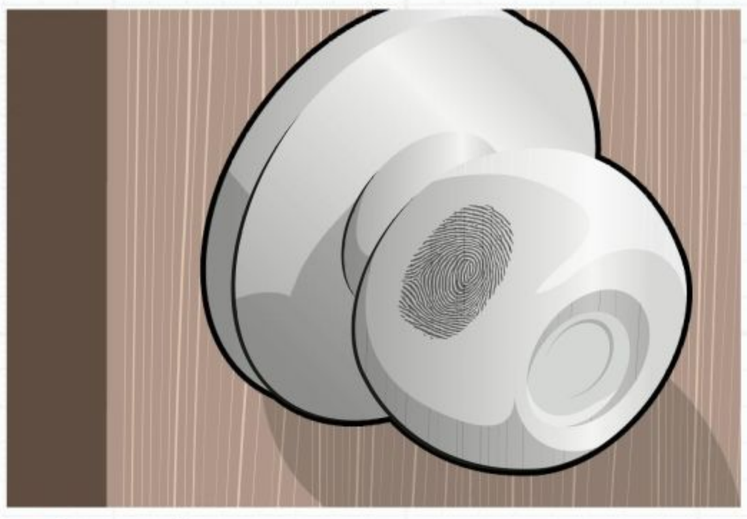
5 Take an imprint

Now cut off a small piece of tape and cover the print. Leave a corner unstuck so it's easier to remove, then carefully peel it off the surface. The powder should stick to the tape.



6 Check the print

The print might be quite hard to see, so find a surface to stick the tape to. For example, if you used cocoa powder, stick it to a piece of white paper. Can you see the individual lines?



7 Try other areas

Now that you have the technique, you can go on the hunt for other fingerprints in your house. Check glasses, doorknobs and other surfaces to see who's been leaving their prints.

SUMMARY...

The natural oils and sweat on your fingers means that you can't help but leave prints whenever you touch smooth surfaces. Because everyone in the world has different fingerprints, police detectives can use similar techniques to this one to find out exactly who's been at a crime scene.

Had a go? Let us know!

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

NEXT ISSUE
How to make a fire snake

INBOX
Speak your mind...

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Research has shown that songbirds are able to recognise the calls of birds from different species

Letter of the month

Translating tweets

Hi **HIW**,

Can blackbirds understand goldfinches? This was the question posed to me by my 11-year-old son Daniel, who loves the magazine. So here's the question for the team at **How It Works**: can one bird understand another of a different kind? Many thanks.

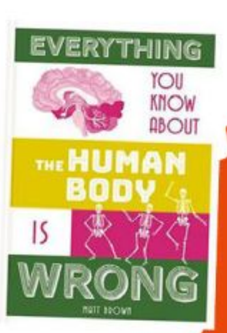
Felicity and Daniel Tomblin

That's a great question! Although the sound of the dawn chorus is a treat for our ears, it also makes you wonder if the bird songs are an exchange of morning greetings or just a ruffled feathered-ruckus. Typically birds will sing or call for one of two reasons. The first is a mating call to attract the attention of a potential suitor, and the second to warn intruding animals to back off from their territory. The tune of a mating song will fall on deaf ears if a bird is outside of their species, but the aggressive nature of a warning call will indicate to other species of bird to be wary. So in that sense, yes there is a basic form of understanding between different birds.

Last year researchers found that different songbirds cohabiting in a territory can recognise the calls of one another. Songbirds are non-migratory and spend their lives in one location, and sometimes have to share that space with different species of songbird.

In a study investigating cohabiting species of fairy-wren, researchers found that these birds can distinguish between the birds of other species they live with, and with species that are only visiting. When exposed to the sound of splendid fairy-wrens from outside their territory, variegated fairy-wrens displayed aggressive behaviour. But when hearing the calls of splendid fairy-wrens they cohabited with, they did not respond. This showed that these songbirds could identify members within a species different from their own, and even with birds from different locations.

© Getty



WIN!
EVERYTHING YOU KNOW ABOUT THE HUMAN BODY IS WRONG
This book debunks many myths about the human body and is packed with facts about our anatomy, answering questions such as 'What will happen if I sneeze with my eyes open?'

Rubbing eyes

Hi **HIW**,

I love your magazines and was wondering if you could please answer my question... Why do we rub our eyes when we are tired?

Haven Barr

After a long day at school or in the office, our eyes can begin to feel sore and dry. By rubbing our tired eyes we stimulate the lacrimal gland above the eyeball, which then produces extra fluid to rehydrate the eye. However, rubbing your eyes can actually make you feel more tired. By putting pressure on the eye, the vagus nerve is stimulated, which can reduce your heart rate, making you feel relaxed and ready for a snooze. Be warned, too much pressure and chronic rubbing can cause a range of health issues, including causing infection or scratching your eye's cornea.

© Getty

Tired eyes are a symptom of computer vision syndrome (CVS), which can cause vision issues later in life

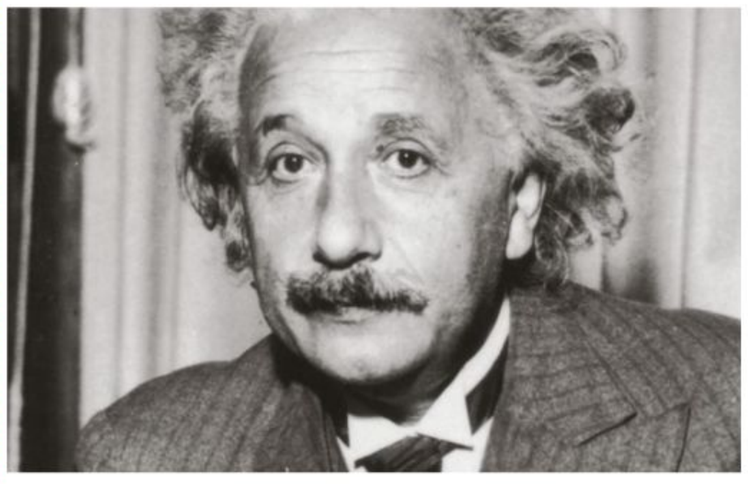
Brain cell count

Hi **HIW**,

Does a smart person have more brain cells than a less intelligent person? I have been wondering about this for a while and it would be great if you could answer it.

Theo Schmidt

Great question Theo and one we've only recently discovered some sort of an answer for. We have around 86 billion neurons (brain cells), but we don't know exactly how many each person has in order to compare. But last year researchers at the Free Amsterdam University found that people with a higher IQ had neurons that were longer, more complex and carried more information around the brain.



© Getty

© Getty

Ragdoll cats get their name from their relaxed and friendly nature

Comfy cats

Hi **HIW**,

As a cat lover, I've adopted a stray cat, Pepper. Unlike other pet kittens, quiet, nice and everything, she is way, way too energetic for our small family, pushing my volleyball around as soon as she gets the chance. In China, nice breeds of cats stay at home to enjoy a generous share of cat food, and every cat likes it! When it comes to Pepper, she'd rather have cockroaches for dinner. So does cat breed affect their lifestyles? Or is it family cats who enjoy the "staycation" more than others? I also wish there was a way to train them quickly, not through long years of Darwin's 'evolution theory', making tamer stray cats. (Pepper! DON'T SCRATCH MY FOOT!)

Monica Liu, aged 11

Thanks for your letter, Monica! It's true that some breeds of cat prefer to lounge around more than others. For example, the ragdoll cat is a great family cat due to its relaxed and docile nature. However, there is no exact science to say that all members of a particular breed will behave in a certain way. Generally speaking, the reason we have different breeds is down to humans selectivity breeding cats over many generations to produce the breeds we know today. Part of the selection process may have been behaviour. Breeding cats that displayed desirable behavioural traits, like docility, with others of the same nature would eventually lead to a common behaviour among a breed of cat.

What's happening on... social media?

If you could create any flavour of ice cream, what would it be and why?

@nicebutdimjim

"Marmite because nothing tastes better!"

@steffsta

"The 'cream' in the middle of a custard cream biscuit. Just for variety - my small person is just a little bit obsessed with these at the moment and I have had enough of discarded biscuits with teeth scrape marks!"

@mangotango1011

"Full English breakfast flavoured ice cream so I could eat it for breakfast!"

@Miserable_Me1

"I would create maple syrup and American pancakes, with crushed pecans, because it's my favourite sweet treat to eat."

@angep1969

"Lavender shortbread flavour. Never mind the taste (lush) imagine the beautiful colour!"

@Summerfun110

"Roast dinner and dessert ice cream. So you start by getting the taste of a lovely chicken roast then after 5mins it moves into Apple crumble"

@MarieCrawley8

"Carrot cake flavour. It would be healthy of course because of the carrots."

HOW IT WORKS

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Photography

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Online orders & enquiries **www.myfavouritemagazines.co.uk**
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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

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FAST FACTS

Amazing trivia to blow your mind

EVEN MICROSCOPIC POLLEN AND SPORES CAN LINK A CRIMINAL TO A CRIME SCENE

7.5 METRES

THE AVERAGE LENGTH OF AN ADULT HUMAN'S INTESTINES

81KPH

ADULT LIONS CAN RUN NEARLY TWICE AS FAST AS AN OLYMPIC SPRINTER

2,000

THE NUMBER OF ASTEROID BELTS IT WOULD TAKE TO EQUAL EARTH'S MASS

1,700 SUNS

THE RADIUS OF THE BIGGEST KNOWN STAR, HYPERGIANT UY SCUTI

40 DAYS

MEDIEVAL DOCTORS WOULD QUARANTINE SUSPECTED PLAGUE CARRIERS FOR NEARLY SIX WEEKS

ANTARCTICA IS THE ONLY CONTINENT THAT HAS NO SPIDERS

-0.3° CELSIUS

A TYPICAL LOW TEMPERATURE MONTH, 8KM DOWN IN THE SOUTH SANDWICH TRENCH

1,000 YEARS

PLASTIC BAGS CAN TAKE A MILLENNIUM TO DECOMPOSE IN A LANDFILL

1934

THE YEAR WALDO WATERMAN INVENTED THE WORLD'S FIRST FLYING CAR

385KG THE BATTERIES IN A FORMULA E RACECAR MAKE UP ALMOST HALF OF ITS TOTAL WEIGHT

5 HOURS

FATTY PORK, HARD CHEESE AND MILK TAKE THE LONGEST TIME TO DIGEST

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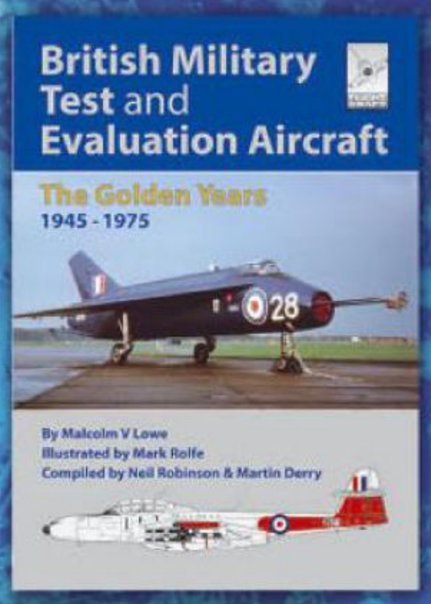

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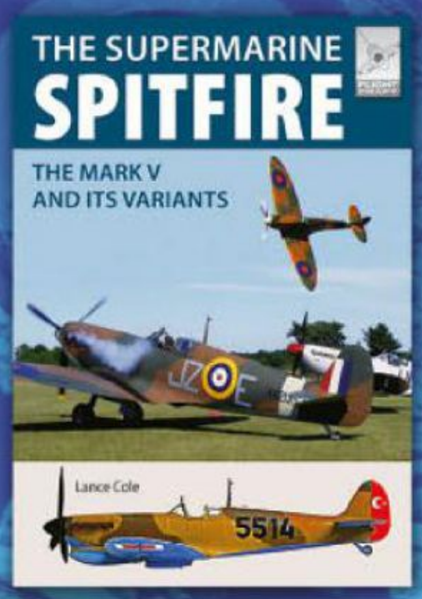

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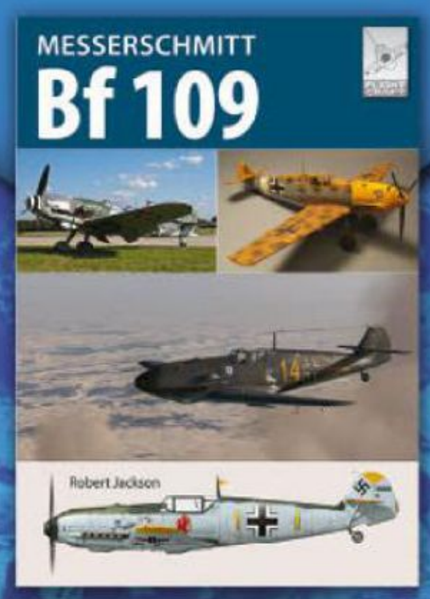

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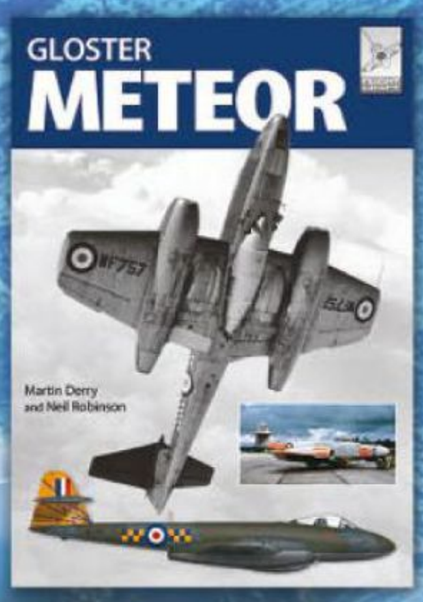

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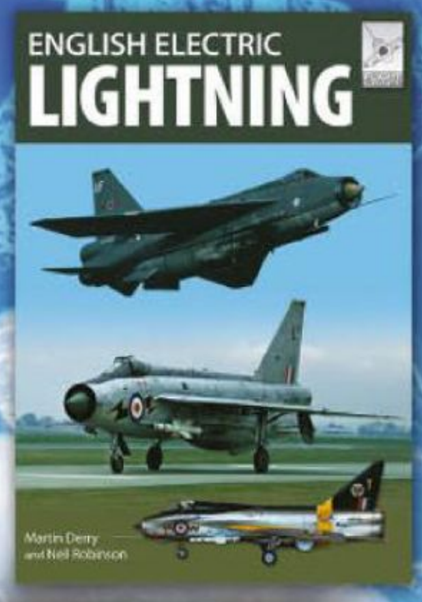

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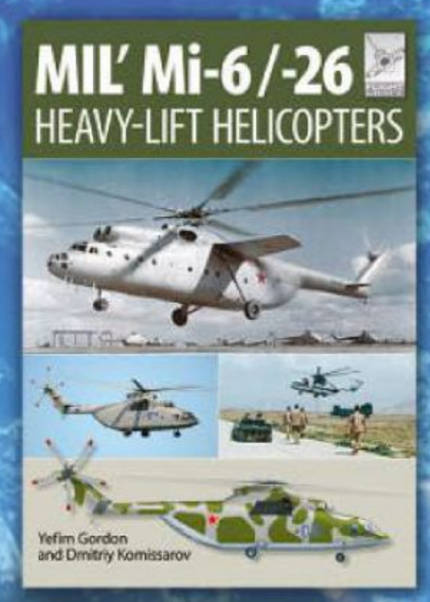

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