FREE 2 eBOOKS 2 POSTERS & WALLPAPERS

HOW MICROCHIPS ARE MADE

HOW IT WORKS

INSIDE THE
LAND SPEED RECORD BREAKER

WIN A 3D PRINTER WORTH OVER £400

12 UNBELIEVABLE INVENTIONS

FAMOUS INNOVATIONS THAT HAD THE STRANGEST OF BEGINNINGS

MOONS, ASTEROIDS AND DWARF PLANETS

THE CHEMISTRY OF TEA AND COFFEE

TREASURES BENEATH THE UK'S RAIL DIG

THESE ANIMALS HAVE THE WEIRDEST BABIES

FUTURE
ISSUE 154

WHAT IS MENINGITIS?
WHY IT'S DEADLY AND HOW IT'S CURED

INSIDE A BIN LORRY
WHAT HAPPENS TO YOUR RUBBISH?

+ HOW RIVERS FORM

TOASTER TECH

MARCUS RASHFORD BOOK CLUB

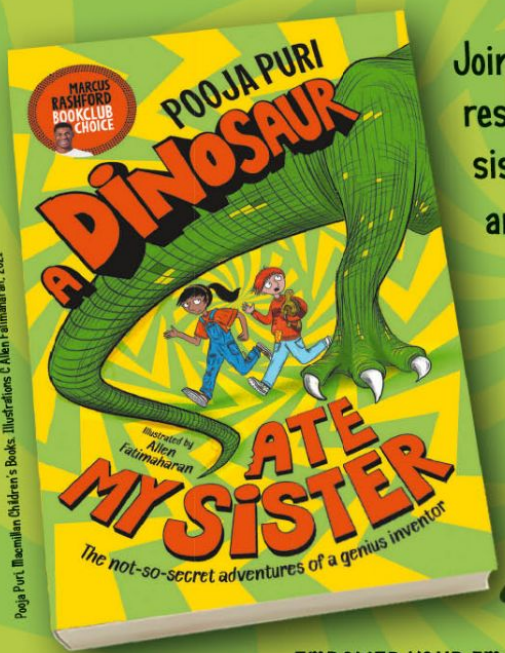
'THE PERFECT STORY TO ESCAPE INTO AND FIND ADVENTURE. POOJA IS SUPER TALENTED AND I'M A BIG FAN!' MARCUS RASHFORD, MBE

A DINOSAUR ATE MY SISTER

Written by Pooja Puri and illustrated by Allen Fatimaharan

ESHA VERMA IS A GENIUS INVENTOR AND SHE'S JUST CREATED HER MOST BRILLIANT INVENTION YET:

A TIME MACHINE.



Pooja Puri, Macmillan Children's Books. Illustrations © Allen Fatimaharan, 2021

Join her on a prehistoric rescue mission to save her sister from the Age of the Dinosaurs, and face **TERRIFYING T-REXES**

MYSTERIOUS WORMHOLES

GLITCHY INVENTIONS

ALL OF SPACE AND TIME

EMPOWER YOUR IMAGINATION WITH THE FIRST BOOK SELECTED FOR THE **MARCUS RASHFORD BOOK CLUB**

OUT NOW!

AVAILABLE EVERYWHERE BOOKS ARE SOLD

MACMILLAN Children's Books

W Waterstones

ISSUE 154

WELCOME

The magazine that feeds minds!

© Alamy

"The treadmill wasn't intended to improve fitness, but to punish prisoners."

12 Unbelievable Inventions, page 26

Meet the team...

Nikole
Production Editor
The Solar System is full of weird and wonderful objects of all shapes and sizes. Explore its moons, comets and asteroids on page 44.

Scott
Staff Writer
Meet some of the animal kingdom's best, worst and weirdest parents, plus some really unusual births and babies on page 72

Baljeet
Research Editor
You might start your day with a hot cup of tea or coffee, but do you know what goes into your drink? Delve into your cup's contents on page 64.

Duncan
Senior Art Editor
See how the construction of a new high-speed railway is unearthing thousands of years of history in the UK on page 50.

Ailsa
Staff Writer
What happens to rubbish after it's collected? Uncover the fate of your waste and see into a trash-crushing lorry on page 58.

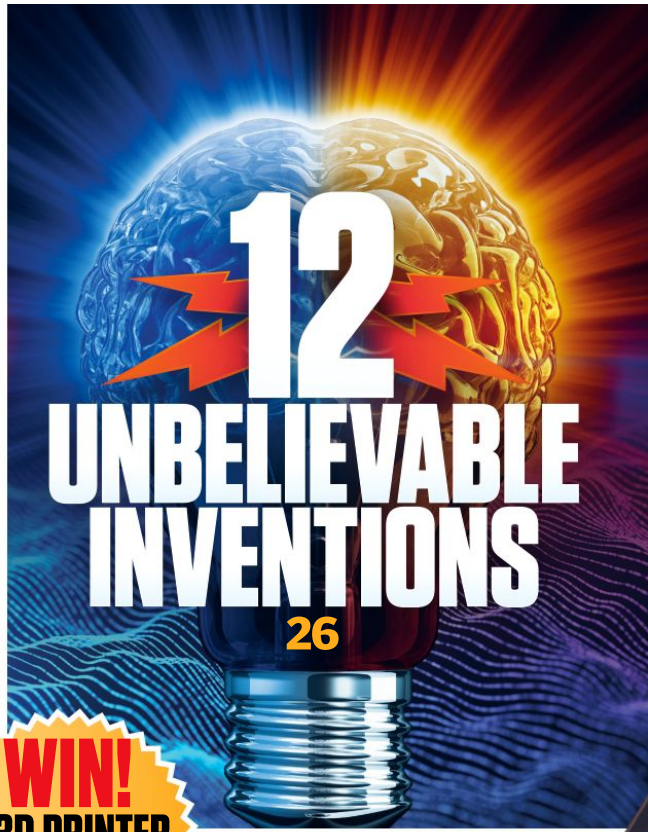
Sometimes the true invention isn't the thing an inventor has made, but the idea of how it can be used to solve a problem, make life easier for us, or entertain us. Many of the technologies and products we take for granted today started life with a completely different purpose, only for some bright spark to realise its potential elsewhere. Take the humble Slinky (picture above), which was originally designed as a nautical tool to stabilise navigational instruments on a ship. But all it required a bit of marketing savvy for this device to become one of the world's best-selling toys. We've chosen more of our favourite Unbelievable Inventions like this, in this issue - enjoy!

Ben Editor

FOLLOW US...

howitworksmag
How It Works magazine
@HowItWorksmag

CONTENTS



WIN!
A 3D PRINTER
WORTH OVER
£400
PAGE 83

SUBSCRIBE NOW!
Go to **page 24** for great deals

MEET THIS ISSUE'S EXPERTS...

Andy Extance
Andy is a freelance science writer based in Exeter, UK. He previously worked in early stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.

Dr Andrew May
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of 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.

Jo Elphick
Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She is also the author of a number of true crime books.

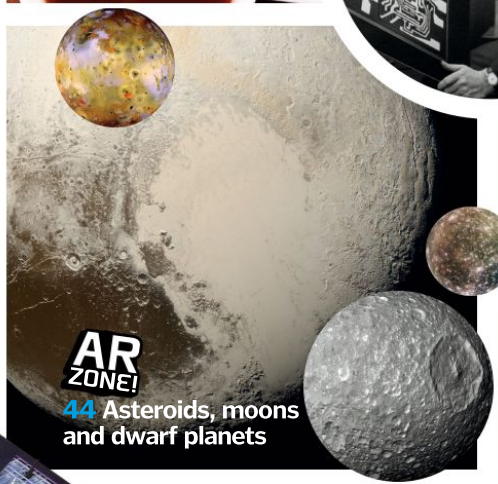
Callum McKelvie
All About History magazine's Features Editor studied history at Aberystwyth University while working for museums and archives.

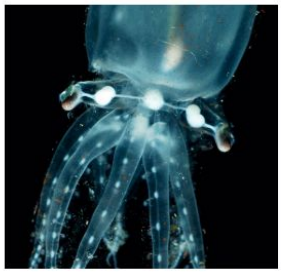
Laura Mears
Biologist Laura escaped the confines of the lab to the rigours of an office desk as a keen science writer and full-time software engineer.

Mark Smith
A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.

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

REGULARS





AR ZONE!

Scan the QR code with your device's camera or download a free QR code reader app. Many iPhone and Android devices include a QR reader

When you see the AR ZONE! logo at the top of a page, use your phone to scan the QR code, which looks like this

Hold your mobile device over the image and watch it come to life! Your device needs to be connected to the internet for this to work

HOW THE AUGMENTED REALITY WORKS

After being launched by the QR code, the app reads anything you point your device's camera at 30 times a second, searching for distinctive shapes we've trained it to recognise. When it sees a familiar picture, it overlays the augmented-reality 3D image we've previously uploaded on your screen.

PARASITE LIPS

Meet the roundworm (*Contracaecum rudolphii*), also known as a nematode, of which there are over 30,000 described species. These invertebrates are parasites, and can find their way into the intestinal tracts of humans who come into contact with either infested soil or dirt, or seafood. This image shows a roundworm's head under a coloured scanning electron microscope. The head is made up of three dorsal lips (pink), each one equipped with small sensory papillae, much like those on a human tongue. These parasites also have a strong muscular pharynx, allowing them to easily crush any eaten tissue collected from their hosts.

BEHIND THE SPACE VEIL

Around 2,100 light years from Earth, in the constellation of Cygnus, is the majestic Veil Nebula. This nebula is the visible portion of a supernova remnant called the Cygnus Loop. The Veil Nebula formed around 10,000 years ago after the death of a massive star, which would have been approximately 20 times the mass of our Sun. The shock waves caused by the star's explosive supernova shaped the emitted cosmic dust and gas into the Veil Nebula. This image was taken by the Hubble Space Telescope using its Wide Field Camera 3 instrument, with enhanced details such as ionised oxygen (blue), and ionised hydrogen and nitrogen (red).

BAT BONANZA

You might think that the animal with the biggest migration in the world would be one of Africa's many iconic mammals, such as zebras or wildebeest. However, you'd be wrong. Between October and December, 10 million straw-coloured fruit bats flock over the Congo and Zambia. These bats fly from all around Africa and converge inside Kasanka National Park in Zambia. Having travelled thousands of miles, upon arriving at the park the bats feast on a wealth of wild fruits from trees such as pod mahogany and milkwood. This frantic feasting makes them vital pollinators, and each one of these bats will disperse seeds across Africa.

BUILDING THE BIGGEST ROCKET

The Artemis program seeks to carry humans farther than any other space mission in history. In order to do that, NASA is building the world's biggest and most powerful rocket, called the Space Launch System (SLS). The core stage, shown in this image, is the largest part of the rocket. Here it's seen being lowered onto the mobile launcher inside High Bay 3 of the Assembly Building at NASA's Kennedy Space Center in Florida. Towering almost 61 metres tall, the core stage will house the rocket's storage tanks, which will hold 3.3 million litres of supercooled liquid hydrogen and liquid oxygen fuel to power its four RS-25 engines.

SPACE

Signs of alien life on Saturn's moon?

Words by **Mike Wall**

The methane wafting from Enceladus may be a sign that life teems in the Saturnian moon's subsurface sea. In 2005, NASA's Cassini orbiter discovered geysers blasting particles of water ice into space from 'tiger stripe' fractures near Enceladus' south pole. That material, which forms a plume that feeds Saturn's E ring, is thought to come from a huge ocean of liquid water that sloshes beneath the moon's icy shell.

And there's more than just water ice in the plumes. During numerous close flybys of the 313-mile-wide Enceladus, Cassini spotted many other compounds as well, for example dihydrogen (H_2) and a variety of carbon-containing organic compounds, including methane (CH_4).

The dihydrogen and methane are particularly intriguing to astrobiologists. The H_2 is likely being produced by the interaction of rock and hot water on Enceladus' seafloor, suggesting the moon has deep-sea hydrothermal vents, the same type of environment that may have been life's cradle on Earth. In addition, H_2 provides energy for some Earth microbes that produce methane from carbon dioxide in a process called methanogenesis. Something similar could be happening on Enceladus, especially given that Cassini also spotted carbon dioxide and a surprising bounty of methane in the moon's plume.

"We wanted to know if Earth-like microbes that 'eat' the dihydrogen and produce methane could explain the surprisingly large amount of methane detected by Cassini," said Régis Ferrière, an associate professor in the University of Arizona's Department of Ecology and Evolutionary Biology.

Ferrière and his colleagues built a series of mathematical models that assessed the probability that Enceladus' methane was generated biologically. These simulations were diverse; the team investigated whether the observed H_2 production could sustain a population of Enceladus microbes, for example, and how that population would affect the rate at which H_2 and methane escaped into the plumes, among other things.

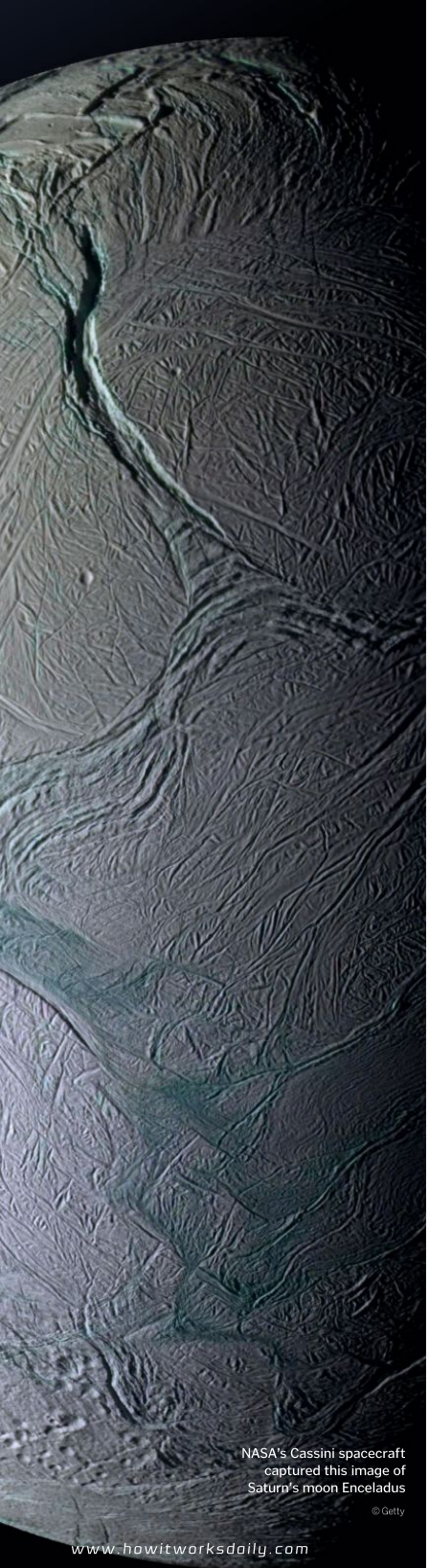
"In summary, not only could we evaluate whether Cassini's observations are compatible with an environment habitable for life, but we could also make quantitative predictions about observations to be expected should methanogenesis actually occur at Enceladus' seafloor," Ferrière said.

That evaluation should cheer those of us who hope that something swims in the frigid, dark Enceladus sea. The team determined that abiotic (without the aid of life) hydrothermal-vent chemistry as we know it on Earth does not explain the methane concentrations observed by Cassini very well. Adding the contributions of methanogenic microbes fills the gap nicely.

To be clear, the new study does not argue that life exists on Enceladus. For instance, it's possible that the icy moon features some types of abiotic methane-producing reactions that aren't prevalent here on Earth, perhaps the decay of primordial organic matter left over from the moon's birth. Indeed, that latter hypothesis would fit nicely if Enceladus formed from organic-rich material delivered by comets, as some scientists believe.

"It partly boils down to how probable we believe different hypotheses are to begin with," Ferrière said. "For example, if we deem the probability of life in Enceladus to be extremely low, then such alternative abiotic mechanisms become much more likely, even if they are very alien compared to what we know here on Earth."

That being said, "biological methanogenesis appears to be compatible with the data," Ferrièr concluded. "In other words, we can't discard the 'life hypothesis' as highly improbable. To reject the life hypothesis, we need more data from future missions."



NASA's Cassini spacecraft captured this image of Saturn's moon Enceladus

© Getty

A new gene-editing approach could one day serve as a treatment for COVID-19

© Getty

HEALTH

Gene-editing stops human coronavirus replicating

Words by **Rachael Rettner**

Scientists have harnessed CRISPR gene-editing technology to block the replication of the novel coronavirus in human cells, an approach that could one day serve as a new treatment for COVID-19. However, the study was performed in lab dishes and has not yet been tested on animals or people, meaning a treatment based on the method could be years away.

CRISPR is a tool that enables researchers to precisely edit DNA. It's based on a natural defence system used in bacteria that allows the microbes to target and destroy the genetic material of viruses. In a recent study, the researchers used a CRISPR system that targets and destroys strands of RNA, rather than DNA. Specifically, their system uses an enzyme called Cas13b, which cleaves single strands of RNA like those found in SARS-CoV-2, the virus that causes COVID-19. Cas13b is similar to Cas9, the enzyme most commonly used in CRISPR gene-editing technology, but Cas9 cleaves DNA, while Cas13b cleaves RNA.

The researchers designed CRISPR-Cas13b to target specific sites on the RNA of SARS-CoV-2; once the enzyme binds to the RNA, it destroys the part of the virus needed to replicate. "Once the virus is recognised, the CRISPR enzyme is activated and chops up the virus," Professor Sharon Lewin of the Peter Doherty Institute for Infection and Immunity at the University of Melbourne said. The researchers also found that their method worked even when new mutations were introduced into the SARS-CoV-2 genome, including those seen in the alpha coronavirus variant, first discovered in the UK.

Effective COVID-19 vaccines are currently being distributed around the world, but there remains a clear and urgent need for effective treatments for the disease. Researchers noted that there are "serious concerns" that the virus will evolve to "escape" current vaccines. An ideal treatment would be an antiviral drug that patients take shortly after being diagnosed with COVID-19. "This approach – test and treat – would only be feasible if we have a cheap, oral and non-toxic antiviral. That's what we hope to achieve one day with this gene-scissors approach," Lewin explained.

Although the new study is a first step towards such a treatment, it will likely be years before this method could be turned into a treatment that's widely available. The researchers now plan to test the method in animal models, and eventually conduct clinical trials in humans. Medicines that use CRISPR technology have not yet been approved to treat any diseases, but multiple studies are underway to test CRISPR-based therapies in people as treatment for various diseases, including cancer and HIV.

HISTORY

New expedition seeks Shackleton's Antarctic wreckage

Words by **Ben Turner**

A team of scientists will attempt to find the remains of Ernest Shackleton's long-lost ship, the Endurance, below the dark and icy waters of the Antarctic Ocean. Shackleton and his crew abandoned the ship in 1915 after it was crushed by ice. The Endurance now lies somewhere at the bottom of the Weddell Sea, a large bay in the western Antarctic. Its exact location remains unknown, but this new expedition plans to find it.

The Endurance22 expedition, slated to begin in February 2022, will navigate the treacherous southern waters, slamming through miles of pack ice in search of locations for state-of-the-art submarines to scan the ocean floor. If the scientists find the lost ship, they plan to survey and film the wreck. But they won't take any artefacts, as the vessel is protected under the international Antarctic Treaty.

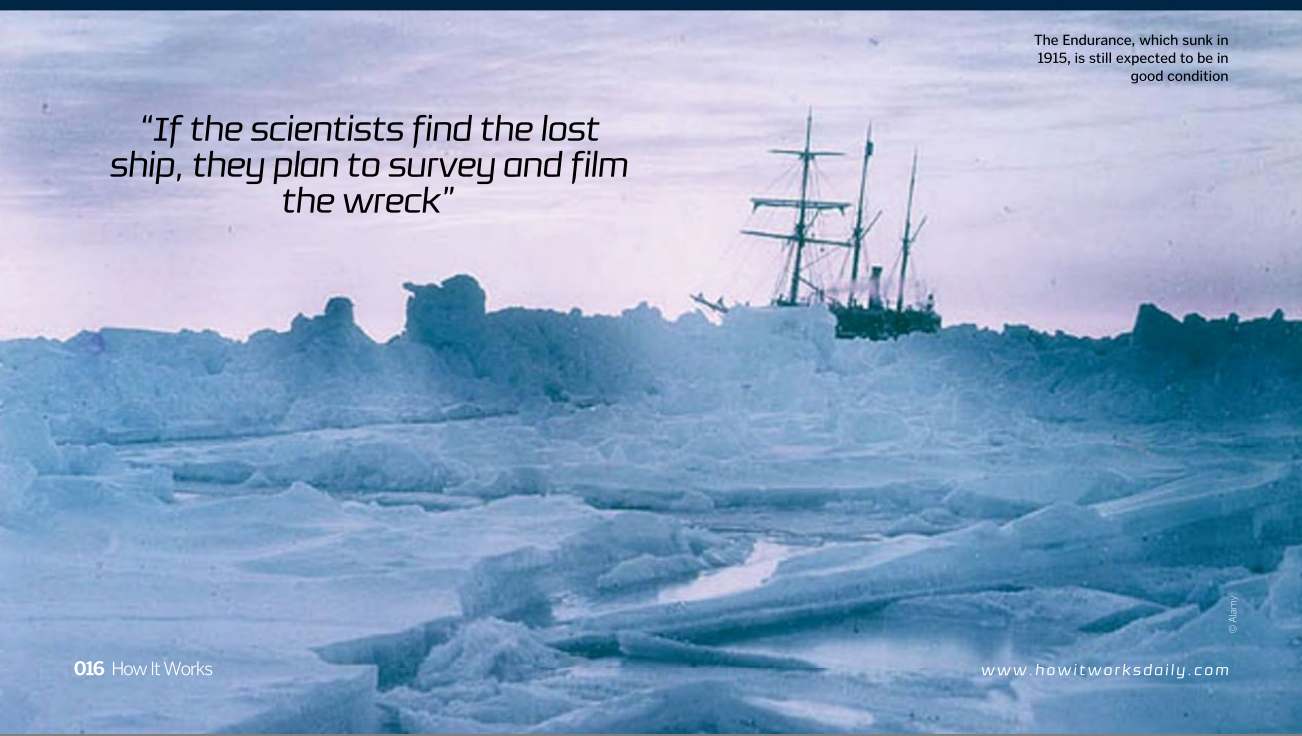
"Attempting to locate the wreck of Endurance, something long thought impossible and out of reach, is an immensely exciting prospect," said Mensun Bound, Endurance22's director of exploration. "Given the harshness of the Antarctic environment, there are no guarantees of success, but we remain inspired by the great Antarctic explorers and embark on Endurance22 with high hopes. With the best possible technology and a world-leading exploration team, we hope and pray that we can achieve a landmark moment in polar history."

Shackleton's herculean attempt to cross the South Pole is perhaps the most legendary story from the 'heroic age' of polar exploration. Embarking from the island of South Georgia, the Endurance worked its way south through pack ice for weeks before becoming trapped just off the Caird Coast. The crew drifted for over a year, first aboard the ship and then on top of the ice floe itself after the Endurance was crushed and sank.

The Endurance now lies below nearly 3,000 metres of dark water, its timbers likely well preserved by the absence of light and low oxygen of its environment. The location where it sank, logged at the time by the ship's captain Frank Worsley, is well known. The real difficulty for the Endurance22 team will be in bulldozing through miles of thick ice in the Weddell Sea.

Although climate change will make the ice floe easier to break through than in Shackleton's day, arriving at the location his ship sank at is still a challenge. The scientists intend to get there by ramming the ice with the icebreakers fitted to their ship, the South African S. A. Agulhas II. Once the researchers are sufficiently close to the documented site of the wreck, they will lower a Saab Sabertooth autonomous submarine into the freezing water and use satellite radar imagery to navigate it to the wreck.

The oxygen levels at the wreck's location are still high enough to sustain life, so the team suspects that a rich and strange ecosystem may have bloomed around the sea-changed Endurance. The researchers said there is even a possibility that they will discover new species.



The Endurance, which sunk in 1915, is still expected to be in good condition

"If the scientists find the lost ship, they plan to survey and film the wreck"

NASA's Chandra X-ray Observatory captured this imagery of a huge, hand-shaped feature about 17,000 light years from Earth

SPACE

X-ray telescope reveals ghostly 'hand'

Words by **Mike Wall**

An enormous, ghostly hand stretches through the depths of space, its wispy fingers pressing against a glowing cloud. It sounds like science fiction, but it's quite real, as imagery gathered by NASA's Chandra X-ray Observatory shows.

The 'hand' was spawned by the death of a massive star in a supernova explosion, which left behind a fast-spinning, superdense stellar corpse known as a pulsar. That pulsar has blown a bubble of energetic particles around itself, which combined with the debris blasted out by the explosion created the hand-like structure, which stretches 150 light years. The glowing feature that it's reaching for, meanwhile, is a mammoth gas cloud known as RCW 89.

The supernova remnant at the heart of the hand, called MSH 15-52, lies about 17,000 light years from Earth. Astronomers think the light from its explosion reached us about 1,700 years ago, making MSH 15-52 one of the youngest supernova remnants known in our Milky Way galaxy. Chandra has imaged the hand before – it was the subject of an April 2009 photo release – but a recent study took a deep dive into the hand's dynamics, using Chandra imagery from 2004, 2008, 2017 and 2018.

The research, which was published in June 2020, found that the supernova blast wave, which lies at the hand's fingertips, is travelling at about 9 million miles per hour, and that material closer to the palm is moving even faster, in excess of 11 million miles per hour. "While these are startling[ly] high speeds, they actually represent a slowing down of the remnant," the research team said.

Researchers estimate that to reach the farthest edge of RCW 89, material would have to travel on average at almost 30 million miles per hour. "This difference in speed implies that the material has passed through a low-density cavity of gas and then been significantly decelerated by running into RCW 89," the researchers added. The dead star likely created such a cavity shortly before exploding, when it shed much of its outer hydrogen layer.

ANIMALS

Florida's manatees die in record numbers

Words by **Yasemin Saplakoglu**

A record-breaking number of manatees have died this year in Florida's waters, mostly due to starvation. Between 1 January and 2 July, 841 manatees died near and off the coast of Florida. Florida's previous deadliest year was 2013, when 830 manatees died, mostly from exposure to toxins from a harmful algal bloom known as red tide.

Most of 2021's manatees died during the colder months, when they migrated to and through the Indian River Lagoon, a group of three lagoons located southeast of Orlando on Florida's east coast, where most of the seagrass had died out. The loss of seagrass, a food that manatees rely on to survive, is likely a result of increasing pollution in Florida's waters; fertiliser runoff and sewage leaks have led to increased levels of nitrogen and phosphorus in the waters, which in turn can drive algal blooms.

Since 2011, persistent algal blooms have reduced the clarity of the water, which has led to less sunlight reaching the seagrass beds; seagrass, like most plants, needs sunlight to survive. The Florida Fish and Wildlife Conservation Commission is now working with other organisations, universities and government agencies to help restore the habitat. In March the commission declared an 'unusual mortality event', a designation that allows the federal government to work with the state government and nonprofit organisations to help the manatees and figure out the cause of the die-off.

About 6,300 manatees currently live in Florida waters

PLANET EARTH

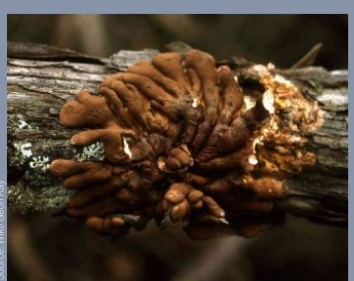
'Zombie fingers' parasitic fungus faces extinction

Words by **Mindy Weisberger**

A fungus that resembles decaying human fingers is endangered but clinging on for dear life in Australia, wrapping its zombie-like digits around fallen trees on an island near the continent's southern coast. *Hypocreopsis amplectens* is known as tea-tree fingers, as its shape resembles pudgy human fingers, though the mottled pinkish-brown colour and texture of the fungus make those fingers look more dead than alive.

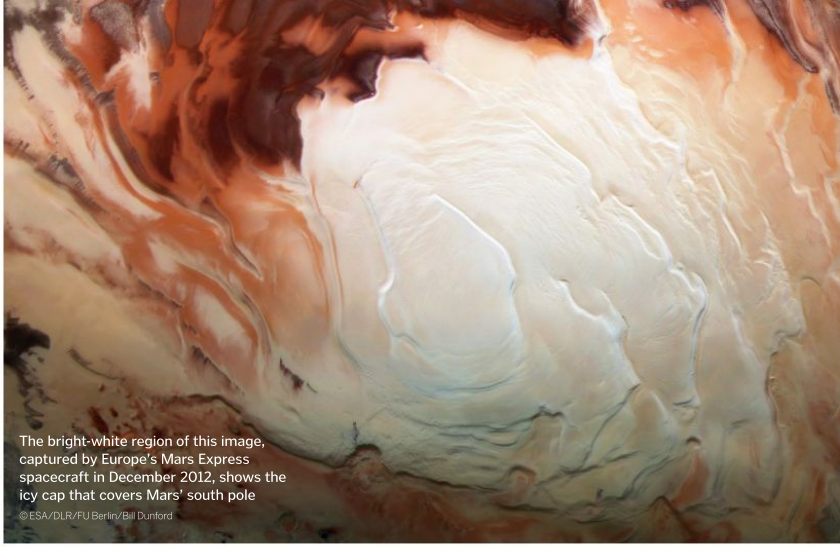
Tea-tree fingers are rare, known to exist in just a handful of locations on the mainland of Victoria in southeastern Australia. But an expedition led by naturalists from Royal Botanic Gardens Victoria recently proved that the fungus has tightened its grip in at least two other places in the Australian state.

A team of researchers and volunteers reported finding tea-tree fingers in two locations at a protected national park on French Island, Victoria. One of those spots holds the largest recorded population of tea-tree fingers – over 100 individual fruiting bodies – more than the total fungus population at all the sites on the mainland. Finding so many examples of these dead-looking digits offers hope for the parasite's future, as a warming climate and habitat loss are causing the fungus to lose its grip on the mainland.



Source: Wiki/Geoff Kay

A fungus resembling zombies' fingers is more widespread in Australia than suspected



The bright-white region of this image, captured by Europe's Mars Express spacecraft in December 2012, shows the icy cap that covers Mars' south pole

SPACE

Mars may have lakes beneath its south pole

Words by **Mike Wall**

Much more liquid water may lie beneath the south pole of Mars than scientists had thought, or there may be something going on down there that they don't fully understand. In 2018, researchers analysing radar data gathered by Europe's Mars Express spacecraft announced they'd found evidence of a big subsurface lake in the Red Planet's south polar region. The lake appears to be about 12 miles wide, and it lies about one mile beneath the dry, frigid surface.

The same core research team soon followed up on the find using the same Mars Express instrument, the Mars Advanced Radar for Subsurface and Ionospheric Sounding, or MARSIS for short, to study the subsurface in a wide area around the apparent lake. This work turned up evidence of three more underground lakes, each of them about six miles wide.

Now a different team has taken a very deep dive into the data. Arizona State University doctoral student Aditya Khuller and MARSIS coprincipal investigator Jeffrey Plaut of NASA's Jet Propulsion Laboratory (JPL) in Southern California analysed 44,000 observations MARSIS made of the Martian south polar region over 15 years. MARSIS was built by the Italian Space Agency and JPL.

The duo found dozens of radar reflections similar to the four that have been interpreted as buried lakes over a wide range of horizontal and vertical distances. But many of the newfound signals were spotted relatively close to the surface in places seemingly too cold to support liquid water, even the briny stuff hypothesised to exist in the Martian underground.

"We're not certain whether these signals are liquid water or not, but they appear to be much more widespread than what the original paper found," said Plaut. "Either liquid water is common beneath Mars' south pole, or these signals are indicative of something else."

It's unclear what could keep so many relatively shallow lakes – if the newfound signals do indeed indicate lakes – from freezing over on frigid Mars. Volcanism is one possibility that researchers have raised, said Khuller, who conducted the new research while interning at JPL. "However, we haven't really seen any strong evidence for recent volcanism at the south pole, so it seems unlikely that volcanic activity would allow subsurface liquid water to be present throughout this region," said Khuller.

Neither Khuller nor Plaut can explain what exactly the newfound MARSIS reflections mean, but they hope their results will not remain mysterious for long. "Our mapping gets us a few steps closer to understanding both the extent and the cause of these puzzling radar reflections," Plaut said.

"The lake appears to be about 12 miles wide, and it lies about one mile beneath the dry, frigid surface"

HISTORY

Scientists may have cracked da Vinci's DNA

Words by **Ben Turner**

Leonardo da Vinci, the great Renaissance artist, inventor and anatomist, has 14 living male relatives, a new analysis of his family tree reveals. The new family tree could one day help researchers determine if bones interred in a French chapel belong to the Italian genius.

Historians Alessandro Vezzosi and Agnese Sabato have spent more than a decade tracing the genealogy of the famed *Mona Lisa* painter. Their map stretches across 690 years, 21 generations and five family branches, and will prove vital in helping anthropologists sequence the DNA of da Vinci by sequencing the DNA of his descendants.

Da Vinci was a painter, architect, inventor, anatomist, engineer and scientist. Primarily self-educated, he filled dozens of secret notebooks with fanciful inventions and anatomical observations, many of which were ahead of his time. To accompany famous sketches such as the *Vitruvian Man*, da Vinci would write messages coded into his own shorthand, mirrored back to front to hide his studies from prying eyes. Along with detailed drawings of human anatomy, taken from observations of dissected cadavers, his notebooks contain designs for bicycles, helicopters, tanks and aeroplanes.

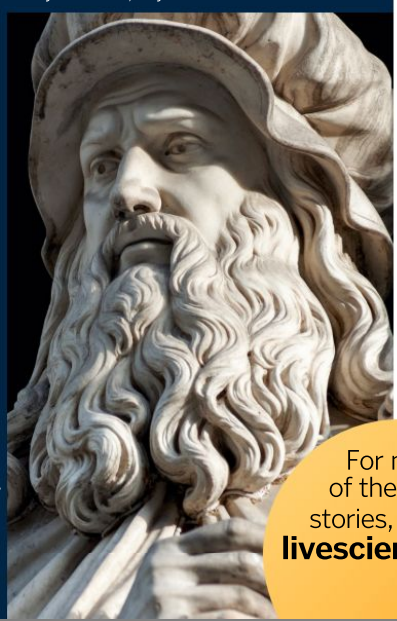
In their recent study, Vezzosi and Sabato used historical documents from archives alongside direct accounts from surviving descendants to trace the five branches of the da Vinci family tree. Leonardo was part of the sixth generation of da Vincis. Researching da Vinci's family history is difficult because only one of his parents can be properly traced. Born out of wedlock in the Tuscan town of Anchiano, Leonardo da Vinci was the son of Florentine lawyer Ser Piero da Vinci and a peasant woman named Caterina. Research by Martin Kemp, an art historian at Oxford University, suggests that Caterina was a 15-year-old orphan at the time of da Vinci's birth. At age five the young da Vinci was taken to his family estate in the town of Vinci, from which his family took their surname, to live with his grandparents.

When da Vinci died on 2 May 1519 at age 67, he had no known children and his remains were lost, meaning there was no reliable DNA to analyse. As a result, parts of his ancestry have become shrouded in mystery. Da Vinci's original burial was recorded at the chapel of Saint-Florentin at the Château d'Amboise, a manor house in France's Loire Valley. The chapel was left to ruin after the French Revolution, and later demolished. Contemporaneous accounts allege that a full skeleton was exhumed from the site and moved to the nearby Saint-Hubert chapel, but whether or not they are actually da Vinci's bones remains a mystery.

The new family tree, which starts in 1331 with family patriarch Michele, revealed 14 living relatives with a wide variety of occupations, including office workers, a pastry chef, a blacksmith, an upholsterer, a porcelain seller and an artist.

The researchers will determine whether the human remains from the Loire Valley chapel belong to da Vinci by comparing the Y chromosome in those bones to the Y chromosome belonging to da Vinci's male relatives. The Y chromosome is passed from father to son and remains virtually unchanged for as long as 25 generations.

A statue of Leonardo da Vinci in the Uffizi Gallery in Florence, Italy



© Getty

For more of the latest stories, head to **livescience.com**

© Getty

In the future, your vanilla ice cream may be made from plastic bottles

SCIENCE

Plastic waste converted into vanilla flavouring

Words by **Yasemin Saplakoglu**

Scientists have figured out a way to convert plastic waste into vanilla flavouring with genetically engineered bacteria. Vanillin, the compound that carries most of the smell and taste of vanilla, can be extracted naturally from vanilla beans or made synthetically. About 85 per cent of vanillin is currently made from chemicals taken from fossil fuels.

Vanillin is found in a wide variety of food, cosmetic, pharmaceutical, cleaning and herbicide products, and demand is growing rapidly. In 2018 the global demand for vanillin was about 37,000 tonnes, and it's expected to grow to 59,000 tonnes by 2025. Demand for vanillin far exceeds the vanilla bean supply, so scientists have resorted to synthetically producing it. Researchers used a novel method to convert plastic waste into vanillin as a way to both supply vanillin and reduce pollution.

Previous studies showed how to break down plastic bottles made from polyethylene terephthalate into its basic subunit, known as terephthalic acid. In a new study, researchers at the University of Edinburgh in Scotland genetically engineered *E. coli* bacteria to convert terephthalic acid into vanillin. Terephthalic acid and vanillin have very similar chemical compositions, and the engineered bacteria only need to make minor changes to the number of hydrogens and oxygens that are bonded to the same carbon backbone. The researchers mingled their genetically engineered bacteria with terephthalic acid and kept them at 37 degrees Celsius for a day. About 79 per cent of the terephthalic acid was subsequently converted into vanillin.

The world's best free divers can survive brain oxygen levels lower than those found in seals

HEALTH

Free divers' heart rates drop to 11 beats per minute

Words by **Yasemin Saplakoglu**

Free divers, those without breathing gear, can hold their breath for more than four minutes and descend to ocean depths of more than 100 metres. But this endurance feat takes a toll on the body's ability to pump oxygen through the blood and to the brain. If not enough oxygen goes to the brain, free divers are at risk of losing consciousness.

"Before now, understanding the effects on these exceptional divers' brains and cardiovascular systems during such deep dives, and just how far these humans push their bodies, was not possible, as all research was done during simulated dives in the lab," said Erika Schagatay, a professor of animal physiology at Mid Sweden University. "The diver can reach a point where hypoxic (low-oxygen) blackout occurs, and the diver then needs to be rescued. One of the main aims of the research is to warn the diver and safety personnel of an imminent blackout."

To understand how this extreme feat affects the human body, Schagatay and her team adapted a biomedical device, previously developed by the Dutch company Artinis Medical Systems, to withstand extreme ocean pressures.

The biomedical device, which is typically used to measure brain function, fires two different wavelengths of light from LEDs onto the divers' foreheads to measure heart rate and oxygen levels in the blood and brain. The device worked at depths of at least 107 metres.

The researchers found that the free divers who reached those depths had brain oxygen levels that dropped to levels lower than those found in seals – some dropped as low as 25 per cent. That's "equivalent to some of the lowest values measured at the top of Mount Everest," said Chris McKnight, a research fellow at the University of St Andrews' Sea Mammal Research Unit.

Brain oxygen levels are typically around 98 per cent, and if they drop below 50 per cent, a person is likely to lose consciousness. Researchers also found that divers' heart rates dipped as low as 11 beats per minute. As divers descend, their heart rates decrease to help preserve blood-oxygen levels. Divers' heart rates were as low as diving seals, whales and dolphins. These marine creatures are some of the world's best athletes; for instance, elephant seals can hold their breath for two hours underwater to hunt for food.

"Beyond the exceptional physiological responses that free divers display and the extremes they can tolerate, they may be a very informative physiological group," McKnight said. "Their physiological reactions are so unique and the conditions they're exposed to are not easily replicated, so they offer a unique way of understanding how the body responds to low blood oxygen, low brain oxygenation and severe cardiovascular suppression." The findings can therefore also inform researchers on how to protect the hearts and brains of patients who undergo surgical procedures or experience cardiac events.

A glass octopus moving in the deep sea of the Central Pacific Ocean

ANIMALS

Elusive glass octopus spotted in remote Pacific

Words by **Laura Geggel**

This rarely seen glass octopus bared all recently, even a view of its innards, when an underwater robot filmed it gracefully soaring through the deep waters of the Central Pacific Ocean. Marine biologists spotted the elusive glass octopus (*Vitreledonella richardi*) during a 34-day expedition off the remote Phoenix Islands, an archipelago located more than 3,200 miles northeast of Sydney, Australia.

Like other 'glass' creatures, such as glass frogs and certain comb jellies, glass octopuses are almost completely transparent, with only their cylindrical eyes, optic nerve and digestive tract appearing opaque. The expedition crew reported two encounters with the glass octopus, an impressive count given that previously there was such limited footage of these clear cephalopods that scientists had to learn about them by studying chunks of them in the gut contents of their predators.

Glass octopuses weren't discovered until 1918. Little is known about these cephalopods, except that they live in tropical and subtropical areas in the deep ocean in the mesopelagic, or twilight zone, 200 to 1,000 metres below the surface, and the bathypelagic, or midnight zone, 1,000 to 3,000 metres below the surface. Glass octopuses' cylindrical eye shape may have evolved to minimise the silhouette of the creatures' eyes when seen from below and is likely part of the animal's camouflage strategy.

The glass octopus was spotted by an expedition aboard the research vessel Falkor, run by the Schmidt Ocean Institute, a nonprofit operating foundation. During the expedition, a crew of marine scientists discovered a handful of what are likely newfound marine animals on nine previously unexplored submarine mountains known as seamounts. The team also completed high-resolution seafloor mapping of more than 11,500 square miles around the archipelago and video recordings of five additional seamounts filmed by the underwater robot SuBastian. SuBastian also snagged footage of a whale shark and a long-legged crab stealing a fish from another crab.

STRANGE NEWS

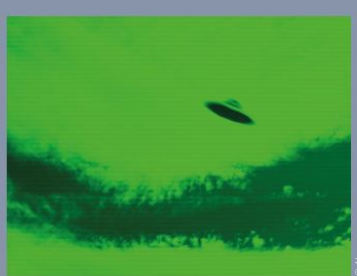
Most Americans think intelligent aliens exist

Words by **Mindy Weisberger**

The release of a US intelligence report on unidentified flying objects (UFOs) has stirred excitement, so it's not surprising to find that most Americans believe in intelligent life inhabiting other worlds. Approximately 65 per cent of Americans concur that extraterrestrials exist, and about 51 per cent say that UFO sightings reported by members of the US military represent visits from intelligent aliens, according to a survey conducted by the Pew Research Center, a nonpartisan think tank in Washington, DC.

Pew released its survey results prior to World UFO Day, an informal holiday celebrated on 2 July by UFO enthusiasts. The date is a nod to the purported 1947 UFO crash on a ranch at Roswell, New Mexico. While the exact date of the alleged Roswell crash is unknown, the US Army issued a press release on 8 July 1947 describing the recovery of a crashed flying disc from the ranch, launching an enduring fascination in the US with extraterrestrials and UFOs – army representatives later identified the mysterious object as an errant weather balloon.

For the survey, Pew representatives questioned 10,417 American adults about aliens and UFOs. They found that about 76 per cent of people between 18 and 29 years of age were likely to believe in intelligent aliens compared with 69 per cent of people aged 30 to 49 and only 58 per cent of people aged 50 to 64.



An image showing a UFO was allegedly captured on closed circuit television (CCTV) in the UK in 2008

WISH LIST

The latest **back to university** gadgets

Talk PRO USB Microphone

Price: **$149 (approx. £108.20)**
www.jlab.com

This professional-grade microphone offers some of the best sound resolutions on the market. Whether you're a music student who can take advantage of its four-directional recording modes or just someone passionate about podcast making, this is a great tool to have. Thanks to the Talk PRO's convenient USB plug-and-play design, it can provide crystal-clear audio for gaming, streaming, voice-overs and more in seconds.

© JLab

© Planet Computers

Cosmo Communicator

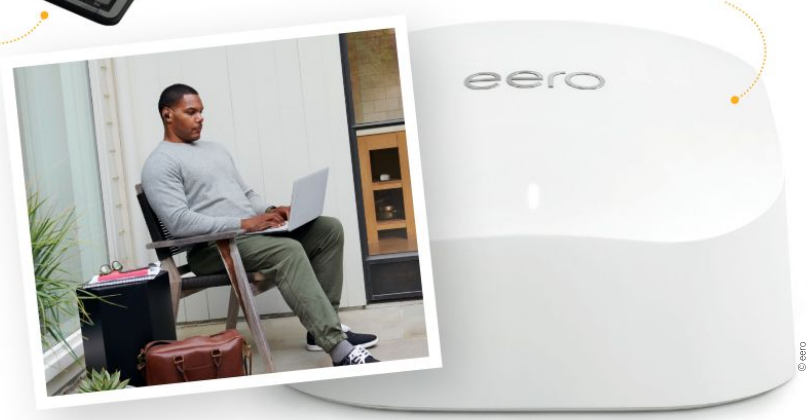
Price: **£721.20 (approx. $993)**
store.planetcom.co.uk

The Cosmo Communicator is a dual-SIM, 4G clamshell smartphone with dual touchscreens, a six-inch FHD+ internal display, a two-inch AMOLED external display, and its highlight feature, a desktop-quality compact keyboard with satisfying mechanical touch. It has a 24-megapixel external camera and a whopping 4,220mAh battery, though for a phone that's designed for continuous usage, that translates to just a couple of long train journeys before it's completely drained. Planet Computers bills this as the "ultimate mobile device that fits in your pocket," and it certainly has more to offer an industrious student than any smartphone on the market right now.

eero 6

Price: **From £97 / $129**
www.amazon.co.uk / www.eero.com

A good internet connection is essential for studying at university, so to ensure that you stay connected, Amazon has created the eero 6 mesh system to increase your internet speed and efficiency. The eero 6 essentially works as a way to extend the reach of your Wi-Fi signal and remove any Wi-Fi blind spots. This system promises to extend coverage by up to 464 square metres and supports speeds up to 900 Mbps. Its bandwidth can also support high speeds for over 75 connected devices and can control compatible devices with its built-in home hub and Alexa app.



© eero

WF-1000XM4

Price: **£250 / $349.99**
www.sony.co.uk / electronics.sony.com

University can be a noisy place, especially when you're trying to study. The latest sound-cancelling, truly wireless headphones from Sony are the perfect way to get some quiet time out in public. As music providers these headphones are incredibly intuitive. Using built-in Adaptive Sound Control technology, these headphones can detect the kind of environment you are in and automatically adjust the ambient sound, such as stripping away background noise on a train or letting some of that noise through while you're walking so that you can stay aware of your surroundings. This technology can also remember and recognise the places you frequently visit, such as the gym or a café, and tailor the sound to suit the environment.

© Sony

© Amazon

Kindle Oasis

Price: **From £229.99 / $269.99**
www.amazon.co.uk / www.amazon.com

You'll need to read countless books while you're completing your degree. But rather than filling up bookshelves, the Kindle Oasis lets you keep all your textbooks in one place, featuring 8 or 32-gigabyte storage options. This latest instalment of the Kindle comes with the ability to adjust the shade of its screen from white to a warm, amber hue. There is even the option to set timers for automatic adjustments. The Oasis has also been protected against immersion in up to two metres of fresh water for up to 60 minutes, but only 0.25 metres for three minutes in seawater. This means you can study in the bathtub, at the pool or by the beach without worrying about damaging your Kindle.

Repaper Tablet

Price: **£223 / $248**
www.iskn.co

The Repaper tablet is perfect for any student who wants to transform their work from pencil to JPEG. Like a pencil-to-pad digital translator, this handy device can detect the pressure applied to a piece of paper and wirelessly send the produced illustration, design or artwork to your computer. The Repaper has a battery life of six hours and can convert your drawings into a range of file types, and can even create time-lapse videos. Should artistic inspiration hit you on the go, this device can also store your designs using its built-in 4-megabyte memory or 32-gigabyte SD card port.


© ISKN

APPS & TOOLS

SimpleMind Lite – Mind Mapping

Developer: **ModelMaker Tools**
Price: **Free / Google Play / App Store**

If you like making mind maps to study, this is the app for you. It can form countless easy-to-create maps on a seemingly endless page size.

Dropbox Paper

Developer: **Dropbox, Inc.**
Price: **Free / Google Play / App Store**

This is a great tool to create a virtual workspace to share ideas, collaborate with classmates and manage the progress of group projects.

Mathway

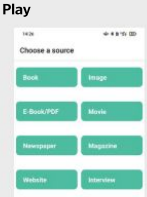
Developer: **Mathway, LLC**
Price: **Free / Google Play / App Store**

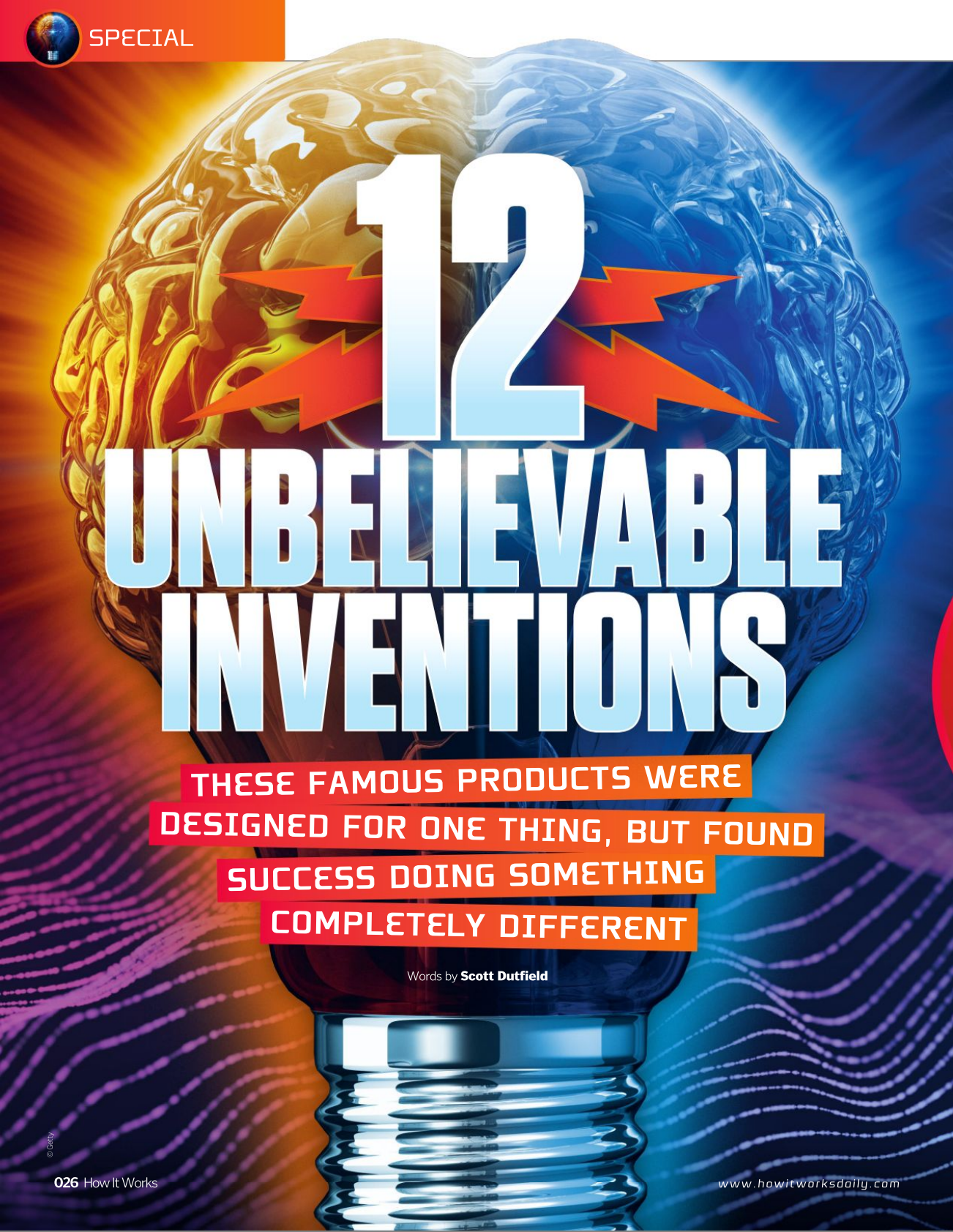
From basic algebra to complex statistics, this calculator app helps students solve difficult math problems in a few seconds.

Referencer – Harvard Style

Developer: **Kevin Ilondo**
Price: **Free / Google Play**

Make Harvard referencing simple with this citation app. Simply input your source and it will generate a Harvard-style reference for you.

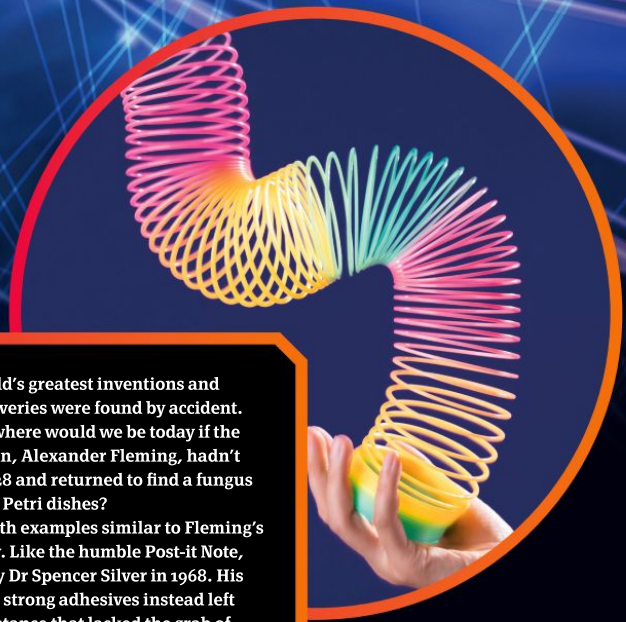




12 UNBELIEVABLE INVENTIONS

THESE FAMOUS PRODUCTS WERE DESIGNED FOR ONE THING, BUT FOUND SUCCESS DOING SOMETHING COMPLETELY DIFFERENT

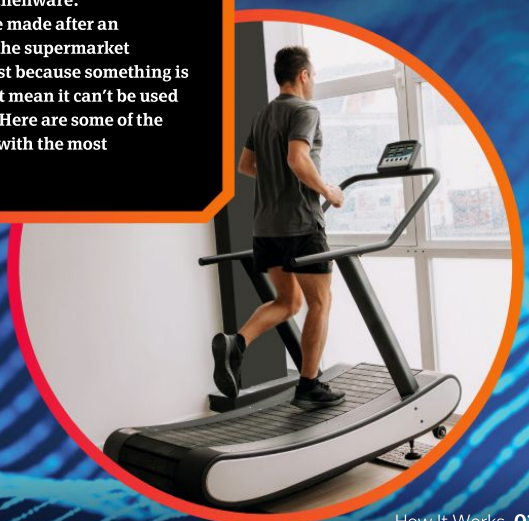
Words by **Scott Dutfield**



Some of the world's greatest inventions and scientific discoveries were found by accident. For example, where would we be today if the discoverer of penicillin, Alexander Fleming, hadn't gone on holiday in 1928 and returned to find a fungus killing bacteria in his Petri dishes?

History is awash with examples similar to Fleming's unexpected discovery. Like the humble Post-it Note, which was created by Dr Spencer Silver in 1968. His experiments with strong adhesives instead left him with a substance that lacked the grab of glue, but could stick to surfaces and peel away easily. Teflon is another product where a discovery was made by chance. In 1938, Dr Roy J. Plunkett was experimenting with different refrigerant gases, including tetrafluoroethylene (TFE). In one refrigerator the gas appeared to be missing, but upon further inspection, Plunkett found that the TFE had polymerised into a white powder called polytetrafluoroethylene (PTFE). This new substance was super slippery and had a high melting point, making it perfect for creating non-stick kitchenware.

Some discoveries were made after an invention had already hit the supermarket shelves. They're proof that just because something is created for one purpose doesn't mean it can't be used more successfully for another. Here are some of the world's most famous products with the most surprising origin stories.



THE SCIENCE BEHIND SLINKIES

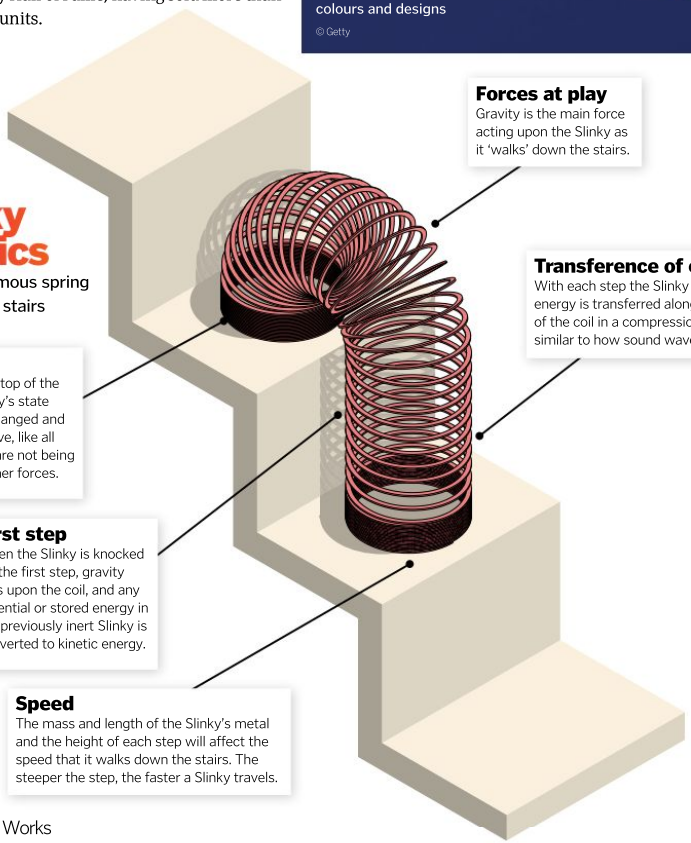
The story goes that the Slinky's inventor, Richard T. James, first discovered the recreational use of the metal spring while working as a naval battleship engineer during the early 1940s. James was developing coils of metal called tension springs that were used on ocean vessels to hold onboard equipment in place. While working at his desk, one of these springs fell and began to 'walk'. Seeing the potential to market the tension spring as a toy, he took the idea home to his wife Betty, who named it the Slinky after looking through a dictionary.

In 1945 James perfected the design of the Slinky, which consisted of approximately 24 metres of wire coiled into a helical five-centimetre-tall spring. The following year, James filed a patent for a machine that could make a Slinky in just ten seconds. The Slinky went on to become the must-have toy of the mid to late 20th century, and in 2000 was inducted into the National Toy Hall of Fame, having sold more than 250 million units.

Slinkies come in lots of bright colours and designs

Slinky physics

How this famous spring walks down stairs



Forces at play
Gravity is the main force acting upon the Slinky as it 'walks' down the stairs.

Transference of energy
With each step the Slinky takes, energy is transferred along the length of the coil in a compression wave, similar to how sound waves travel.

Inertia
Sitting at the top of the stairs, a Slinky's state remains unchanged and it will not move, like all objects that are not being moved by other forces.

First step
When the Slinky is knocked off the first step, gravity acts upon the coil, and any potential or stored energy in the previously inert Slinky is converted to kinetic energy.

Speed
The mass and length of the Slinky's metal and the height of each step will affect the speed that it walks down the stairs. The steeper the step, the faster a Slinky travels.

MR CELLOPHANE

In the kitchen drawers of countless homes around the world, you'll probably find a roll of cling film, or Cellophane. This clear roll of plastic has been around since 1908, when Swiss chemist Jacques E. Brandenberger created a waterproof film intended for coating fabrics.

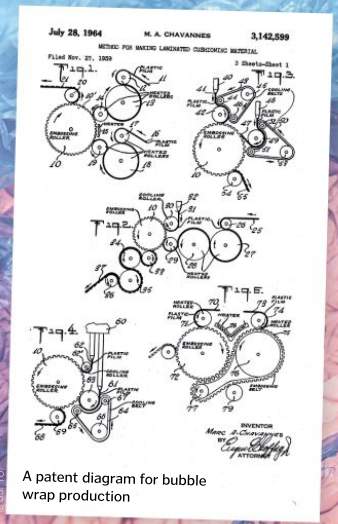
The film appeared after Brandenberger applied a liquid viscose rayon on materials and then peeled away the transparent layer. He saw potential for this new material in the packaging industry, and so patented his creation 'Cellophane', named after the raw material cellulose – the main substance of plant cell walls – and diaphane, an obsolete word meaning transparent.

BUBBLE WRAP WALLPAPER

Bubble wrap is synonymous with sending packages or protecting your precious belongings. However, in the 1950s you were more likely to see it covering your walls than crammed into a box. The idea for bubble wrap came from the minds of Alfred Fielding and Marc Chavannes, who made an attempt to create a textured wallpaper in 1957. Having heated two sheets of plastic shower curtain together, the pair created a single sheet with several trapped air bubbles.

The coinventors obtained several patents for their creation, making attempts to market it as wallpaper and even as greenhouse insulation, but bubble wrap never took off as an interior decoration. The two coinventors founded Sealed Air Corporation in 1960, and the following year diversified their product as a packing material, which soon found success.

The soft bubbles keep what's wrapped inside safely cushioned


July 28, 1964 M. A. CHAVANNES 3,142,599
METHOD FOR MAKING LAMINATED CUSHIONING MATERIAL
Filed Nov. 27, 1959 3 Sheets-Sheet 1

A patent diagram for bubble wrap production

© USPTO

© Getty

Building bubble wrap

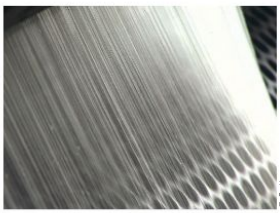
How plastic is transformed from pellets into poppable packaging


© Alamy

1 Plastic pellets
Bubble wrap starts its life as pellets of polyethylene resin. These are vacuumed through pipes to an extruder.


© Alamy

2 Heating up
The resin pellets are heated at temperatures over 260 degrees Celsius. The pellets melt as a result, forming a film.


© Getty

3 Sucking up
One layer of film is placed on a cylinder coated with small holes. Using a vacuum, the film is then sucked into the holes.


© Getty

4 Trapping air
A second layer of plastic film is then rolled on top of the vacuumed film to create a seal, trapping the air bubbles within.


© Getty

5 Cut to size
The now-joined films are rolled into large sheets of bubble wrap and cut into smaller pieces.

PLAY-DOH CLEANER

Around 318 million kilograms of Play-Doh has been squashed between the fingers of children around the world. But did you know that Play-Doh was initially invented as a cleaning tool, rather than a toy? The malleable material was created by Cincinnati-based cleaning company Kutol in the early 1900s. Its intended use was to remove the soot from people's wallpaper, which accumulated from coal-burning fireplaces. However, with the introduction of wipeable vinyl wallpaper and the increase in household oil, gas and electric heating, the need for Kutol's putty quickly declined. Its rebranding was down to the sister-in-law of Kutol's cofounder, who proposed that the putty's non-toxic ingredients meant it would be perfect for playtime.


Play-Doh is completely safe in the hands of children

© Getty

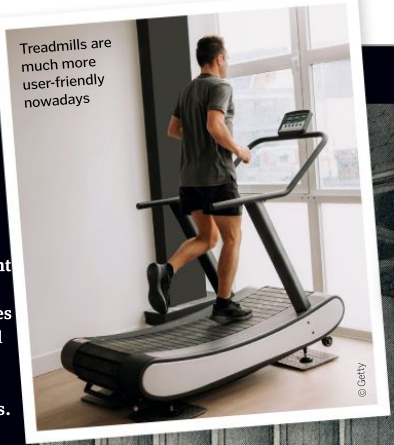
PENAL TREADMILLS

After gorging on a takeaway, hopping onto the treadmill in the morning may feel like atonement for a crime. But that's exactly what treadmills were created for during the early 1800s. Examples of treadmill-like contraptions have been around since the Romans constructed large cranes powered by people walking on a wheel. But the modern-day article was conceived of in the 1800s.

As a cruel method of enforced exercise, the evolution of the treadmill began in 1818, when civil engineer William Cubitt created the treadwheel. It was intended not to improve the fitness of the public, but to punish prisoners.

Installed into Brixton Prison, London, the treadwheel turned under the feet of up to 24 prisoners, each stepping on the wooden slats of an elongated wheel. It included dividers so that prisoners could not socialise, and it could be ten hours before prison guards would let them off the torturous device. Although the invention of the treadwheel was initially designed as a punishment, over time prison officials put them to practical use to pump water or grind corn.

It wasn't until 1902 that the penal treadmills such as Cubitt's creation were abolished in Britain, but treadmill technology continued to evolve for personal fitness.



Treadmills are much more user-friendly nowadays

© Getty

Enforced fitness

How these immoral machines kept prisoners walking for hours

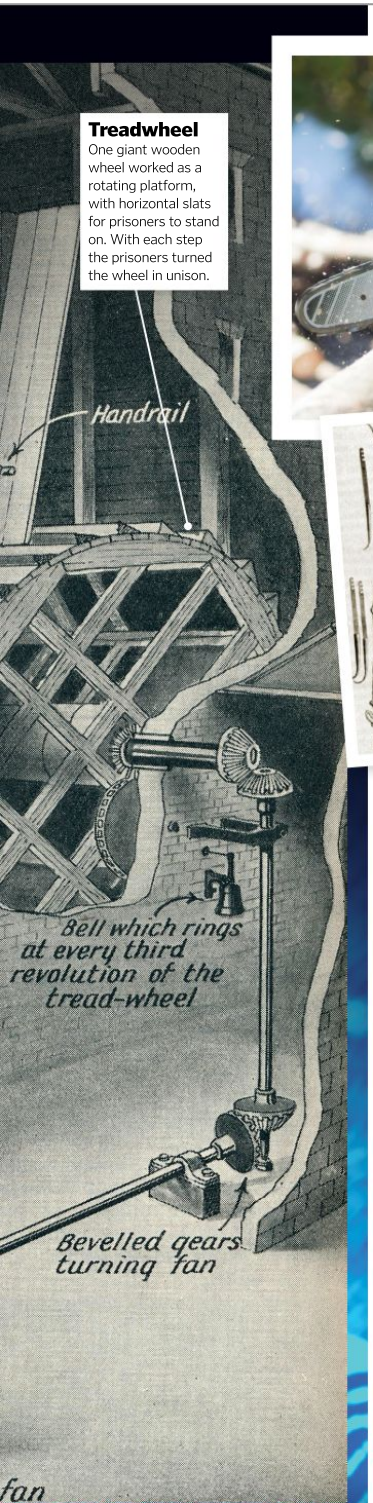
© Alamy

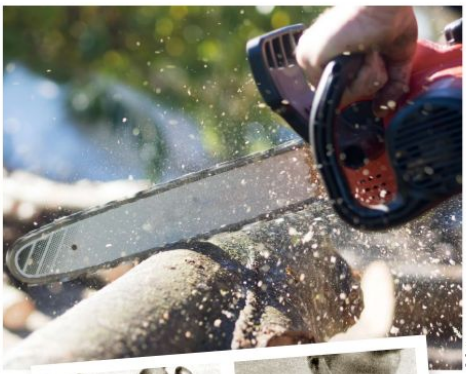
BATTLE-BORN BOTTLE OPENER

Although the exact origin of the corkscrew remains unclear, it's believed that its design was developed from 'gun worms'. These military screws were commonly used in the 1600s to extract trapped musket balls from the barrels of guns. The corkscrew-like devices would twist into the lead of the ball, allowing the soldier to swiftly remove it.

It's believed that this military kit inspired the first generation of simple wine 'cork worms'. It wasn't until 1795 that a British clergyman, Reverend Samuel Henshall, filed the first patent for the corkscrew.

Source: Nkiz/Unknown artist




© Getty


Source: Wiki/Hans555

Chainsaws weren't made with trees in mind

CHAINSAW OPERATIONS

Chainsaws are pretty effective at ripping into wood, but back in the late-18th century, it was bone rather than bark that they tore through. The evolution of the chainsaw began between 1783 and 1785, when two Scottish doctors called John Aitken and James Jeffray invented the chain hand saw. This serrated link chain was used to successfully cut away diseased bone and remove afflicted joints such as the knee or elbow. Over time Aitken and Jeffray's simplistic design was developed, and in 1830 Bernhard Heine created a drive more reminiscent of the modern-day version.

Known as the chain osteotome, Heine's device also used a serrated chain, but included a handle mechanism. It worked in a similar way to hand-powered rotary whisks, but instead of beating eggs, it could precisely cut through bone quickly. The osteotome meant that surgeons could perform surgeries without the restrictions of bone splinters or damaging the surrounding tissue.

The chainsaw's move from bone to bark came about when American inventor Samuel J. Bens patented the first 'endless chainsaw' in 1905. The stationary device consisted of a large, looped, 'endless' secreted chain which was "furnished with driving power, such as a steam-engine, gas-engine or motor of any kind".

WD-40

It's now a household product around the world, but WD-40 was initially created to assist the aerospace industry as a rust-prevention solution. It took WD-40's inventors, a company called Rocket Chemical Company, 40 attempts to perfect this water-displacement formula, hence the name. It was used to coat the skin of the Atlas missile, the US Air Force's first operational intercontinental ballistic missile (ICBM), to prevent it from corroding.

Seeing its potential as a household product and a useful tool for car mechanics, WD-40 hit supermarket shelves in 1958. Although initially perfected in 1953, the same formula for WD-40 is still in use today. Now the iconic blue-and-yellow cans can be found in their millions around the world, and in 2020 the revenue of WD-40 Company reached $408.5 million (£295 million).


© Alamy

WD-40 can hold back rust from rockets

© Getty

THE MANY USES OF LISTERINE

© Getty

© Getty


© Alamy

Other than providing a cool, refreshing oral feeling, Listerine was created to offer an antiseptic solution in the operating theatre. Named after its inventor Sir Joseph Lister, the founder of the practice of antiseptic medicine, the alcohol-based formula was created in 1879 to remove disease-causing organisms and was a good disinfectant for surgical instruments. It was also used as a solution for treating wounds, curing dandruff and cleaning floors. Eventually dentists got hold of Listerine and used it to improve oral hygiene in dental patients. In the 1920s, a marketing campaign that branded Listerine the treatment for the relatively unheard of 'halitosis', or bad breath, made it the go-to mouthwash for the public.

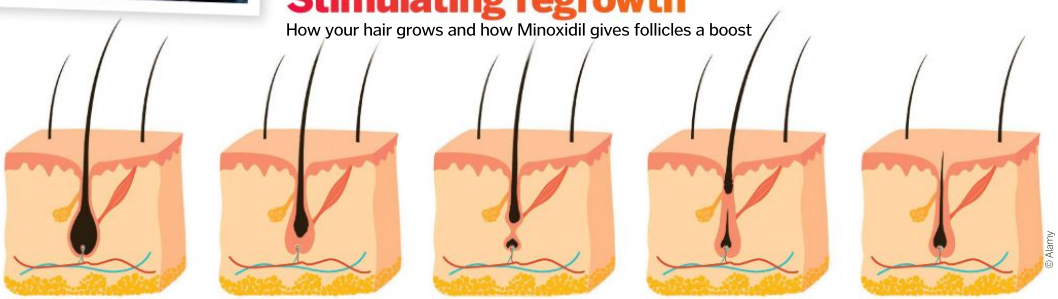
ROGAINE REGROWTH


© Alamy

In the 1960s, pharmaceutical company Upjohn, now part of Pfizer, created a new kind of medicine to treat hypertension (high blood pressure). This medication was called minoxidil and proved popular with clinicians, so much so that the US Food and Drug Administration (FDA) approved it as an emergency protocol for severely ill patients in 1971. It was later discovered that 60 to 80 per cent of hypertensive patients developed an unusual side effect, called hypertrichosis. This condition results in excessive hair growth anywhere on the human body. Researchers quickly found that minoxidil stimulates follicular growth. As a result, in 1988 the new 'Rogaine 2% Minoxidil Solution for Men' was introduced as a prescription-only solution to hereditary hair loss.

Stimulating regrowth

How your hair grows and how Minoxidil gives follicles a boost


© Alamy

Anagen
In the first stage of hair growth, specialised cells divide into cells that make up the shaft of a hair, receiving nutrients from a capillary loop at the base of a follicle.

Catagen
At this stage the hair follicle shrinks, detaches from the capillary loop and moves towards the skin's surface.

Telogen
For around three months a hair will sit in this resting phase before moving on to the exogen phase.

Exogen
In the shedding phase, the hair is discarded from your body. Between 50 and 100 hairs are shed from your body each day.

Rogaine
To tackle hair loss, typically known as androgenic alopecia, minoxidil works to prolong the anagen phase and promotes regrowth via the follicle capillary loop.

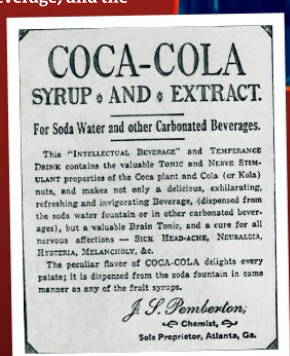
CRAVING COCA-COLA

Arguably one of the most beloved carbonated drinks on the market, today Coca-Cola sells more than 1.9 billion servings, enjoyed in 200 countries every single day. The original recipe of the drink, however, would not be so well received these days.

Coca-Cola began as a way for its pharmacist creator John Pemberton to tackle his dependence on morphine. He'd been injured in the Battle of Columbus in the late-19th century, and like many veterans, Pemberton became dependent on pain relief medicines such as morphine. Seeking an alternative to this addictive opiate, Pemberton came across a tonic called French Wine Coca, made by Parisian chemist Angelo Mariani. The tonic promised health rejuvenation from its Bordeaux wine and coca-leaf extract mixture.

The energy-boosting effects of the drink were likely due to the presence of cocaine, the active ingredient in coca-leaf extract. Until 1914 cocaine was not illegal, and was often used in tonics and pills to treat a myriad of medical conditions causing nausea, asthma and constipation.

Pemberton created his version of the wine to sell commercially, but a local prohibition law in 1887 saw quick removal of the tonic because of its alcoholic content. Quickly reformulating the popular beverage, Pemberton substituted the drink's alcohol content, replacing it with sugar syrup and adding caffeine-rich kola-nut extract. The coca-leaf extract remained in the beverage, and the drink became completely cocaine-free in 1929, when scientists removed the psychoactive components of the leaf extract.


COCA-COLA
SYRUP AND EXTRACT.
For Soda Water and other Carbonated Beverages.
This "Intellectual Beverage" and Temperance Drink contains the valuable Tonic and Nerve Stimulant properties of the Coca plant and Cola (or Kola) nuts, and makes not only a delicious, exhilarating, refreshing and invigorating Beverage, (dispensed from the soda water fountain or in other carbonated beverages), but a valuable Brain Tonic, and a cure for all nervous affections — Sick Headache, Neuralgia, Hysteria, Melancholy, &c.
The peculiar flavor of COCA-COLA delights every palate; it is dispensed from the soda fountain in same manner as any of the fruit syrups.
J. S. Pemberton,
Chemist,
Sole Proprietor, Atlanta, Ga.

Coca-Cola's original recipe was a cocaine cocktail

© Getty

Source: Wiki/Unknown

Secret ingredients and colour: 0.17307%

A secretive blend of natural flavours are added. Besides coca extract, it's speculated that this includes lots of natural oils, including those from nutmeg, lemon, coriander, cinnamon and orange. Coca-Cola Original uses a colourant called caramel 150d. This additive uses a combination of sulphite and ammonia reactants to create its brownish colour.

Energy boost: 0.00972%

In a standard can of Coca-Cola there is around 34 milligrams of caffeine. However, in the diet version this amount rises to 46 milligrams.

Acidity: 0.1719%

To add tartness, Coca-Cola includes a small amount of phosphoric acid. However, this acid wreaks havoc on the enamel of your teeth.

Inside Coca-Cola

Take a look at what's inside that classic red bottle

Sweet taste: 10.8%

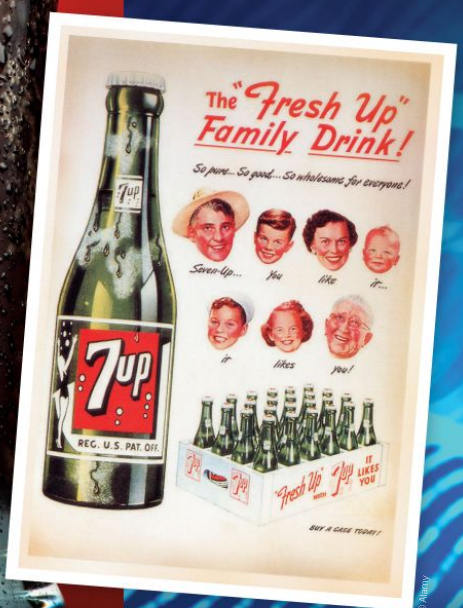
In around half a litre of Coca-Cola there is approximately 65 grams of sugar.

Fizz: ~89%

Around 90 per cent of Coca-Cola is water, which has been pumped with purified carbon dioxide to give it its fizz.

THE MOOD BOOSTER

Similar to the creation of Coca-Cola, the refreshing taste of 7UP was concocted as a life-changing elixir. In 1929, Charles Leiper Grigg created a new lemon-flavoured drink called 'Bib-Label Lithiated Lemon-Lime soda'. The formula for the drink contained lithium, which continues to be used as a mood enhancer to treat conditions such as depression and bipolar disorder. 7UP hit supermarket shelves only two weeks after the American stock market crash in 1929 and the start of the Great Depression. Lithium was removed from 7UP's recipe in 1948 following a government ban in America of its use in soft drinks.



Old branding for 7UP marketing it for the whole family

© Alamy

INVENTIONS BY NUMBERS

3.1%

A significant fraction of all beverages consumed around the world are Coca-Cola products

3,500 BEVERAGES

If you were to drink a different Coca-Cola product every day, it would take you over nine years

If every drop of Coca-Cola ever made was bottled and stacked, the tower would reach the Moon and back over 2,000 times

97%

Listerine claims its mouthwash can kill nearly all germs in your mouth

There are more than 50 colours of Play-Doh

90%

In 2005, fingerprints pressed into Play-Doh could fool the majority of fingerprint scanners

30 The record number of steps a Slinky has descended

30 METRES

When fully extended, the largest Slinky on Earth is as tall as a nine-storey building

The initial run of 400 Slinkies sold out in just 90 minutes

UP TO 14,000

The average number of rotations a chainsaw chain makes per minute

6.98 METRES LONG 1.83 METRES HIGH

'Big Gus' is the largest working chainsaw in the world

39 LAYERS

One estimate says that it would take several dozen sheets of bubble wrap for you to survive a six-storey fall

2,681

The record for the most people popping bubble wrap simultaneously

© Getty

1952

It wasn't until the mid-20th century that the first motorised treadmill was invented

13 HRS 42 MINS 33 SECS

The record speed for running 100 miles on a treadmill

HOW A CITY WORKS

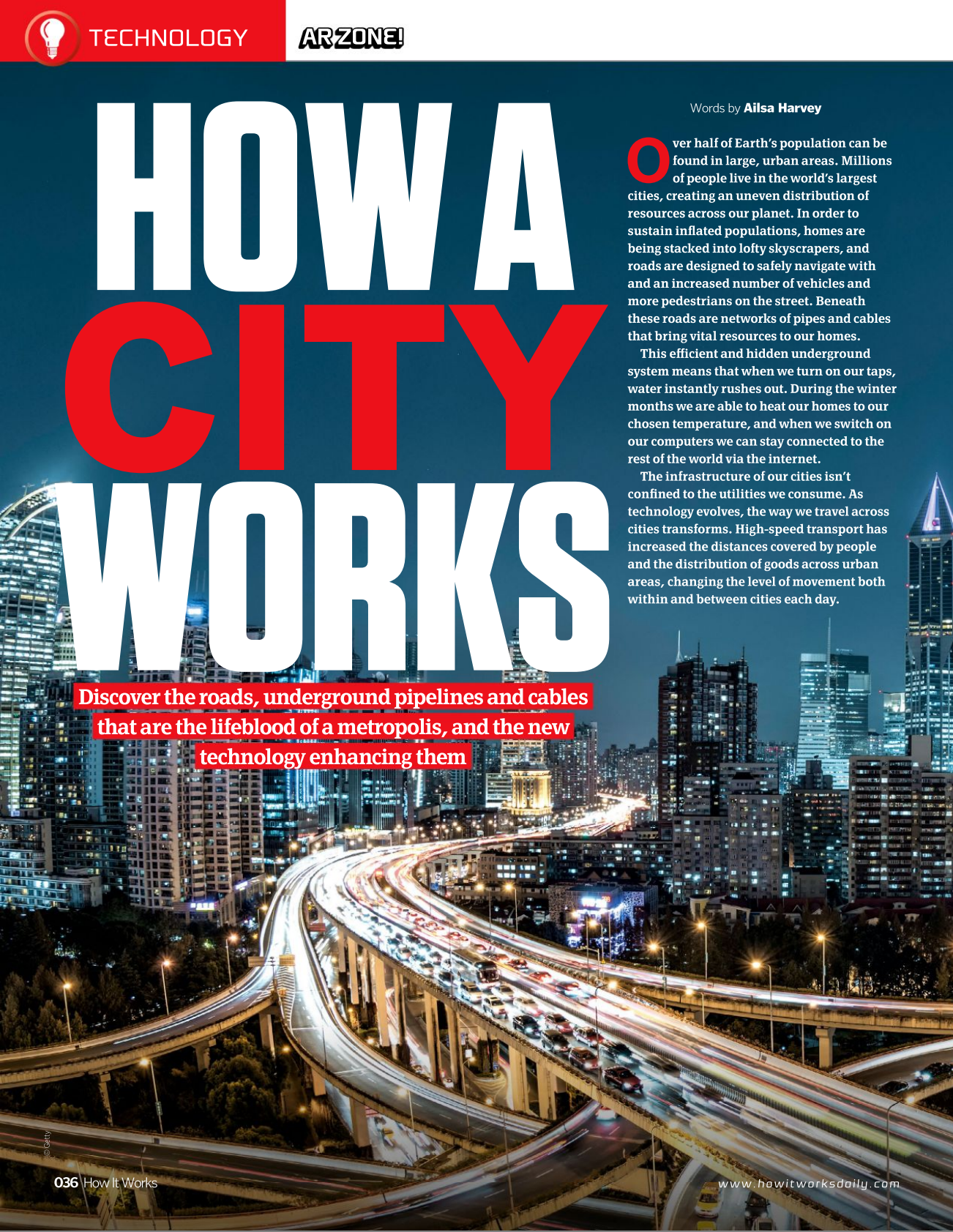
Words by **Ailsa Harvey**

Discover the roads, underground pipelines and cables that are the lifeblood of a metropolis, and the new technology enhancing them

Over half of Earth's population can be found in large, urban areas. Millions of people live in the world's largest cities, creating an uneven distribution of resources across our planet. In order to sustain inflated populations, homes are being stacked into lofty skyscrapers, and roads are designed to safely navigate with and an increased number of vehicles and more pedestrians on the street. Beneath these roads are networks of pipes and cables that bring vital resources to our homes.

This efficient and hidden underground system means that when we turn on our taps, water instantly rushes out. During the winter months we are able to heat our homes to our chosen temperature, and when we switch on our computers we can stay connected to the rest of the world via the internet.

The infrastructure of our cities isn't confined to the utilities we consume. As technology evolves, the way we travel across cities transforms. High-speed transport has increased the distances covered by people and the distribution of goods across urban areas, changing the level of movement both within and between cities each day.



SMARTER BUILDINGS

Emerging technologies can help future buildings run more efficiently

Underneath this road, utility pipes cross over to reach multiple houses

Activity sensors

Office blocks within cities have multiple rooms for different purposes. Often these remain fully lit and heated for employees or customers. Using sensors that are connected to these electrical systems, energy usage can be limited to the rooms being used. This reduces the building's costs and increases energy efficiency.

Building assistance

Image-recognition software can scan building work as it is being carried out to detect any errors. Automatically flagging these up means that mistakes can be corrected and serious problems averted. This makes new builds in cities quicker and more reliable.

Entry security

Installing more biometric entry methods to buildings can prevent trespassers from gaining entry. Keyless methods like facial recognition and fingerprint technologies reduce the chances of intrusion.

Remote tracking

Smart devices such as cameras, lights and computers can be tracked via a mobile phone. These can send images from security cameras and alert messages from a triggered security alarm or overrunning lights to building managers in another location. The managers can then act instantly to solve problems.

Record referral

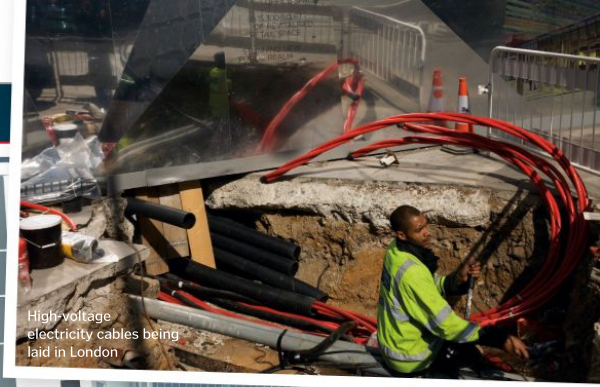
This wireless sensor detects the temperature and humidity in a specific area of the building. The data is linked to maintenance records and can be used to track any changes in the durability and quality of building materials. For example, increased humidity levels may detect leaks quicker than human monitoring.

"Homes are being stacked into lofty skyscrapers"

AR ZONE! SCAN HERE

UNDERGROUND UTILITIES

Take a look beneath the roads and see the hidden engineering running our cities



High-voltage electricity cables being laid in London

Distribution pipes
Large pipes split off into smaller pipes so that water and gas can be directed to individual houses. This creates an extremely complex network in busy cities.

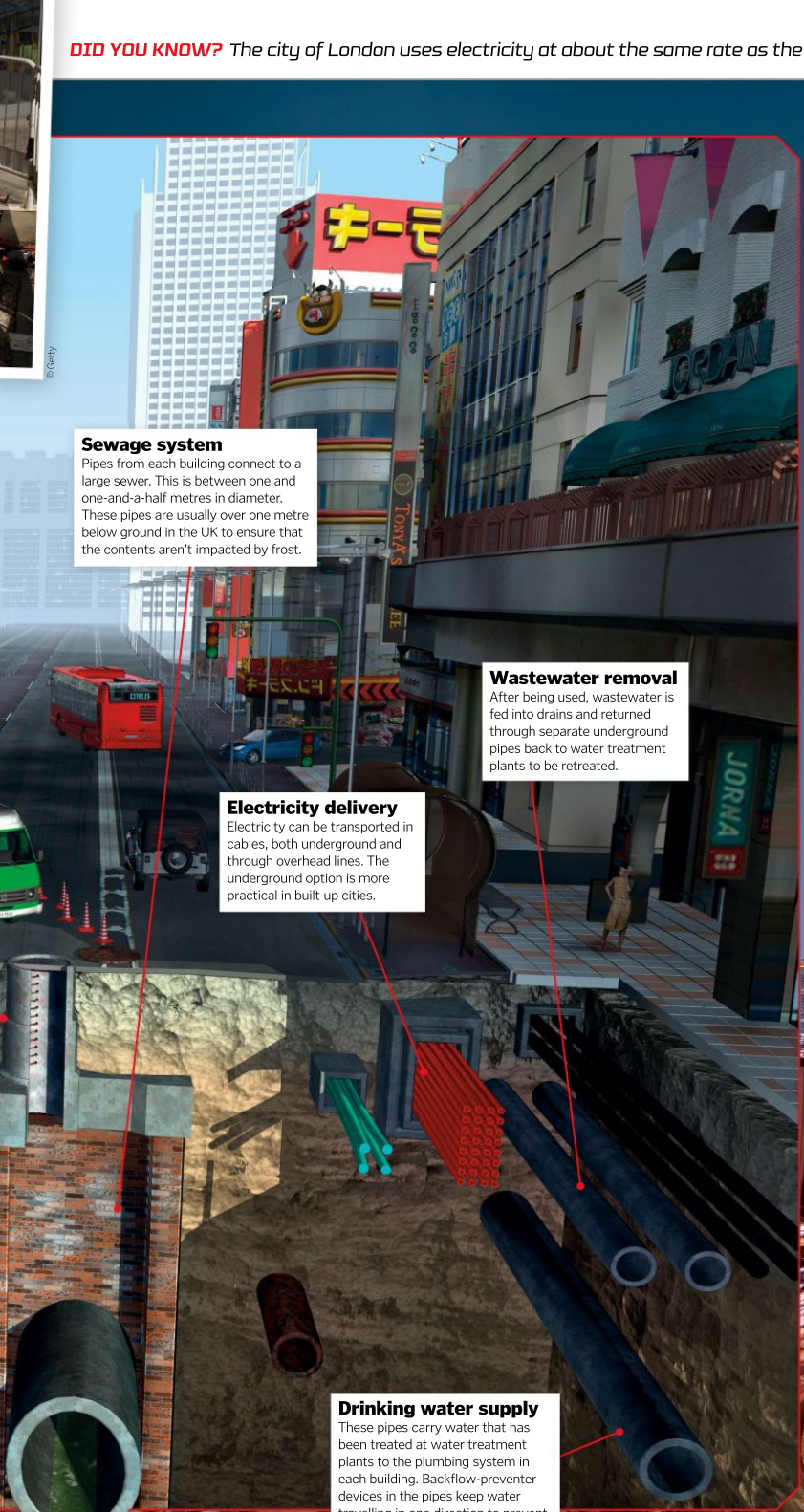
Data cables
Cables as thin as rope transport data for television and internet connections. These coaxial cables run from massive data storage units and consist of a copper core insulated with aluminium.

Inspection chamber
Sewage pipes have vertical access points that allow workers to monitor the state of the pipes and carry out any work on them.

"Beneath roads are networks of pipes and cables"

Gas pipes
The gas used in your house, for purposes such as central heating and cooking, arrives through an underground pipe that connects to your gas meter. Compressors in these pipes work to make pressure gradients, forcing the gas to move from areas of high to low pressure.

DID YOU KNOW? *The city of London uses electricity at about the same rate as the output of five nuclear power stations*



© Getty

Sewage system
Pipes from each building connect to a large sewer. This is between one and one-and-a-half metres in diameter. These pipes are usually over one metre below ground in the UK to ensure that the contents aren't impacted by frost.

Wastewater removal
After being used, wastewater is fed into drains and returned through separate underground pipes back to water treatment plants to be retreated.

Electricity delivery
Electricity can be transported in cables, both underground and through overhead lines. The underground option is more practical in built-up cities.

Drinking water supply
These pipes carry water that has been treated at water treatment plants to the plumbing system in each building. Backflow-preventer devices in the pipes keep water travelling in one direction to prevent pipes becoming contaminated.

© Science Photo Library

5 LAYOUTS FOR SAFER ROADS

Shorter blocks
Shorter blocks mean more junctions between them. As drivers come to the end of each block, they are required to stop, reducing their speed in built-up areas.

© Getty

Narrower roads
Wide roads might seem easier to drive on, but narrow roads have been proven to make people drive more cautiously. This makes them more likely to spot other surrounding dangers.

© Getty

Roundabouts
Roundabouts are designed to slow traffic upon its approach. Although they have been known to cause collisions, because these systems keep traffic moving the same way, crashes are often less severe than the alternative of junctions.

© Getty

Raised crossings
The simple enhancement of raising a pedestrian crossing can make those crossing busy roads more visible. Putting them more level to the eyeline of drivers, they are more likely to be noticed and less likely to be hit.

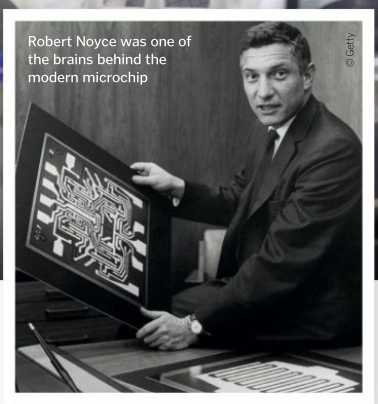
© Getty

Chicanes
These indentations create sections of road whereby only one vehicle can pass through at a time. Chicanes force drivers to slow down and analyse the road ahead, while narrowing part of the road can also create more room for pedestrians.

© Getty

Workers in China on the production line of silicon wafers

How microchips are made



Robert Noyce was one of the brains behind the modern microchip

© Getty

These tiny, silicon devices power the modern world

From the mobile phone in your pocket to the computers that make spaceflight possible, virtually no piece of modern electronic equipment would function without the humble microchip. Also called a chip, a computer chip, an integrated circuit or IC, a microchip is just a set of electronic circuits on a small, flat piece of silicon.

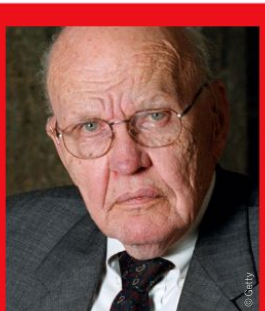
Sitting on top of the chip are components called transistors, which act like tiny electrical switches that can turn a current on or off. You can fit a huge amount of transistors on a chip, with one the size of a fingernail containing billions of them. The chips themselves are made from silicon, which is in turn made from a type of sand called silica. The sand, which is made from silicon dioxide, is melted down and cast to form a big cylinder known as an ingot, which is then sliced up.

A layer of silicon dioxide is grown on the surface, which is covered with a photosensitive chemical and exposed to ultraviolet light that's shone through a patterned plate, or 'mask', that kind of acts like a stencil. This hardens the areas exposed to the light. These hardened bits then get stripped away, leaving a three-dimensional landscape on the chip that looks just like the original circuit design on the mask. Wiring and transistor components are then built onto it.

There are two main types of microchip: memory chips store information, while logic chips function as the brains of electronic devices. In 2019 more than 634 billion chips were manufactured around the world as part of an industry worth £410 billion ($567 billion) a year. But the last year or so has seen a shortage of chips, as manufacturing slowed during the coronavirus pandemic. Changing consumer habits mean there's also been a spike in demand for electronic devices.

History of the microchip

The first microchip was produced in 1974, and two men are credited with having the original idea. In 1958, engineer Jack Kilby had recently joined a company called Texas Instruments. Because he hadn't accrued as much holiday time as his colleagues, he found himself alone in the lab with time on his hands. It was then that he conjured up the idea for what would become the microchip. But over in California, another man had similar ideas. In January of 1959, Robert Noyce was working at the small Fairchild Semiconductor start-up company, where he conceived the idea for a whole circuit which could be made on a single chip. In 1961 the patent office awarded the first patent for an integrated circuit to Robert Noyce while Kilby's application was still being analysed. But both men are now acknowledged as having independently conceived the original idea.



© Getty

Nobel Prize winner for physics Jack Kilby at the Swedish Academy in Stockholm in 2000

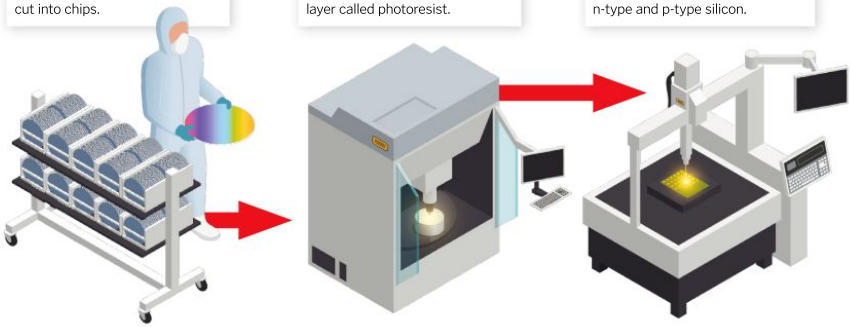
Forging a microchip

The industrial process that produces the integrated circuit is well-established

1 Making wafers
Silicon crystals are grown into long cylinders, which are sliced into 'wafers'. These can then be cut into chips.

2 Masking
Wafers are heated to coat them in silicon dioxide. Ultraviolet light is then used to add a hard layer called photoresist.

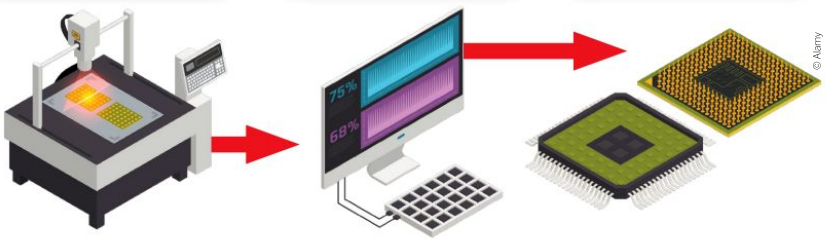
3 Etching
A chemical is used to remove the photoresist, making a template pattern which shows where to put n-type and p-type silicon.



4 Doping
The etched wafers are heated with gases to make areas of n-type and p-type silicon. More masking and etching may follow.

5 Testing
Long metal connection leads run from a testing machine to the terminals on each chip. Any chips that don't work are rejected.

6 Packaging
The working chips are cut out of the wafer and packaged into protective plastic, ready to be used.



© Alamy

5 FACTS ABOUT MICROCHIP TECHNOLOGY

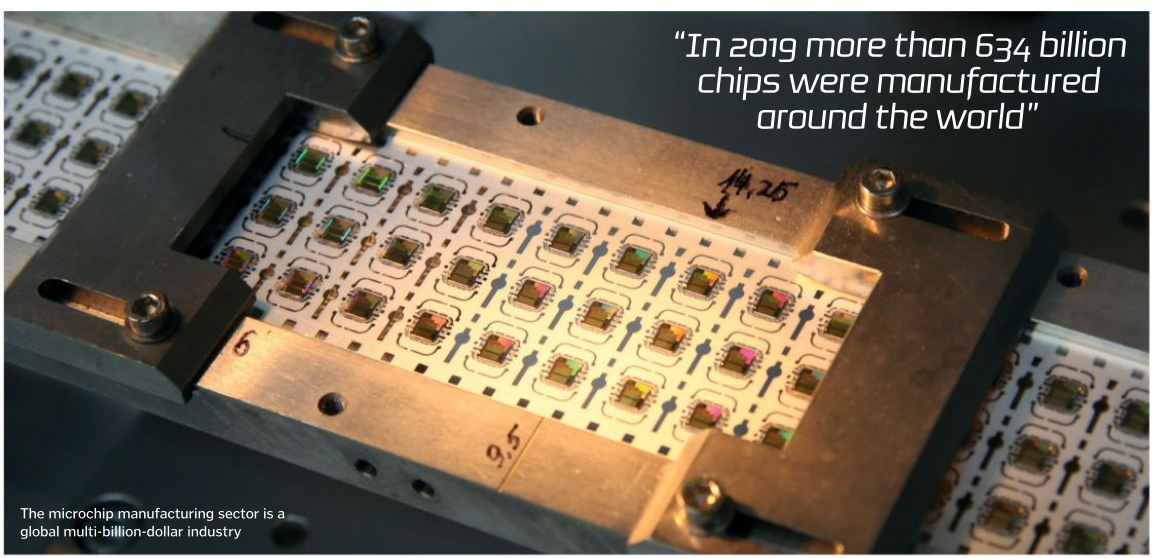
1 Smaller and smaller
When integrated circuits were created you could only fit one transistor, three resistors and a compactor on one the size of your middle finger; now you can fit 125 million transistors.

2 Calculating success
Jack Kilby is also well known as the inventor of the portable calculator, which he created in 1967. In 1970 he was awarded the National Medal of Science.

3 Famous founder
As well as having the idea for the microchip, in 1968 Robert Noyce also founded Intel, the company responsible for the invention of the microprocessor.

4 Abundant substance
The building block of chips, silicon, is one of the most common substances on the planet. It is found in minerals that make up 90 per cent of Earth's crust.

5 The world's purest
The purest silicon is found in quartz rock, and the purest quartz in the world comes from a quarry near Spruce Pine in North Carolina.



The microchip manufacturing sector is a global multi-billion-dollar industry

© Getty

Toaster technology

How these appliances transform a slice of bread into a tasty toasted snack

Have you ever wondered how the heat that is produced inside a toaster converts your soft, pale bread into bronzed, crispy toast? Inside a toaster, intense heat is concentrated evenly onto the surface of the bread. This dry heat removes moisture from the bread, which evaporates out of the top, leaving a crunchy layer on the surface.

Aside from texture, a toaster alters the taste and colour of bread. This is the result of the Maillard reaction. Two main ingredients of bread, carbohydrates and protein, interact with each other at temperatures between 120 and 160 degrees Celsius. Amino acids in the protein combine with the sugars in the bread, caramelising and turning it brown. Furanones are the compounds that release the sweet, charred smell of toasting bread.

The longer the toast remains in the toaster, the browner and crunchier it becomes, until it forms a blackened layer made of the compound acrylamide. Although each individual will interpret the 'perfect' piece of toast differently, the laboratories of breadmaker Vogel carried out research using 2,000 pieces of light, seeded bread to decide its vision of the perfect piece of toast. The conclusion was that it took 216 seconds when set to number five on the dial of a typical toaster for the ideal sliced snack. This setting made the bread 12 times crunchier on its surface than at the centre.

A slice of smart

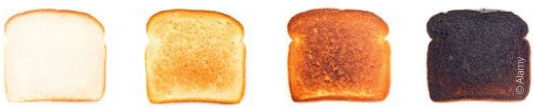
You can cook a piece of bread to your taste in the average toaster by selecting a number from one to six on the dial. However, as technology advances and our culinary tastes become more sophisticated, smart toasters can provide a range of toasting options. These include selecting the specific bread type, such as gluten-free, white or brown bread. Then the progress can be monitored and controlled from a smartphone. Phone notifications can be used to alert you to when the bread is ready, and the toaster can be popped remotely.

Some appliances have a touchscreen display that presents a digital image of what the colour and crispiness of the toast should look like after its time on the chosen setting. After selecting your ideal outcome, smart toasters can remember these options for the next time you opt for a toasted treat.

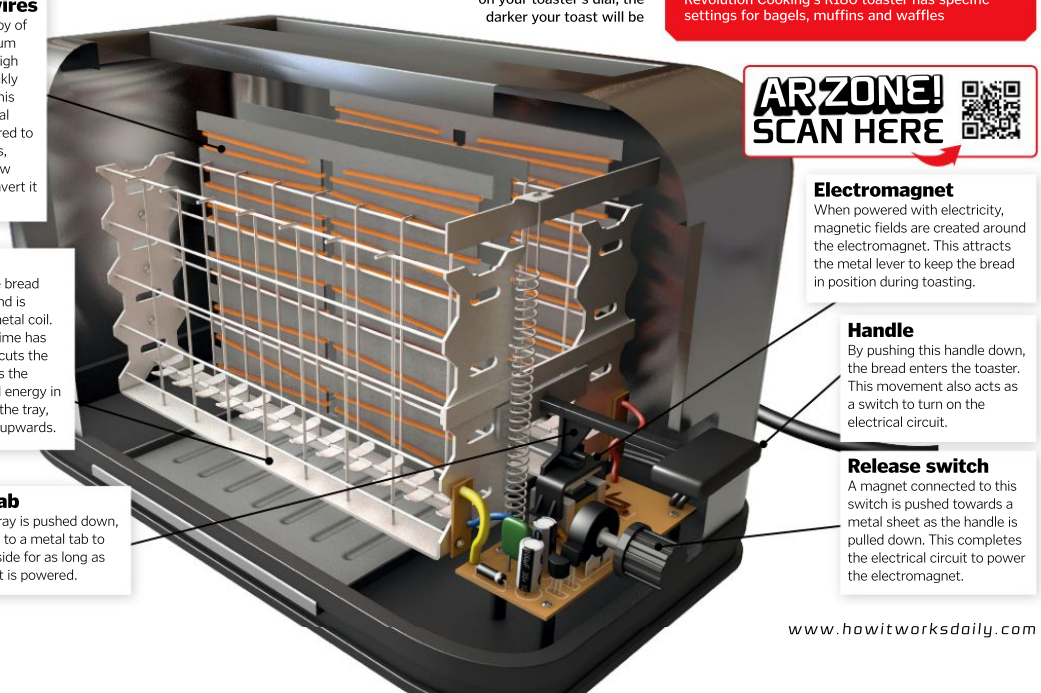
Revolution Cooking's R180 toaster has specific settings for bagels, muffins and waffles

Hot stuff

There's more to toaster tech than meets the eye



The higher the number on your toaster's dial, the darker your toast will be



AR ZONE! SCAN HERE

Nichrome wires
Nichrome is an alloy of nickel and chromium which can reach high temperatures quickly without rusting. This has a high electrical resistance compared to many other metals, meaning it can slow electricity and convert it to heat energy.

Lifting tray
This tray holds the bread straight and still and is equipped with a metal coil. After the chosen time has passed, the timer cuts the circuit. This causes the stored mechanical energy in the coil to release the tray, popping the toast upwards.

Lever and tab
When the bread tray is pushed down, the lever attaches to a metal tab to keep the bread inside for as long as the electromagnet is powered.

Electromagnet
When powered with electricity, magnetic fields are created around the electromagnet. This attracts the metal lever to keep the bread in position during toasting.

Handle
By pushing this handle down, the bread enters the toaster. This movement also acts as a switch to turn on the electrical circuit.

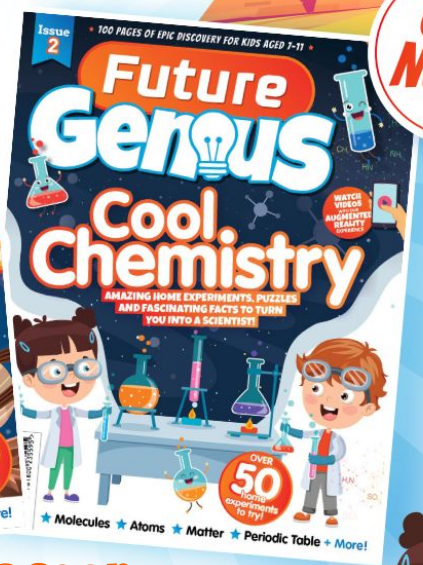
Release switch
A magnet connected to this switch is pushed towards a metal sheet as the handle is pulled down. This completes the electrical circuit to power the electromagnet.

© Adrian Mann

Future Genius

THE BRAND ★ NEW EDUTAINMENT ★ BOOKS FOR KIDS!

For ages 7+



OUT NOW!

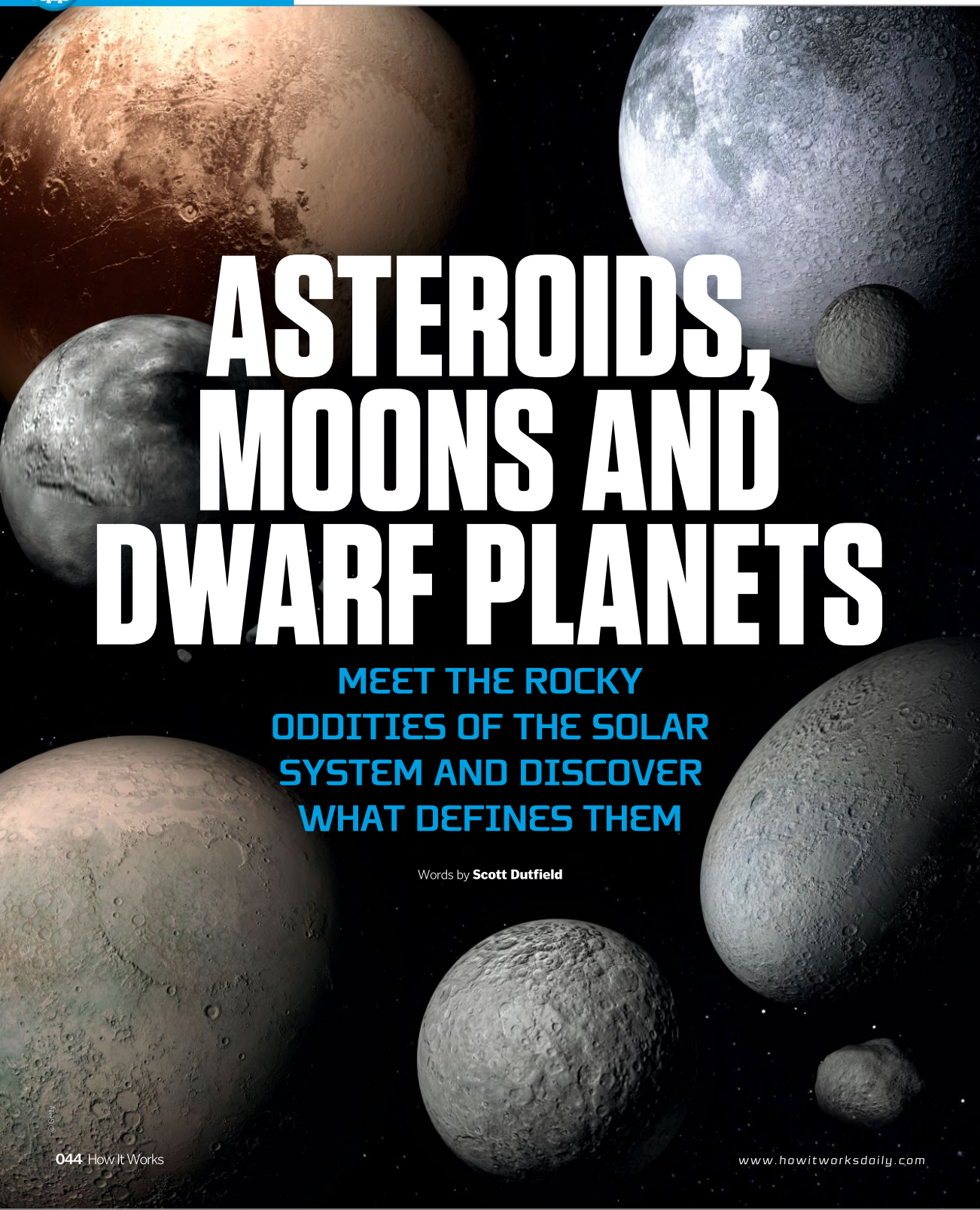
WATCH VIDEOS WITH OUR AUGMENTED REALITY EXPERIENCE

COMING SOON

- ★ Animal Kingdom - OUT 26 AUGUST
- ★ Human Body - OUT 31 AUGUST
- ★ Ancient Egyptians - OUT 30 SEPTEMBER
- ★ Computers & Learn to Code - OUT 30 SEPTEMBER

GET YOURS NOW FROM MAGAZINESDIRECT.COM AND ALL GOOD SUPERMARKETS AND NEWSAGENTS

✚ Puzzles ✚ Activities ✚ Experiments ✚ Facts ✚ More!



ASTEROIDS, MOONS AND DWARF PLANETS

MEET THE ROCKY ODDITIES OF THE SOLAR SYSTEM AND DISCOVER WHAT DEFINES THEM

Words by **Scott Dutfield**

Our Solar System is essentially made up of different sized and shaped rocks, and a couple of big balls of gas, which are all orbiting a hydrogen-burning behemoth we call the Sun. To give this interconnected system order, scientists throughout history have categorised the Solar System's largest celestial bodies into terrestrial planets, gas giants and ice giants. But what about the smaller stuff?

Dwarf planets, moons and asteroids fill our Solar System. At the current count there are five dwarf planets, over 200 moons and between 1.1 and 1.9 million asteroids that are over 0.6 miles in diameter residing in the Solar System. But how do you define what's what? There is a whole host of criteria that the International Astronomical Union (IAU) has outlined to determine whether a celestial body is a dwarf planet, moon or asteroid.

In brief, a dwarf planet is a celestial body that orbits the Sun and assumes an approximate spherical shape, and has also cleared the area around its orbit of other comparatively sized bodies. Moons, on the other hand, are natural satellites that orbit other larger celestial bodies. However, the IAU provides no scientific definition of what it means to be a moon.

Asteroids are smaller than planets and moons, but share the behaviour of orbiting the Sun. These rocks fail to meet the classification criteria of planets and dwarf planets, particularly because of their lack of mass and irregular shapes. Like wood shavings on the floor of a carpenter's workshop, asteroids are leftover chunks of rock from when the Solar System formed. They can vary in size and shape, but all of them have a mass smaller than Earth's Moon.

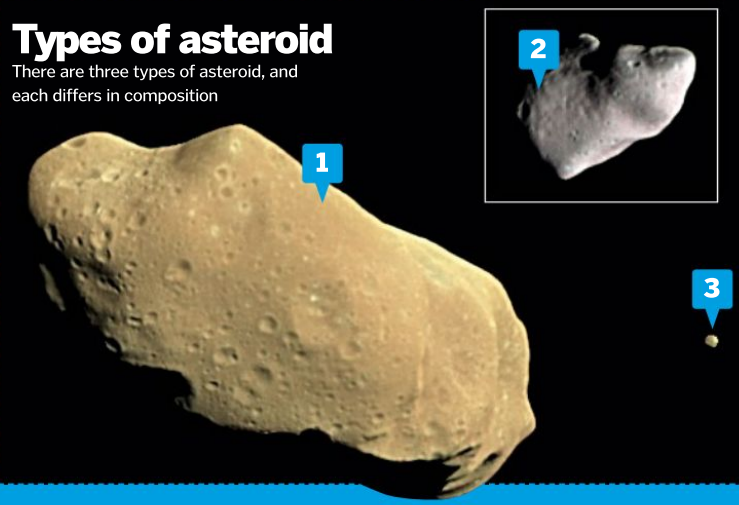
The majority of asteroids in the Solar System can be found in the asteroid belt, which sits between Mars and Jupiter, though some trojan asteroids share the orbit of other planets. 150 known asteroids also have a smaller companion, such as the asteroid Ida and its mini-moon Dactyl.

Dwarf planets, moons and asteroids have been circling the Sun ever since our Solar System formed 4.6 billion years ago, but it wasn't until the early 1800s that scientists around the world started recording the existence of dwarf planets.

The earliest dwarf planet discovered, called Ceres, sits between Mars and Jupiter and only spans 580 miles in diameter. It was spotted by Italian astronomer Giuseppe Piazzi in 1801. Because of its relatively minute size – around 0.015 per cent of Earth's – Ceres was initially classified as both a dwarf planet and an asteroid. The first study of moons, on the other hand, is more tricky to pinpoint, considering there's one that's been noticeably sitting in our sky since before humans were capable of asking what it was. However, the Nebra sky disk, an ancient artefact dating back around 3,800 years, is thought to be the first known depiction of the cosmos, and includes Earth's Moon.

Types of asteroid

There are three types of asteroid, and each differs in composition



© NASA/JPL/USGS

1 C-type
Also known as carbonaceous chondrite asteroids, around 80 per cent of the asteroids in the outer edges of the asteroid belt are C-type rocks. These, almost coal-black asteroids contain large amounts of carbon and are mostly solid, indicating that they may have been molten at some point in time.

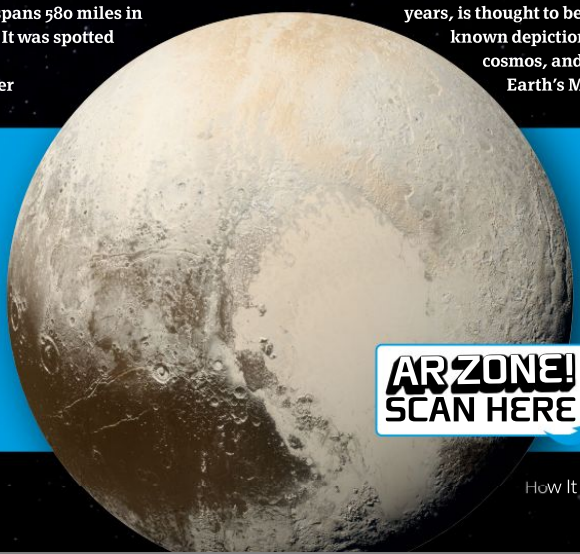
2 S-type
These are stony asteroids that contain both silicates and nickel-iron metal. They also appear brighter than the dark, carbonaceous chondrite C-type asteroids. These stony S-type asteroids make up nearly a fifth of all known asteroids in the Solar System.

3 M-type
Metallic asteroids are mostly made of nickel and iron. The differences in their composition relate to their proximity to the Sun. During their formation, while exposed to high temperatures close to the Sun, these asteroids were partly melted. This resulted in the formation of an iron core and basaltic surface.

The problem with Pluto

Arguably one of the most controversial decisions ever made in the field of astronomy, in 2006 the International Astronomical Union announced that the planet at the end of the Solar System would be stripped of its planetary status. Joining the likes of Eris and Ceres, Pluto was demoted to dwarf planet.

Although Pluto meets some full planetary criteria, such as its spherical body, which has been rounded by gravity, and the fact that it orbits the Sun, the problem with Pluto is that it hasn't cleared away its 'neighbourhood' of other objects. During and since its formation, Pluto didn't hoover up or eject other celestial bodies from its orbital path like its planetary superiors.



Pluto as imaged by the New Horizons spacecraft

© NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute/Alex Parker

AR ZONE! SCAN HERE

CELESTIAL BODIES

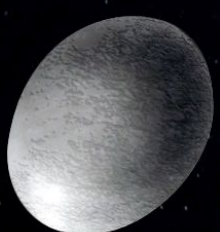
DISCOVER SOME OF THE MANY DWARF PLANETS AND MOONS ORBITING IN OUR SOLAR SYSTEM

AR ZONE! SCAN HERE

Makemake

Found around 4.2 billion miles from the Sun, just outside the orbit of Neptune, this dwarf planet is the second-brightest object in the Kuiper Belt – the first being Pluto. Its discovery in 2005 prompted the International Astronomical Union to form a new classification of celestial bodies, called dwarf planets.

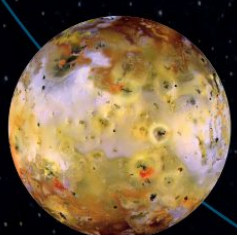
© NASA



Haumea

Haumea sits in the Kuiper Belt and is one of the fastest rotating large objects in the Solar System. A single day on Haumea is equivalent to four hours on Earth, but due to its proximity to the Sun, one Haumean year is equal to 285 Earth years. This oval-shaped dwarf planet also has two moons: Namaka and Hi'iaka.

© NASA



Io

Io is one of the most volcanically active bodies in the Solar System. There are hundreds of volcanoes covering the moon's surface, each of them spewing lava dozens of miles high, along with lakes of molten silicate. It's thought that Jupiter's intense gravitational pull is the reason for Io's explosive nature.

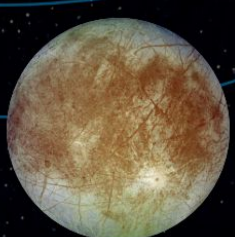
© NASA/JPL

Callisto

Callisto has a circumference of 9,410 miles, which is almost as big as Mercury. Not only is this moon impressively large, it also has a salty secret deep below its icy surface. Discovered in 1610, it wasn't until the 1990s that scientists proposed the moon has a subsurface ocean about 155 miles below its surface.

© NASA/JPL/DLR

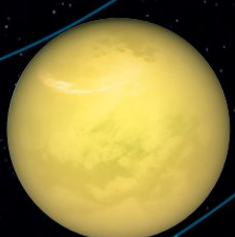
"Asteroids are leftover chunks of rock from when the Solar System formed"



Europa

Another of Jupiter's many moons, Europa is one of the oddest. With a surface temperature of around -160 degrees Celsius, this frozen satellite bears strange streaks. These markings are thought to be cracks in the moon's icy surface, which may have been caused by the tidal forces of an ocean deep beneath it.

© NASA/JPL/DLR



Titan

Although the structure of Titan remains unclear, scientists think its core is made of rock around 2,500 miles in diameter, surrounded by layers of water ice. This satellite has a dense atmosphere, which gives it its yellow hue. The composition of this atmosphere is primarily nitrogen and some methane.

© NASA/JPL-Caltech/Space Science Institute

Mimas

Often called the Death Star moon for its similarity to the space station in *Star Wars*, Mimas is one of Saturn's smallest inner moons. Its iconic impact crater, named Herschel after English astronomer William Herschel, who discovered Mimas in 1789, spans 80 miles and reaches 3.5 miles high at its peak.

© NASA/JPL-Caltech/Space Science Institute

Hyperion

Not all moons are spherical. Some, like Saturn's sponge-like moon Hyperion, are irregular and filled with deep caverns. With a lower density than water, this moon is made up of water ice and likely frozen methane or carbon dioxide. Hyperion's appearance is thought to be the result of its distance from Saturn.

© NASA/JPL/Space Science Institute

How satellites fall to Earth

Satellites do fall out of orbit, but it takes longer than you might think

Words by **Andrew May**

The old saying 'what goes up must come down' isn't always true. In the 17th century, Isaac Newton showed that an object launched with sufficient speed goes into orbit rather than falling back down to the ground. In the absence of air resistance it would stay in orbit forever, but in practice the tiny amount of atmospheric drag at orbital altitudes gradually reduces its speed. Satellites do fall back to Earth – but only very slowly.

The higher a satellite is, the longer it takes to fall back to Earth. One reason is that the air density – which is low in space anyway – drops dramatically with increasing altitude, so there is less and less air resistance. Another reason is that even though satellites in high orbits travel more slowly than those in lower orbits, they have more energy – a function of both speed and altitude – and it's the loss of energy, rather than speed, that brings them down to Earth.

A falling satellite may sound like a dangerous thing, but it isn't really. Unless it's very large, it's likely to burn up completely as it re-enters the dense lower atmosphere. Even large objects, such as rocket stages and space stations, break up into relatively harmless fragments before they reach the surface. A much bigger problem than a falling satellite is a non-falling one – once it's completed its mission – because it adds to all the space junk in orbit and increases the collision risk for other satellites. Space agencies like NASA and the European Space Agency (ESA) are looking for ways to make high-altitude satellites fall faster, such as attaching a large 'drag sail' to increase the effects of air resistance.


© NASA

When a Delta third stage re-entered the atmosphere in 2001, debris landed in Saudi Arabia

"The higher a satellite is, the longer it takes to fall back to Earth"

Newton's cannonball

In the absence of gravity, an object launched into space would shoot off at a tangent and continue forever. In practice, this only happens if its speed is higher than Earth's escape velocity. At slower speeds, gravity causes the object's trajectory to curve back towards Earth. At intermediate speeds, it can enter orbit and go round and round indefinitely. Isaac Newton explained the situation using a 'thought experiment' in which a cannonball is fired with different velocities from the top of a high mountain.

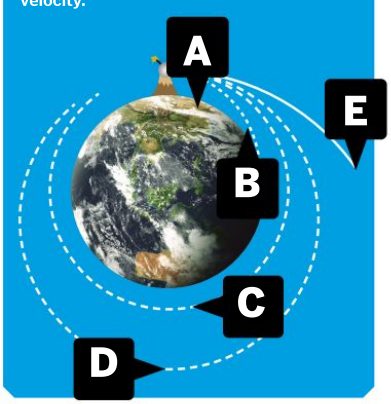
A A few metres per second: the ball soon falls to the ground.

B 6,000 metres per second: the ball travels an eighth of the way around.

C 7,300 metres per second: the ball enters a circular orbit.

D 8,000 metres per second: the orbit is an elongated ellipse.

E 11,200 metres per second: escape velocity.



Controlled and uncontrolled re-entry

When a disused satellite is on course to re-enter the atmosphere, its operators try to ensure it lands in a safe location, such as the South Pacific Ocean Uninhabited Area – or 'spacecraft cemetery', as it's known – 2,485 miles from New Zealand. But they can only do this if the satellite is still under control. If it isn't, it could potentially come down anywhere under its orbital path.

This was the case with China's 8.5-tonne, ten-metre-long Tiangong-1 space station. A few years after its last human visitors departed in 2013, the station unexpectedly stopped responding to ground control. It could still be tracked using telescopes and radar, but nothing could be done to prevent its eventual uncontrolled re-entry. This took place on 2 April 2018, and by pure luck the debris splashed down harmlessly in the Pacific, not far from the official spacecraft cemetery.


© Getty

A rendering of the Tiangong-1 space station, with a Shenzhou spacecraft on the right

5 FACTS ABOUT FALLING SATELLITES

1 A growing problem
The number of satellites in orbit is increasing all the time. Over 1,200 were launched in 2020, and this year will probably see even more than that.

2 Almost a vacuum
There is very little air to slow satellites down. The pressure at 310 miles altitude is less than a trillionth of its value at sea level.

3 Largest object to fall from orbit
Mir, a Russian predecessor of the International Space Station, weighed in at 135 tonnes. It was intentionally de-orbited into the Pacific Ocean in March 2001.

4 Nothing to worry about
According to the ESA, the chance of being injured by falling space debris is around one in 100 billion per year – 60,000 times less likely than being hit by lightning.

5 Defying the odds
One person actually has been hit by space debris. It happened to Lottie Williams of Oklahoma in 1997, but the fragment bounced off her shoulder and she wasn't hurt.

Satellite falling times

The higher a satellite is, the longer it takes to fall to Earth

2,235 miles
This is the much used geosynchronous belt, where satellites orbit at the same rate the Earth rotates on its axis.
Estimated falling time
Hundreds of millions of years
Satellites found here
There are large communications satellites, including Astra 2E, which broadcasts Sky and other satellite TV channels to the UK


© ESA

745 miles
This is the start of the 'medium-Earth orbit' range, where satellites get a broader view of the planet's surface
Estimated falling time
2,000 years
Satellites found here
Sentinel 6. A state-of-the-art climate-monitoring satellite, this was launched by the ESA in November 2020


© NASA


© NASA

310 miles
This is a typical 'low-Earth orbit', which is where the bulk of satellites are. They have relatively short lifetimes.
Estimated falling time
25 years
Satellites found here
The Hubble Space Telescope. Left to itself this would have fallen to Earth by now, but NASA periodically boosts it back to a higher altitude

TRAIN JOURNEY BACK IN TIME

England's high-speed rail link is currently being built and lines dug, transporting archaeologists hundreds of years into Britain's past

Words by **Joanna Elphick**

It seems impossible to turn on the television in the UK at the moment without seeing the latest update on High Speed 2 (HS2), the new high-speed railway that will link the UK's capital to the Midlands, up through the North and eventually into Scotland. The UK government is quick to point out the benefits of such a venture, highlighting the positive three Cs – Capacity, Connectivity and Carbon – but commuters and politicians aren't the only ones getting excited.

Archaeologists have been given unprecedented access to the route, allowing them to set up Britain's largest dig. Hundreds of archaeologists, anthropologists (human historians), osteologists (bone experts), historians and conservationists, working in conjunction with the HS2 team, are excavating more than 60 key archaeological sites along the planned route in a bid to uncover 10,000 years of Great Britain's past.

Cutting through the English landscape, the sites represent a multitude of significant periods across the nation's history, ranging from an early prehistoric settlement in Colne Valley, with three further sites later taken over by the Romans, to an expansive burial ground in Birmingham, where the dig has uncovered the toil and hardship of those living through the North's Industrial Revolution.

The route also passes through Grim's Ditch, a Bronze Age land boundary, and a number of medieval sites, including a manor house, a church with accompanying burial ground and an abandoned village. As the train line runs alongside Edgcote Viaduct, it passes through the site of an unexplored 15th-century battlefield, while in London, Georgian life has been unearthed at a vast cemetery close to Euston Station, where 61,000 men, women and children from all walks of life and differing social backgrounds have been interred.

Beneath a gigantic tent, intended to protect the dig from the elements, diggers delicately remove the soil in order to reveal thousands of coffins

© mediacentre.hs2.org

While archaeologists are uncovering the physical remains, historians are beginning to piece together many of the fascinating stories that were buried with them, making this the largest social history investigation in Europe.

To begin with, the entire route was surveyed using laser scanners in order to create a Light Detection and Ranging map, or 'LiDAR' for short. This was followed by a number of geophysical surveys so that any potential site of interest could be picked up and registered. But now HS2's extensive archaeology program is underway, what will happen to the bodies and objects that have already been discovered?

Many have been concerned that the thousands of bodies exhumed along the way will be lost or mistreated, but HS2 official Helen Wass has been quick to point out that this is not the case, claiming that "all artefacts and human remains uncovered will be treated with dignity, care and respect". Each skeleton has been carefully extracted, examined and, where possible, identified before being transported to a nearby burial site for reinterment.

Objects, some of which are of national importance, are being shared with local communities in 'pop-up' museums and in lecture theatres across the country after they have been analysed and catalogued. It's intended that the information gathered will be published both in academic articles and across a range of popular publications. Some of the archaeological digs have even been filmed for the BBC, fronted by anthropologist Alice Roberts and historian Yasmin Khan. The digs and all post-excavation work will be overseen by Historic England in conjunction with the appropriate local authorities, so while many people have reservations over the development of HS2, archaeologists and history buffs wait with bated breath for the next amazing find.

"Historians are beginning to piece together many of the fascinating stories"

© Getty

A protester is forcibly removed from his position inside a tunnel at Euston Gardens

Clash with the eco warriors

Not everyone is excited by the development of HS2. Environmentalist groups are horrified by the potential damage caused to areas of outstanding beauty and special scientific interest. River corridors, ancient woodlands and hundreds of unique habitats will be lost, instigating the formation of a protest group, 'HS2 Rebellion', based at the Colne Valley Regional Park. The Wildlife Trust, Woodland Trust, Green Party, RSPB and Extinction Rebellion have banded together to protest against the inevitable loss of wildlife habitats, particularly the 21 nature reserves that will be destroyed. The tension between activists and HS2 workers has resulted in repeated clashes, some ending in violence, while others have focused their anger towards the government, who many believe have failed to uphold their pledge to protect UK wildlife.

Bodies are catalogued and carefully removed from St James' burial ground

© Getty

Train line treasure trail

Some fascinating finds have been discovered along the route of HS2 Phase One

1 Baptist house burial ground

The 'Brummies' who built the city of Birmingham during the Industrial Revolution were laid to rest in Park Street burial ground, close to the Curzon Street station roundhouse.

Curzon Street station roundhouse is thought to be the oldest railway roundhouse in the world

2 Coleshill Manor

Along with a medieval manor house, the archaeology team has discovered a beautiful Elizabethan pleasure garden with paths, flower beds and the foundations of a pavilion.

Pottery, musket balls and 13th-century coins have all been discovered in and around the octagonal moat

3 Offchurch settlement

This long-lost Roman settlement lies very close to the Fosse Way, a mid-first-century Roman road and site of great historical significance.

Geophysical surveys have picked up a network of roads and large houses at Offchurch, along the Fosse Way

4 Radbourne deserted village

Still to be fully explored, earthworks are visible from aerial photographs, as well as documentary evidence to suggest there was once a thriving village at this site.

5 Wormleighton settlement

The area is thought to have been used by both Bronze Age settlers and later the Romans, who further developed the site.

A Bronze Age speartip or arrowhead has been unearthed, confirming the presence of prehistoric dwellers

6 Blackgrounds villa and farm

This site consists of an Iron Age settlement which later became a large Roman farmstead. This would have been an extensive rural estate comprising both domestic and agricultural buildings.

Although only trial trenches have been dug so far, it appears there may be a small Roman village here

7 Edgcote Viaduct

This is the site of the Battle of Edgcote during the War of the Roses, where the army of the Earl of Pembroke was defeated by Robin of Redesdale and his rebel group.

8 Doddershall settlement

The site is thought to represent over 500 years of medieval village life and should be considered an important heritage site. The dig has not started yet.

In the past, medieval bottles, bullets, buckles and coins have been unearthed at this location

© Getty

9 Fleet Marston

This Romano-British town has been discovered at the junction of a number of converging Roman roads, and it's hoped that the site will also reveal a cemetery.

10 St Mary's Church and burial ground

The site consists of a derelict medieval church and accompanying burial ground spanning a buried population of 900 years, which will allow anthropologists to compare skeletons from differing centuries.

Witch marks designed to ward off evil have been uncovered at the site

© HS2 Ltd

11 Grim's Ditch

A site of significance since the Middle Bronze Age, this series of ditches and banks is thought to show where large social groups congregated and possibly even lived.

Linear earthworks and features possibly highlighting important boundary lines

© Getty

12 Colne Valley

To the west of London, Colne Valley was once a Mesolithic floodplain, where humans lived alongside herds of wild animals continuously from 8,000 BCE until the medieval period.

© Getty

Evidence of herds of reindeer and horses that wandered across the plains have been uncovered, as well as a variety of settlers' tools

13 St James' burial ground

Thought to be the largest exhumation of Georgian and Victorian human remains, St James' cemetery contained over 61,000 bodies, including famous figures of the time, such as Bill 'The Terror' Richmond, an American boxer.

© HS2 Ltd

The coffin and breast plate containing the remains of Royal Navy explorer Captain Matthew Flinders, who led the first circumnavigation of Australia

© Nicholas Forder

HS2 in numbers

© Getty

10,000 years
The length of British history covered across the archaeological sites

140 miles
The length of dedicated track needed for Phase One

900m²
Size of the Elizabethan pleasure gardens discovered at Coleshill Manor

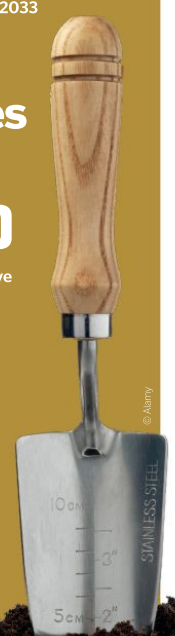
8-12 years
HS2 Phase One is estimated to be completed between 2029 and 2033

Six metres
The depth of the dig at St James' burial ground

6,500
Thousands of bodies have been disinterred at Park Street burial site

1,000+
The number of experts involved in HS2 makes it Europe's biggest archaeological event

50,000m³
Thousands of cubic metres of soil was shifted at St James' burial ground



© Alamy

Tanning leather

Discover the historical methods used to produce this versatile material from animal skin

The warmth provided by a leather jacket, or the comfort experienced when you sit on a leather seat, is a result of a complex process. Leather was first made when hunter gatherers sought to maximise use of the materials around them. While modern leather mostly comes from cattle, it first originated from the skin of almost any wild animal.

After tracking them down to eat, people began to experiment with different parts of the animals. This meant that the bits they didn't benefit from by eating wouldn't necessarily go to waste. The skins were prepared, cut and shaped to make clothes and tools, just as they are today.

Proper preparation of leather is essential for converting decomposable matter into long-lasting material. This involves saturating the skin with chemicals called tannins. These chemicals can be found in high concentrations within plants, which is why vegetable tanning is one of the oldest methods of leather production. The tannins bind to proteins in the animal skin and stop the fibres from disintegrating. Ancient Greeks are thought to have produced the first successful vegetable tanning formulae.

Skins are hung to dry after being treated

© Alamy

"Skins were prepared, cut and shaped to make clothes"

From hide to leather

Follow the ancient process still widely used today

Salting

After washing it, the animal skin is covered in salt for about ten days. This will saturate the entire skin to prevent the growth of microorganisms.

Wetting

Because salting dries out the hide, the skin is then soaked to restore moisture and remove salt.

Dehairing

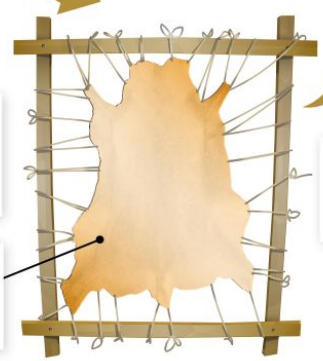
Before machines were invented to remove hairs in the mid-19th century, blades and other sharp objects, such as antlers, were used to remove the hair. Soaking and dehairing can take between one and two days.

Defleshing

Scraping off the animal's flesh and fat helps to stop the skin from rotting. Any remaining flesh and fat needs to be removed to prevent decomposition.

Vegetable tanning

The hides are left to soak in natural tannins for around two weeks. Traditionally used plant material that is rich in tannins includes the bark of willow and birch trees.



Drying

The leather is hung up to dry and stretch. After a few days it will have dried and become more flexible. Air drying can take several weeks.

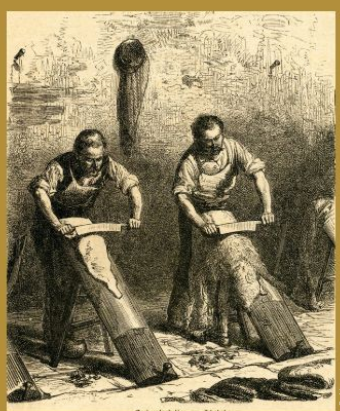
Sorting

At the end of the process, the quality of the leather is analysed. It is sorted based on size and thickness.

Ancient techniques

There were plenty of options when it came to preserving hides. Materials that were used for tanning needed to contain the right chemicals and acids to turn the skins into dry leather. Because fats were found to work well for this process and the fatty brains of hunted mammals were often the perfect volume to cover the skin, they were an ideal choice. After an animal was hunted, it took hard manual labour to press the brain into the skin. Records of this method are mainly traced back to Native Americans.

When removing the hair and flesh from the animals' skins thousands of years ago, it was common practice to soak them in urine, or to urinate on the toughest parts of the hide. This is because urine's high pH could break down this organic material and separate it from the skins. To thin the skins and reduce grease, animal dung could be used to cover them. This included dog, hen and pigeon poop. Dung from these animals contains proteolytic enzymes that break down the long-chain proteins of collagen and soften leather fibres.



Soaking skins in alkaline substances first can make it easier to remove hair

Early uses

The first references to leather were made around 1300 BCE, but this material has been used to keep people warm, comfortable and sheltered for long before that. Leather was used for clothing to protect people from the elements, shoes to allow people to walk more efficiently over rough ground and bags for easier transportation of belongings. Ancient artefacts and artwork from around 5000 BCE portray leather sandals, gloves, containers and weapons being used.

Being both a tough material and a comfortable one, leather is often used to cover seats in vehicles. Throughout history this has proven no different to today, with the material being widely used for saddles on horse-drawn transport, and from the Middle Ages on chairs and other furniture.

This 5,500-year-old leather shoe was found preserved under sheep dung

The lost settlement of Qumran

Home of the Dead Sea Scrolls, this ancient ruin still holds many secrets

Words by **Callum McKelvie**

Located on the west coast of the Dead Sea, the mysterious ruins of Qumran were occupied during the Greco-Roman period, which lasted from 150 BCE to 68 CE. However, the site itself is even older, with evidence suggesting an Iron Age settlement dating back some 2,600 years. Qumran may have had a population of no more than a few dozen people, never being much larger than a single acre, and was most likely the home of a religious sect. In 68 CE the settlement was captured by the Roman Army, and the resulting fire was so intense that glass vessels have been found melted by the heat.

Initial excavations focused on the cemetery and took place as early as 1851. Thanks to the work of amateur archaeologist Louis Félicien de Saulcy, after the discovery of the Dead Sea Scrolls in a cave close to the site, a renewed interest developed in Qumran. Perhaps the most detailed work at the site was carried out by Roland de Vaux between 1951 and 1956, though his report was incomplete upon his death.

Who exactly occupied the site remains a source of argument among historians. For decades it was believed that a Judaist religious sect known as the Essenes lived there, and also authored the scrolls. However, there are a variety of other theories as to the site's origins.

One suggests that Qumran was a Hasmonean military outpost, part of a dynasty that ruled the area from 140 BCE to 37 BCE, whose purpose was to watch for enemies approaching from the Red Sea and to protect Jerusalem. Another theory is that it may have been a luxury villa, though this has been widely disputed. It's argued that Qumran's water supply expanded following the Roman occupation and that it may have become a pottery production centre.

© Getty

The ruins of one of the cisterns, where water would have been stored

© Alamy

These are steps to one of the baths that were used for ritual purification

Potter's kiln
This pottery kiln may have been responsible for the majority of the ceramics found at the site.

Refectory
In this room, meals would have been served, with the members only allowed to enter if they were 'pure'.

Scriptorium
The discovery of two inkwells indicates a scriptorium, designed for the copying of manuscripts.

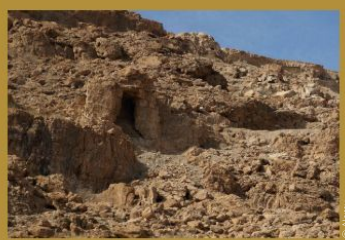
Cistern
Due to the extreme summer temperatures of the desert, the cisterns would have been essential to any settlement at Qumran.

Bath
Discovered during de Vaux's excavations, these pools are suspected to have been used for ritual purification.

The Dead Sea Scrolls

In 1946 or 1947, a group of shepherds were tending their sheep when one threw a stone into a cave, and was surprised to hear the sound of something shattering. Inside he discovered a cluster of clay jars, each containing a series of scrolls that in total comprised some 800 documents. The scrolls were made of papyrus, animal skin and copper, and upon researching the finds it was discovered that all were early Hebrew religious texts.

The texts contain parts of every book in the Hebrew canon, more commonly referred to as the Old Testament. 230 of the scrolls are 'biblical scrolls', while the remainder comprise hymns, prayers and other texts. While they do not refer directly to Jesus or any form of early Christianity, they do provide a wealth of information regarding the early Jewish world in which Jesus may have lived.



© Alamy

Cave 3, where the copper scroll was discovered in 1952 during excavations

Who were the Essenes?

Much of our information on the possible inhabitants of Qumran, the Essenes, comes from first-century historian Flavius Josephus. He describes this Jewish sect as shunning world pleasures and vices, with every member required to give up their funds to the order. They supposedly always wore white and made a point to keep their skin hard and dry. Their clothing would only be replaced after it had been made ragged and threadbare. Any nakedness or accidental exposure of a member's genitalia would be punished, as they were required to always cover themselves. Whether this group truly were the authors of the scrolls remains a mystery and a continuing source of archaeological debate.

Flavius Josephus, the first-century historian who wrote extensively on the Essenes

© Alamy

HERE COMES THE BIN LORRY

YOU BAG IT, BIN IT AND TOSS IT OUT ON THE STREET, BUT WHAT HAPPENS TO YOUR RUBBISH WHEN IT'S COLLECTED?

Words by **Ailsa Harvey**

The arrival of a bin lorry is often announced by the loud, piercing sound of its back-up beeper, the clattering of wheelie bins and the satisfying crunch of bin bags being swallowed by mighty metal machinery. But behind the chaos, a vital system is being carried out. Without these loyal visitors to our homes, our streets would be filled with the stench of bin juice, the threat of disease and mounds of unsanitary waste.

The invention of motor vehicles led to the first bin lorries being used in the 1890s, which transported rubbish further from urban areas. With disposable packaging increasing in popularity, the amount of rubbish produced by UK households has risen to 26 million tonnes per year – that's equivalent to the weight of around 260 large cruise ships.

This weighty garbage production gives bin workers a relentless and ever-growing task to tackle every day. The reason we don't often see the true extent of our rubbish production is due to the effective and evolving system involving bin lorries. Their trash-crunching mechanics and regular visits can help sweep up our rubbish at around the same rate that we produce it, keeping our homes and cities clean.

"Rubbish produced by UK households has risen to 26 million tonnes per year"

Waste collectors empty both private and public bins

© Getty

Lorries are designed to easily tip out rubbish at disposal sites

© Getty

Where does your rubbish go?

How you sort your trash determines where it is taken

© Getty

General waste, limited space

If an item being thrown away can't be recycled or isn't biodegradable, it is placed in 'general waste' bins. These are the most problematic for the environment, as the materials disposed of don't break down easily.

More often than not, these bins will be taken to landfill sites. At landfill sites, rubbish is poured into holes in the ground and covered with earth. With limited space, these form great mounds above surface level.

© Getty

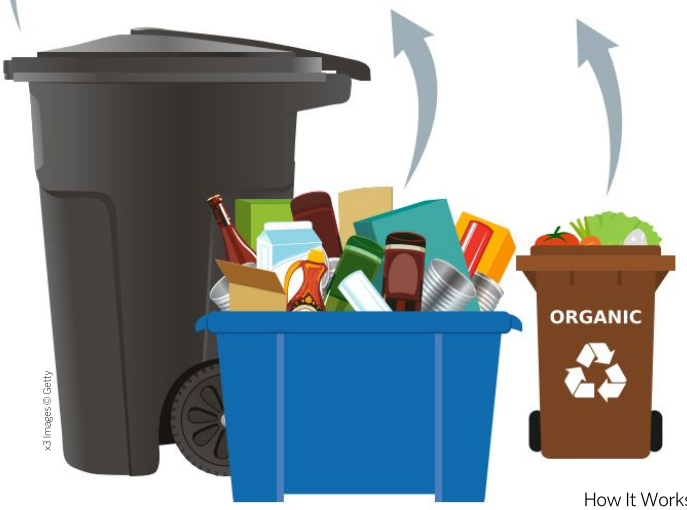
Recycling sorting

Items that can be broken down relatively easily and their materials reused to make new products are taken to recycling plants. Recycling collections are transported to mixed-recovery facilities. Here the contents are sorted into individual materials, and any missed non-recyclables are removed and disposed of. Items are sorted into specific materials, such as glass, plastics, aluminium and paper. Most materials are cleaned and crushed into blocks called bales to be sold to companies that will reuse them.

© Alamy

Food waste helps to grow new food

Most food waste is sent to anaerobic digestion plants, where it is debagged. Then the food is mixed together into a pulp to form a thick and consistent liquid. As it's been exposed to the air for a while, bacteria and other microorganisms will have grown on the food. The paste is heat-treated to kill these microorganisms before beneficial bacteria is added to break down the food. This releases carbon dioxide and methane, used to make electricity, while the liquid can be used on farmland as fertiliser.



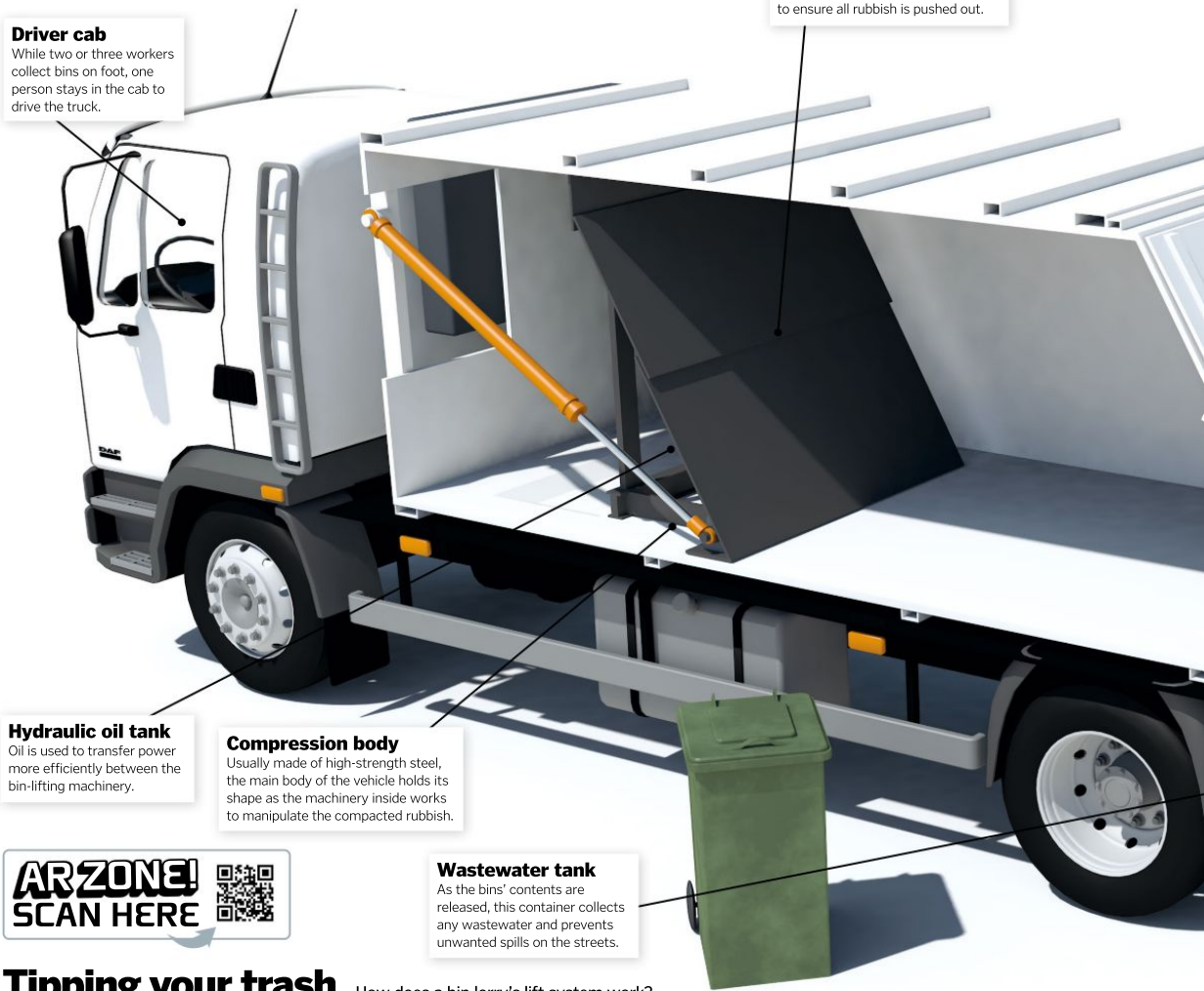
x3 images © Getty

Truck components

Piece together this garbage-gobbling machine

Driver cab
While two or three workers collect bins on foot, one person stays in the cab to drive the truck.

Discharge plate
Some bin lorries are equipped with a discharge plate. When emptying the vehicle at a dump, this panel extends to ensure all rubbish is pushed out.



Hydraulic oil tank
Oil is used to transfer power more efficiently between the bin-lifting machinery.

Compression body
Usually made of high-strength steel, the main body of the vehicle holds its shape as the machinery inside works to manipulate the compacted rubbish.

Wastewater tank
As the bins' contents are released, this container collects any wastewater and prevents unwanted spills on the streets.

AR ZONE! SCAN HERE

Tipping your trash

How does a bin lorry's lift system work?

1 Attaching
The bin is loaded onto the tipping mechanism by the rubbish collector. This will hold the bin in place as it is lifted and tilted upside down to be emptied.

2 Picking up
When the bin is raised, its lid latches onto the steel frame at the top. As the tipping mechanism continues to move and tip the bin upside down, the lid is held open.

3 Containing
As the bin is lowered to the ground to be returned to the street, a compaction plate comes down to block the back of the truck. This contains all rubbish – and the stench!

4 Compacting
The compaction plate is forced towards the front of the truck, compressing the rubbish as much as possible and helping to make the most of the space inside the lorry.

Tailgate
The end of the truck is separate from the main body to enable it to rotate when filling and emptying the vehicle.

The first collections

In 1297, the first law was made in Britain that controlled where citizens could leave their rubbish. The aim was to clean up the streets and prevent people from leaving waste outside their homes – unless it was in a gutter. This was also the time that the first organised rubbish collections began to take place.

Called 'rakers', people would carry out weekly sweeps of the gutters of London. As the litter was loose, as opposed to being in bins, the rakers would use their rakes to transport the garbage into their carts. These carts were the beginning of the evolution towards bin lorries.

© Wikimedia Commons/Science Museum Group/Wellcome Images

Rakers became more common in London after unsanitary streets exacerbated bubonic plague

"Without these loyal visitors to our homes, our streets would be filled with the stench of bin juice"

Compaction plate
The panel that compacts the collected waste is made of high strength steel.

Container holder
There are usually two cylinders where the bins' handles can attach. This allows two to be emptied at the same time to increase efficiency.

Extra precautions are needed when dealing with medical waste

© Getty

5 FACTS ABOUT FUTURE WASTE-MANAGEMENT PLANS

Unlocking energy from waste
As a way to make our future waste useful, a process called plasma gasification could use intense heat to convert organic waste into gases such as hydrogen. This could then be used to produce clean fuel.

Smarter bins
Bin collections are usually timetabled. However, the installation of smart bins, connected to a central server, could allow bin workers to know when bins need to be emptied. This is tracked by sensors that detect the height of rubbish in bins.

Waste vacuums
Underground pneumatic tubes could remove bin lorries from our roads completely. Sucking rubbish straight to landfills and recycling plants, fans create a partial vacuum to pull bin bags through a network of pipes.

GPS route optimisation
As technology becomes more connected, bins and their collectors can work together to improve efficiency. Communicating with smart bins, GPS could be used to find the quickest routes to the bins most in need of emptying.

AI rubbish sorting
Some people struggle with knowing what packaging can be placed in which bin. In the future, robots could carry this work out for us. After all the rubbish is collected by one truck, machines at refuse-collection sites could scan each item to detect structure, shape and material.

Inside the world's fastest car

Words by **Mike Jennings**

No car has ever gone as fast as ThrustSSC – here's the story behind its record-breaking speed

You might think you've driven quickly on the motorway, but that's nothing compared to ThrustSSC. This British-built beast became the fastest car on the planet on 15 October 1997, and it drove so quickly that no car has been able to match it since.

ThrustSSC hit a top speed of 763.035 miles per hour and became the first land vehicle to break the sound barrier. Unbelievably, that was ThrustSSC's second record-breaking run – the car had smashed the record nearly a month earlier when it hit a speed of 714.144 miles per hour.

It's no surprise that this car made waves. Two Rolls-Royce engines were hauled out of RAF fighter jets to provide the grunt, and it had an eye-watering 102,000 brake horsepower – more than 670 times more than the average family hatchback. ThrustSSC hit 600 miles per hour in just 16 seconds before accelerating to its record-breaking top speed.

ThrustSSC was built in 1996 and tested in Jordan, but the record-breaking runs occurred at Black Rock Desert in Nevada. It's a long way to go to drive a car, but it makes sense: the desert used to be an ancient body of water called Lake Lahontan, and its surface is now made of flat, dry mud. It's smooth and firm, and worked exceptionally well with ThrustSSC's solid metal wheels.

The design team was led by project director Richard Noble, Ron Ayers, Glynne Bowsher and Jeremy Bliss, and that first name is particularly notable: Noble was the pilot of Thrust2, which held the land speed record before ThrustSSC. It's safe to say that they knew what they were doing. And then there's the pilot: wing commander Andy Green drove ThrustSSC. He was previously an RAF fighter pilot, so he was used to travelling at extreme speeds.

ThrustSSC was exhibited to the media before it broke records back in 1997

© Getty

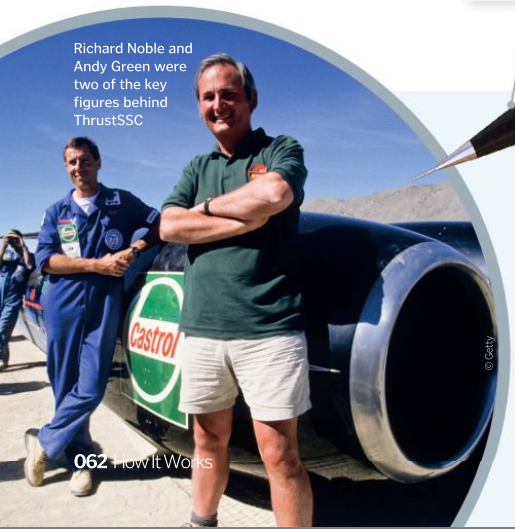
ThrustSSC Explored

It's the fastest car ever built – but just what allows ThrustSSC to hit those high speeds?

AR ZONE! SCAN HERE

Wheel deal
This record-breaking car was steered by a jet-style yoke rather than a conventional wheel.

Pointy nose
Aerodynamics are vital at high speeds, and the SSC's pointed nose enabled it to slice through the air.



Richard Noble and Andy Green were two of the key figures behind ThrustSSC

© Getty

Increasing speeds

39.24 MILES PER HOUR – 1898
Gaston de Chasseloup-Laubat drives a 36 brake horsepower Jeantaud Duc, establishing the first land speed record.

65.79 MILES PER HOUR – 1899
Camille Jenatzy pilots La Jamais Contente, the first purpose-built land speed racer, in the first attempt to pass 60 miles per hour.

125.94 MILES PER HOUR – 1909
This record-breaking run takes place at Brooklands in Surrey, and it's the first attempt that uses electronic timing.

146.16 MILES PER HOUR – 1924
Malcolm Campbell breaks the record in a Sunbeam 350HP, and he'll eventually hold the record a further eight times.

What's it like to drive at 763 miles per hour?

Andy Green, ThrustSSC's pilot, has some unique perspectives on high-speed travel. When he broke the sound barrier in the high-speed vehicle, Green described it as "the loudest, highest pitched scream I've ever heard". When you're at that sort of speed, he says, "the wheels are skimming across the surface, and shock waves generate uneven forces". Combine this with crosswinds and it's no surprise that "the car is sliding all over the track".

In fact, the car pulled to the left during acceleration, so Green had to hold the wheel 90 degrees to the right to keep it in a straight line.

Record attempts regularly take place in Nevada, where conditions are perfect for high-speed driving

© Getty

Downforce

ThrustSSC's rear wing creates downforce, which pushes the car to the floor and keeps it stable at high speeds.

Dragged back

A huge parachute produced 400 to 500 tonnes of drag to help slow the ThrustSSC after its record-breaking attempts.

Traction control

The car's staggered rear wheels were supposed to make it slimmer, but actually created instability when driving.

Closed cockpit

ThrustSSC's cockpit was tiny, cramped and not particularly advanced – Green was surrounded by basic dials and buttons.

Powerful boost

ThrustSSC's two engines each weigh 1,856 kilograms, and they're usually found inside F-4 Phantom II jet fighters.

© Nicholas Forder

Fully fuelled

ThrustSSC consumed 18 litres of fuel every second, which means a microscopic fuel economy figure of 0.04 miles per gallon.

Bloodhound has made test runs, but the project is on hold after hitting financial issues

© Getty

Could a new contender break the land speed record at over 1,000 miles per hour?

ThrustSSC's project director, Richard Noble, also built and piloted Thrust2, the car that held the land speed record from 1983 until 1997. Thrust2 was no slouch, with 30,000 horsepower provided by a single jet engine.

Noble wasn't satisfied with ThrustSSC, but his latest project hasn't gone to plan. He helped develop Bloodhound SSC, which was a car that aimed to hit a monstrous 1,000 miles per hour. Ayers was involved once more, and Green would again pilot the car to high speeds.

Bloodhound tested in South Africa in 2019, but the COVID-19 pandemic robbed the team of the opportunity to run the car, and the project ran out of money before they had a chance to integrate the engine that would have got them to 1,000 miles per hour.

Sadly the project is dormant, and the car is for sale. Unless someone coughs up cash, they won't break the 1,000 miles per hour barrier any time soon.

203.79 MILES PER HOUR
1927
Henry Segrave pilots the Sunbeam Mystery at Daytona Beach, and it's the first car to exceed 200 miles per hour.

301.129 MILES PER HOUR
1935
This is the first time the record is broken at Bonneville Salt Flats in Utah, and it becomes a popular record-breaking venue afterwards.

407.447 MILES PER HOUR
1963
The Spirit of America uses jet power to hit a new record, but legal complications mean it doesn't become official until later.

403.10 MILES PER HOUR
1964
Donald Campbell achieves this record in the Bluebird-Proteus CN7, and it's the last record achieved before jet propulsion becomes commonplace.

622.407 MILES PER HOUR
1970
Gary Gabelich breaks the record with a car called Blue Flame – the only rocket-powered vehicle to hold the record.

633.47 MILES PER HOUR
1983
Richard Noble pilots Thrust2 to this record speed at Black Rock Desert, and his car uses one Rolls-Royce jet engine.

763.035 MILES PER HOUR
1997
Andy Green breaks Noble's Thrust2 record with ThrustSSC, and it's so fast that it's never been beaten... yet!

THE CHEMISTRY OF TEA & COFFEE

Whichever of these hot beverages you prefer, find out exactly what you're drinking

Words by **Baljeet Panesar**

For many of us, our day starts with a cup of coffee or tea. Without them, many of us simply wouldn't be able to think straight in the morning, and some of us continue to rely on tea and coffee to feel mentally alert during the day. We even drink tea and coffee as a social activity, whether that's with our friends, colleagues or on a date. Together they are two of the most popular beverages in the world, with more than 2 billion cups of coffee and 3.7 billion cups of tea consumed globally each day.

Both tea and coffee contain hundreds of compounds that give them their aroma and flavour, but one well-known component of both is caffeine, a stimulant that acts on the central nervous system and the compound that gives us that characteristic 'buzz'. Each type of tea – there are six different types: black, green, white, oolong, yellow and pu-erh – comes from the *Camellia sinensis* plant, but all have different tastes. This is due to how the leaves are processed after they've been picked. Black and oolong tea undergo a process called oxidation, where the enzymes in the leaves react with the oxygen in the air.

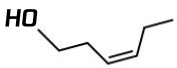
Another interesting group of compounds found in our hot beverages are polyphenols. They have antioxidant properties that protect against heart disease and cancer, as well as contributing to the taste and colour of tea and coffee. Different polyphenols are found in both: black tea contains theaflavins, thearubigins and catechins, while coffee contains chlorogenic acid and flavonoids. Whether you drink coffee to wake up or tea to relax, these are the chemicals that make your drink.

The aromas of tea

Different compounds make up the characteristic smell of tea

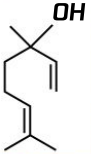
(z)-3-hexen-1-ol

This is the main compound that contributes to the distinctive smell of tea.



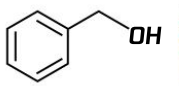
Linalool

A floral, sweet-smelling molecule that is mostly found in oolong and black tea.



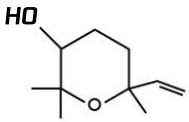
Benzyl alcohol

This naturally occurring compound gives tea its sweet, honey-like smell.



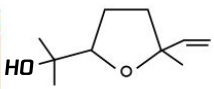
Pyranoid

An oxide of linalool, it gives tea an earthy aroma. It can be found in green, black and oolong tea.



Furanoid

Another oxide of linalool, it too has a sweet and floral aroma, but also a creamier scent, too.



The history of tea and coffee

Tea and coffee have been around for millennia, so their origins are surrounded by mystery and folklore. According to legend, tea was made 5,000 years ago in ancient China by Emperor Shennong after tea leaves flew into a boiling pot of water. As a renowned herbalist, Shennong decided to taste the infused water concoction, and so tea was born. After its serendipitous discovery, tea became increasingly popular, and was used as an aid for digestion and in tea ceremonies.

Some 3,000 years later, an Ethiopian goat herder called Kaldi noticed his goats behaving erratically after eating red berries from the *Coffea arabica* tree. Having tried some himself, Kaldi also experienced similar effects to the goats, earning him the moniker of 'the happiest herder in happy Arabia'. But this is just a story. The Oromo people are thought to have chewed the coffee plants' beans and leaves for thousands of years before, and they would mix them with fat to make 'power' bars.

Tea plants grow in warm climates and can reach heights of 18 metres

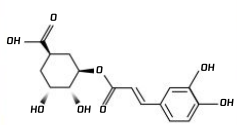
Inside a cup of coffee

Coffee contains over 1,000 compounds. Here's just a small selection that can be found in your coffee cup

Arabica coffee makes up 60 per cent of all coffee worldwide. Robusta makes up the other 40 per cent

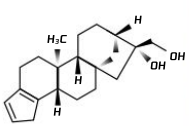
Chlorogenic acid

Much of the bitter taste of coffee comes from chlorogenic acid. This antioxidant and anti-inflammatory may help reduce the risk of developing type 2 diabetes and heart disease, but further studies are needed.



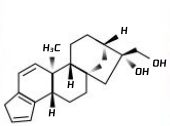
Cafestol

Cafestol reduces the body's ability to regulate cholesterol levels. Drinking five cups of unfiltered coffee for four weeks can increase cholesterol levels between six and eight per cent.



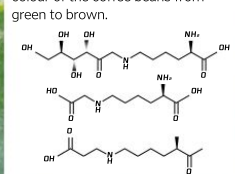
Kahweol

Like cafestol, kahweol can also cause an increase in blood cholesterol levels. But it also has anti-inflammatory and anticancer properties.



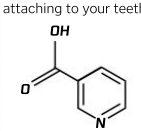
Melanoidins

Melanoidins are formed during the roasting process. These compounds are responsible for the change in colour of the coffee beans from green to brown.



Trigonelline

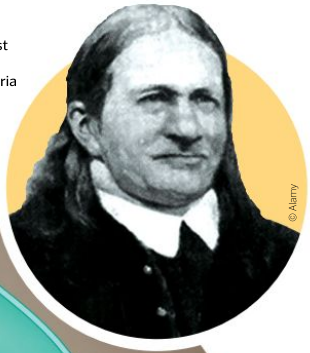
This molecule gives coffee its sweet, earthy taste. It also fights cavity-causing bacteria *Streptococcus mutans* and stops them from attaching to your teeth.



Caffeine chemistry

How caffeine wakes you up

Caffeine is the common name for trimethylxanthine, and is naturally produced by several plants, including coffee beans, cacao beans and tea. It was first isolated from coffee beans by German chemist Friedlieb Ferdinand Runge in 1819. In its pure state it is a white powder, which can also be added to soft drinks. A German merchant called Ludwig Roselius completed the first commercially successful decaffeination of coffee in 1903.



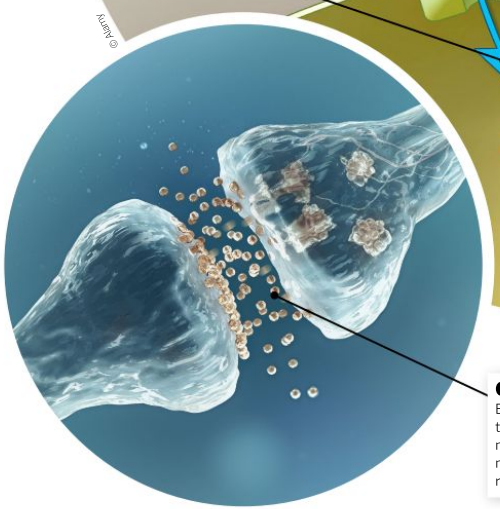
Runge was also one of the first scientists to isolate quinine, a drug that's used to treat malaria

Dopamine
Dopamine is responsible for pleasure, pain, emotions and muscle control.

Adenosine
Adenosine, a neurotransmitter, is produced in the brain and binds to adenosine receptors, making us feel sleepy and more relaxed.

Dopamine activity
Caffeine-binding makes dopamine receptors more active, which makes us feel good. A similar effect can be observed when we eat chocolate.

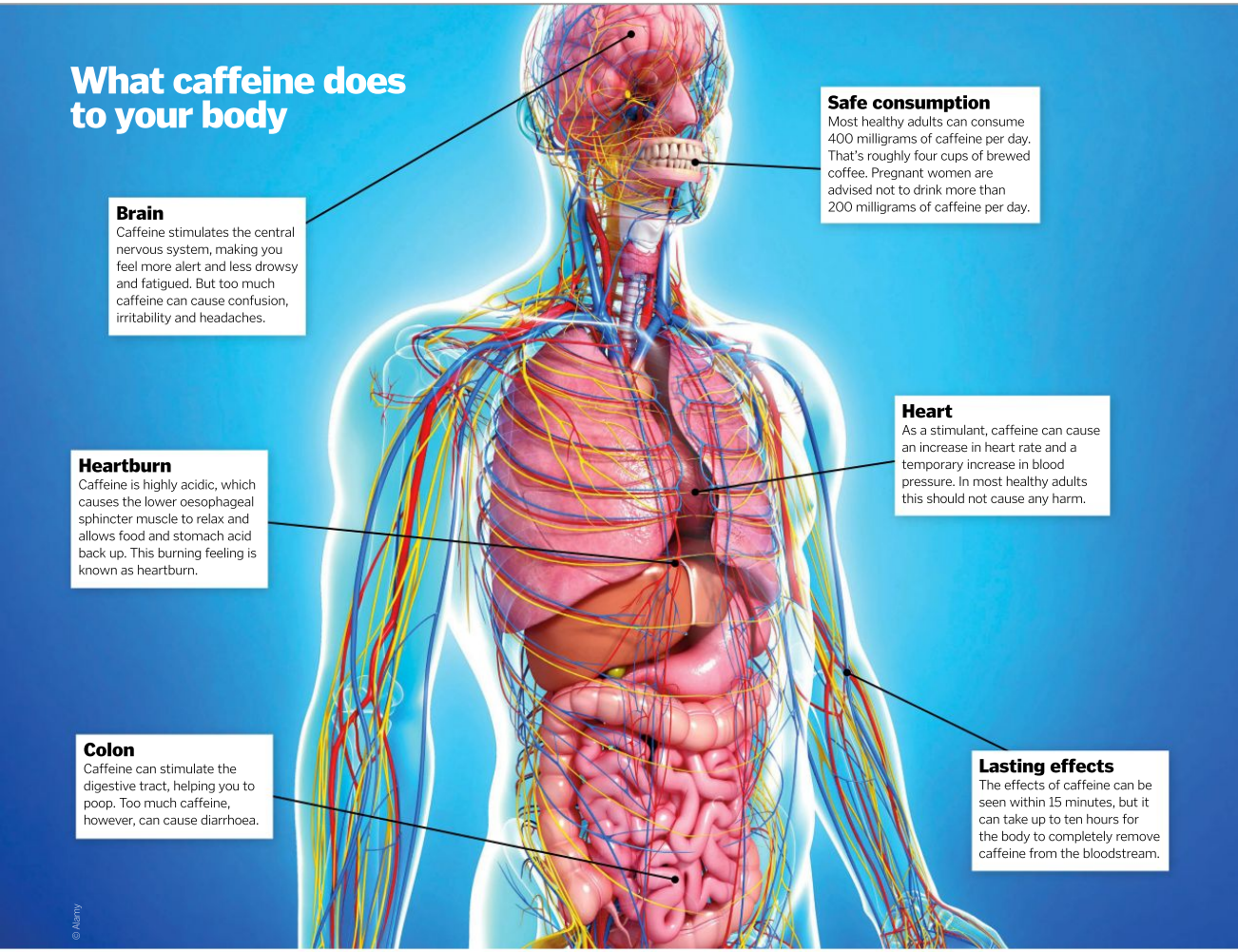
Fooling adenosine
Caffeine has a similar structure to adenosine, allowing caffeine to bind to adenosine receptors. As caffeine blocks adenosine from binding, it makes us feel more alert and awake.



Communication
Electrical signals move between two nerve cells as neurotransmitters – chemical messengers in the body – are released and absorbed.

"In its pure state it is a white powder, which can also be added to soft drinks"

What caffeine does to your body



Brain
Caffeine stimulates the central nervous system, making you feel more alert and less drowsy and fatigued. But too much caffeine can cause confusion, irritability and headaches.

Safe consumption
Most healthy adults can consume 400 milligrams of caffeine per day. That's roughly four cups of brewed coffee. Pregnant women are advised not to drink more than 200 milligrams of caffeine per day.

Heart
As a stimulant, caffeine can cause an increase in heart rate and a temporary increase in blood pressure. In most healthy adults this should not cause any harm.

Heartburn
Caffeine is highly acidic, which causes the lower oesophageal sphincter muscle to relax and allows food and stomach acid back up. This burning feeling is known as heartburn.

Colon
Caffeine can stimulate the digestive tract, helping you to poop. Too much caffeine, however, can cause diarrhoea.

Lasting effects
The effects of caffeine can be seen within 15 minutes, but it can take up to ten hours for the body to completely remove caffeine from the bloodstream.

Decaffeinating coffee

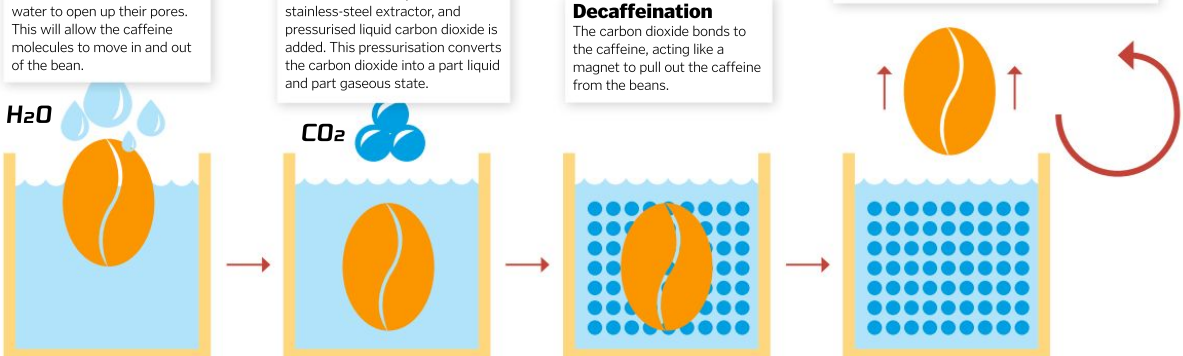
Discover the process that prevents some beans from keeping you up at night

Preparation
The beans are first soaked in water to open up their pores. This will allow the caffeine molecules to move in and out of the bean.

Pressurisation
The beans are then placed in a stainless-steel extractor, and pressurised liquid carbon dioxide is added. This pressurisation converts the carbon dioxide into a part liquid and part gaseous state.

Decaffeination
The carbon dioxide bonds to the caffeine, acting like a magnet to pull out the caffeine from the beans.

Decaffeinated beans
After 12 hours, the carbon dioxide gas is removed, leaving the decaffeinated beans in a separate chamber. This process removes 96 to 98 per cent of the caffeine that was originally present in the coffee beans.




A meningitis rash doesn't go away when you press it with a drinking glass

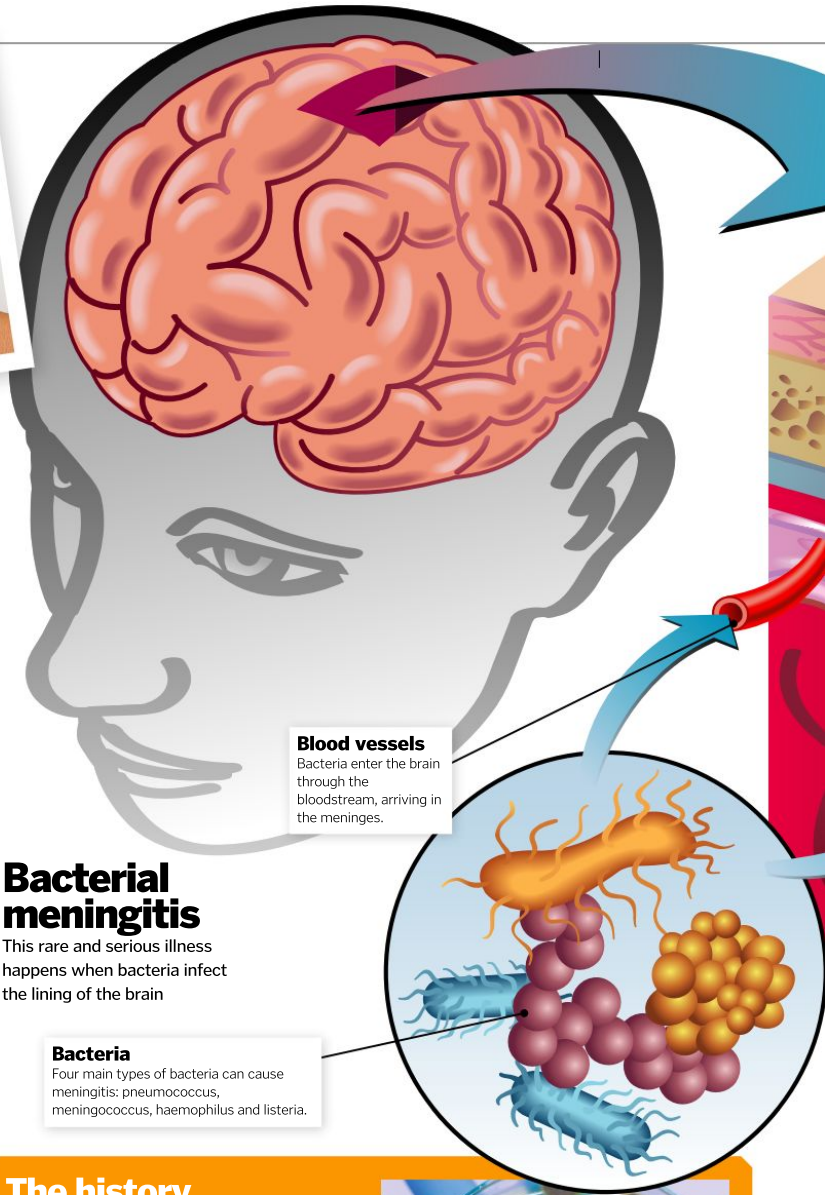
Meningitis

Recognising this illness could save someone's life

Meningitis means inflammation of the meninges, the tissues that cover the brain and spinal cord. Normally a shield called the blood-brain barrier (BBB) keeps bacteria, viruses and fungi away from this delicate structure, but sometimes they manage to break through. When this happens, an infection can start to grow in the fluid that surrounds the brain. As the immune system tries to bring the infection under control, the meninges become inflamed. This leads to three classic symptoms: a very bad headache, a fever and a stiff neck.

Risk of meningitis is highest in the very young, the very old and people with weakened immune systems. But the disease can strike anyone. Meningitis is most serious when bacteria are the cause. If these germs get into the bloodstream, they not only cause swelling in the brain, they can also lead to blood poisoning, sometimes known as septicaemia. The bacteria damage the walls of blood vessels, causing blood to leak out. This creates a distinctive rash that looks like pink, red or purple pinpricks under the skin. This rash doesn't fade away when you press it with a drinking glass.

Viral meningitis is usually less serious, and rarely leads to septicaemia, but it can be hard to tell at an early stage which kind of organism is making someone sick. For that reason, suspected meningitis is always a medical emergency. Looking at a person's blood, or at a sample of the fluid from around their spine, can reveal exactly which organism is causing the meningitis. But getting the results of tests like these takes time. If there's any chance that bacteria might be responsible, doctors have to respond quickly, delivering antibiotics directly into a person's blood through a vein.



Blood vessels
Bacteria enter the brain through the bloodstream, arriving in the meninges.

Bacterial meningitis

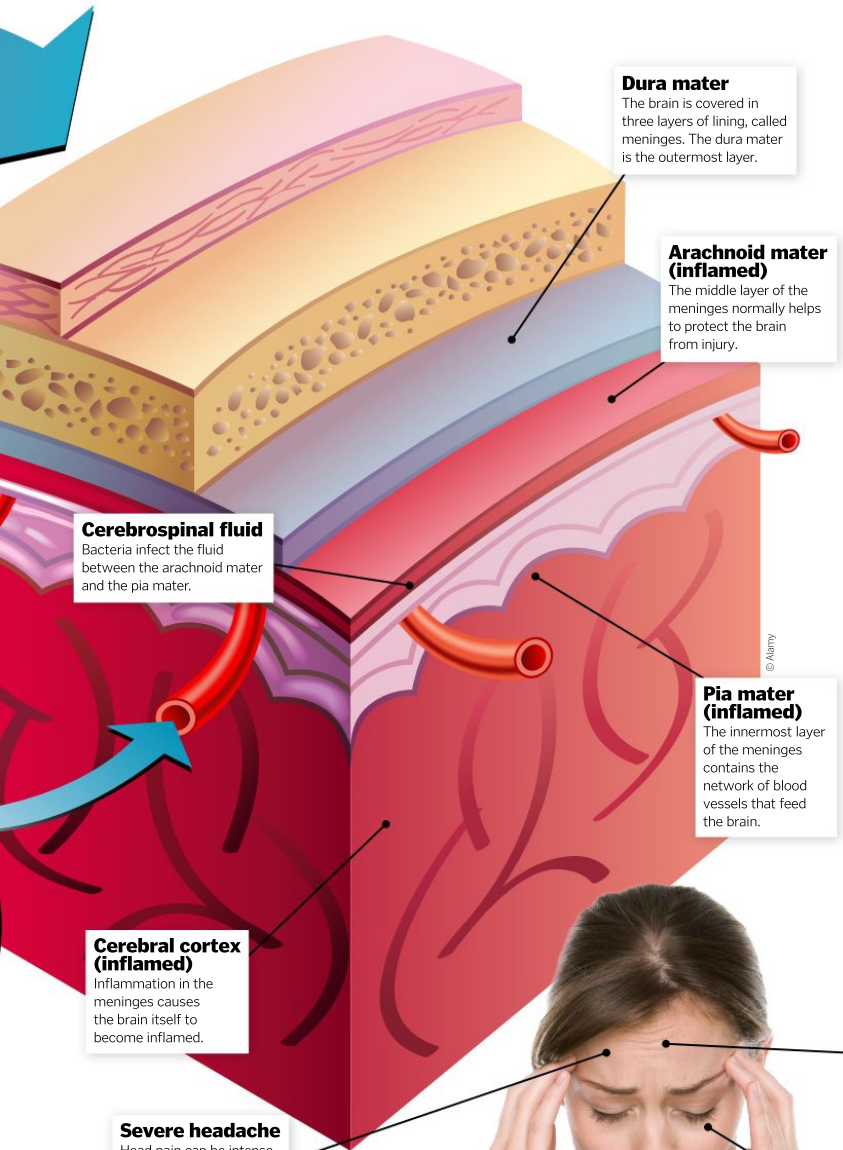
This rare and serious illness happens when bacteria infect the lining of the brain

Bacteria
Four main types of bacteria can cause meningitis: pneumococcus, meningococcus, haemophilus and listeria.

The history of meningitis

It wasn't until the late 1800s that doctors realised bacteria caused meningitis. Around the same time, the first successful treatment was developed. Known as antiserum, this was packed with immune molecules called antibodies. Doctors gathered it from horses or people that had already recovered from meningitis. The antibodies worked like homing missiles, tracking down and eliminating bacteria. But treatment was risky. A much safer solution came along when Alexander Fleming discovered the first antibiotic, penicillin. It is still used to treat bacterial meningitis today.

The discovery of penicillin revolutionised meningitis treatment



Dura mater
The brain is covered in three layers of lining, called meninges. The dura mater is the outermost layer.

Arachnoid mater (inflamed)
The middle layer of the meninges normally helps to protect the brain from injury.

Cerebrospinal fluid
Bacteria infect the fluid between the arachnoid mater and the pia mater.

Pia mater (inflamed)
The innermost layer of the meninges contains the network of blood vessels that feed the brain.

Cerebral cortex (inflamed)
Inflammation in the meninges causes the brain itself to become inflamed.

© Alamy

Preventing meningitis

The best way to protect people against meningitis is vaccination. But because meningitis can have many causes, there isn't a one-shot solution. Instead researchers have developed a whole range of vaccines to protect against as many bacteria and viruses as possible.

A number of these vaccines target meningococcal bacteria. These include the MenB vaccine and the meningitis ACWY vaccine. The letters indicate the strains of meningococcal bacteria that the shots protect against.

Another set of meningitis vaccines teach the immune system to fight *Haemophilus influenzae* type B bacteria, or Hib for short. Hib used to be the leading cause of meningitis in under fives before these vaccines were introduced. Now babies receive a six-in-one vaccine that protects them against this dangerous infection. A combined Hib/MenC vaccine is also available.

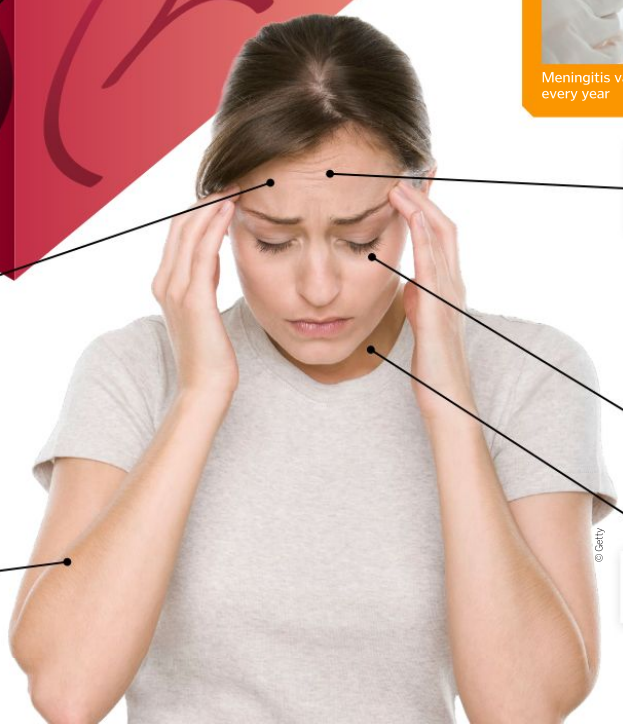
There is also the pneumococcal vaccine, which protects against pneumococcal bacteria, and the MMR vaccine, which protects against viral meningitis caused by measles, mumps and rubella.

© Getty

Meningitis vaccines save thousands of young lives every year

Spot the signs

Knowing the symptoms of meningitis and responding rapidly can be life-saving



© Getty

High temperature
Body temperature rises suddenly, reaching up to 39 degrees Celsius. The hands and feet may be cold.

Severe headache
Head pain can be intense, causing nausea, vomiting and confusion.

"Suspected meningitis and septicaemia are always medical emergencies"

Photophobia
Bright lights become uncomfortable, or even painful, to look at.

Stiff neck
It can be difficult to tilt the neck forwards towards the chest.

Rash
Pink, red or purple marks may appear on the skin. They do not fade when pressed with a glass.

Weird and wonderful ANIMAL BABIES

From hazardous births to deceptive parenting, explore the funny world of newborns

Words by **Ailsa Harvey**

Pouch-dwelling joeys

Koalas are part of the marsupial family, meaning that their young are referred to as 'joeys'. When born, the hairless, fragile koala is only two centimetres long, and is not yet ready to face the world alone. Instead the blind baby crawls into its mother's pouch, where it will live for around six months. The joey usually makes it to the pouch by itself, using its sense of smell and touch to climb up its mother. Once there, the baby will feed on one of her nipples to grow further. For the second half of its first year, the young koala will cling onto its mother's back and eat leaves. The baby is escorted around by its mother while it gets used to life outside the pouch. When she has new offspring to care for, the young koala is forced to fend for itself. This means that the longer the interval between babies being born, the higher the chance of survival is for the older animal in its younger years.

This tiny baby koala can be seen inside its mother's pouch

© Getty

Koalas remain with their mothers until the next season's offspring is born

© Alamy

Black bears can be found across North America

© Getty

Black bears: cub life

After around seven months of pregnancy, black bear cubs are usually born between mid-January and early February. A female bear usually gives birth to two or three cubs. These babies are blind and have entered the world during the harshest months of winter. To keep them alive, the cubs are raised in a den until spring arrives. During hibernation in their dens, the cubs will grow quickly. When leaving the den after winter passes, the bears already weigh around 2.3 kilograms, compared to their birth weight of just 0.2 kilograms. Over the next two years the bears stay with their mother, taking advantage of the food, protection and care until they need to leave to look for their own den to call home.

Sea turtle hatchlings know to run straight into the ocean after hatching

© Alamy

Newborn instincts

When sea turtles emerge from their nests, their first action is to race in waddling armies towards the sea. This instant attraction to the water is an innate behaviour, or instinct. Innate behaviours are those that don't need to be learned. Instead they're genetically built into each member of a species. Without prior life experience, the newborns respond to a particular cue. The first cue used by sea turtles is the brighter natural light reflected along the ocean's horizon. When reaching the waves, the turtles know to swim further out into the safer, deeper water, and can navigate by sensing Earth's magnetic fields.

A newborn's instincts can help it survive the time when it's most vulnerable to predators and the surrounding environment. For example, whales have the instinct to swim straight to the surface after birth to take their first breath. Meanwhile, goats don't need to learn how to walk. They can stand up within minutes of being born to avoid becoming prey.

Unusual births

Mouthbrooding cichlids

These freshwater fish store their unborn babies in their mouths for safety

Nest preparation
The male cichlid digs into the bed of the lake to create an indent for eggs to be laid in.

Pair attraction
The female is often lured to the nest site when the male dances and shakes its fins.

Breeding
When both fish are over the nest, they begin breeding. The female releases her eggs and the male fertilises them.

Collecting eggs
After the eggs have been fertilised, the female collects the eggs from the nest by picking them up in her mouth.

Swimming free
The fish hatch in the cichlid mother's mouth around 10 to 15 days after fertilisation. They will be kept in her mouth for another two weeks, occasionally being let out to be fed.

Catfish intrusion

Cichlid mothers are very protective of their young, which can be seen in their behaviour after birthing. If danger arises, she will quickly suck her babies back into her mouth. But often danger arises before birth. The cuckoo catfish will sneakily place its own fertilised eggs among the cichlid's. In a panic to protect her own, the female cichlid will quickly collect her eggs in her mouth, taking the catfish's with her. The catfish are born before the cichlids, and eat the unborn cichlids. When the catfish young emerge from the cichlid's mouth, the cichlid will raise another fish's babies as her own, perhaps unaware of the extent of the destruction they have caused.

Cuckoo catfish are not fully dependent on cichlids, as they can survive without using them

Young prehensile-tailed porcupines often have to cling onto trees after they're born

Spiky tree birth

During the birth of a baby prehensile-tailed porcupine, the mother will hope that her baby will emerge headfirst, because these animals are born with their spiny quills intact. During the pregnancy their spiky coating is soft, but as they become exposed to air the quills harden.

If this wasn't challenging enough, these animals also give birth in trees. This means the porcupines need to find a suitable branch on which to release their young, while the babies require good balance on their first day of life.

FIVE ABANDONED BABIES

1 Maculinea blue butterflies
These butterflies' caterpillar babies have a waxy outer coat of chemicals similar to those of Myrmica ants. The butterflies leave their young outside the ants' nests so passers-by will mistake their scent for ant larvae, taking them in to feed and raise.

2 Geckos
Like many lizards, geckos lay their eggs in secluded and often shaded locations, but don't stick around to watch them hatch. During their lives, leopard geckos produce 80 to 100 eggs in the hope that some will survive.

3 Cuckoos
The cuckoo is the only British bird that doesn't raise its own babies. Instead the mothers lay their eggs in the nests of other species. The conned birds raise the cuckoo babies, often providing them with more food than their own young if the cuckoo is the largest of them.

4 Cats
A cat might abandon one of its kittens if it fears that it will infect the rest of the litter. This survival technique means that only one of the kittens will die, rather than risking the spread of illness.

5 Rabbits
Rabbits abandon their newborns during the day, but for good reason. They only visit at dusk and dawn because their strong scent might attract predators.

Right after birth a baby giraffe is encouraged to stand next to its mother

This giraffe is being born after around 15 months of developing in the womb

Falling into the world

It might seem like a hazardous way to come into the world, but giraffe mothers give birth to their young while standing up in order to avoid damaging them. As the baby emerges, the mother's stance means more room for the lengthy neck, helping to avoid breaking or injuring it. The fall from the mother doesn't seem to hurt the baby giraffes, which are usually around 1.8 metres tall. Instead the impact breaks the umbilical cord, and the shock of hitting the ground causes the newborn giraffes to take their first breaths. Baby giraffes will normally be able to stand within half an hour of birth.

Alien offspring

Meet the babies that have little resemblance to their family

COLOUR-CHANGING MONKEYS

Silvered leaf monkeys, which are found in the forests of Indonesia and Malaysia, are named for the colour of their silvery-grey fur. However, newborn monkeys are born with a vivid orange coat of hair. Scientists aren't entirely sure why this species has evolved to have such colourful babies, but they have plausible theories. The first benefit is that mothers can easily locate them among the trees if they decide to leave their parent's side. Secondly, the orange may be a form of camouflage. Due to their predators being mostly colour-blind felines that struggle to differentiate between reds and greens, the orange colour blends in well with the green trees to a hungry leopard.

When the baby monkeys are around three to five months old, they start to lose their distinctive colouring. Starting with the fur on their heads, the monkeys become silvery-grey like their parents.

This female silvered leaf monkey holds her one to two-week-old baby

© Getty

TAPIR PATTERNS

Tapirs are large mammals with long snouts that mostly live in the forests of Central and South America. While the adults are plain and grey in appearance, baby tapirs don a coat of stripes and spots. Found in wooded areas, rainforests and grasslands, this patterned appearance helps young tapirs hide from their predators in the undergrowth. In the six months following their birth, their fur will subtly change to become more uniform.

This young Brazilian tapir is two weeks old

© Alamy

Unlike adult ladybirds, larvae have soft outer bodies

© Alamy

LADYBIRD LARVAE

The red-and-black spotted beetle we know as a ladybird, or ladybug, doesn't always have a glossy shell. As one of many insects that undergoes metamorphosis, a baby ladybird is a transformation away from the appearance the species is most famous for.

The elongated ladybird larvae emerge from their eggs after between two and ten days of being laid. Then they spend the first two weeks of their life constantly feeding on smaller insects and growing bigger. They have also been known to eat other unhatched ladybird eggs during this period.

When ready to transform, the ladybird attaches to a leaf for one or two weeks. During this time, cells in their bodies called histoblasts break down the body and rebuild it in the form of a red-and-black adult ladybird.

TEENY-TINY GIANT PANDAS

What would you expect the newborn of a giant black-and-white furry creature to look like? Chances are your first guess wouldn't be a tiny, pink and naked rat-like baby. However, this is what a giant panda's baby looks like.

The size of a newborn panda is just 1/900th that of their parents, which is the lowest birth weight ratio of all placental mammals. One factor of its incredibly tiny size could be the delayed implantation of the panda embryo in the womb. For several months before the embryo attaches to the wall of the pregnant panda's uterus, it floats inside the womb. Only after this attachment is made can the panda foetus receive the nutrients required to develop and grow.

Pandas are born blind

© Alamy

Pandas often carry their newborns in their mouths

© Alamy

Biggest and smallest

These two animal babies are both mammals, but their difference in size is enormous

BLUE WHALE

Blue whale newborns are the biggest animal babies in the world. They can be found in all oceans around the world, with the exception of the Arctic Ocean. These big babies are born between December and February and will stay by their mothers' sides for up to seven months.

8 metres

A newborn blue whale is 16 times as long as the average newborn human

10

Blue whales can produce up to ten babies in their lifetime

90 kilograms

The milk from a baby blue whale's mother allows it to put on substantial weight every day

4,000 kilograms

A baby blue whale is four times as heavy as an adult cow

HONEY POSSUM

These nocturnal marsupials create the smallest babies of all mammals. They have long snouts and large black eyes in comparison to their tiny bodies. Living on a diet of pollen and nectar, the honey possum has a tongue that can extend out of its mouth the same length as its own head.

4

Honey possum mothers have room for a limited number of babies in their pouches

2.5 grams

Eight weeks after birth, honey possums are 500 times their birth weight

3 to 13 weeks

Some honey possum pregnancies can last four times longer than the minimum period

0.005 grams

The weight of a newborn honey possum is the same as one-quarter of a grain of rice

How Monument Valley formed

Words by **Charlotte Hartley**

Made famous by the cowboys of the Wild West, Monument Valley harbours a fascinating history

With its striking sandstone buttes and dusty red landscape, Monument Valley appears more Martian than Earthly. This ancient, desert plain forms part of the Colorado Plateau, snuggled between Utah and Arizona in the US.

This remote landscape has belonged to the Navajo Nation, a Native American territory, for hundreds of years. But its big break came in the 1930s, when director John Ford shot several Westerns using the majestic, rocky scenery as a backdrop for his films.

Monument Valley itself is millions of years old. When dinosaurs roamed the Earth, it formed part of a seafloor where sediments built up in layers over time. Tectonic forces then hoisted the seabed 1,500 metres above sea level, forming an elevated desert plateau.

Gradually, over millions of years meandering rivers and streams worked their way into cracks in the sandstone. These cracks widened and deepened into gullies and canyons, eventually carving out the vast wilderness we see today. Exposed iron oxide from years of weathering gives the sandstone its iconic shade of red.

But perhaps Monument Valley's biggest attraction is the buttes. These picturesque towers of sandstone have steep, almost-vertical sides with a flat top. They were once part of the main plateau, but as water, wind and ice chiselled away at the surrounding rock, the sturdy top layer resisted erosion. It protected the vulnerable softer layers below, leaving isolated columns intact.

In the end, even buttes fall prey to erosive forces. As the rock is slowly chipped away, buttes become narrow spires. In Monument Valley, the East and West Mitten Buttes both comprise a slender spire beside a thicker column of sandstone, giving them the appearance of a giant pair of mittens – hence their name.

Monument Valley's famous buttes are an iconic picture of the American Wild West

© Alamy

"When dinosaurs roamed the Earth, it formed part of a seafloor where sediments built up in layers over time"

The geology of Merrick Butte

This pillar has peculiar layers that allow the rock to poke out of the horizon

CAPROCK
This thin, horizontal layer of hard sandstone has a reddish hue from exposed iron oxide.

CLIFFS
Steep sides form a sheer cliff face. Large slabs of rock fall away as the cliff is undercut from below.

TALUS
A gentle incline of soft clay and siltstone. These rocks are eroded easily and can undercut the harder rock above.

Where rivers come from

The vital waterways that transport water around continents begin as just a tiny trickle

Whether they gush dramatically down a rock face or subtly slip through the landscape, the transportation of water in rivers is essential to many life forms on Earth. Rivers are natural channels of water that carry surface freshwater to seas and lakes. As well as relocating the water to a larger body, they also distribute nutrients such as nitrogen and phosphorus around the planet and to oceans.

Rivers are responsible for draining water from three-quarters of Earth's land surface. As they can stretch across thousands of miles, humans have relied on rivers to increase travel routes and provide a constant fresh source of water. A multitude of animals, including thousands of fish species, insects, reptiles and mammals, make the most of the unique habitats supported by rivers.

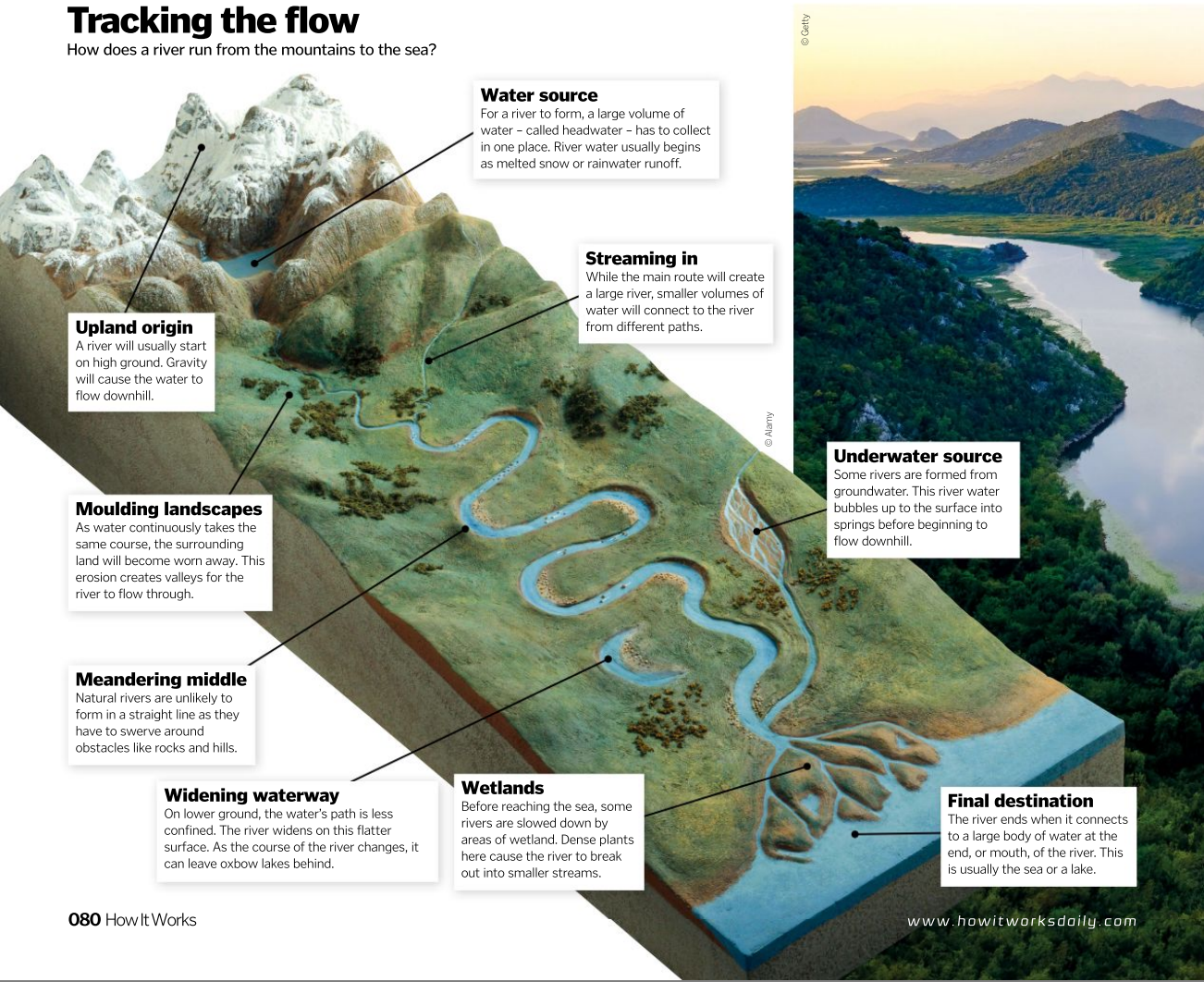
As much as rivers cut and shape Earth's landscape, the opposite can also be said: the existing landscape determines a river's path. They continuously erode the landscape, while gravity steers water off the hills and into the course of the river.

Many different types of river can be found on Earth. Alluvial rivers are formed in areas that are frequently flooded. This means the riverbed is made of loose, mobile sediment. They usually consist of a constantly flowing central river with sediment surrounding its sides, which can be used to make new river channels with overflowing water in the event of flooding.

Alluvial rivers can change their paths regularly, but not all rivers run through freely moving sediment. Bedrock rivers are those that have eroded directly into the bedrock beneath the softer surface layers. These rivers are likely to have become trapped in a more fixed location, as the erosion of harder material requires more time and strength. Some rivers flow through areas both with and without loose sediment, and are known as bedrock-alluvial rivers.

Tracking the flow

How does a river run from the mountains to the sea?



© Getty

© Alamy

Water source
For a river to form, a large volume of water – called headwater – has to collect in one place. River water usually begins as melted snow or rainwater runoff.

Streaming in
While the main route will create a large river, smaller volumes of water will connect to the river from different paths.

Upland origin
A river will usually start on high ground. Gravity will cause the water to flow downhill.

Underwater source
Some rivers are formed from groundwater. This river water bubbles up to the surface into springs before beginning to flow downhill.

Moulding landscapes
As water continuously takes the same course, the surrounding land will become worn away. This erosion creates valleys for the river to flow through.

Meandering middle
Natural rivers are unlikely to form in a straight line as they have to swerve around obstacles like rocks and hills.

Widening waterway
On lower ground, the water's path is less confined. The river widens on this flatter surface. As the course of the river changes, it can leave oxbow lakes behind.

Wetlands
Before reaching the sea, some rivers are slowed down by areas of wetland. Dense plants here cause the river to break out into smaller streams.

Final destination
The river ends when it connects to a large body of water at the end, or mouth, of the river. This is usually the sea or a lake.

The world's largest

The Amazon River stretches a vast 3,980 miles through South America. While the River Nile in Africa is longer, the volume of water in the Amazon is around one-fifth of the planet's total surface water. Every second, an estimated 219,000 cubic metres of water enters the Pacific Ocean from this river.

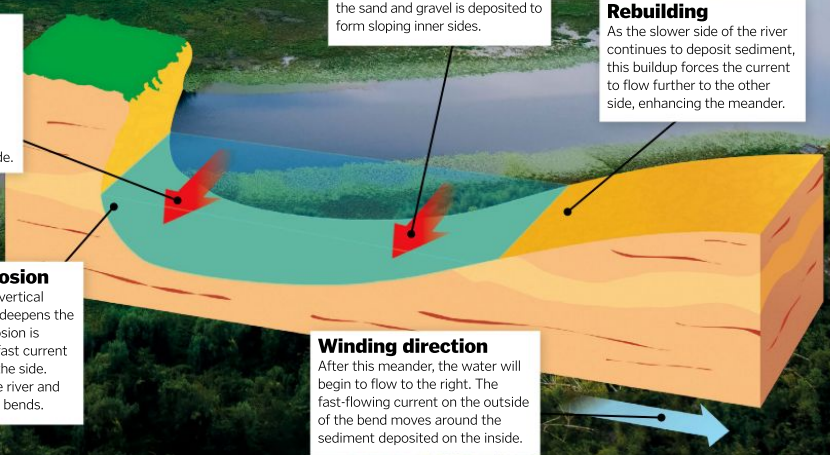
Scientists believe that this mighty river formed around 11 million years ago, but was reshaped by a mighty force to take its current path 2.4 million years ago. One theory is that when the Andes mountain range was created 15 million years ago, the previously existing west-flowing river's route was blocked, creating a lake that gradually filled. As this lake grew in size, the marine species that could no longer reach the sea evolved into freshwater creatures. This would explain the diverse species found in the river today that are closely related to their marine relatives in the Pacific, such as stingrays.

Around 5 million years later, the trapped water eroded away the sandstone to move slowly eastward. During the ice age, as sea levels dropped, the water began to flow down into the sea, giving birth to the Amazon River.

The Amazon River, pictured in Ecuador, also flows through Colombia, Venezuela, Bolivia and Brazil

Meandering water

What forces create the bends in the course of a river?



Fast current
The fastest flowing water gets pushed to the outside of a river bend. Carrying more energy, this water erodes the land at a quicker rate on this side.

Slow current
The slower water gets pushed to the inside of the bend. With less energy to carry sediment, much of the sand and gravel is deposited to form sloping inner sides.

Rebuilding
As the slower side of the river continues to deposit sediment, this buildup forces the current to flow further to the other side, enhancing the meander.

Lateral erosion
As opposed to vertical erosion, which deepens the river, lateral erosion is caused by the fast current wearing away the side. This widens the river and creates greater bends.

Winding direction
After this meander, the water will begin to flow to the right. The fast-flowing current on the outside of the bend moves around the sediment deposited on the inside.

BRAIN DUMP

Because enquiring minds need to know...

MEET THE EXPERTS

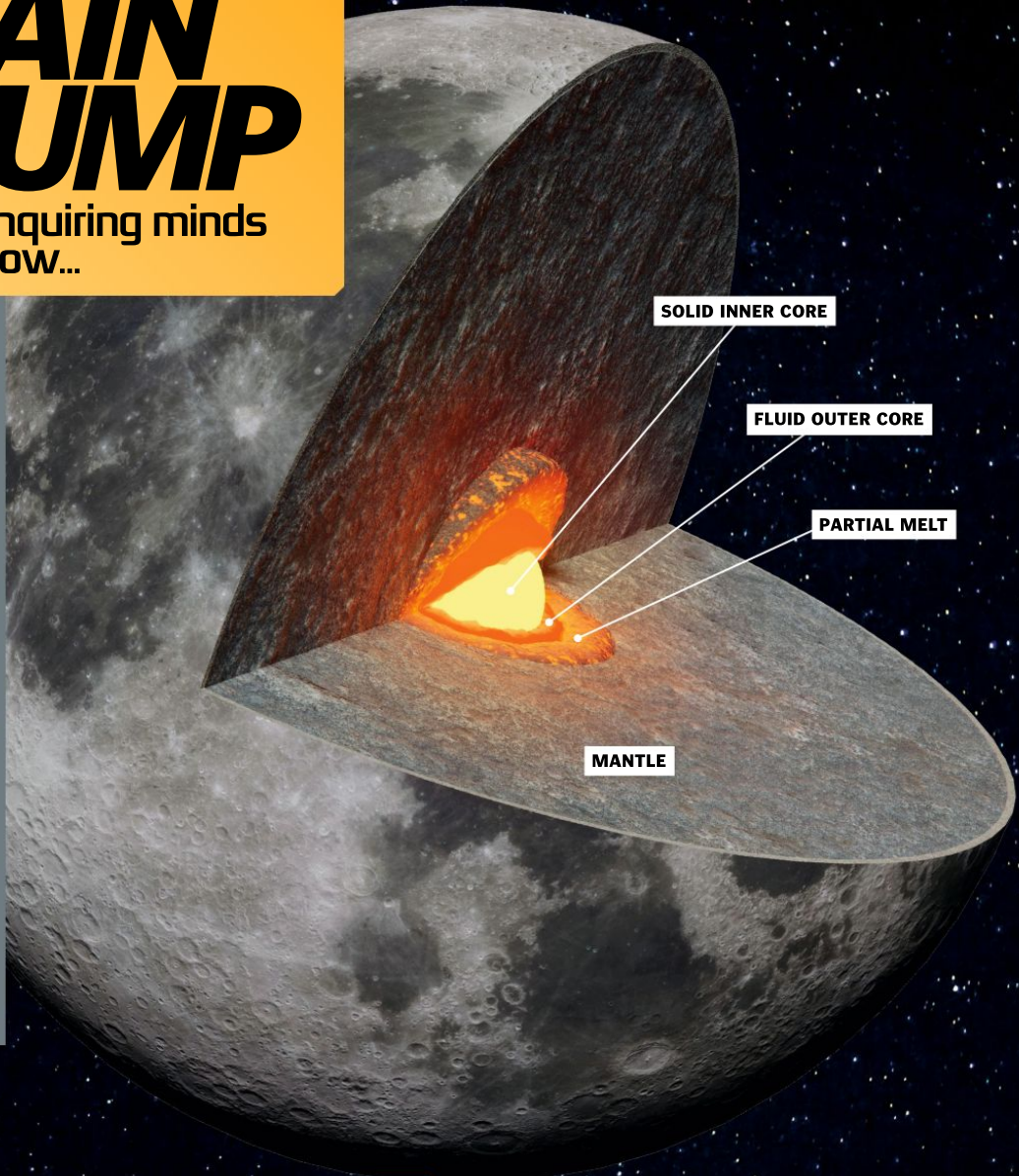
Who's answering your questions this month?


JO ELPHICK


ANDY EXTANCE


ANDREW MAY


VICKY WILLIAMS



SPACE

Does the Moon have a core?

Yes. The Moon has a layered internal structure similar to Earth, with a solid, metallic inner core surrounded by a fluid outer core of molten iron. AM

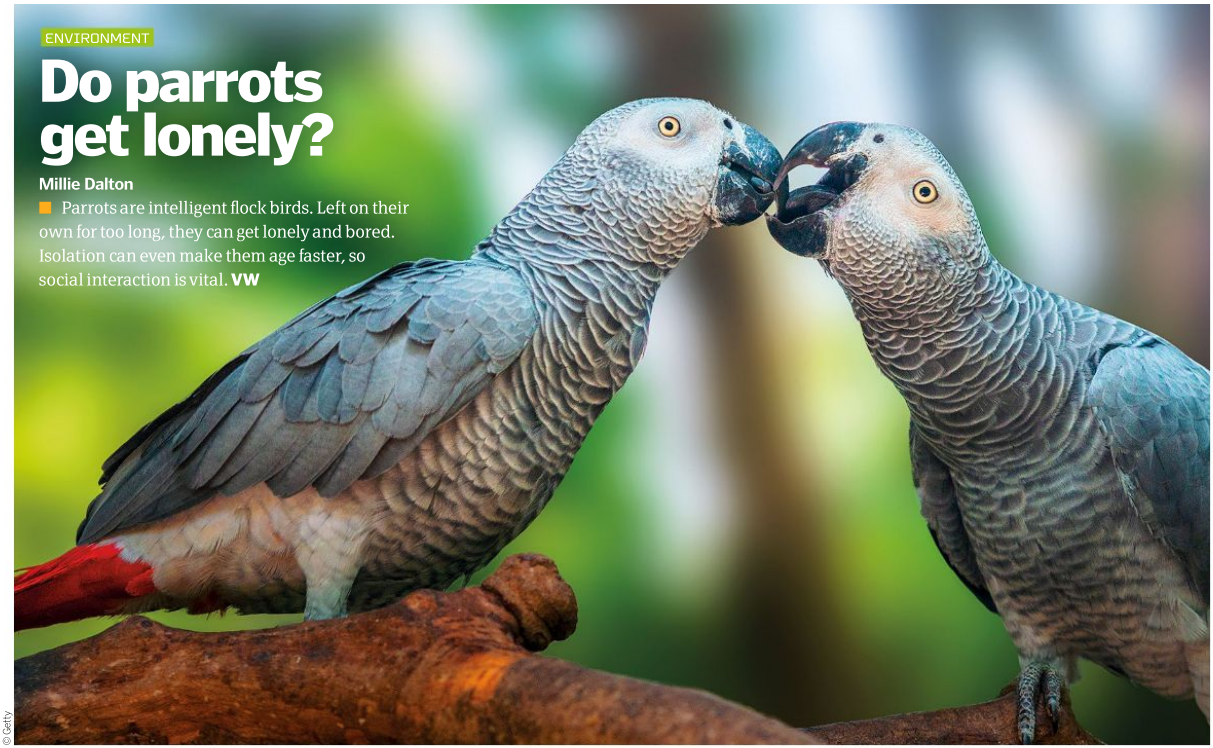
WANT ANSWERS? Send your questions to... How It Works magazine @HowItWorksmag @howitworks@futurenet.com

ENVIRONMENT

Do parrots get lonely?

Millie Dalton

Parrots are intelligent flock birds. Left on their own for too long, they can get lonely and bored. Isolation can even make them age faster, so social interaction is vital. **VW**



© Getty

© Getty

SCIENCE

Why does your taste change when you have a fever?

Stefanie Richardson

Food and drink flavours combine taste and smell. When you have a cold, your nose often gets blocked up. Without the important smell component, the flavours you like are much blander. **AE**

© Getty

HISTORY

When did humans first start to write?

Helen Crew

The first type of writing, called cuneiform, was developed in Mesopotamia in 3400 BCE – that's almost 5,500 years ago. Pictorial signs became characters representing sounds of the Sumerian language. **JE**

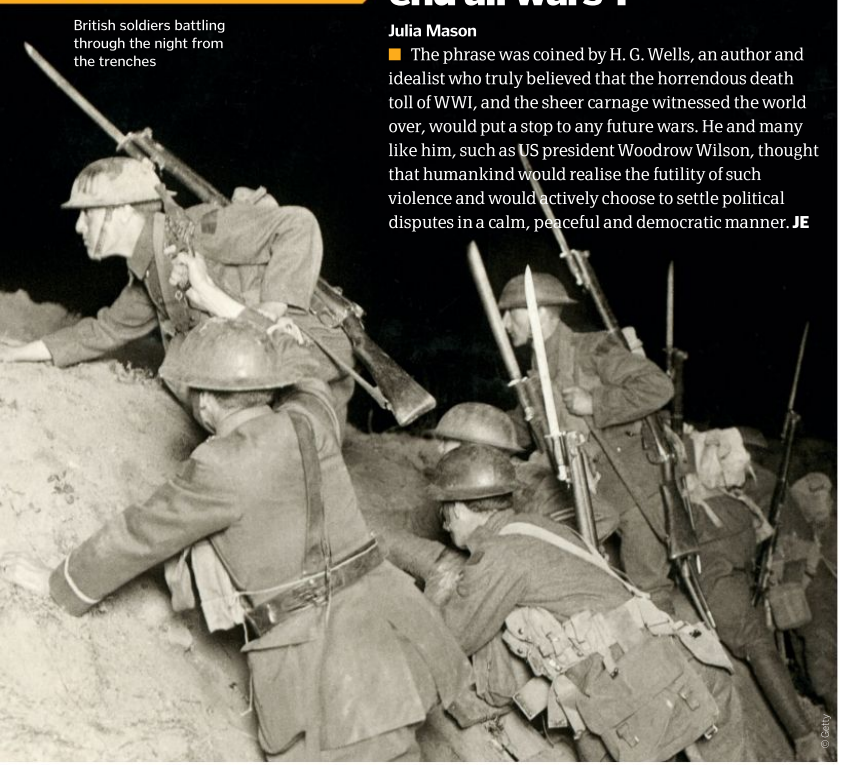
BRAIN DUMP

HISTORY

Why did people say that WWI was the 'war to end all wars'?

Julia Mason

British soldiers battling through the night from the trenches



© Getty

The phrase was coined by H. G. Wells, an author and idealist who truly believed that the horrendous death toll of WWI, and the sheer carnage witnessed the world over, would put a stop to any future wars. He and many like him, such as US president Woodrow Wilson, thought that humankind would realise the futility of such violence and would actively choose to settle political disputes in a calm, peaceful and democratic manner. **JE**

ENVIRONMENT

What's the least explored wilderness on Earth?

Cerys Wicks

At 7,570 metres, Gangkhar Puensum is Earth's highest unclimbed peak

© Alamy

Almost half the land on Earth is still wilderness, home to just two per cent of the human population, but we've found a way to scale, cross and map most of it. A few areas remain relatively unexplored, like northern Patagonia and the Star Mountains of Papua New Guinea. Gangkhar Puensum in Bhutan is the world's tallest unclimbed mountain, and it's likely to remain that way since the government has banned any attempt to reach the top. If you want completely uncharted territory, you'll need to head underwater. It's estimated that over 80 per cent of the ocean remains unexplored. VW

© Getty

ENVIRONMENT

Why do birds sing?

Karishma Kirkland

Male birds sing more than females. Their songs usually convey one of two messages: "I'm here, so go away," if the listener is another male, or "I'm here and healthy, come mate with me" if it's a female. Birdsong is most intense in spring, when male birds compete over territories and partners. **VW**

© Alamy

TRANSPORT

If we can use vegetable oil to fuel cars, why do we bother pumping oil out of the ground?

Sophie Decker

At first glance vegetable oil is a great idea, because growing the plants used to make it absorbs at least as much carbon dioxide from the atmosphere as the oil emits when it's burned – it's carbon neutral, in other words. But there's nowhere near enough waste vegetable oil to fuel all the cars in the world, so plants would have to be grown specially. This raises a whole new set of problems, such as taking land usage away from food production and forestry. All in all, it's better to ditch internal combustion altogether in favour of electric vehicles. **AM**

© Getty

You crave the taste, but you might crave the feeling of being rewarded even more

SCIENCE

What makes you crave certain foods?

Jin Yang

Although evolution has hard-wired us to favour salty, sweet and oily foods because they're rare in nature and provide a calorie or vital mineral boost, most common food cravings today have an emotional root. You might have been given a boiled sweet as a reward as a child, for example, and the same feeling of being rewarded when you unwrap that sweet can carry into your adulthood. These deep-seated psychological responses are subtle, but powerful, and can compel you to seek the same boiled sweet out time and time again. You might think that the crunch and the sweetness or flavour is all you crave, but the feeling of being rewarded is playing its part as well. **BB**

© Getty

TECHNOLOGY

Why aren't birds electrocuted when they land on power lines?

Hakim Heath

They are electrocuted sometimes. You shouldn't see birds on very high-voltage transmission lines on big pylons because these can kill them. Birds use magnetic fields to navigate. Magnetic fields from high-power lines can steer birds away. On lower voltage power lines, birds can usually survive because they're small. As long as they don't touch anything else, very little electricity flows through them, which is not enough to give them a shock. **AE**

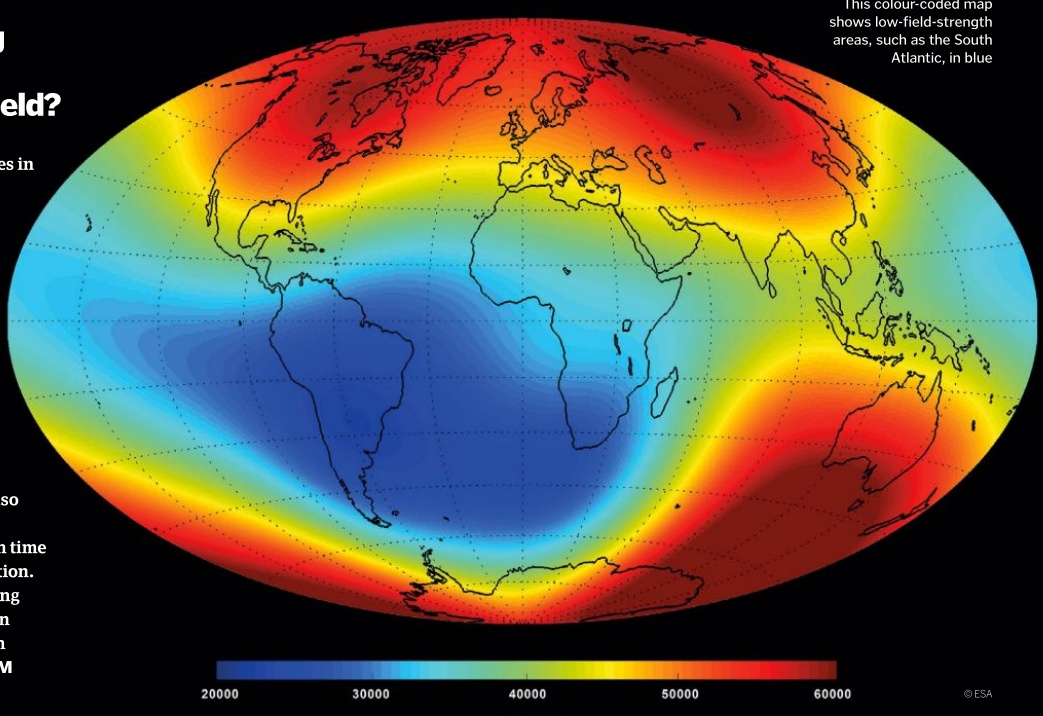
Birds might perch on pylons carrying high-power lines, but know to avoid the lines themselves

SPACE

How strong is Earth's magnetic field?

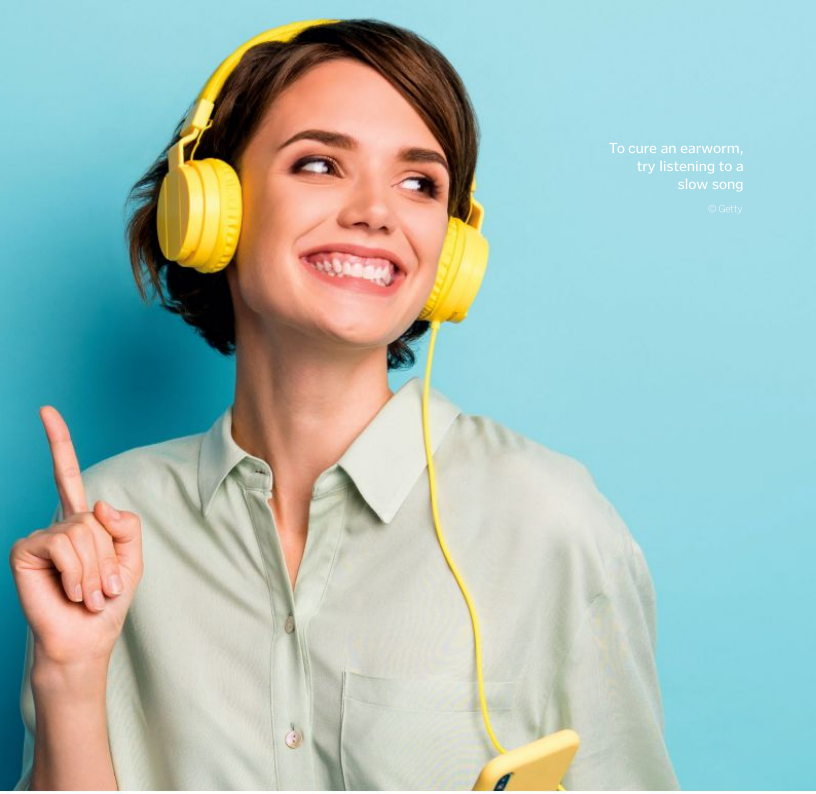
Greg Peel

The field originates in Earth's outer core, which is a swirling mass of molten iron that generates electricity and magnetism, rather like a bicycle dynamo. Although very powerful at its source, the field intensity at Earth's surface is about 200 times weaker than a fridge magnet. It's also far from constant, fluctuating both with time and geographic location. It's currently declining quite noticeably in an area called the South Atlantic Anomaly. AM



This colour-coded map shows low-field-strength areas, such as the South Atlantic, in blue

BRAIN DUMP



To cure an earworm, try listening to a slow song

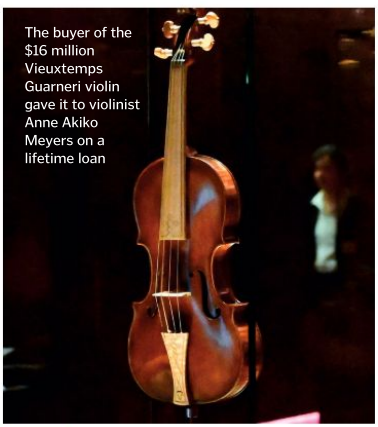
© Getty

SCIENCE

Why do I get songs stuck in my head?

Veronika Noble

'Earworm' songs seem to get stuck in a certain area of your brain responsible for music memory. The types of songs that become earworms are personal, but there are some common factors. They tend to be faster songs, with common structures and beats. You've probably heard the earworm recently, or have heard it a lot. An earworm can apparently only be stopped by activating the same music memory part of the brain. Reading, thinking about words or pictures, physical activity and talking don't stop it. To stop an earworm, try listening to a song you don't find catchy. **AE**



The buyer of the $16 million Vieuxtemps Guarneri violin gave it to violinist Anne Akiko Meyers on a lifetime loan

© Getty

HISTORY

What is the most expensive instrument?

Anna Fuerst

Grand pianos have extravagant price tags that can start in the low thousands for an entry-level model, while a new oboe won't leave you much change out of a thousand pounds. The most expensive instrument ever sold was the Vieuxtemps Guarneri violin, which was made in 1741, owned by 19th-century violinist Henri Vieuxtemps and sold at auction for $16 million (£10.5 million) in 2010. **BB**

HISTORY

Did pop music exist in Victorian times?

Carolyn Edwards

There wasn't any pop music as we think of it today, but an alternative to the traditional grand orchestral pieces did appear in Victorian England, and could be classed as a kind of pop music. Great British Music Hall theatres offered entertainment to the masses, and this included lots of songs with a chorus that the audience could join in with. The songs were sometimes sad, often quite cheeky and always extremely catchy so everyone could pick them up and sing them at home. Alternatively, people could enjoy the comic operas of Gilbert and Sullivan, whose songs became very popular. **JE**

Sheet music of *I'll Be No Submissive Wife*, a popular hit in 1838

© Getty

© Alamy

SCIENCE

How is paint made with so many different colours?

Aaisha Yu

The secret lies in dyes and pigments, which today are created synthetically and come in a huge variety of colours. Previously they had to be made from natural minerals and organic materials, some of which were very expensive or hard to source. That's why certain shades of blue are so rare in old paintings. **AM**

© Getty

TECHNOLOGY

Why is downloading much faster than uploading?

Denis Little

Many broadband companies deliberately design their networks this way for home users because it's cheaper. Most people at home download far more than they upload, so we don't really need fast uploads. But businesses that rely on cloud computing often have symmetric broadband, where upload and download speeds are the same. **AE**

© Getty

HISTORY

Did medieval explorers expect to find new land when they discovered the Americas?

Glen Hardcastle

European medieval explorers actually found the Americas by accident. They were not looking to discover new continents. Instead they were trying to establish a new trade route across the seas to reach China, India and Southeast Asia. They were hoping to bring back exotic goods such as spices and silk. **JE**

Sperm whales spend less time asleep than any other mammal

© Alamy

ENVIRONMENT

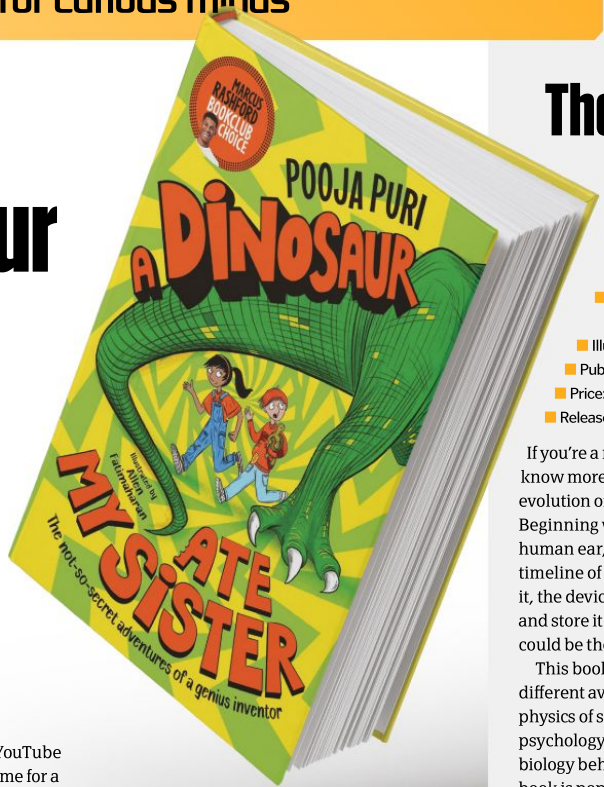
Why do whales sleep vertically?

Malcolm Avery

Vertical sleeping in sperm whales was first documented in 2008. A study found that they spend seven per cent of each day still and upright, napping near the surface in stints of 10 to 15 minutes. To get into this unusual position they dive down, then stop swimming and let their heads drift up. Vertical sleeping could make it easier to snatch a breath when they wake up, or it could just occur because their heads are the least dense parts of their bodies. VW

BOOK REVIEWS

The latest releases for curious minds



A Dinosaur Ate My Sister

THE NOT-SO-SECRET ADVENTURES OF A GENIUS INVENTOR

- Author: **Pooja Puri**
- Illustrator: **Allen Fatimaharan**
- Publisher: **Macmillan Children's Books**
- Price: **£6.99 / $11.34**
- Release: **Out now**

Put your musty textbooks, science documentaries and educational YouTube videos aside for a few hours. It's time for a silly and fun science-fiction adventure into the Cretaceous age. Child prodigy and genius inventor Esha Verma is so keen on winning the Brain Trophy for 'young inventor of the year' that she decides to go a few steps better than the auto-drying towel that won the previous year's competition, and invent a time machine.

Surely something that the world's greatest scientists have decided is impossible for humans to do would win this coveted award? Unfortunately, Esha is successful in her endeavour – unfortunate for her older sister Nishi, that is, who manages to get herself zapped back into the age of the dinosaurs. Esha is so excited about winning the Brain Trophy that she nearly forgets that she needs to rescue her sister. And so with the help of her intrepid assistant Broccoli – you'll have to see the illustrations to fully appreciate this nickname – she sets out on a prehistoric rescue mission in the hope that they can find Nishi before she creates a butterfly effect that destroys the universe… or something like that.

It's all a bit mad, to be honest, but *A Dinosaur Ate My Sister* is great fun. Pooja Puri's suitably puerile sense of humour will appeal to younger children and big kids alike, as will this fantastic adventure through the age of the dinosaurs, wormholes and all of space and time. There's even some learning to be done, cleverly woven into the text between jokes and references to bogeys, farts and dinosaur poop.

Alongside Allen Fatimaharan's cartoon sketches, which are often used to pace and punctuate the plot, there's something about *A Dinosaur Ate My Sister* that's reminiscent of Mark Allen's *The Curious Incident of the Dog in the Night-Time*. The method is light and fun, but there's a more earnest intent behind Puri's writing: to encourage young readers to experiment, get creative and perhaps even try their hand at inventing themselves.

> *Puri's suitably puerile sense of humour will appeal to younger children and big kids alike*

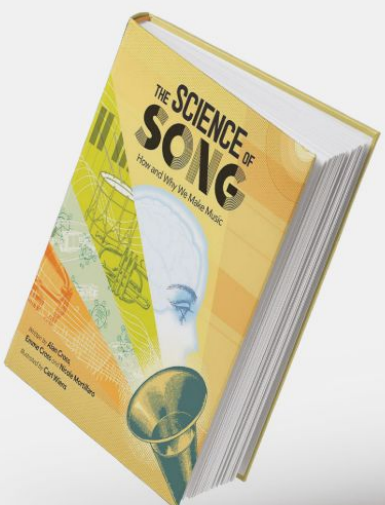
The Science of Song

HOW AND WHY WE MAKE MUSIC

- Author: **Alan Cross, Emme Cross and Nicole Mortillaro**
- Illustrator: **Carl Wiens**
- Publisher: **Kids Can Press**
- Price: **£14.99 / $17.99**
- Release: **9 September**

If you're a music enthusiast and want to know more about the history and scientific evolution of sound, this book is a must-read. Beginning with the science inside the human ear, it takes the reader along the timeline of music, how we've learned to play it, the devices humans have made to record and store it and how artificial intelligence could be the next generation of musician.

This book lives up to its title, exploring different avenues of science such as the physics of sound, the mechanics of a CD, the psychology of music preferences and the biology behind earworms. Although the book is populated with some in-depth pieces of science, it's written to appeal to a wide audience. A fun addition to the book is a suggested playlist of popular hits to enjoy while you read.



Super Animals: The Largest

MEET SOME OF THE BIGGEST ANIMALS ON EARTH

- Author: **Reina Olliver and Karel Claes**
- Illustrator: **Steffie Padmos**
- Publisher: **Clavis**
- Price: **£14.99 / £26.22**
- Release: **Out now**

This illustrative guide showcases some of the most enormous creatures on our planet. From tree-top-grazing giraffes to ocean-dwelling colossal squids, this book takes its young audience on a journey to discover wildlife from all corners of Earth. It's filled with beautiful illustrations of each of the nine featured animals, accompanied by snippets of information about the animal's size, diet, behaviour and habitat. For example, did you know that a newborn moose will double in weight in just a month? This is the third book in the Super Animals series, following *Super Animals: Builders* and *The Best Mommies and Daddies*, which are all aimed at budding zoologists aged over five years old.

Back to Earth

AN ASTRONAUT'S REFLECTION ON EARTH FROM SPACE

- Author: **Nicole Stott**
- Publisher: **Seal Press**
- Price: **£22 / $30**
- Release: **11 November**

Sometimes you need to take a step back from something to appreciate its full beauty. For astronaut and author Nicole Stott, her heightened appreciation of our planet came from taking far more than just a step. As you read this book, the change in perspective she witnessed alters your own.

In *Back to Earth*, Stott shares how viewing Earth from the International Space Station (ISS) made her more passionate about the planet we live on and feel closer to its population. The experience, which she says nothing could prepare her for, revealed to her how interconnected we all are on an incredible yet fragile planet.

You may think you can't relate much to life in space, but *Back to Earth* is expertly written to engage all readers as you share the lessons learned there. Descriptions of these personal experiences provide insight into the emotions felt by Stott on the ISS and how they relate to life on Earth. This encapsulating read will make you better appreciate the planet that supports us and provide you with new ways to combat today's global issues. It's a reminder that we all need to appreciate the small beauties in life and protect the thin blanket of atmosphere that supports us all.

Planet Protectors

52 WAYS TO LOOK AFTER THE PLANET

- Author: **Paul Kerensa and Ruth Valerio**
- Illustrator: **Fay Austin**
- Publisher: **SPCK Publishing**
- Price: **£7.99 / $16.99**
- Release: **Out now**

Do you and your family have what it takes to be 'Planet Protectors'? This book is designed to help children and their families make small changes while teaching them about the big differences they can make. Whether it's opting to walk instead of jumping in the car or thinking about where your daily meals come from, you are sure to find new ways that you can help the environment.

This book doesn't just provide you with ideas, but is filled with activity pages to plot progress and help others to follow you. Whether you decide to write to your local supermarket about the impact of their plastic packaging or plan ways to save energy at home, you are provided with the templates to plan and act effectively. With a total of 52 ideas, the chapters are packed with interesting facts to increase your knowledge and fun activities to make your work as a Planet Protector both helpful and fun.

It's filled with activity pages to plot progress

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 Who is recognised as the inventor of the modern computer?
- ○ Bill Gates
- ○ Socrates
- ○ Galileo Galilei
- ○ Charles Babbage

Q2 How does a microwave oven heat your food?
- ○ It vibrates water
- ○ By irradiating it
- ○ With infrared waves
- ○ Using hot steam

Q3 Which space telescope is due to launch in 2021?
- ○ Hubble
- ○ Fermi
- ○ Chandra
- ○ James Webb

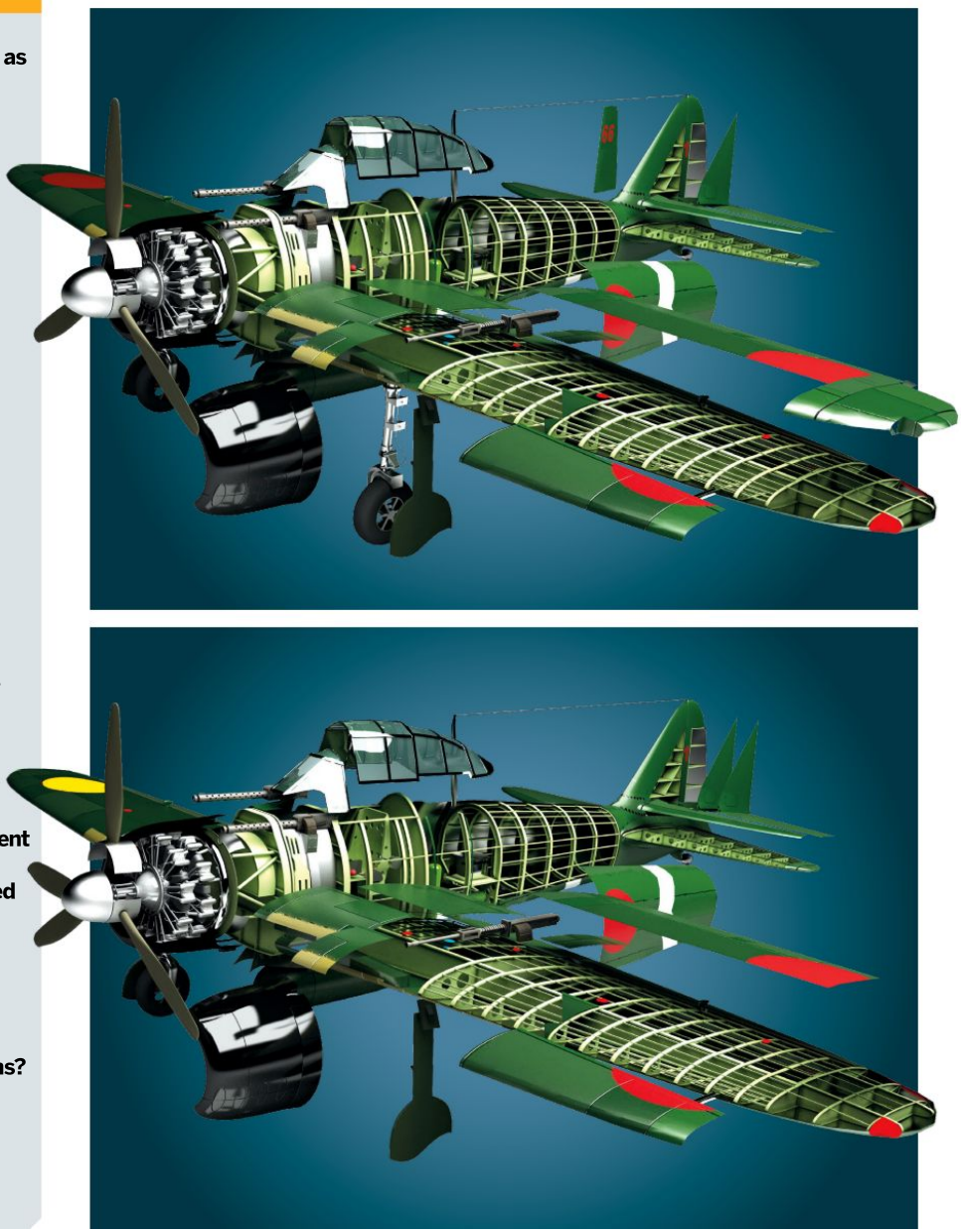
Q4 Which of these organs feels no pain?
- ○ Kidneys
- ○ Brain
- ○ Heart
- ○ Skin

Q5 What was the ancient Greek Antikythera mechanism, discovered in 1901?
- ○ An alarm clock
- ○ A computer
- ○ A calorie counter
- ○ The first iPad

Q6 What is an aurochs?
- ○ A golden bracelet
- ○ A pest insect
- ○ A weather phenomenon
- ○ An extinct ox

Spot the difference

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



Sudoku

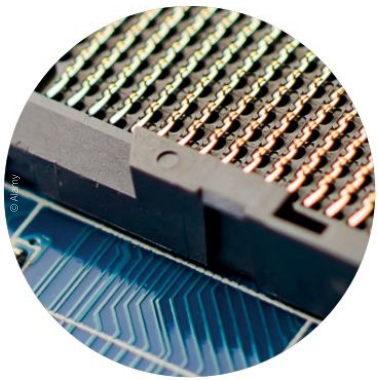
Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

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

DIFFICULT

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



What is it?

Hint: Not the tastiest of chips...

A .....

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

Wordsearch

FIND THE FOLLOWING WORDS...

INVENTION
SATELLITE
BRAIN
ROMAN
COMPUTER
MOON
TEA
LORRY
RIVER
QUMRAN
BABY
THRUST

Check your answers

Find the solutions to last issue's puzzle pages

SPOT THE DIFFERENCE

QUICKFIRE QUESTIONS

Q1 1694
Q2 1,190.49kg
Q3 86 billion
Q4 14 billion miles
Q5 Ten miles per hour
Q6 Aeroplane takeoff

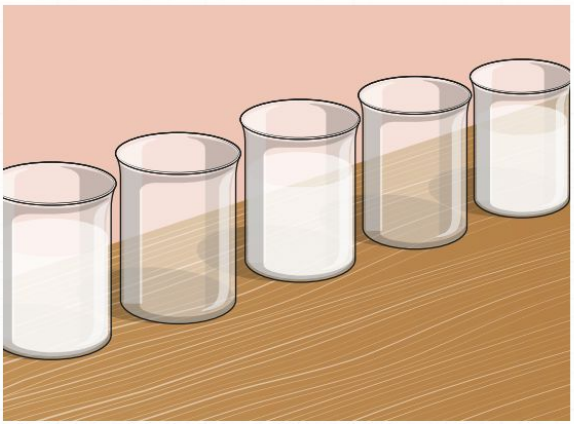
WHAT IS IT? ...FRECKLES

Get in touch
Send your ideas to...
How It Works magazine
howitworks@futurenet.com
@HowItWorksmag
howitworksmag

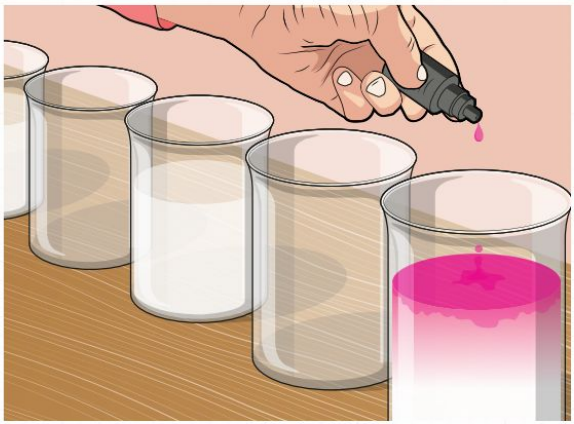
YOU WILL NEED:
- Five clear cups
- Water
- Food colouring – we used red, yellow and blue in our experiment
- Four paper towels

Make water travel against gravity

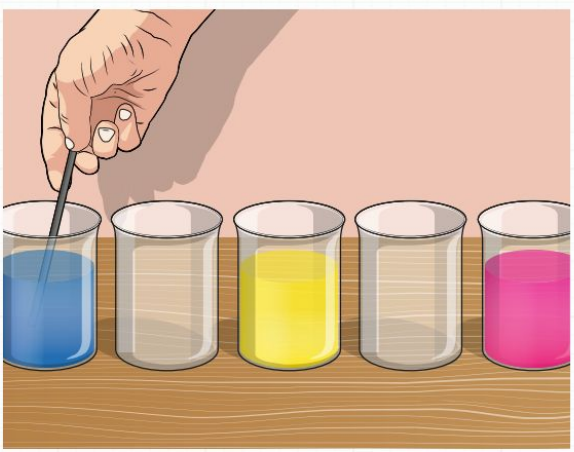
Watch as coloured water moves between cups and changes its hue



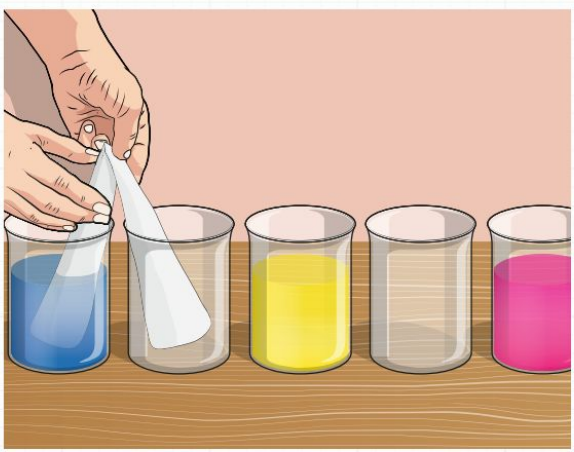
1 Set up your cups
Place your five clear cups in a line, with each around five centimetres apart. Then pour some water into the first, third and fifth cups so that they are half-full.



2 A dash of colour
Add a few drops of food colouring into each water-filled cup. For the best effect, make each a different colour. We have used the primary colours in our experiment: red, yellow and blue.



3 Mix the dye
Give the three cups a stir so that the food colouring is evenly distributed in the water. This will help you to clearly see the water's movement.

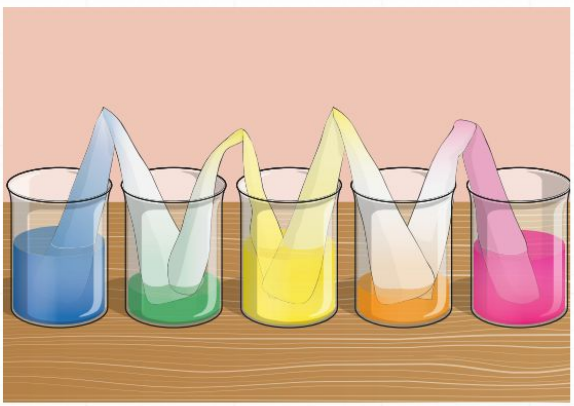


4 Form a bridge
Fold the towels lengthwise so that they are just a few centimetres wide. Then fold them in half the other way so that you have an upside-down 'V'.

NEXT ISSUE...
Make a bug catcher

5 Connect the colours

Now that you have four paper towel bridges, you can place them in the cups. Each one should have one end in water and the other in an empty cup.



7 New hues

Eventually, when the water reaches the end of the paper towel, it will begin to drip into the empty cup. As two colours begin to mix in the middle, watch as the two empty cups fill with new colours.

SUMMARY

As well as creating a spectacular colour spectrum, this experiment demonstrates a natural process called capillary action. This is the ability of water molecules to travel against gravity through small spaces, and is essential for the transport of water upwards through plants' stems. In this experiment, the paper towel contains the same fibres that are found in plants, called cellulose. The water is pulled through the gaps in these fibres as the water molecules are attracted to the cellulose. This attraction is caused by positive and negative charges within the water molecules creating bonds with the opposing charges of the fibre's molecules when placed in the water. Water molecules are also attracted to each other, causing them to stick together. When one molecule is pulled upwards through the paper, the adjoining molecules move with it in a process called cohesion.

6 Walking water

You should soon start to see the water travelling along the white paper towels, colouring them in the process. Track the water as it's pulled across the bridges towards the empty cups.

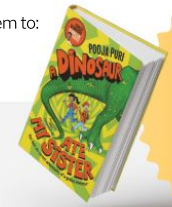
HAD A GO? LET US KNOW!
If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

8 An even fill

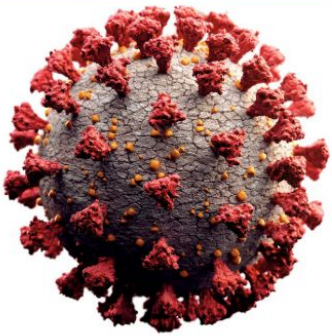
When all the cups have the same level of water inside them, the movement is equal in both directions and the water levels will remain the same.

INBOX
Speak your mind...

Get in touch
If you have any questions or comments for us, send them to:
How It Works magazine @HowItWorksmag
howitworks@futurenet.com howitworksmag



WIN!
A DINOSAUR ATE MY SISTER
Esha Verma has invented a time machine for a competition. But Esha's big sister hijacks the time machine and gets lost in the Cretaceous age.


© Getty

The bumps on coronavirus' surface are called spike proteins, which attach to human cells

Delving into delta
Hi **HIW,**
What is the delta virus? How serious is it compared to COVID-19?
Vanessa Chen

This is a question that many readers may currently be wondering about. Delta is a variant of COVID-19, caused by genetic changes in the coronavirus. Viruses constantly mutate over time, which results in slightly new versions of the virus. Some of these changes will benefit the virus, helping it to spread and thrive, while others might weaken it.

The delta variant was first identified in India in October 2020, and is thought to be more infectious than the original virus. This version of the virus causes similar symptoms in people, but with slightly different outer proteins, it has spread quickly around the globe. Luckily, the relatively small mutations mean that the vaccines that have been developed for COVID-19 also work to protect people from the delta variant.

LETTER OF THE MONTH

Balance in space
Hi **HIW,**
Do astronauts experience disorientation as the balance fluid in their ears is affected by zero gravity? Thank you for the amazing magazine; I particularly liked this month's issue on the Olympic Games.
Albie (age 12)

Thank you Albie for your letter and question. We hope you enjoy this issue as much as the last! You're absolutely right that the ear's balance system relies on gravity to work effectively. In your inner ear, fluid and small, hairlike structures work to monitor the position of your head in relation to gravity. As there is very little gravity in orbit, astronauts spend their time floating around the International Space Station. Because the ear usually uses motion and Earth's gravity to keep us balanced, it's unable to work properly in space.

Our ears have evolved to work well on Earth, but when moving in limited gravity, the information received from the movement of ear fluid doesn't match up with the visual information coming from the eyes. For example, an astronaut may be facing upright, but gravity isn't working to pull the fluid inside the ears quickly to the base. The brain will struggle to interpret the conflicting signals, and many astronauts will feel sick and dizzy upon arrival in space. Over time the ear's balance system is used less, to reduce this conflict. But the astronaut will then face a similar feeling of disorientation when returning to Earth. Their bodies can take a while to remember which way is up and down as their brains refamiliarise themselves with the information being sent from the ears again.


© Alamy

Astronauts Jim Dutton, Stephanie Wilson and Clayton Anderson on the International Space Station


The Sun is 93 million miles away from Earth on average
© Getty

Sun sight
Hi **HIW,**
If the Sun had eyes and was looking directly at Earth, would it see any shadows?
Owen Su

This all depends on the ability and qualities of the 'eyes' you speak of. Human and animal eyes are pretty fragile, and would have no chance of surviving in the temperatures that are produced at the Sun's surface, being near 6,000 degrees Celsius. Also, its high luminance means the eyes would be engulfed by the bright light and would struggle to see anything past it.

If the Sun was able to see the details of Earth clearly, everything facing it would be lit up. Shadows on Earth represent areas that sunlight can't reach due to obstacles blocking its path. This is because light travels mostly in straight lines through space and air particles, filling the air until blocked by a solid object. If these shadowed areas can't see the Sun, then the Sun wouldn't be able to see the shadows either.

Fred's experiments

Hi **HIW,**

I'm writing on behalf of my son Fred (11), who has a subscription to **How It Works**. He absolutely loves it. Last week he decided to try the experiment to extract banana DNA. He was so excited, and delighted when it worked. He and his friend then took the banana DNA to school. He came home so proud as they both received a Head Teacher's Award, and yesterday I received a card from the head teacher to say how impressed she was with his "expert explanation" as to how they'd made the banana DNA. I'm so impressed with the school for taking the time to listen to their enthusiasm, and so impressed with your magazine for setting an experiment that's sufficiently complex to excite him, yet clear enough for him to be able to follow entirely independently. As a mum who is constantly trying to keep up with my son's absolutely wonderful inventions, experiments and views on life and the world, I'm incredibly grateful that he is getting his regular input of expertise and inspiration from you.

Alex H

Hi Alex and Fred. Thank you for your letter. It's great to hear about a reader not just trying out our experiment, but also sharing their findings with friends. It sounds as if you both have a passion for science, and we are so happy you received recognition for this. Hopefully you will keep trying new experiments and inspiring others with your work.

Reader Fred extracted DNA from a banana following an experiment in issue 152 of HIW

The creation of new brain cells is called neurogenesis

Question on the brain

Hi **HIW,**

If your brain dies, can it be brought back to life?

Alice

Good question, Alice. When someone completely loses brain function, they are confirmed to be brain dead. At this point, no life-support machines can assist them, and the damage is irreversible. Other parts of the body can continue to function, but only for a short while. Without the brain, which secretes the hormones needed for basic biological processes, the rest of the body will shut down. However, when just a small part of it dies, the brain can show flexibility and regain function. Other brain cells can adapt, taking on the role of the damaged part.

What's happening on... social media?

This month on social media we asked you: What is the cutest or most interesting baby animal you have ever seen?

@jonesy_rhys
Baby clouded leopard

@scimaxfacts
The most interesting baby animal I have seen is a baby naked mole rat!

@_ross_1468
Koala

@max.fx.shorts
I find baby sheep really cute as they are so small and sweet!

@vikramdiscovers
Otter

@definitely.notmax
Definitely baby chickens as they are so soft!

@maia_h3
Stingray!

NEXT ISSUE...

Issue 155 on sale **2 SEPT 2021**

Available in print from all good newsagents and **magazinesdirect.com**, or as a digital edition for iOS and Android. To enjoy savings on the RRP and to make sure you never miss an issue, check out our subscription offers on pages 18 (UK) and 57 (US).

HOW IT WORKS

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

Editorial
Editor **Ben Biggs**
Senior Art Editor **Duncan Crook**
Research Editor **Baljeet Panesar**
Production Editor **Nikole Robinson**
Staff Writer **Scott Dutfield**
Staff Writer **Ailsa Harvey**
Editor-in-Chief **Gemma Lavender**

Contributors
Andrew May, Andy Extance, Jo Elphick, Laura Mears, Mike Jennings, Mark Smith, Charlotte Hartley, Victoria Williams

Cover images
Getty; HS2 Ltd, Space Science Institute

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

Advertising
Media packs are available on request
Account Manager **Garry Brookes**
garry.brookes@futurenet.com
0330 390 6637
Advertising Director **Matt Johnston**
matthew.johnston@futurenet.com
07974 408083

International Licensing
How It Works is available for licensing and syndication. To find out more, contact us at **licensing@futurenet.com** or view our available content at **www.futurecontenthub.com**.
Head of Print Licensing Rachel Shaw

Subscriptions
Enquiries **help@magazinesdirect.com**
UK orderline & enquiries **0330 333 1113**
Overseas order line & enquiries **+44 (0)330 333 1113**
Online orders & enquiries **www.magazinesdirect.com**
CRM Director **Louise Dudfield**

Circulation
Head of Newstrade **Tim Mathers**

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

Management
Managing Director **Sarah Rafati Howard**
SVP Magazines **Angela O'Farrell**
Commercial Finance Director **Dan Jotcham**
Head of Art & Design **Greg Whittaker**
Chief Growth Officer **Claire MacLellan**

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

FAST FACTS

Amazing trivia to blow your mind

13%

THE AMOUNT OF TIME YOU SPEND NOT FOCUSING ON ANYTHING

£100 MILLION

THE APPROXIMATE VALUE OF ALL ONE-PENCE COINS IN CIRCULATION IN THE UK

2,617

THE AVERAGE SMARTPHONE OWNER TOUCHES THEIR PHONE THOUSANDS OF TIMES A DAY

1918

STONEHENGE WAS PRIVATELY OWNED UNTIL THE END OF WORLD WAR I

1913

JUST OVER 100 YEARS AGO, IT WAS STILL LEGAL TO SEND CHILDREN BY POST IN THE US

TWITTER IS ALSO A 19TH-CENTURY NAME FOR AN ABSCESS ON A HORSE'S FOOT

DINOSAURS LIVED ON EARTH BEFORE SATURN GOT ITS RINGS

13 MILLISECONDS

ASTRONAUT SCOTT KELLY WAS A TINY BIT YOUNGER THAN HIS TWIN BROTHER AFTER HE RETURNED FROM THE ISS

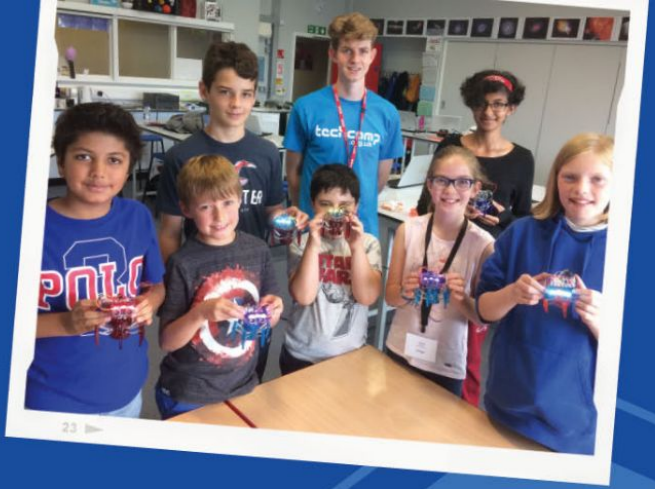
200 MILLION

THE DROPLETS IN A COUGH CONTAIN MILLIONS OF VIRUS PARTICLES

38 MINUTES

THE SHORTEST WAR EVER FOUGHT, BETWEEN BRITAIN AND ZANZIBAR IN 1896, DIDN'T LAST VERY LONG

ICE CREAM IS A SOLID, A LIQUID AND A GAS



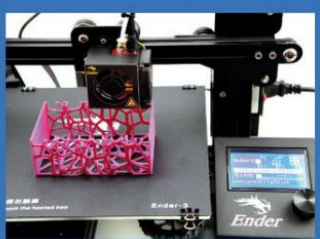
Covid-safe Tech Camps

techcamp.org.uk

Hard year for the KIDS?

Send them on the ultimate Tech staycation at our Covid-safe camps

- Residential week-long camps in single en-suite rooms
- Non-residential options in London, Abingdon & Winchester
- 100% cancellation refund



Build your Own...

- 3D GAMES
- RACING DRONES
- GAME CONSOLES
- FIGHTING ROBOTS
- HIGH-SPEED CARS
- 3D PRINTERS

Reserve Today
www.techcamp.org.uk
0118 380 5678

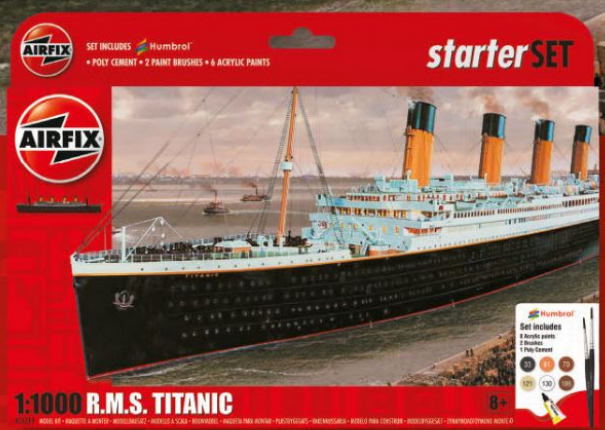
R.M.S. TITANIC

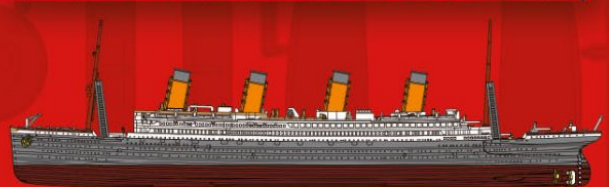
1:1000 A55314

The RMS Titanic will go down in maritime history as not just the largest and most luxurious passenger ship afloat upon its launch in 1912, but also as the most infamous, due to its now legendary maiden voyage. Despite warnings given to it by other ships, the Titanic steamed into the side of an iceberg on the night of the 14th April 1912. This tore a large hole in the side of the hull, overwhelming the ship's famed, watertight compartments. As water poured in, the order was given to abandon ship, with women and children being prioritised over the men. Of the 2224 passengers on board, just 711 survived, with the vast majority being women and children of the first and second class. Today, more than 100 years after its maiden voyage and sinking, the legend of the Titanic continues to capture the imagination of the world.

Ideal for beginners or those with less display space, this set comes complete with six paints, glue and two paintbrushes. A fantastic addition to your collection or a welcome gift for any time of the year.

Length 270mm Width 30mm Pieces 80





Display stand included

Airfix.com
and all good retail stockists
You Tube

Start as you mean to finish
Humbrol

Use your smartphone to find out more!

HORNBY HOBBIES
Official Product

9000