



THE SCIENCE AND TECH OF

BBC

DOCTOR WHO

HOW IT WORKS



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PLUS WWI TANK HARRY HOUDINI CT SCANS

FUTURE
ISSUE 117

BBC

DOCTOR WHO

Officially licensed Doctor Who first-of-kind...

TARDIS Mechanical Watch

KEEP TRACK OF YOUR 'TIMEY-WIMEY STUFF' IN TIME LORD STYLE

Yours for just £29.99 now,
followed by four further interest-free instalments of £29.99



In his many adventures the Doctor has to manage time, space and relative dimensions: luckily though, those of us on Earth just need to manage our time. Now you, or someone you love, can do just that with this **handcrafted mechanical watch**.

Knowing the Doctor's fondness for mixing classical and high-tech, this watch combine Roman numerals and a TARDIS-blue leather strap with a mechanical movement, exposing the inner workings of the watch.

In a reference to the opening sequences of Doctor Who, the watch face also features **a gold-plated time spiral** - the mysterious 'Time Vortex' - with a miniature TARDIS tumbling along it. On the rear of the casing is engraved the name of the watch and Time Lord symbols from Gallifrey.

This high quality collector's timepiece is official merchandise of Doctor Who and will only be available from The Bradford Exchange. It will be covered by our **120-day guarantee**. Applications are now open and this offer is likely to attract considerable interest, and not just from fans of the Time Lord, so don't delay your application - apply now.



Watch face:
42mm
diameter (1.65")
inc casing.
Strap: 180mm
length
(7") x 20mm
width (0.75")



KEY DETAILS

DESIGN: 'Time Vortex' spiral with miniature TARDIS detail and exposed mechanical movement.

HANDCRAFTED: Ancient Roman numerals combine with futuristic 'Time Vortex' spiral to create a watch that doesn't conform to conventional time and space - just like the Doctor!

HIGH SPECIFICATION:

Intended as a collector's timepiece, this watch features a visible mechanical movement, gold plated casing and TARDIS-blue leather strap.

YOURS FOR ONLY £149.95 (plus £9.99 S&H)* and subject to availability. That's only five interest-free instalments of £29.99 each. Pay nothing now.

FORMAL APPLICATION: THE DOCTOR WHO TIME VORTEX MECHANICAL WATCH

DO NOT SEND ANY PAYMENT WITH THIS APPLICATION: if successful, you will be notified in writing within 7 days

YES, I wish to apply for _____ (Qty) **Doctor Who Time Vortex Mechanical Watch** for just £149.95 (plus £9.99 S&H)* subject to availability. That's just five interest-free monthly instalments of just £29.99 each. This handsome collector's timepiece will be accompanied by both a Certificate of Authenticity and custom-designed presentation case. **I do not need to send any money now.**

If my application is successful I will be notified in writing within 7 days. I understand the watch is covered by your 120-day money-back guarantee. I confirm I am 18 years or over.

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BBC

DOCTOR WHO



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The magazine that feeds minds!



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Doctor Who celebrates its 55th anniversary when it returns to our screens this month. The hit show is the world's most prolific sci-fi series, with over 800 episodes, a movie, spin-off shows and millions of dedicated fans all over the world. But it's not all fantasy – some of the principles explored in the series, from time travel to regeneration, have links to real-world scientific concepts and technologies.

Also this month, we prepare for Halloween with our spooky special, revealing the science behind freaky phenomena. Meanwhile, over in the history section we tour the Tower of London to reveal its chilling history as both a palace and a prison. October also marks NASA's 60th birthday, so what better time to look back at some of the space agency's greatest achievements. Enjoy the issue!

Jackie **Jackie Snowden**
Editor

"The clouds of the Ghost Nebula look like human figures fleeing from a phantom..."
Creepy cosmos, page 48

Meet the team...



Charlie G
Production Editor

I was rather intrigued to read about out-of-body experiences in this issue. I reckon if I had one I'd be beside myself!



Baljeet
Research Editor

To celebrate the 60th anniversary of NASA this month we take a look at some of its greatest achievements (page 42).



Charlie E
Staff Writer

A ferocious prehistoric predator, with a giant head, huge horns... and tiny, useless arms? Meet the Carnosaurus on page 58!



Scott
Staff Writer

Double double, toil and trouble, tongues and worms make cauldrons bubble. For potions deadly every time, head over to page 39.



Duncan
Senior Art Editor

From Daleks to Weeping Angels, this issue's Doctor Who special is fraught with danger. Be careful not to blink when you get to page 26!

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MEET THIS ISSUE'S EXPERTS...



Ella Carter
With a marine science degree, Ella is fascinated by our oceans. She writes about all aspects of the natural world, from blue whales to barnacles.



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



Jo Stass
Jo has been a writer and editor for over six years. She is particularly interested in the natural world and technological innovations.



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



Jonathan O'Callaghan
With a background in astrophysics, former **HIW** and **All About Space** journalist Jonathan enjoys delving into the wonders of space.



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



Lee Cavendish
Avid stargazer Lee writes for our sister magazine, **All About Space**, and has a degree in observational astronomy.



Stephen Ashby
Stephen has been a writer and editor for over seven years. He is endlessly intrigued by technology and Earth science.



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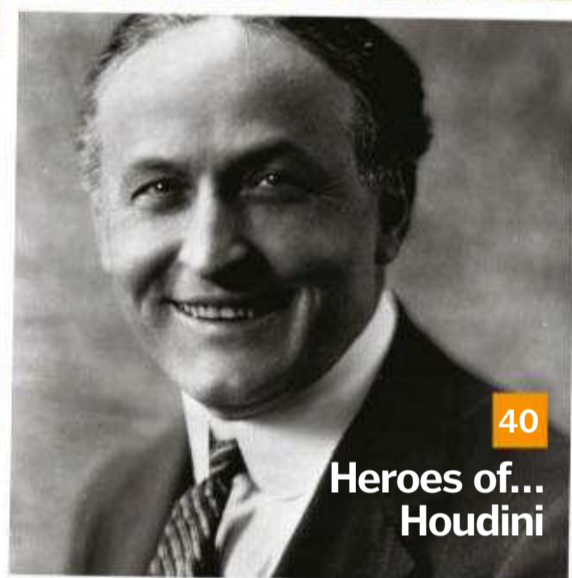
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The Tower of London



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GO TO PAGE 32 FOR GREAT DEALS



Steve Wright
Steve has worked as an editor on many publications. He enjoys looking to the past, having also written for **All About History** and **History Of War**.



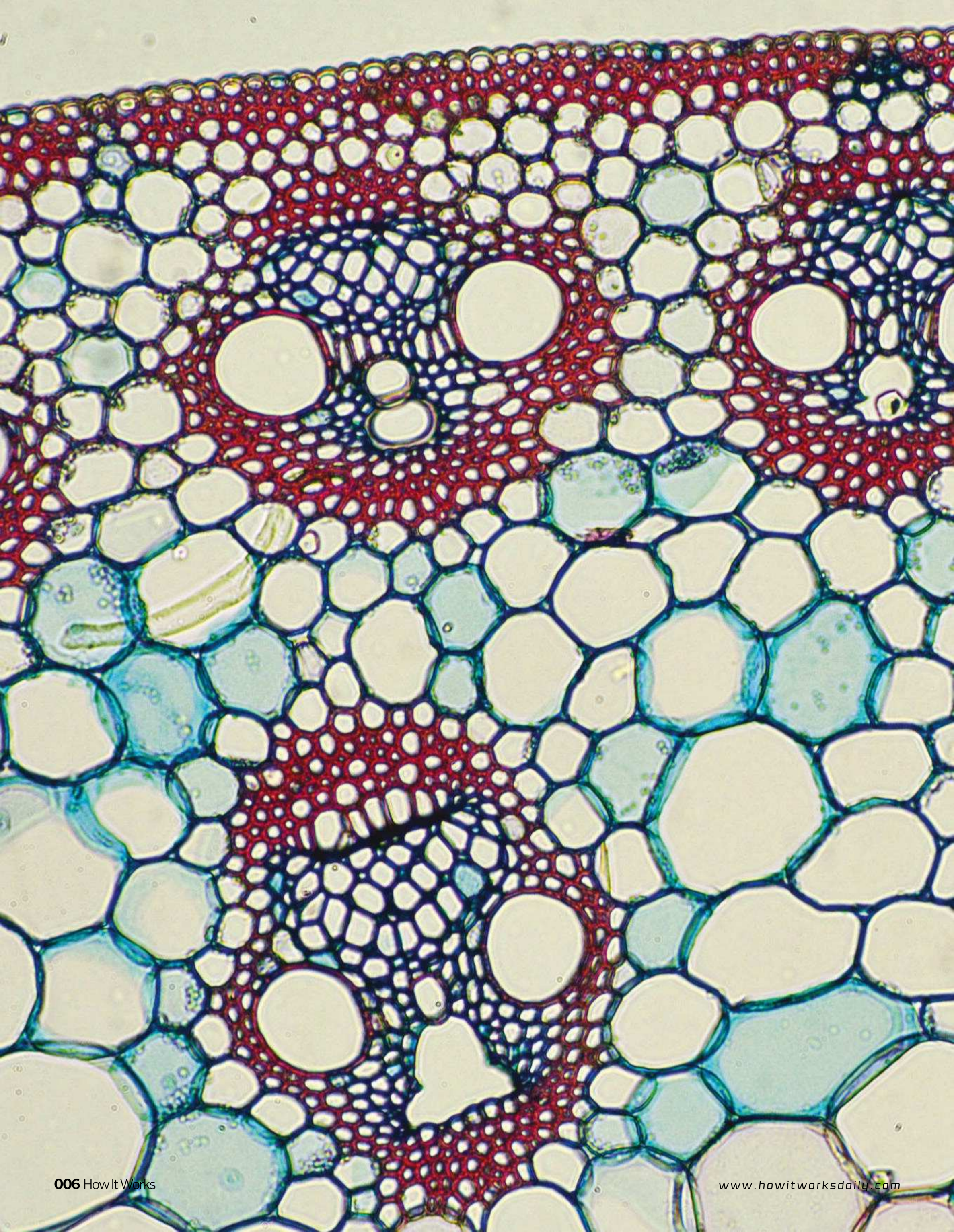
Tim Williamson
History Of War Editor Tim has a passion for all things military but studies and writes about a range of historical eras.



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



Victoria Williams
Evolutionary biologist and **World of Animals** writer Vicky is fascinated by the natural world and happiest when she's outdoors.





Phantom phloem

The spooky, wide-eyed faces in this image are in fact vascular bundles in a cross-section of an Indian maize stem. Vascular bundles contain phloem and xylem cells, which transport food, water and minerals throughout the plant.



Bleeding fungus

This devil's tooth fungus (*Hydnellum peckii*) secretes a deep red, sap-like substance. If its roots get very wet, moisture is forced to the fungus' surface by osmosis and oozes out like blood. The crimson colour comes from pigments within the organism.





Mighty megabat

The Indian flying fox (*Pteropus giganteus*) is one of the largest bat species in the world, with a wingspan of up to 1.5 metres. This photo shows the arm structure, visible through its membranous wings, revealing how the arrangement of its elongated finger bones form a wing frame.



The Sahara engulfs most of North Africa, covering approximately 9.4 million square kilometres

ENVIRONMENT

Simulation promises rain for the Sahara

Solar and wind farms could bring water and greenery to this giant desert

With its blistering sunshine and strong winds, the Sahara attracts numerous energy projects, but new research suggests that these wind and solar farms are doing more than just producing clean renewable energy.

"We found that the large-scale installation of solar and wind farms can bring more rainfall and promote vegetation growth in these regions," explains Eugenia Kalnay from the University of Maryland, US. "The rainfall increase is a consequence of complex land-atmosphere interactions that occur

because solar panels and wind turbines create rougher and darker land surfaces."

A modelling technique has revealed that the environment around the turbine blades and solar panels may be transformed, which could more than double rainfall in the area.

"As a result vegetation cover increases by about 20 per cent," says the first author of the study, Yan Li. "This increase in precipitation in turn leads to an increase in vegetation, creating a positive feedback loop."

The transformation is a result of the turbines contributing to the mixing of heat in

the atmosphere by pushing the warmer air down to the surface and increasing land surface friction, which leads to a higher chance of rain. Solar panels also reduce the amount of light reflecting from the desert, further increasing the likelihood of rainfall.

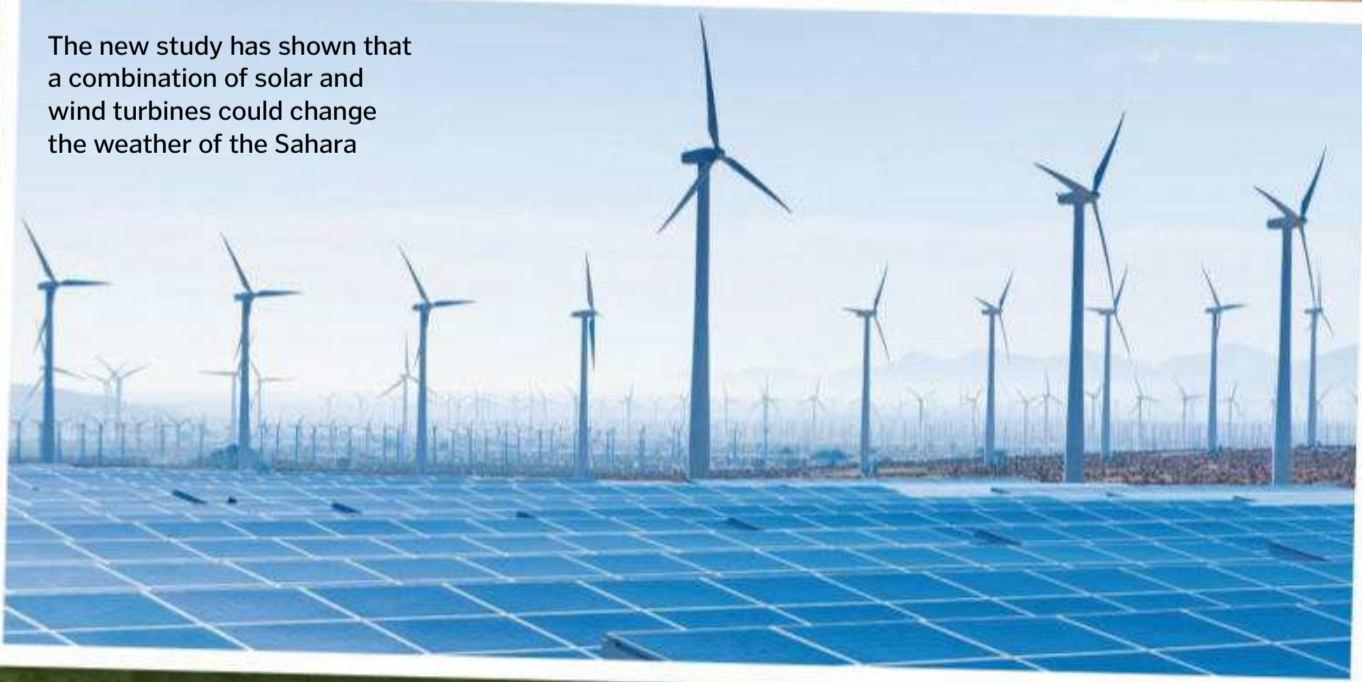
The simulation was based on a solar farm about the size of the United States built alongside wind turbines covering around 20 per cent of the Sahara. If a project of this size was established, it would mean not only the greening of the desert but also the production of significant amount of green energy.



The cycles of the Sahara

The Sahara is hot, dry and mostly devoid of any vegetation. The central and eastern parts see almost no rainfall at all. But this is just part of the wet and dry cycle that this ancient piece of land undergoes every 41,000 years. Changes in the North African climate cycle occur as the Earth's tilt varies between 22.1 and 24.5 degrees. The Sahara will naturally become green again in an estimated 15,000 years, but until then half of the desert will receive less than 2.5 centimetres of rain per year, while the rest receives up to ten centimetres.

The new study has shown that a combination of solar and wind turbines could change the weather of the Sahara



Some specialised plants are still able to find a way to survive in the arid conditions of the Sahara

© NASA/Getty

HISTORY

'Siberian unicorn' skull discovered in Kazakhstan

The extinct species was walking on Earth as recently as 29,000 years ago

Tens of thousands of years ago, a real-life unicorn walked our planet. But these creatures weren't like the magical glittering equines of children's books. Instead, they were shaggy-haired giants, each with a long single horn extending from their forehead. The Siberian unicorn (*Elasmotherium sibiricum*) would

The Elasmotherium is an extinct genus of giant rhinoceros that lived in Eurasia during the Pliocene and Pleistocene eras



have stood at roughly two metres tall, 4.5 metres long and weighed roughly four tons – think mammoth rather than horse.

The almost perfectly preserved skull of one of these beasts was discovered in 2016 in the Pavlodar region of Kazakhstan. Researchers expect the animal was a very old male, but they have not established a cause of death.

Using radiocarbon dating techniques, they have discovered that it would have walked on Earth about 29,000 years ago. Before the finding of this skull it was thought they went extinct much earlier in history, nearer 350,000 years ago. This means that the Siberian unicorn would have walked on the Earth alongside early humans!



SCIENCE

You'll see male spiders at 19:35

A free app called 'Spider in da House', created as part of a citizen science project, has made some interesting arachnid discoveries. Between August 2013 and January 2014, 9,905 spider sightings in homes across the UK were recorded. The results showed 82 per cent of sighted spiders are male and are logged between 6pm and 9pm.



SPACE

Lost lunar orbiter finally found

The SMART-1 lunar orbiter was crashed into the surface of the Moon on 3 September 2006 and has only just been located. Images captured by NASA's Lunar Reconnaissance Orbiter last year show the location as 34.262 degrees south by 46.193 degrees west.



TECHNOLOGY

Smart tech to fight sepsis

A paper published in the *Canadian Medical Association Journal* has called on researchers to consider using smart technology and artificial intelligence to better diagnose fatal sepsis in children by optimising the algorithms within existing technologies.

SCIENCE

CRISPR relieves muscular dystrophy symptoms

The gene-editing technology has enjoyed success in treating dogs with the condition

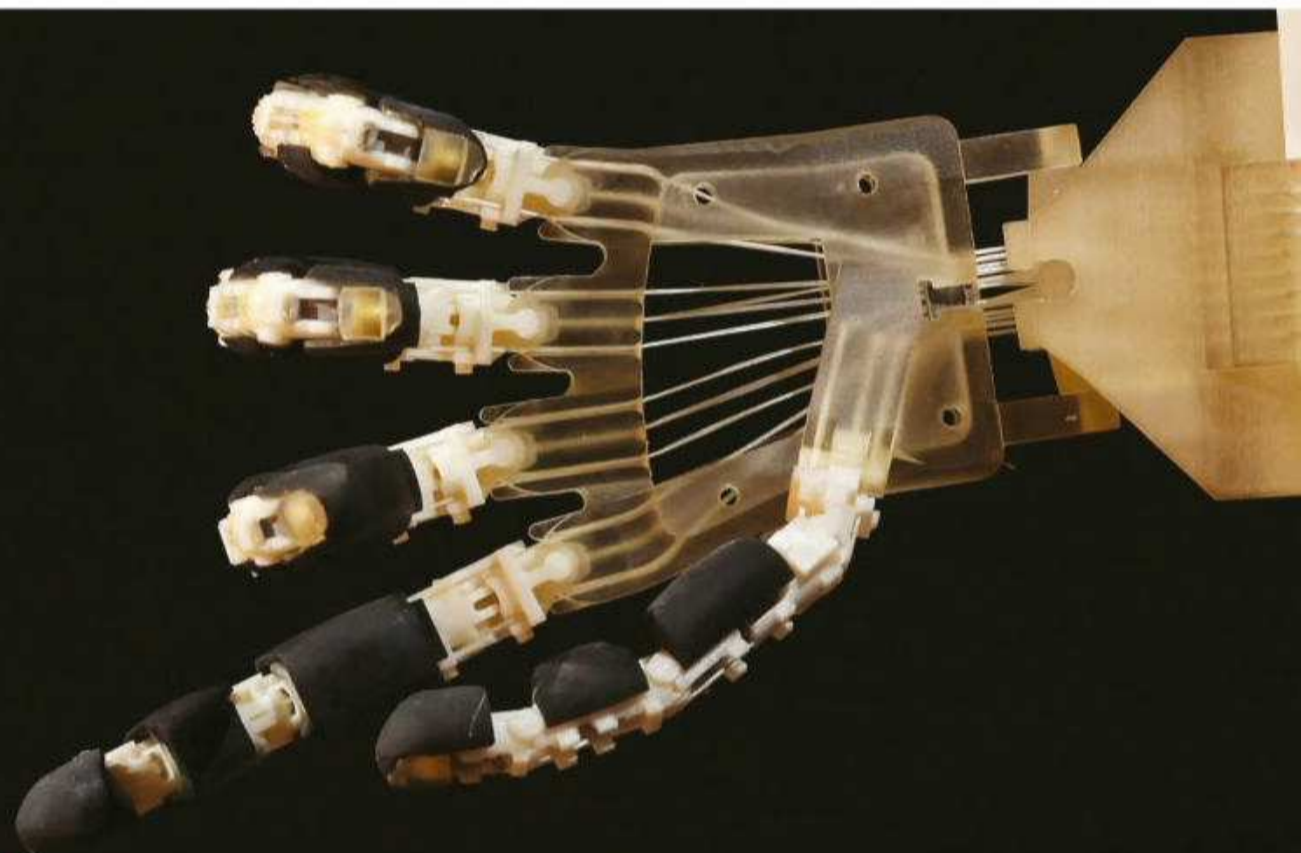
CRISPR/Cas9 has been used in a study to relieve symptoms of muscular dystrophy in beagle puppies. The debilitating condition causes severe muscle weakness and degeneration and is caused by a genetic mutation. CRISPR/Cas9 is a revolutionary DNA-editing molecular tool that can repair genetic mutations, and for the first time it has been successful in treating the condition in a larger mammal. The research being carried out at the University of Texas is among the first to use the technology in an attempt to cure the disease. It's hoped that the work will be a step towards treating humans with muscular dystrophy.

CRISPR/Cas9 can target genes and disable or repair them or insert new bits of DNA



TECHNOLOGY

New robot has learned how to delicately hold objects



The neural network designed by MIT is one step closer to intelligent grasping systems

Grasping systems of modern robotics come in two groups – either they are taught task-specific actions or they have generalised grasping algorithms. If we want robots to start sorting out our laundry or washing our dishes then they need to start thinking more like humans.

A new neural network developed by MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) can inspect an object, generate an internal impression to learn a sense of its shape, and then go around the task of picking it up. It might sound easy for us, but it's a true feat for robots.

Further development of artificial intelligence is needed to give robotic grasping systems more control and autonomy

TECHNOLOGY

NEC hosts UK's biggest game festival

Thousands of fans gathered at Birmingham's main arena to attend this year's Insomnia63

A sea of gaming enthusiasts packed out the NEC as they sought to get their hands on the latest games and tech. From *Fortnite* to drone football, gamers put their skills to the test in championships and competitions over the four-day festival.

HTC Vive and Playstation VR were popular features this year, giving attendees the chance to test out the new *Ready Player One*, *Beat Saber* and *Firewall Zero Hour* VR games. The long-awaited *Spider-Man* PS4 game was also available for players to experience ahead of its release date of 7 September (check out our review on page 82).

The event not only featured the games of the future but also much-loved games of years gone by. In the retro zone players could

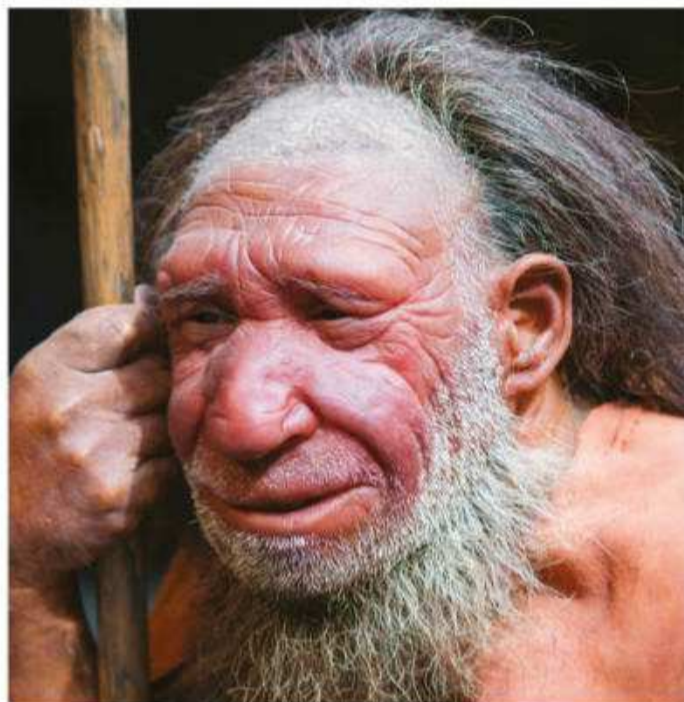
relive classic gaming memories on Sega Mega Drive and PlayStation One consoles, along with pinball machines and legendary *Pacman* arcade games.

14 world records also broken at the event, including the fastest time to build a three-storey wooden fort in *Fortnite* by Alex Fern Newby, achieved in 50.12 seconds. Thomas Hall and Alex Dunsmore also broke the world record for completing the *Trackmania Turbo* racetrack in one minute 0.78 seconds.

Not just a computer screen event, live shows including NXT UK wrestling matches, a drone football tournament called 'flightball' and appearances of popular YouTubers such as Alfie Deyes also entertained the thousands of visitors.



Around 70,000 people attended the event over four days



HISTORY

Cold may have killed Neanderthals

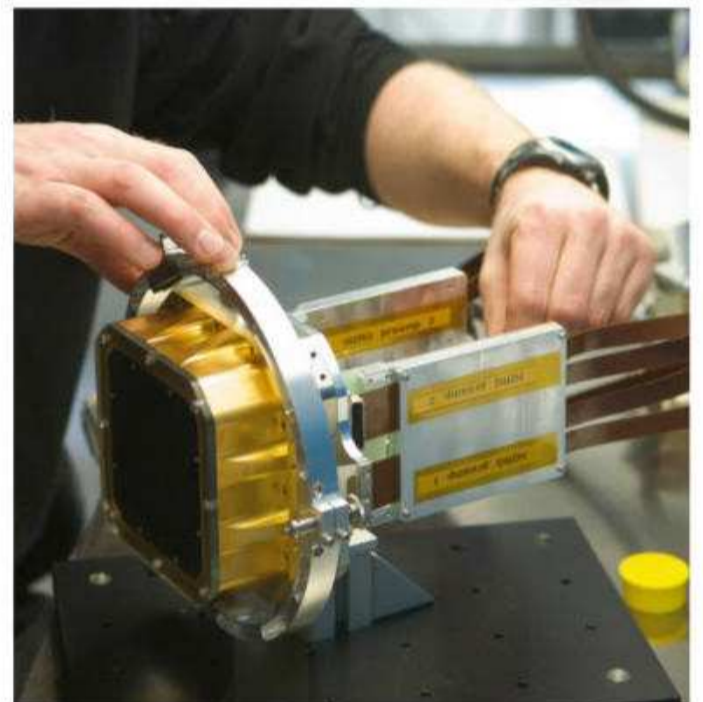
A team of researchers have compared palaeoclimate records against Neanderthal archaeological records and found a correlation between cold periods and the absence of Neanderthal tools. This suggests population numbers reduced at these times, implying that cold conditions contributed to their extinction.



ENVIRONMENT

Spix's macaw is the first bird to go extinct this decade

The Spix's macaw is one of eight species having its status changed to Extinct In The Wild after a study by Birdlife International. The eight-year project showed that, for the first time, mainland extinction is surpassing island bird extinctions.



SPACE

Millions invested into detection and imaging technology

€17 million (approx. £15 million / \$20 million) has been invested by the ATTRACT project – in which the European Southern Observatory is a partner – to fund 170 projects developing breakthrough detection and imaging technologies in Europe.

SCIENCE

Half of airport trays contain traces of viruses

Cold and flu viruses were found on half of the trays sampled

A collaborative study conducted by the National Institute for Health and Welfare in Finland, the University of Eastern Finland and the University of Nottingham has revealed that half of airport security trays have traces of cold or flu viruses. Samples were taken from various surfaces at Finland's main international airport in

Helsinki in 2016. The study was conducted at the height of the country's flu season, with DNA samples swabbed from tray surfaces. The results of the study showed that four out of the eight trays sampled held traces of viruses such as the common cold and flu. The results act as a reminder to use hand sanitisers before and after airport security.

Samples were taken weekly at three different times of the day between 4 and 17 February 2016



The EQC boasts an impressive range of over 450km on a single charge

TRANSPORT

The car to make Elon tsk

Mercedes-Benz reveals the new all-electric EQC SUV ahead of going on sale next year

Tesla has been the leading developer and manufacturer of electric cars in recent years, but could Mercedes-Benz be about to give Mr Musk's company a serious run for its money by shaking up the electric car market?

The EQC is the first of its kind for Mercedes-Benz, who are dedicated to converting to electric vehicles. Its sleek and stylish design houses two electric motors, one to control the front wheels and the second to power the rear, and it is powered by an 80-kilowatt-

hour battery. Mercedes claims the EQC will have a total power output of 300 kilowatts and reach 100 kilometres per hour in just 5.1 seconds. The EQC is said to be the first in a growing family of all-electric vehicles from Mercedes-Benz.

It is estimated that The Ocean Cleanup's systems will be able to remove half the Great Pacific garbage patch in just five years



The skirt (pictured below) will extend beneath the float to sweep up plastic debris near the surface



ENVIRONMENT

Ocean clean-up underway

The world's first system designed to remove plastic from our oceans launches from San Francisco Bay

On 8 September, The Ocean Cleanup's System 001 (known as Wilson) began its epic journey towards the Great Pacific garbage patch – a huge mass of floating debris caught by circulating currents in the middle of the Pacific Ocean.

The system consists of a 600-metre-long float with a three-metre-deep skirt attached below to catch debris. This creates a kind of artificial coastline but is not closed like a net, so marine wildlife won't get trapped. It floats along the surface propelled by the currents, waves and wind – just as ocean plastics are. Gradually, the ends of the linear system curve around towards each other to form a C shape, concentrating the collected plastic in the middle. Every few months, vessels will collect the waste and take it back to shore for proper recycling.

Wilson will first be tested 463-649 kilometres offshore for a few weeks before completing its journey to the Garbage Patch over 2,200 kilometres away to begin the clean-up in earnest.



This innovative system is the brainchild of 24-year-old Dutch inventor Boyan Slat (centre), founder and CEO of The Ocean Cleanup

SPACE

New satellite will watch the world's ice and forests

NASA has launched the newest version of a global monitoring satellite, which sends thousands of lasers down to the surface

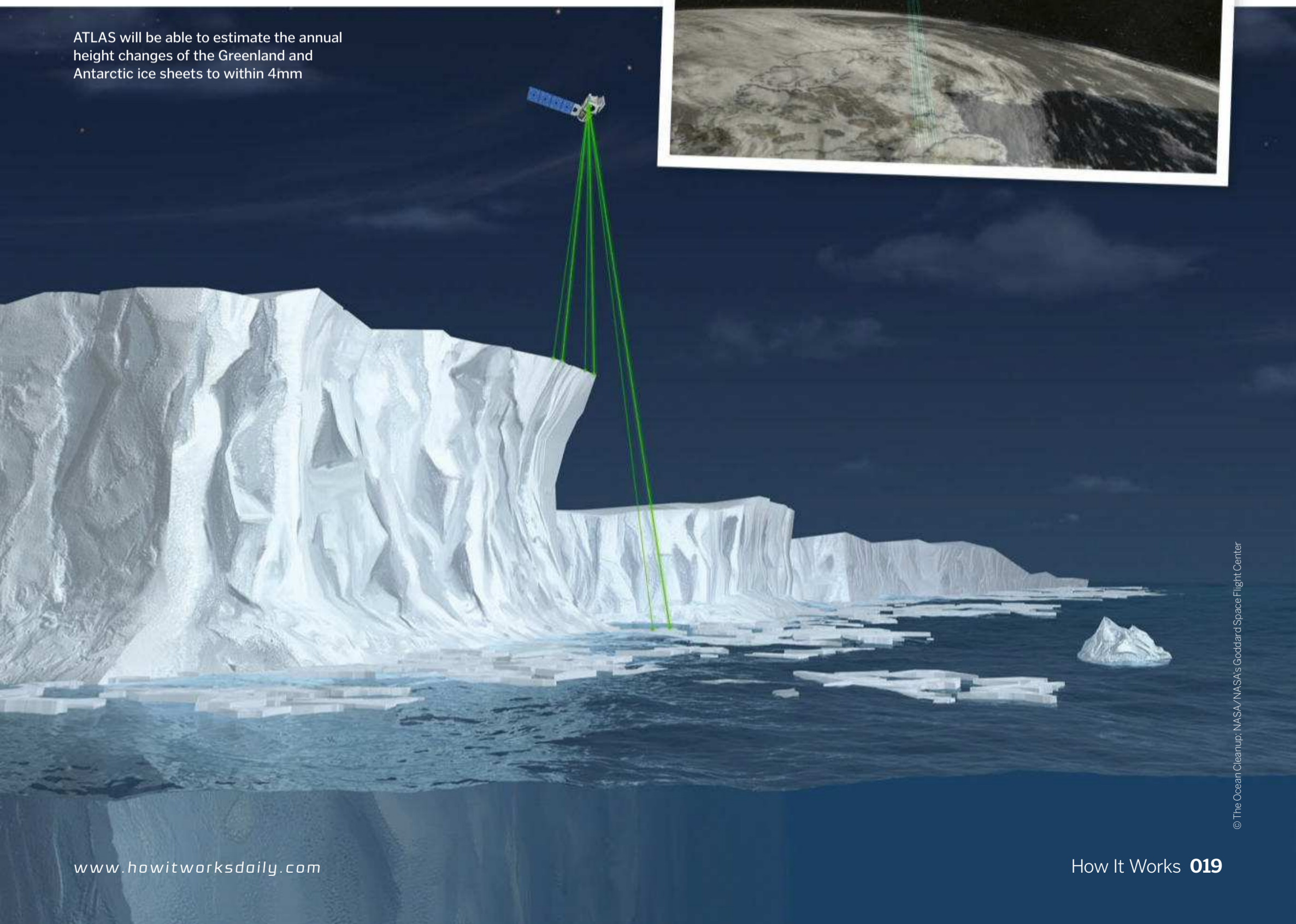
Photons emitted from ATLAS are precisely timed during the journey from orbit to Earth and back again

On 15 September at 9:02am EDT, NASA launched the Ice, Cloud and land Elevation Satellite-2 (ICESat-2) into orbit from Vandenberg Air Force Base in California. The satellite's primary objective will be to collect data about the Earth's frozen and icy regions, known as the cryosphere, and forests.

A single instrument called the Advanced Topographic Laser System (ATLAS) will measure the heights of ice sheets, glaciers, sea ice, land surface, water, clouds and vegetation to build a more precise picture of our planet. ATLAS will send 10,000 laser pulses a second to the Earth's surface, and about 20 trillion photons will leave the ATLAS box structure with each pulse. However, only a dozen or so will return to the ATLAS telescope to be recorded. ATLAS can then use the travel time of these laser pulses to measure ice sheet elevation, sea ice thickness and forest height more accurately than ever before.



ATLAS will be able to estimate the annual height changes of the Greenland and Antarctic ice sheets to within 4mm



WISH LIST

The latest must-have technology



Dyson Pure Hot + Cool Link™ purifier

■ Price: £499.99 / \$599.99 / dyson.com

You can't see pollution in the home – it's not like the dark smog hanging over a city. Instead, the microscopic allergens and atmospheric pollutants hang in your house invisible to the naked eye. While conventional vacuums tackle the pollutants on your floors and other surfaces, the Dyson purifier is the solution to cleaning your air, as well heating or cooling your room to a comfortable temperature.

This hi-tech purifier can remove 99.95 per cent of allergens and pollutants as it cycles air through its filter system. The 360-degree glass HEPA filter can capture microscopic particles from all angles, including pollen, bacteria and dander from pets. You can also connect the device to the Dyson Link app to monitor the purification of the air in your home, receive information on indoor air quality, and schedule to make sure the device is working when you need it.



Sony XB501G EXTRA BASS™ Speaker

■ Price: £300 / \$299.99 / sony.com

Sony have created the perfect portable party speaker in the XB501G EXTRA BASS™, which can give any event a festival feel. Thanks to the Digital Signal Processor (DPS) technology, the XB501G can enhance your music to produce powerful sounds.

While its rounded appearance may make it look like an old-school television, its shape serves to minimise vibrations and decrease sound interference. Then there is its water- and dust-resistant casing, which means that whether it's poolside or sitting on the patio, your party sound is safe, and thanks to a 16-hour battery life it can play all night long.

With the help of the built-in Google Assistant, the XB501G can be voice activated to play your favourite playlists or check the weather or traffic reports. It also has the ability to integrate seamlessly with your other smart devices.

Anki Vector

■ Price: £249.99 / \$249.99 / anki.com

If you've been dreaming of your very own robot sidekick then you're in luck. The Anki Vector is a home robot full of personality. With his charming facial animations and expressive movements, Vector is more of an addition to the family than to your gadget collection.

Vector is powered by innovative AI and equipped with a whole host of advanced technology, including a Qualcomm 200 Platform (powerful enough to run a smartphone), an HD camera and a beamforming four-microphone array. Vector is fully autonomous and always aware of its surroundings thanks to its array of visual and infrared sensors.

On top of this, Vector can recognise and remember faces, map out the room and even search the web. You can ask him questions if you lead with, 'Hey, Vector. I have a question...' – he will find the answer in no time. It can also lend a hand around the house by showing you the weather, setting a timer for your cooking, taking photos and much more.

Thanks to cloud connectivity, Vector can also be upgraded with new features as they become available. Possible future abilities include smart home integration, music recognition and messaging services. The future's bright for this handy little bot.



Siesta Charge

■ Price: £129.99 (approx. \$170) / pure.com

While you recharge in the comfort of your bed, your phone can do the same with the Siesta Charge DAB+ alarm clock. The Siesta Charge combines the functionality of a radio alarm clock with the finesse of a wireless charging station and speaker. It's compatible with any Qi-enabled smartphone for wireless charging, but also comes with a standard USB slot for connected charging if required.

You can select from up to 40 preset DAB/FM stations or use the Siesta Charge as a speaker to stream songs using Bluetooth and an accompanying app. The Siesta is packed with extra features such as sleep and kitchen timers, an auto-dimming display and a headphone connection, combining your technological bedside routine in one compact device.



Microsoft Surface Pro 4

■ Price: From £799 / \$799 / microsoft.com

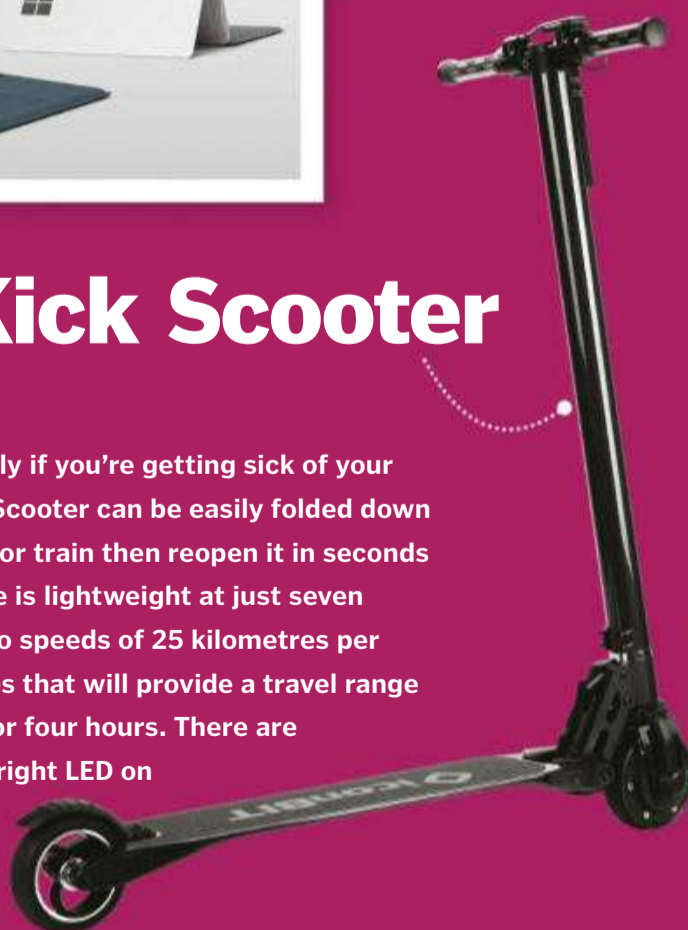
The versatility of this laptop is fantastic. You can work in Laptop Mode by opening the built-in Kickstand and using the full-sized keyboard, or Studio Mode by lowering the Kickstand to sit at the perfect angle for reading, writing or drawing, or completely close the Kickstand to use the Surface Pro as a tablet. It's perfectly designed for working on the go due to the all-day battery life and portability; it's so lightweight (under 800 grams) that it's really easy to just pop into your bag and take it with you. It's also super quiet thanks to a new hybrid cooling system and can easily run the most powerful apps using the Intel® Core™ processor, including Windows Ink and 3D effects and full Windows 10 and Office, all on a vibrant display.



Iconbit Smart Kick Scooter

■ Price: £499 (approx. \$655) / iconbit.co.uk

This gadget is part fun and part practical, particularly if you're getting sick of your boring drive into the office. The Iconbit Smart Kick Scooter can be easily folded down into a compact size so you can carry it onto the bus or train then reopen it in seconds when you need to ride again. The carbon-fibre frame is lightweight at just seven kilograms, and the 350-watt motor can get you up to speeds of 25 kilometres per hour! The scooter is powered by lithium-ion batteries that will provide a travel range of up to 30 kilometres and can charge in just three or four hours. There are some great safety features too, including an ultra-bright LED on the front and an electronic braking system that recharges the battery as you brake.



www.howitworksdaily.com

APPS & GAMES



Bridge Constructor

■ Developer: ClockStone STUDIO

■ Price: Free / Google Play / App store

Put your engineering skills to the test with the Bridge Constructor. Build bridges over valleys, rivers and canals and discover if you have what it takes to build a sturdy span structure.



History Time

■ Developer: Kabum42

■ Price: Free / Google Play

How well can you navigate through the events of history? History Time is an addictive trivia game that tests your knowledge about the chronology of the world's events in relation to each other.



Ultimate Dinopedia

■ Developer: National Geographic

■ Price: £4.99 / \$4.99 / App store

With over 700 dinosaur species to learn about through collections of stories, facts and size comparisons, not to mention beautiful illustrations, this app (based on National Geographic's book of the same name) is both entertaining and educational.



Waze

■ Developer: Waze

■ Price: Free / App store / Google Play

Thanks to millions of users uploading information on traffic, roadworks and accidents in real time, this easy-to-use map with GPS, traffic alerts and live navigation is a fantastic way to help you plan your journeys and get a heads up on what you might encounter on your route.





THE SCIENCE AND TECH OF DOCTO

From the Daleks to Dyson spheres, discover the science and tech behind the Time Lord

Words by **Scott Dufield**

The Doctor has always stretched the boundaries of space and time, literally. Since it first hit the TV screens in 1963, *Doctor Who* has continued to stretch our imaginations, journeying to alien worlds in far-off galaxies and delving into the complexities of time travel. Science and science fiction are carefully intertwined to create an entertaining combination of fantasy and reality, supported by somewhat accurate depictions of various scientific principles. From venturing through wormholes to battling the Cybermen, *Doctor Who* is filled with hidden science that seems completely impossible.

As a Time Lord, the Doctor is attuned to the fine stitches in the fabric of space-time and how best to navigate through them. The show tackles both the limitations and endless possibilities of space and time travel according to Einstein's theories of special and general relativity. Even creating violent villains based on quantum mechanics (the Weeping Angels) and advanced bionics (the Cybermen) or harvesting energy from the stars (like the Tardis) are just some of the ways *Doctor Who* is keeping science at the forefront of science fiction.

BBC

RWTHO



THE SCIENCE OF SPACE-TIME

We often think about space and time as two different entities. Space is perceived in three dimensions, but we view time in a singular dimension, always flowing 'forward' into the future. However, the truth is that space and time are integrated together as the four-dimensional space-time, or as the Doctor puts it, "a big ball of wibbly-wobbly timey-wimey...stuff".

Space-time can be thought of as a stretchy sheet, and masses – such as planets – sitting in space-time distort it in the same way a bowling ball would create a dip on the surface of a trampoline. If a bowling ball's

mass were great enough, the dip would continue to travel downwards and potentially connect with another sheet. This would theoretically connect the two sheets of space-time by a tunnel called a wormhole, or an Einstein-Rosen bridge. In theory, these connected folds of space-time could be used to create an interstellar shortcut between different regions of the universe.



"Mass distorts space-time like a bowling ball would create a dip on the surface of a trampoline"

General relativity

Presented in 1915, this theory explains space-time



Free-fall and floating

Einstein explained in his theory of general relativity that free-falling is the same as floating in space, therefore Newton's theory of gravity alone couldn't be correct.



Gravity and acceleration

Accelerating in a vehicle feels the same as the effects of gravity. Einstein postulated that both are caused by curved paths through space-time.

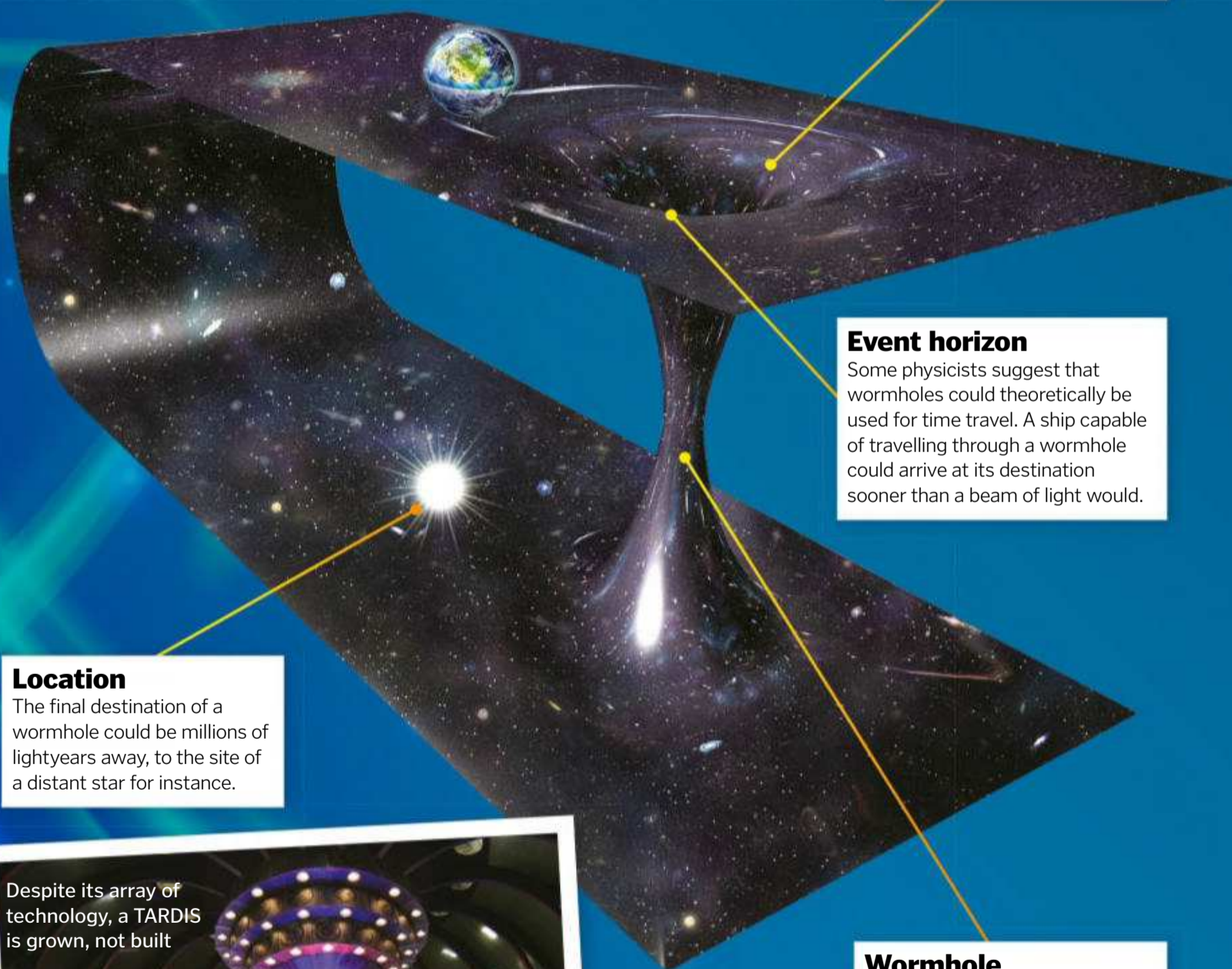


Bending of light

While accelerating in your vessel, the path of light from a source would appear to bend due to the curvature of space-time.

Crossing space-time

If Einstein's theory of general relativity is correct, what would a wormhole look like?



Curved space-time

Space-time is distorted by concentrated mass – the greater the mass, the more space-time will curve.

Event horizon

Some physicists suggest that wormholes could theoretically be used for time travel. A ship capable of travelling through a wormhole could arrive at its destination sooner than a beam of light would.

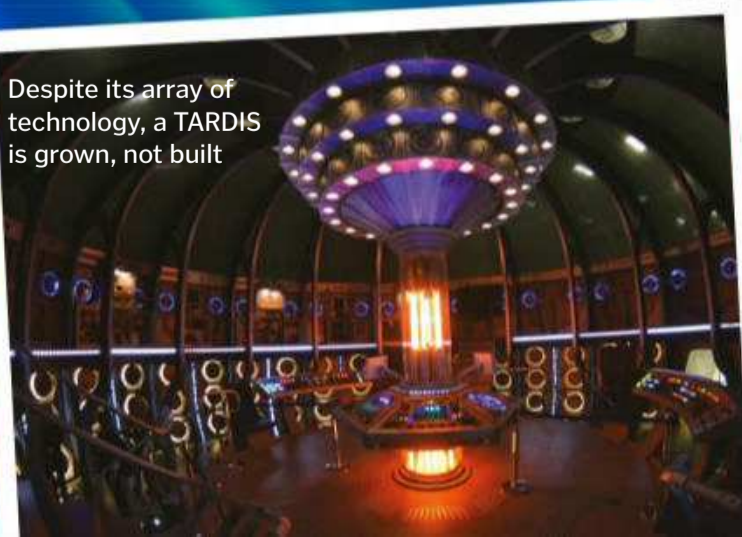
Location

The final destination of a wormhole could be millions of lightyears away, to the site of a distant star for instance.

Wormhole

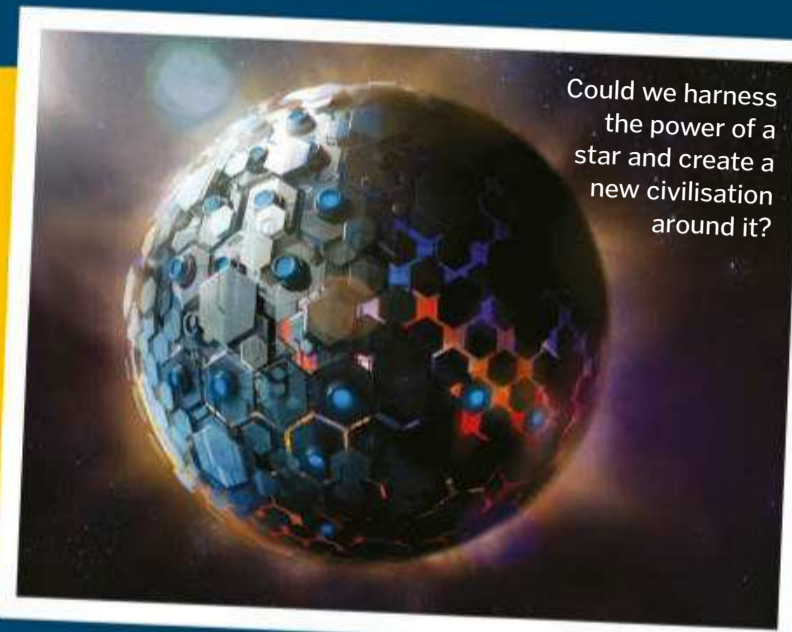
This gravitational well connects two singularities – such as black holes – creating a cylindrical tunnel through space-time.

Despite its array of technology, a TARDIS is grown, not built



The ultimate solar power

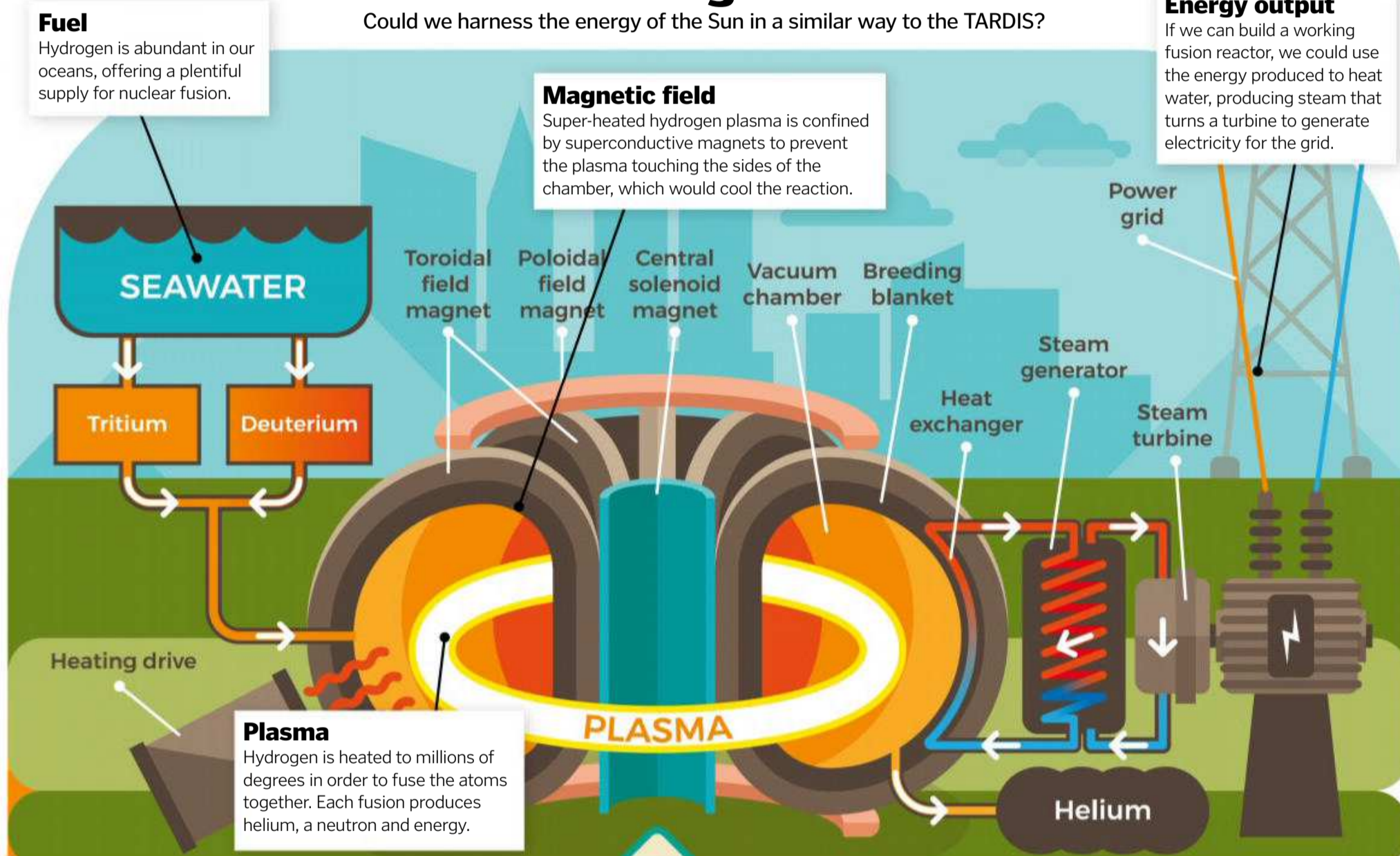
The Doctor uses the energy of a star to power the TARDIS (more about this on page 30), but can humans truly tap into such solar energy potentials? If we wanted to harness the full energy of a star, we would need to create what is known as a Dyson sphere. In 1960, scientist Freeman Dyson first described the concept of a network of solar panels to completely envelop a star and tap into its immense energy output. The solar mega structure of a Dyson sphere, or shell, would theoretically comprise of millions of individual solar panel satellites capable of capturing, storing and transmitting the energy back to Earth for use. However, in order to construct such an array around a Sun-like star, we would require more material than currently exists in our entire Solar System!



Could we harness the power of a star and create a new civilisation around it?

Recreating the Sun

Could we harness the energy of the Sun in a similar way to the TARDIS?



Fuel

Hydrogen is abundant in our oceans, offering a plentiful supply for nuclear fusion.

Magnetic field

Super-heated hydrogen plasma is confined by superconductive magnets to prevent the plasma touching the sides of the chamber, which would cool the reaction.

Energy output

If we can build a working fusion reactor, we could use the energy produced to heat water, producing steam that turns a turbine to generate electricity for the grid.

Plasma

Hydrogen is heated to millions of degrees in order to fuse the atoms together. Each fusion produces helium, a neutron and energy.

BOTTTLING A STAR

If Earth's engineering can't reach the Sun to create a Dyson sphere, then why not recreate a star on Earth? The Sun's nuclear fusion is made possible due to its immense mass and gravity heating its core to 15 million degrees Celsius. Within its internal incinerator, hydrogen atoms can fuse together to form helium. It's this reaction that releases energy, and it's a process that we could try to replicate.

Currently, we have mastered the process of splitting the atom to release energy, known as

nuclear fission. However, if we could take inspiration from the Sun and succeed in engineering a viable fusion reactor to stick atoms together, our power-producing potential could be out of this world.

There are two main approaches to achieve nuclear fusion: magnetic or inertial confinement. Inertial confinement uses laser beams to focus energy and heat up hydrogen isotopes, forcing the atoms to come together to form helium. Magnetic confinement, however,

uses magnetic fields to confine and compress hydrogen plasma at high temperatures until fusion occurs, generating helium and energy.

In both cases the energy released from fusion can be used to heat water, creating steam that in turn spins a turbine that can power a generator, ultimately producing electricity. With our current fusion reactor technology, however, the energy required to power the process of fusion is greater than the energy output of the reactors.



DESIGNING THE DALEKS

From the writer's room to the planet Skaro, Daleks were brought to life in the creative mind of Raymond Cusick. Designs started from a script direction that read, "Standing in a half circle in front of them are four hideous machine-like creatures. They are legless, moving on a round base. They have no human features. A lens on a flexible shaft acts as an eye. Arms with mechanical grips for hands." The Daleks were born.

The arch-nemesis of the Doctor, Daleks are the destroyer of worlds. Their shared goal is 'exterminate' the human race and anyone who stands in their way. Built from the unbreakable 'bonded polycarbide' called Dalekanium, these interstellar soldiers are feared throughout the galaxy.

Anatomy of a Dalek

Inside the most feared and deadly creatures in the universe

Telescopic arm

Usually deployed to manipulate controls, the plunger on the end of this arm could also be used to suffocate or crush enemies.

Directional audio receptor

Located just behind the eye lens, this receptor enables a Dalek to detect which direction a sound is coming from.

Mutated brain

A Dalek's more complex functions are controlled by a mutated organic brain.

Don't blink!

As one of the more creepy *Doctor Who* villains, the Weeping Angels can only be stopped when met with a human gaze – that is until you blink, of course. This sinister skill, however, isn't just a sci-fi trick – it's based on quantum physics.

Known as the quantum zeno effect, this is when a particle moving through space is halted when it is continually observed in what is essentially a particle game of *What's the time Mr Wolf?* Several experiments, including one known as the 'double-slit' test, have found that particles act differently when observed, providing some of the first displays of the quantum zeno effect phenomenon.



The Weeping Angels are able to send their victims into the past and feed off their remaining time energy

Directed-energy weapons

The Dalek's gunstick is reminiscent of today's laser directed-energy weapons, which produce a beam of concentrated electromagnetic energy or atomic/subatomic particles.



Sensors

Much like the sensors in any modern-day car, a Dalek has collections of globular sensors on its exterior to monitor its surroundings and detect temperature changes and movement/proximity.



Sensors are vital in many industries, including the development of driverless cars

Kaled mutant

These octopus-like aliens originate from the planet Skaro. Normally reliant on their armoured exterior for protection, they are almost as deadly without it.



Doctor Who is well established within British culture – a Dalek featured on a set of Millennium stamps celebrating the 20th century

Hover-mode

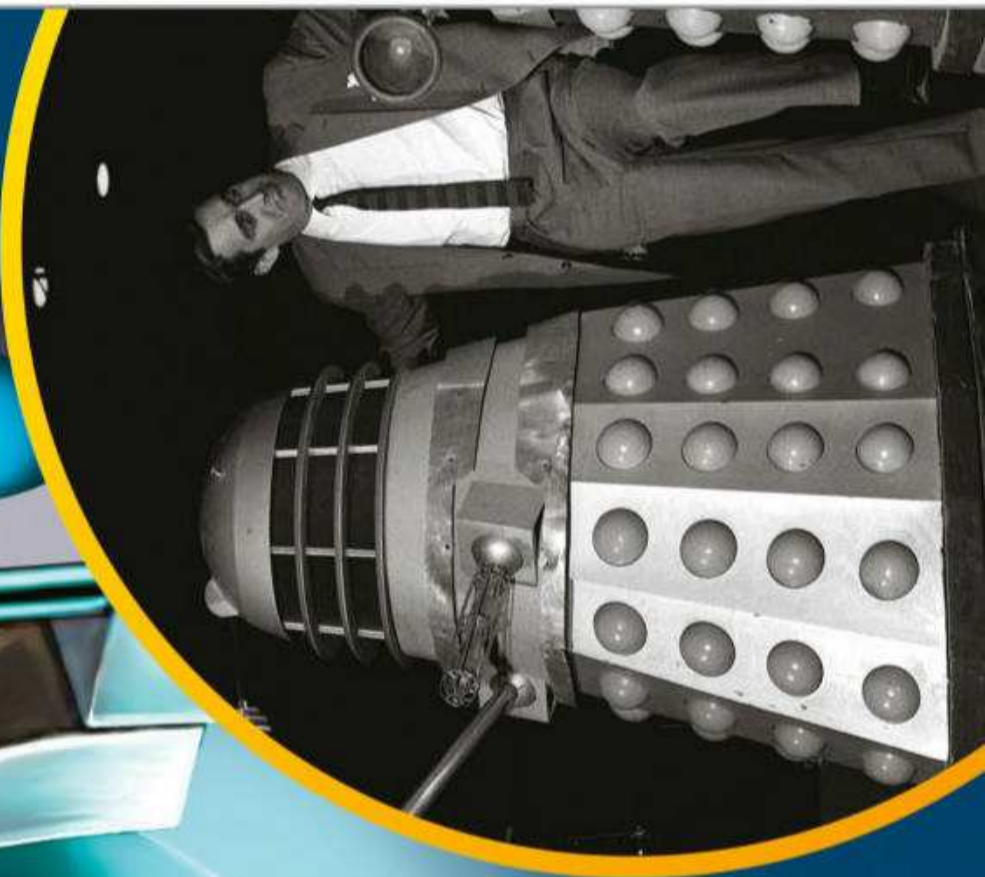
Daleks are also equipped with anti-gravitational discs in order to levitate off the ground.



We may not have anti-gravity tech, but we can use magnetic levitation to float

© Illustration by The Art Agency/Jean-Michel; Alamy; Lexus

Science-fiction writer Terry Nation (pictured) first created the Daleks, before Raymond Cusick brought them to life





HUMAN UPGRADE

As an evil race of robots hell-bent on converting unsuspecting humans into technological terrors, the Cybermen have taken bionics to the dark side. Thankfully, real-world bionics are far less sinister and are used to enhance, not end, the lives of many people. The advancements to date have exceeded all expectation.

Brain-computer interfaces pose a potentially revolutionary advancement in bionic technology. The first application of this type of technology is hearing restoration. However, developers are also working to use our brainpower to control high-tech prosthetic limbs. Through the use of sensors and implants it is possible to interpret brain activity as specific functions, such as to lift an arm or stretch an exoskeleton leg. This technology is still very much in its infancy with regards to commercial use, but has the potential to change the way many people interact with the world.

Engineers are also making waves in bionic eye technology. Researchers at the University of Minnesota, US, have developed a 3D-printed bionic eye prototype using semiconducting polymers to print devices that convert light into electrical signals.

Inside a Cyberman

What makes up a Cyberman and how do we use similar technologies today?

Cybernetic limbs

As a race of super soldiers, the Cybermen are equipped with cybernetic limbs to enhance their strength and add weaponry.



Bionic prosthetics can now use several methods to recreate the function and form of limbs

Brain-computer interfaces

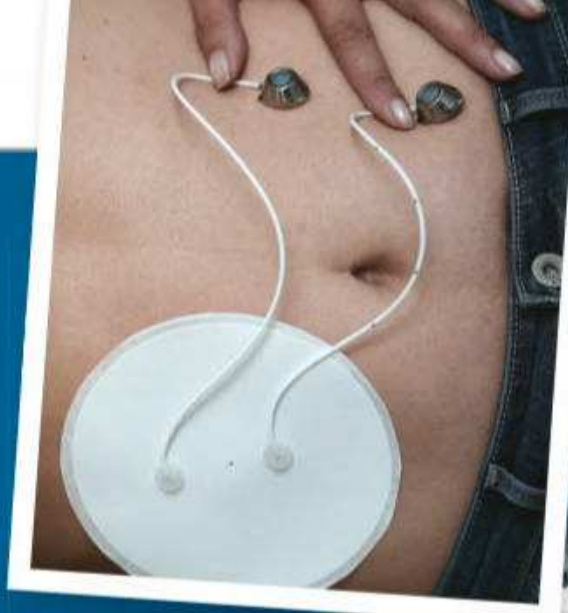
In order to convert humans into Cybermen, their neural functions and signals are connected to cybernetics throughout their new exoskeleton.



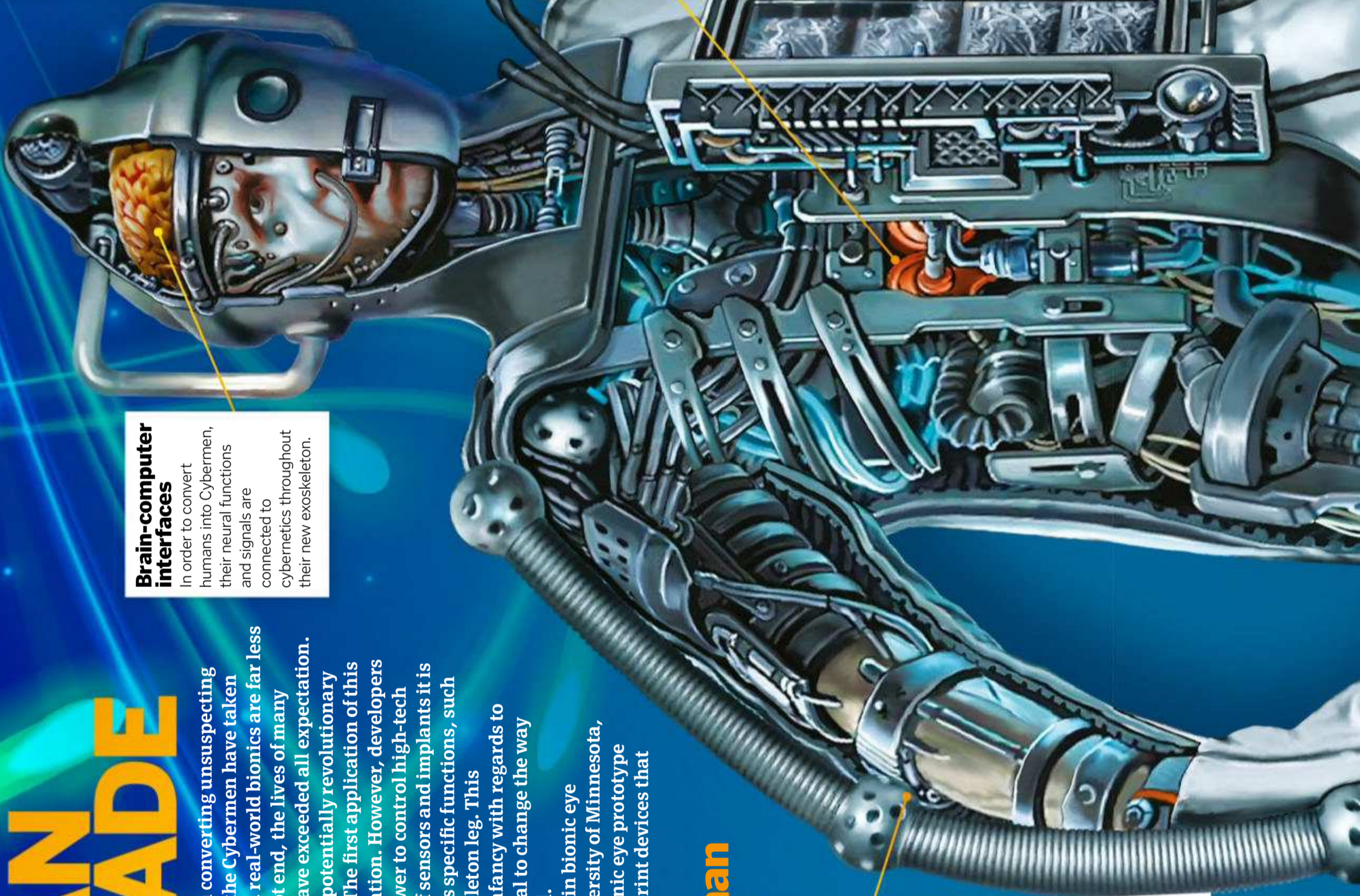
Internal or external sensors monitor brain function and electrical activity and interpret those signals to operate bionics

Artificial organs

Replacing a human's internal organs with circuit boards, the Cybermen's internal regulation is machine-reliant.

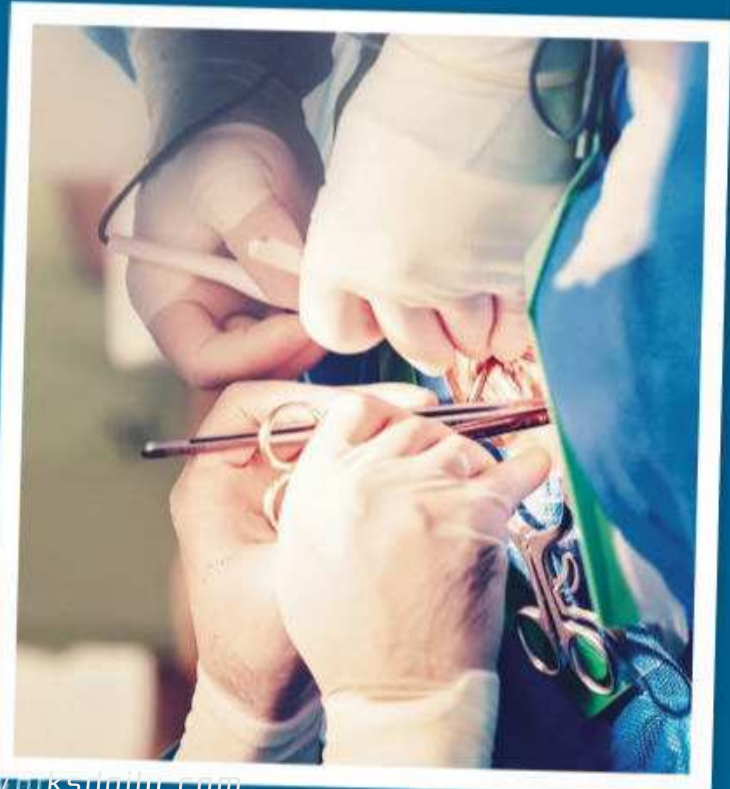


Devices such as artificial pancreases have demonstrated the potential of artificial organs



Suspended animation

Waiting dormant, the Cybermen are held in suspended animation before being awakened for battle.



In some surgical procedures, patients can be held in temporary suspended animation to decrease the oxygen requirement of the body and allow surgeons more time to perform operations

The Cybermen that terrorise our screens today have come a long way since their first appearance

Flight

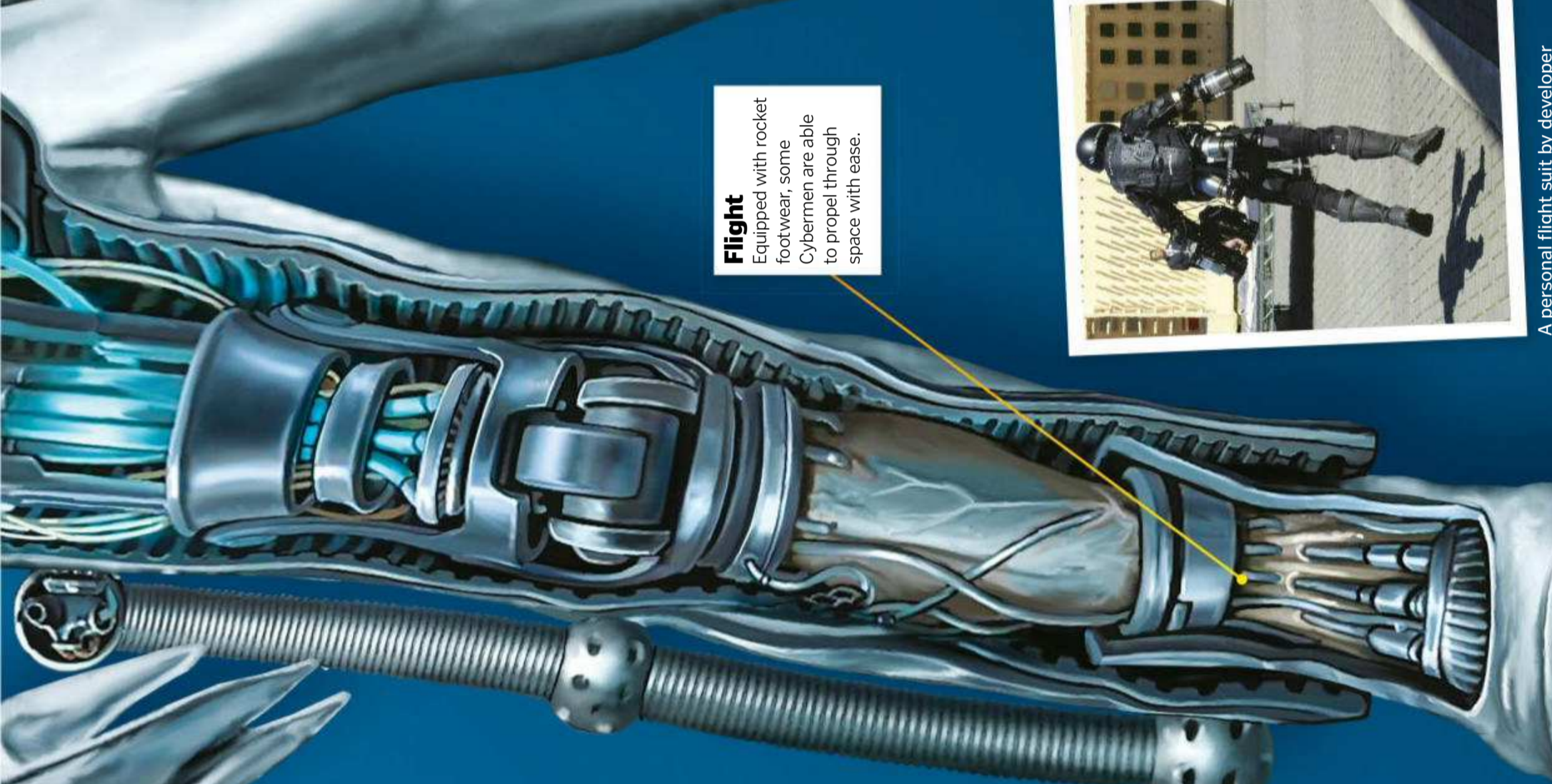
Equipped with rocket footwear, some Cybermen are able to propel through space with ease.



A personal flight suit by developer Richard Browning uses miniature jet engines to propel him through the skies

Hydraulics

A network of hydraulic pipes control the wires and cables that dictate the movements of the emotionless Cybermen.





LITTLE BLUE BOX

Reverberating sound waves are able to hold objects in a state of levitation due to sound pressure

'Time And Relative Dimension In Space' sounds more like a physics paper than a spaceship. Nevertheless, the TARDIS - in the guise of a blue police phone box - is capable of travelling anywhere and anywhen.

It does so by ripping through the fabric of space-time to journey into a connecting wormhole. In order to travel through space and time, the TARDIS needs an exceptional

amount of power and energy, and what more bountiful source of both can there be than that generated by a star?

The TARDIS is powered by a dying star in the process of decaying into a black hole, known as the Eye of Harmony. Using Time Lord knowledge, this cataclysmic event is suspended in time while the TARDIS utilises this energy as a power source.

It's bigger on the inside

What makes the TARDIS tick?

Directional unit

The directional unit once helped in navigating to specific locations.

Fluid links

These links require mercury to function and are one of the components that helps provide power to the TARDIS.

Time rotor

The time rotor column stores the energy for the TARDIS' engines, preventing its escape.

Chameleon circuit

This manifests the outside of the spaceship to fit in with its surroundings. However, this technology is broken, hence the permanent police box exterior.

Artron mainframe

The mainframe connects all the computer networks and systems aboard the TARDIS and acts as its interface for the Doctor.



The energy produced through the death of a star is held in time beneath the TARDIS console and used for power

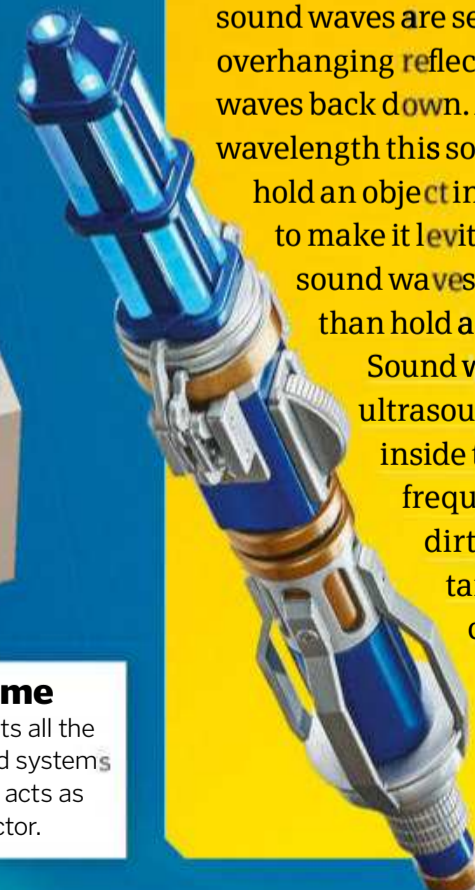


Sonic science

A screwdriver, pen, lipstick and gun - sonic technology has always been in the firm grip of the Doctor, her friends and enemies. At the press of a button, the Doctor can disarm a Silurian soldier, sever a suspended rope and crack any lock... as long as it's not made of wood.

The power of the sonic screwdriver is not merely the product of mechanical make-believe but follows the logic of high-kinetic sonic waves. The physical abilities of sonic technology can be demonstrated in acoustic levitation. Using a sound-emitting transducer, sound waves are sent upwards to an overhanging reflector, which reflects the waves back down. At a specific wavelength this sound pressure can hold an object in its grasp and appear to make it levitate. However, these sound waves can do much more than hold a ball in mid-air.

Sound waves, such as ultrasound, can be used to see inside the body, used at high frequencies to vibrate the dirt away when cleaning tanks, while infrasound can even be weaponised to affect hearing, balance and induce headaches.



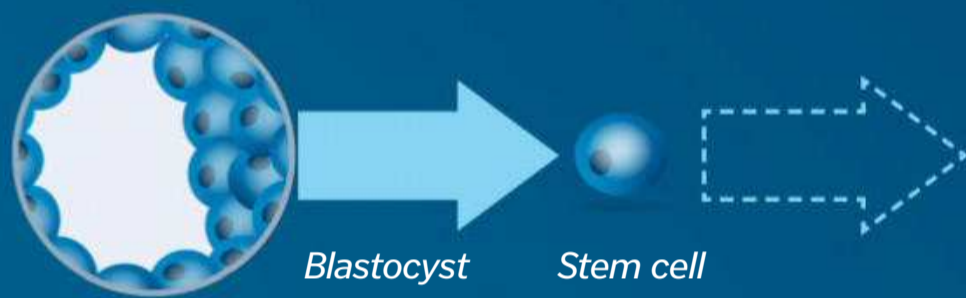
REAL-LIFE REGENERATION

The Doctor has experienced 14 regenerations, whereby her physical form is renewed to heal injuries. Every cell in her body changes during this process, and with each regeneration her cells become new.

In order to achieve this total transformation, the Doctor uses latent regeneration energy. The human body has no such energy, but does have some regenerative capacity. Stem cells are unique in their ability to perform no specialised function in the human body.

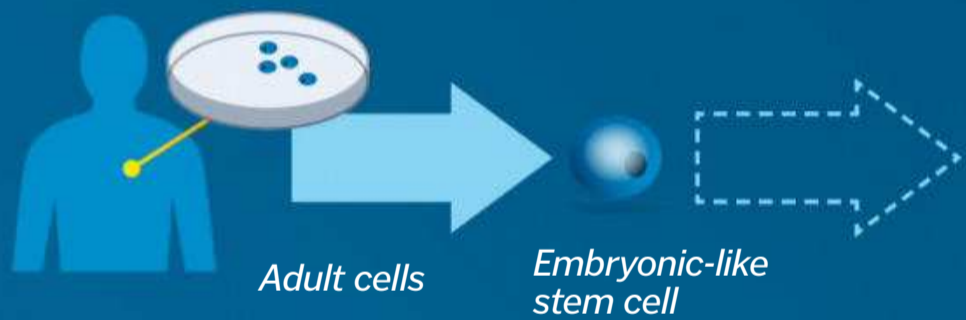
These cells cannot carry oxygen like red blood cells, nor can they absorb the nutrients in the intestines like microvillus cells.

However, through a process known as differentiation, they can transform into different cell types to complete any cellular function. These cells act as the understudy in the human body, waiting for their time to play a variety of roles. They are found in specific tissues, such as the bone marrow and skin, but scientists have developed several ways of producing these valuable cells.



Embryonic stem cells (ESCs)

These are derived from blastocysts – an embryo that is just a few days old and a ball of approximately 100 cells. These stem cells are pluripotent, meaning they can develop into any cell within the body.



Induced pluripotent stem cells (iPSCs)

Scientists have found methods to convert adult cells, such as fibroblasts in the skin, back into pluripotent-like cells. From these iPSCs a range of different cell types can be made, containing the DNA of the original adult cell.



Direct conversion

Recently, scientists have developed ways to turn cells of one type directly into cells of another type, without passing through an intermediate, pluripotent stage. Examples include skin cells into liver cells, and astrocytes into neurons.

Applications

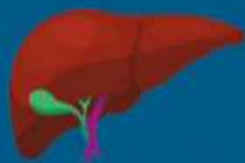
Stem cells can be used to produce heart, brain, pancreas and blood cells (among others) in efforts to regenerate and repair the body's tissues.



Heart cells



Brain cells



Pancreas cells



Blood cells

Regeneration in the wild

A lost limb is of little concern to these remarkable creatures

Starfish

The Indo-Pacific starfish genus *Linckia* can regenerate a lost arm or even its entire body from a single separated arm.



Giant day gecko

These lizards can detach their tail as a defence mechanism then regenerate a replacement with a rod of cartilage.



Immortal jellyfish

These jellies are arguably the real-life Time Lords, able to revert to their younger cellular polyp form.



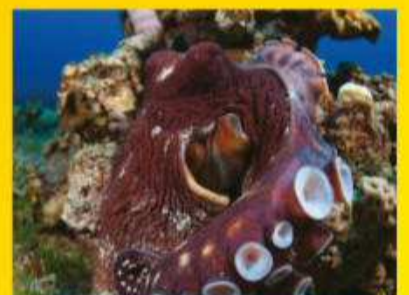
Salamander

Similarly to the giant day gecko, the salamander is able to lose limbs such as arms in a bid to escape and then regenerate them over time.



Cephalopods

When mating, males will detach their hectocotylus and leave it in the female. They will regenerate a new one later.



"The power of the sonic screwdriver is not merely the product of mechanical make-believe but follows the logic of high-kinetic sonic waves"



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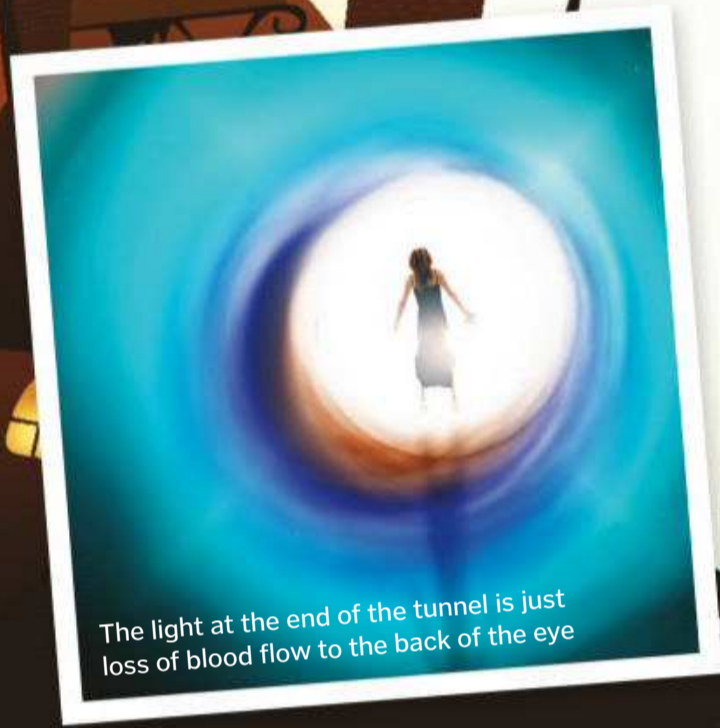


FREAKY PHENOMENA

Don't be alarmed – science shows that the paranormal is normal after all

We are masters of pattern recognition, taking in vast quantities of data and searching for the links that make sense of the world around us. As humans, we are always seeking to explain the unexplained, and there's nothing we find more disturbing than not being able to find an answer.

For centuries, the paranormal explained the unexplained, but now science is stepping in. Think you've seen a ghost? You're probably over tired. Sure you've heard voices in a backwards music track? It's more likely to be your brain desperately looking for patterns. Extraordinary occurrences almost always have a mundane explanation.



The light at the end of the tunnel is just loss of blood flow to the back of the eye

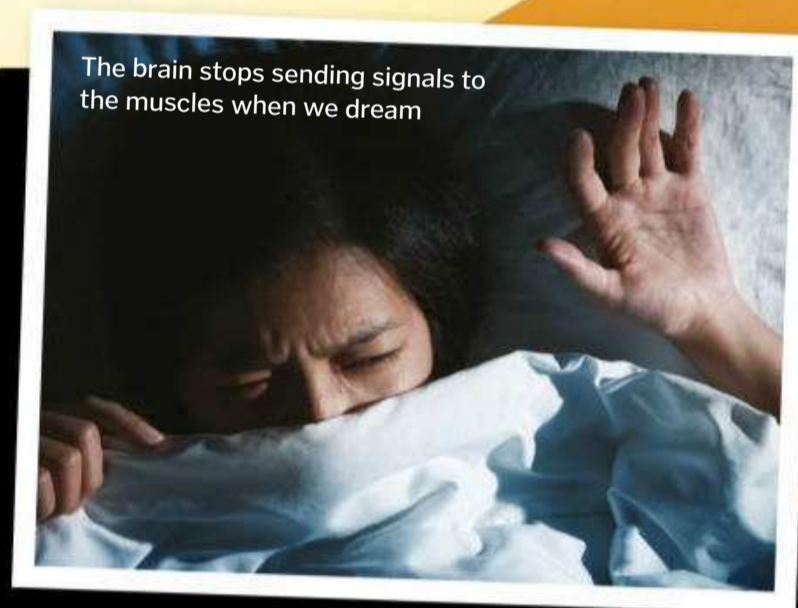
Seeing faces

Have you ever woken up in the middle of the night to find a figure looming over your bed, only to realise that it's actually a pile of clothes? Or perhaps you've seen a spooky face peering in through your window only to have it disappear when the wind ruffles the leaves. You might have experienced pareidolia. The word literally means 'wrong image', and it's down to the way our brains search for patterns.

We process a constant stream of sensory information, and our brains have fractions of seconds to make decisions. This means storing and recalling simple patterns so that we can quickly scan through the noise. In much the same way as your smartphone camera looks for patterns to draw boxes around faces, your brain hones in on anything that might have two eyes and a mouth.



Our facial recognition system looks for two eyes and a mouth



The brain stops sending signals to the muscles when we dream

Sleep paralysis

Waking to the awful feeling that you've lost control of your limbs can be terrifying, but sleep paralysis is essential to keep you safe at night. When we dream during rapid eye movement (REM) sleep, our brains run through vivid simulations and try to send messages to our muscles. But two signalling chemicals, gamma-aminobutyric acid (GABA) and glycine, stop messages reaching the motor neurons. This prevents us from acting out our dreams and harming ourselves and others, but sometimes the system can malfunction.

The frightening experience of sleep paralysis happens when our brains enter this dream-like state when we're still awake. It's rare, but occurs more often if we're over tired, have jet lag or work irregular shifts that mess with our body clocks.

The body's spirit level

Twisted tubes of fluid in the ears tell the brain which way is up

Crista ampullaris

Each canal contains a cone-shaped structure covered with tiny hairs in a jelly-like cap.

Semicircular canals

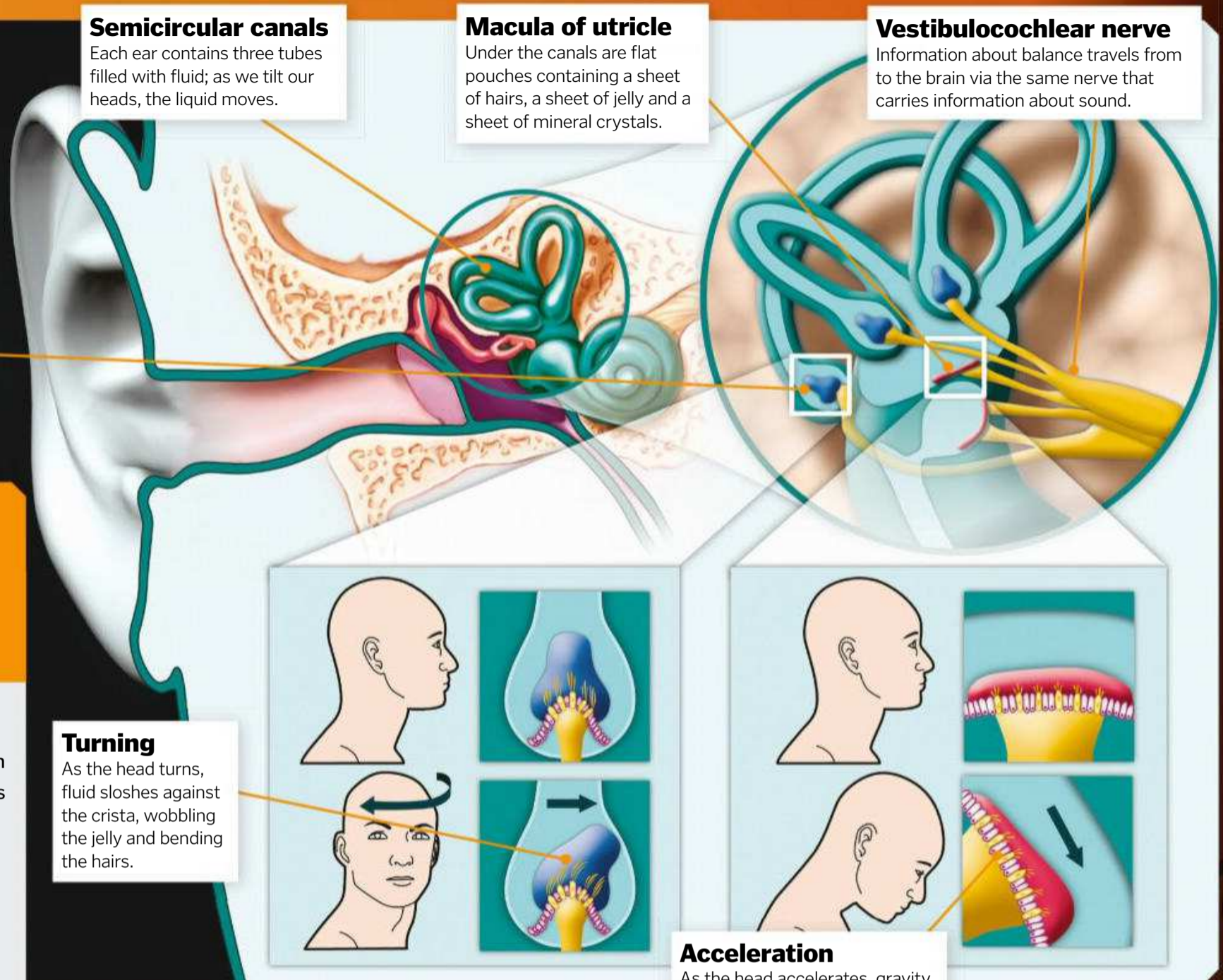
Each ear contains three tubes filled with fluid; as we tilt our heads, the liquid moves.

Macula of utricle

Under the canals are flat pouches containing a sheet of hairs, a sheet of jelly and a sheet of mineral crystals.

Vestibulocochlear nerve

Information about balance travels from to the brain via the same nerve that carries information about sound.



THE SCIENCE BEHIND NEAR-DEATH EXPERIENCES

1 Feeling like you're dead

In rare situations, problems with the brain can make the living feel as though they are dead. Known as Cotard's delusion, or 'walking corpse syndrome', this rare mental illness can occur when certain neurological disorders interfere with signals in the brain.

2 Moving towards the light

The infamous light at the end of the tunnel might simply be down to a loss of blood flow triggered by fear or disease. When the back of the eye can't get enough oxygen, the edges of your vision can start to disappear.

3 Seeing dead people

Hallucinations can make us believe that we can see or hear long lost loved ones, but they are just a trick of the brain. They can occur for many reasons, ranging from brain damage and mental illness to medication, fever and even just being tired.

4 Feelings of euphoria

Fear triggers the body's fight or flight response, making the brain produce powerful chemicals that change the way we think and feel. These include adrenaline, dopamine and opioids, which kill pain and can induce intense feelings of elation and euphoria.

Turning

As the head turns, fluid sloshes against the crista, wobbling the jelly and bending the hairs.

Acceleration

As the head accelerates, gravity tugs on the crystals, pulling the jelly and bending the hairs.

Out-of-body experiences

Few experiences could be weirder than finding yourself looking down at your own body from above. However, there may be a solid scientific explanation. People with certain neurological disorders are more likely to have an out-of-body experience, so studying their brains can reveal clues about why they happen.

In 2002, while undergoing an evaluation for epilepsy, a patient allowed scientists to insert electrical signals into their brain. Some of these signals triggered an out-of-body experience. The part of the brain responsible was the right angular

gyrus, which links information from the eyes and the inner ear. The inner ear contains a set of fluid-filled tubes that work as the body's spirit level. Problems here can literally throw you off balance, triggering a spell of dizziness, floating feelings and disorientation.

A larger study in 2017 found that people with inner ear problems were almost three times as likely to have had an out-of-body experience. It seems that a mismatch between what you see and what you feel can trick your brain into thinking that you've left your body behind.

Inner ear problems can make you feel disconnected from your physical self





Debunking the vampire myth

How science can explain the phenomena that led many people to believe in the undead

Legends of beings that defied death and preyed on the living date back to ancient times. Many early civilisations featured vampiric creatures in their lore, such as the child-eating demon Lamia of ancient Greek mythology and the life-sucking edimmu ghosts of Mesopotamian legend.

The belief in vampires became particularly common in the folklore of medieval Europe

and persisted for hundreds of years, the superstitions often resurfacing during outbreaks of plague and other illnesses. But as our scientific understanding improved, the mysteries at the root of these beliefs were unravelled. Large fangs, hypersensitivity to sunlight and blood around the mouth could all be explained by then-unknown diseases and the natural process of decay after death.



Porphyria makes sunlight painful and can even cause blistering

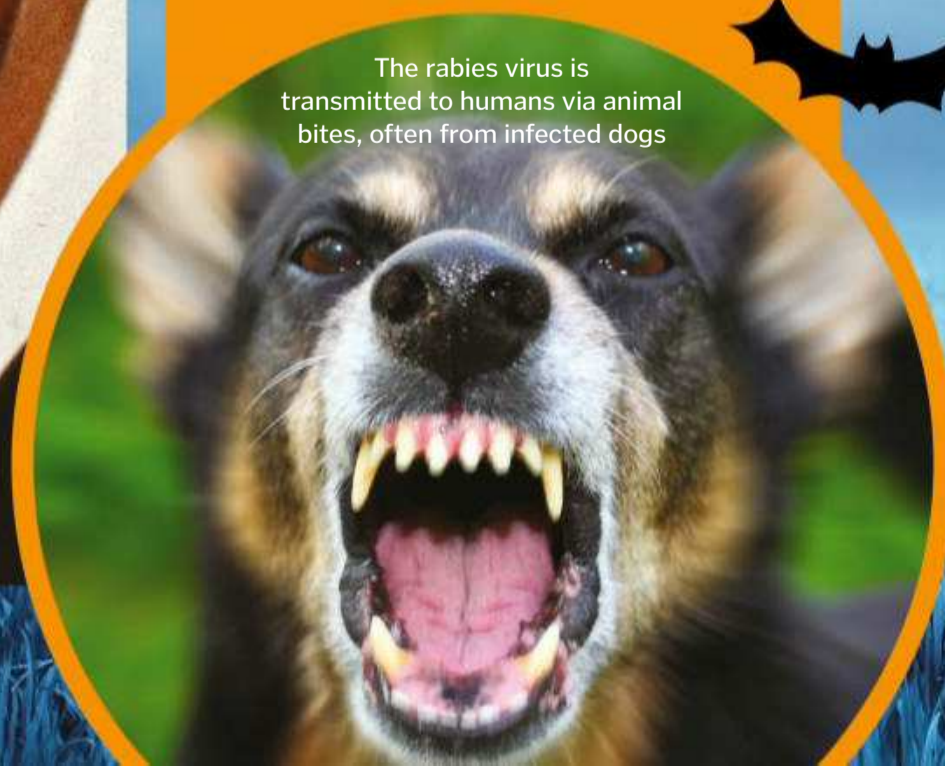
Fangs, sunlight and garlic

The classic vampires of legend have prominent fangs to pierce their victims' necks, are nocturnal and have pale skin due to their aversion to sunlight. They can also be warded off with garlic. Thanks to medical advances, these days we know of several conditions that could actually explain some of these features.

Porphyria is a group of conditions that may have contributed to the vampire myth. One type, called congenital erythropoietic porphyria (CEP), causes a toxic build-up of light-activated molecules in the skin. When sufferers are exposed to sunlight these toxins can eat away at the skin, damaging the gum tissue to make teeth look longer and fang-like. As well as Sun sensitivity, porphyria can also make people hypersensitive to foods high in sulphur, such as garlic.

Similar symptoms can be experienced by those suffering from rabies, a deadly virus that can be transmitted to humans if bitten by an infected animal. Rabid people can develop insomnia, become aggressive – even trying to bite people – and demonstrate an aversion to strong stimuli, including bright light and strong smells like garlic. The diagnosis of rabies also fits the common depiction of male vampires pursuing female victims. The condition is seven times more common in men and can cause an increased libido by affecting the body's limbic system.

The rabies virus is transmitted to humans via animal bites, often from infected dogs



Reports of fingernail scratch marks on the inside of re-opened coffins suggest that premature burials were not unheard of



Buried alive

Fear of the dead rising again meant that the living would sometimes take some rather macabre precautions to ensure this didn't happen. Positioning a sickle around the body's neck in the coffin, stabbing the corpse through the chest or slicing its knee tendons were just some of the methods used during burials to make sure the dead couldn't escape.

The belief that the dead might not stay that way was likely influenced by horrifying cases of people being buried alive. Poor medical knowledge meant that victims could be mistakenly declared dead and buried prematurely, only to regain consciousness when it was too late. For example, people with catalepsy can have seizures in which the body goes stiff and the breathing and heart rate slows dramatically, which could easily lead to a false diagnosis of death.

A thirst for blood

In times when people were wary of vampires, corpses were occasionally dug up to check they were still dead. People's fears were exacerbated when bodies were found to have blood oozing from the nose and mouth. In reality, what looked like blood was actually 'purge fluid', the result of the natural decay process as the internal organs start to break down.

Symptoms of disease also contributed to the blood-sucking myth. Tuberculosis (TB) is a bacterial infection that primarily affects the lungs and causes sufferers to cough up blood. Before the illness was understood people blamed these mysterious deaths on supernatural forces. The New England 'vampire panic' in the early 1800s, for example, was a TB outbreak that affected entire families. The deaths were blamed on the first victim of the family somehow feeding off their surviving relatives from beyond the grave.

When they exhumed bodies to try and prevent what they assumed was vampiric activity, their worries were (mistakenly) 'confirmed' by the fact that TB victims would often be found with their mouths full of blood.

Right: German physician Robert Koch won the 1905 Nobel Prize for discovering that TB was caused by the *Mycobacterium tuberculosis* bacteria (pictured)



A symptom of TB is coughing up blood, which could have contributed to vampires' bloodthirsty reputation

Mange and movie mania

In the 1990s, stories of a mysterious creature feeding on the blood of livestock started to emerge in Puerto Rico. Locals called the culprit the chupacabra ('goat eater'), describing it as a beast with long claws and spikes along its spine. Its victims would be found with vampire-like puncture wounds on their necks but no sign of other injuries. The tale of the chupacabra soon spread across Latin America and the southern US, but by the 2000s witnesses' descriptions became far less alien. The creature was said to be hairless and canine.

Investigator Benjamin Radford, a research fellow for the Committee for Skeptical Inquiry, set out to find the truth. Over five years he interviewed witnesses and collected evidence, including specimens of livestock victims and alleged chupacabra bodies. DNA analysis of the 'chupacabras' revealed they were coyotes, dogs, or even racoons that suffered from mange, which causes itching, hair loss, inflammation and gauntness. It's also not unusual for dogs and other canines to kill prey with a bite to the neck and not eat them.

Interestingly, the first sighting of a chupacabra came not long after the alien horror film *Species* was released in Puerto Rico. Radford tracked down the first chupacabra witness and discovered she had watched the film sometime before her sighting, making it likely that the initial reports were the product of an overactive imagination.



A fox cub with sarcoptic mange, a disease caused by mites that infest the skin. Mange symptoms explain the appearance and behaviour of supposed chupacabras



Undead cells

As we age, our bodies clog up with zombie cells that just won't die

Cells have a built-in safety switch that turns them off when they start to get old. They stop dividing, entering a quiet retirement period that scientists call senescence. The old cells send out signals to the immune system, letting it know that they've reached the end of their lives. Then they wait patiently for white blood cells to arrive and shut them down.

As we get older and more cells enter their twilight years, the immune system can't always keep up with demand. As more and more cells cross over the threshold, the white blood cells get overwhelmed and they stop responding. Undead cells start to build up in tissues, still alive but unable to do their jobs. These zombie cells keep sending out distress signals in the hope that the immune system will come, but all this does is inflame the

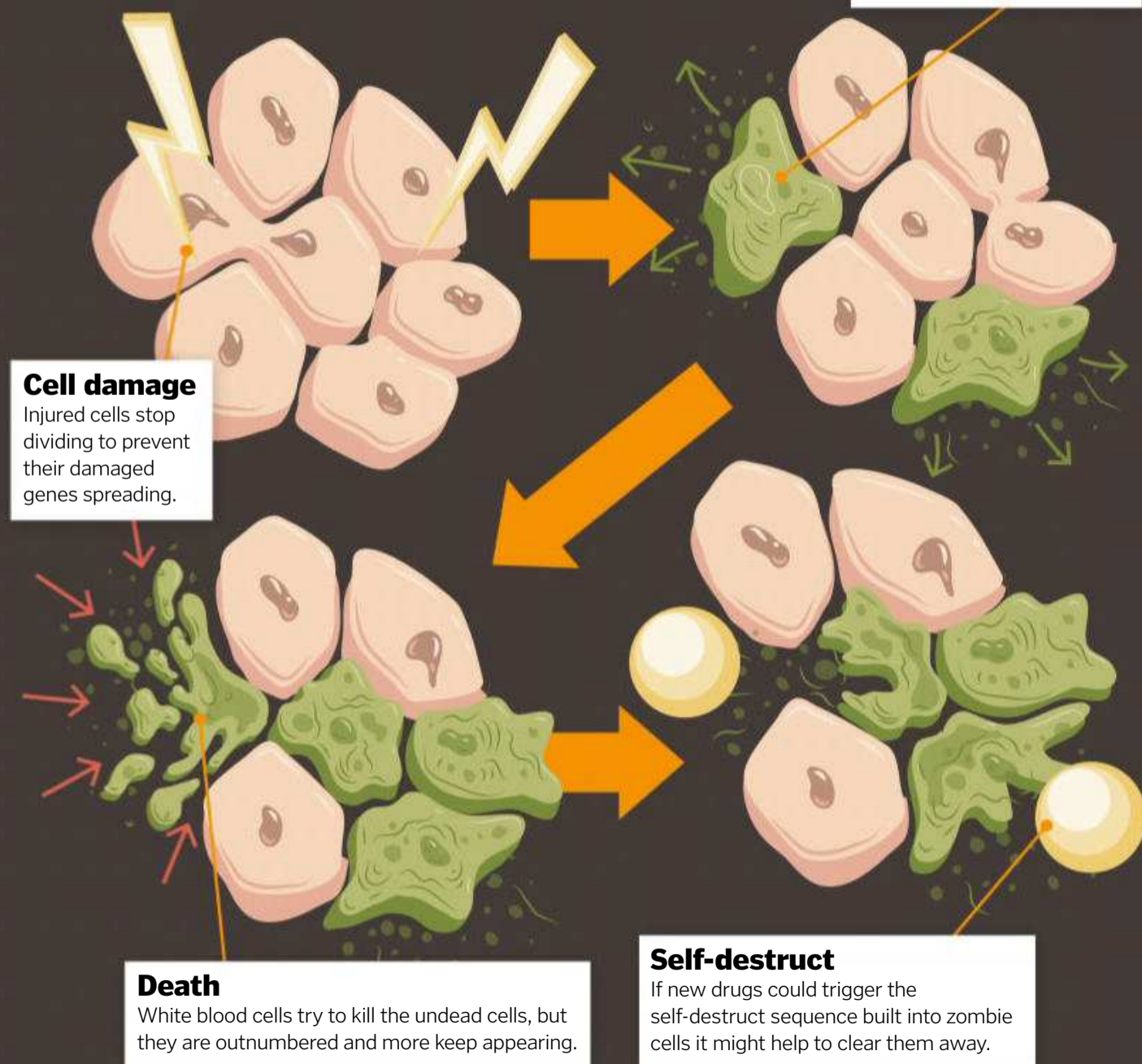
surrounding tissues. This harms nearby cells, which contributes to ageing.

Scientists found that clearing the undead cells in mice helps to kick-start tissue repair, reversing signs of ageing. Now pharmaceutical companies are racing to find new drugs that can help the immune system to eliminate the undead cells in our own bodies. These zombies have one major weakness – an in-built self-destruct sequence called apoptosis. We just need to find a drug that can push the button and set it off.

"These zombie cells keep sending out distress signals"

Zombie killers

How can we get rid of the undead cells clogging up our bodies?

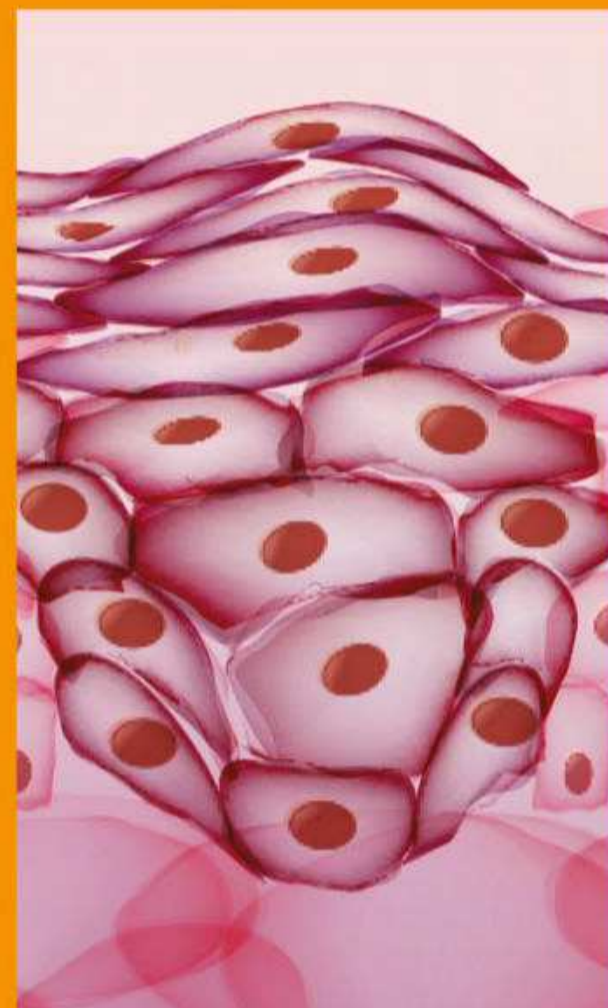


Cells only divide a limited number of times before entering a zombie-like state

What is senescence for?

Senescence is a pre-programmed state that cells can trigger if they've started to go wrong. It puts them safely into rest mode, where they can no longer make copies of themselves, preventing more faulty cells appearing inside the body. Not only does this keep organs and tissues working as normal, it also helps to protect against cancer. One of the hallmarks of cancer cells is that they ignore instructions to stop dividing and carry on replicating forever.

Senescence also happens to young, healthy cells, and it plays an important role in growing embryos. Halting cell division in certain places, while allowing it to continue elsewhere, helps to shape the body as it develops.



Senescence helps to stop old cells from passing on faulty DNA

© Getty, illustration by Ed Crooks

Tongue of dog

More of a play on words than the literal ingredient, houndstongue (*Cynoglossum officinale*) is poisonous to livestock rather than humans. Within the leaves of this plant are pyrrolizidine alkaloids, toxins that lead to liver damage and failure. These toxins are transported to the liver through intestinal absorption and are metabolised in liver cells called hepatocytes. There they stop the process of mitosis (cell division) and cause the formation of thick, scarring connective tissue known as fibrosis, ultimately killing the liver and causing death.

Eye of newt

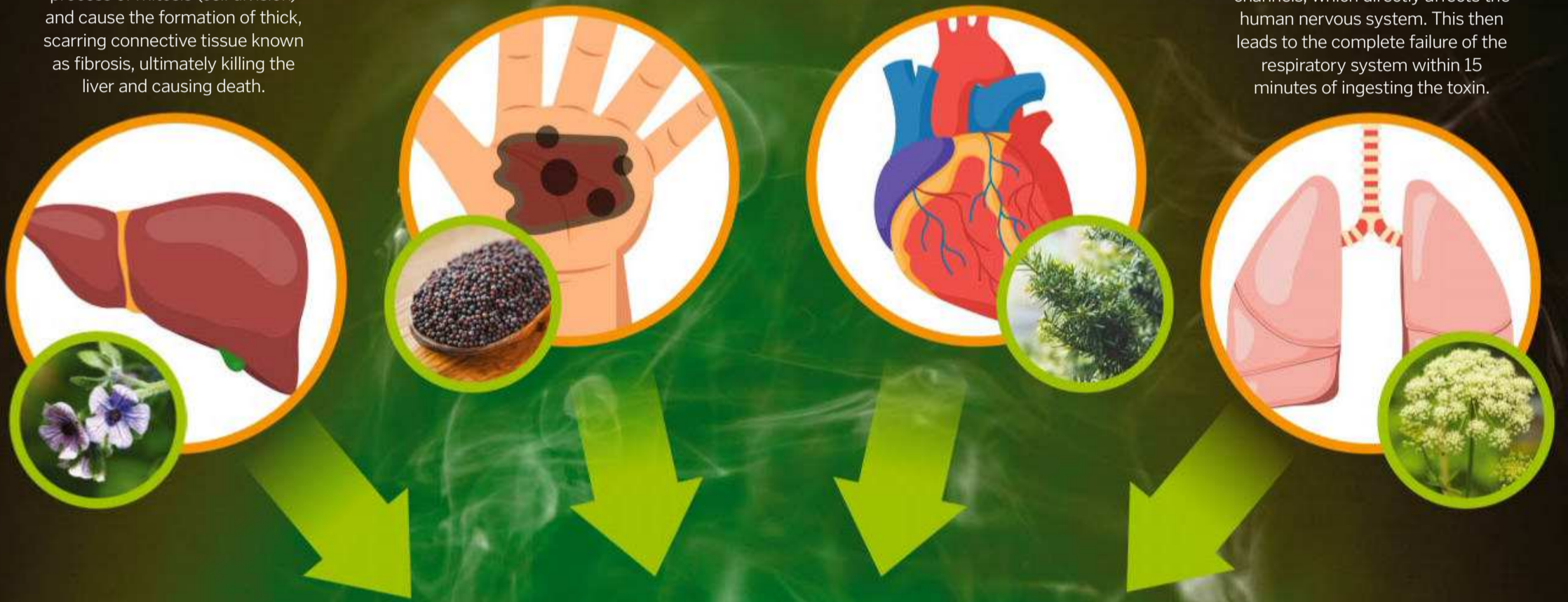
This is one of the most commonly known ingredients in a witch's pantry. Its name suggests the suffering of a small amphibian for a witch's gain. However, the eye of newt is not what it seems – it may even be in your cupboard. They are, in fact, mustard seeds. While these 'eyes' do not hold any magical properties, they certainly pack a powerful punch in flavour. Mustard seeds can also be used to create a powerful irritant. They contain the compound sinigrin which when crushed releases an enzyme called myrosinase, forming an oil. When mixed with cold water this combination can cause blistering when applied to the skin.

Slips of yew

Yew trees (*Taxus baccata*) are found spread across the Northern Hemisphere, reaching heights of between ten and 15 metres. Each branch is lined with sharp blades of pine leaves that have the potential to take down a horse in 15 minutes. This tree's deadly weapon of choice is a group of cardiotoxins called taxine alkaloids. Once ingested, taxines affect the electrical activity within the heart. These toxins can block calcium channels and reduce blood flow, resulting in death by way of ventricular fibrillation, where the heart stops pumping blood and only quivers until cardiac arrest occurs. The lethal dose for a human is 50 grams, and death will follow between two to five hours after.

Root of hemlock

The root of the North American water hemlock (*Cicuta*) can cause a fatal reaction to any that ingest it. Seizures, respiratory failure and tremors are just some of the precursor symptoms of this deadly plant. Its potent killing powers come from its levels of cicutoxins. Yellow in colour, these toxins are quickly absorbed by mucous membranes in the body. They can block sodium and potassium channels, which directly affects the human nervous system. This then leads to the complete failure of the respiratory system within 15 minutes of ingesting the toxin.



Potion chemistry

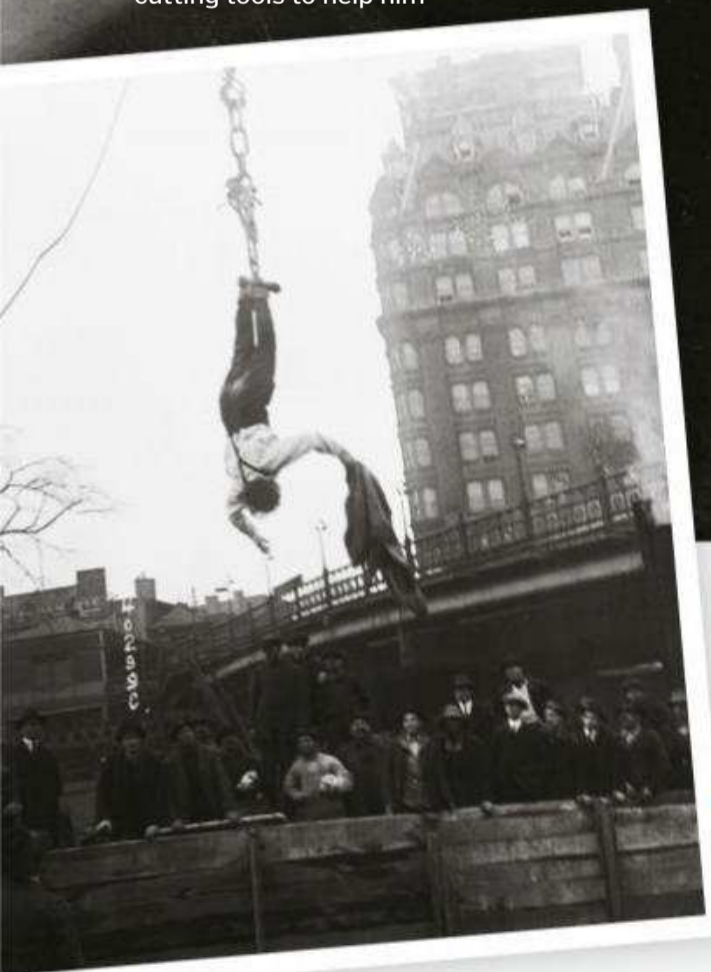
Double, double, toil and trouble: discover the deadly ingredients added to the bubbling cauldron of Macbeth's witches



HEROES OF... SCIENCE

Harry Houdini's sensational escape acts made him one of the world's most famous magicians

Houdini could wriggle free from straightjackets, although he sometimes used concealed cutting tools to help him



"He became more interested in shattering illusions rather than creating them"

A life's work

From Hungary to Houdini

1874
On 24 March, Erik Weisz is born in Budapest, Austria-Hungary, to a Jewish family.

1878
Erik moves to the United States with his family, where his name is changed to Ehrich Weiss.

1894
He adopts the stage name Harry Houdini and begins performing with his brother as The Brothers Houdini.

1899
Martin Beck becomes Houdini's manager and sends him on a tour of America and Europe.

Harry Houdini

Discover how scamming spiritualists could not escape the escapologist

Hanging upside down with his ankles locked in stocks, a crowd watched as Harry Houdini was lowered into a tank of water. Once the stocks were fixed to the top of the tank, a curtain was drawn and the audience collectively held their breath wondering how he would make it out alive. Minutes later, a soaked and unshackled Houdini would emerge unscathed from behind the curtain to huge sighs of relief and rapturous applause. This was just another one of Harry Houdini's spectacular escapes, which proved much more dramatic for the crowd than they did for the skilled escapologist himself.

Having worked for a locksmith at a young age, Houdini had learnt how to pick any lock, and so, with the help of slight of hand, some rigged equipment and his gymnastic abilities, he could free himself from the trickiest of situations with very little trouble.

One of seven children, Houdini was born in Budapest, Austria-Hungary, in 1874. He developed a fascination with magic from a young age and performed in circuses and vaudeville shows throughout his teenage years, but it wasn't until he met showman Martin Beck at age 25 that his career reached new heights.

He began touring America and Europe, and breaking free from various contraptions became the main part of his act. To promote his shows he would often hang upside down from cranes above the city streets, freeing himself from a straightjacket as crowds of thousands gathered below. He achieved great fame with his daring escapes, but in his later life he became more interested in shattering illusions rather than creating them.

After his beloved mother Cecilia died in 1913, Houdini was devastated and believed that by



Houdini became known as The Handcuff King and often challenged police to restrain him

visiting mediums he could make contact with her beyond the grave. However, knowing the art of trickery himself, he was angered to discover that every one of the so-called psychics he visited was simply a fraud dishonestly exploiting the bereaved. He became a member of the *Scientific American* committee and offered a cash prize to anyone who could demonstrate actual supernatural abilities. He attended many séances to debunk their methods.

Thanks to his efforts no one was ever awarded the prize, but he continued to believe that it was possible to speak with the dead. He regularly visited mediums for the rest of his life hoping to find one that was honest, and he even told his wife Wilhelmina Beatrice Rahner (better known as Bess Houdini) that he would try to contact her after he had passed away. Sadly that day came sooner than he thought, as he died of peritonitis aged just 52.

For the following decade his wife diligently listened out for his secret message on the anniversary of his death, but with no success she eventually gave up, saying, "Ten years is long enough to wait for any man."

THE BIG IDEA

Debunking Margery the Medium

In the wake of WWI many people began searching for ways to contact the deceased. Several mediums exploited their desperation, and one of the most famous was Mina Crandon, known to fans as Margery. As part of the *Scientific American* committee investigating spiritualism, Houdini attended one of Crandon's séances and prepared by tying a bandage under his right knee. The constriction made his skin tender, enabling him to feel when Crandon, who was sitting next to him, shifted and flexed her feet to ring a bell and move a table in the dark, exposing her as a fraud.



Houdini (left) with Mina Crandon (centre) and members of the *Scientific American* committee

5 THINGS TO KNOW ABOUT... HARRY HOUDINI

1 He criticised his idol

His stage name came from his nickname 'Ehrie', pronounced 'Harry', and the surname of his idol, French conjurer Jean-Eugène Robert-Houdin, who he later accused of stealing people's tricks.

2 He loved to fly

In 1909 Houdini bought a French Voisin biplane, which he then crashed during his first flight. Some historians credit him today with being the first person to ever pilot an airplane in Australia.

3 His cause of death is debated

Many believe he was punched while boasting about his strong abdominal muscles, failing to tense them in time for the impact, while some think he was killed by spiritualists seeking revenge.

4 His wife was his assistant

He met dancer Bess Rahner while performing in Coney Island, and she replaced his brother as his stage assistant. She continued to work with him for the rest of his career.

5 He helped in WWI

As well as entertaining soldiers and raising money for the war effort, Houdini also trained American troops to escape from restraints in the event of capture by the Germans.

1917

Houdini becomes President of the Society of American Magicians and holds the post until his death.

1922

The *Scientific American* contest to find a true medium is launched, with Houdini on the judging committee.

1975

Houdini is given a star on the Hollywood Walk of Fame at 7001 Hollywood Boulevard.

1912

Houdini debuts one of his most famous escapes, the Chinese water torture cell, at the Circus Busch in Berlin, Germany.

1921

After starring in several films, Houdini starts his own movie studio - The Houdini Picture Corporation.

1926

Houdini dies aged 52 in Detroit, Michigan, US, of peritonitis after rupturing his appendix.



60 YEARS OF NASA

We run through the most amazing achievements
of the world's greatest space agency

Words by Jonathan O'Callaghan

When NASA first opened its doors on 1 October 1958, humans had never been to space. We had no idea what most of the other planets really looked like, we'd never even seen a comet or asteroid up close, and setting foot on another world was the stuff of dreams. Fast forward to today and our knowledge of space – thanks to NASA – is unlike anything we had thought possible.

The agency was born out of a battle to decide whether the American space agency should serve the military or civilians. Facing a

growing threat from the Soviet Union, the US saw space as an opportunity to flex its considerable muscle and show off its envious technological prowess. However, numerous scientists argued in favour of NASA being used for strictly peaceful purposes, highlighting some of the grand questions about our universe that it could potentially answer and some of the fantastic locales that could be explored. Thankfully, they won out – NASA was set up with science at its core, and we're all the better for it.

NASA's primary goals were to expand human knowledge about space and develop vehicles that could take us to the stars. They tackled these challenges with aplomb, and today we've been treated to an endless cavalcade of science, from Moon landings to images of strange alien worlds.

The agency isn't going anywhere yet, and the future promises even more groundbreaking milestones. NASA's achievements of the past 60 years are incredible, but the best might be yet to come.

NASA

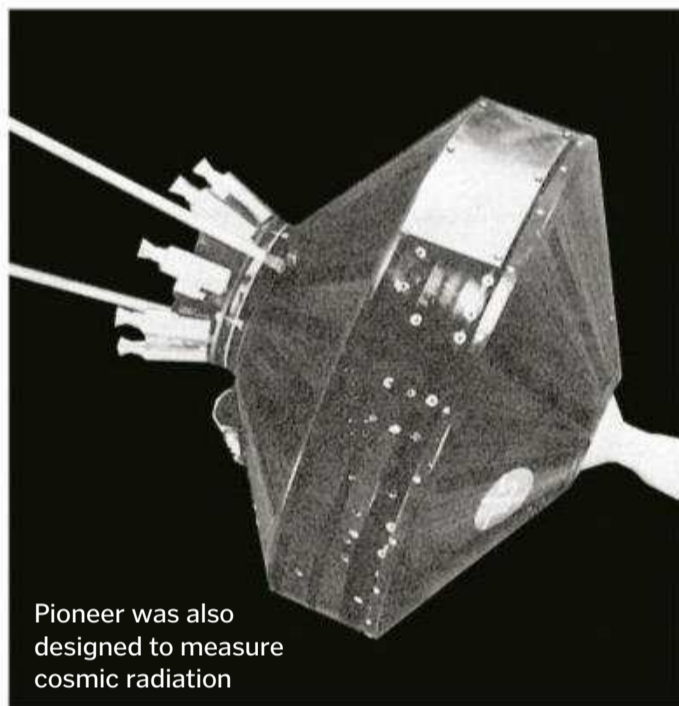
1 October 1958

01 The National Aeronautics and Space Administration (NASA) opens its doors, becoming a civilian and scientific space agency for the United States. NASA was born from the ashes of the preceding National Advisory Committee for Aeronautics (NACA), with some debate over whether the American space agency should be run for civilian or military purposes. After much conjecture from scientists and researchers, the former ultimately won out.

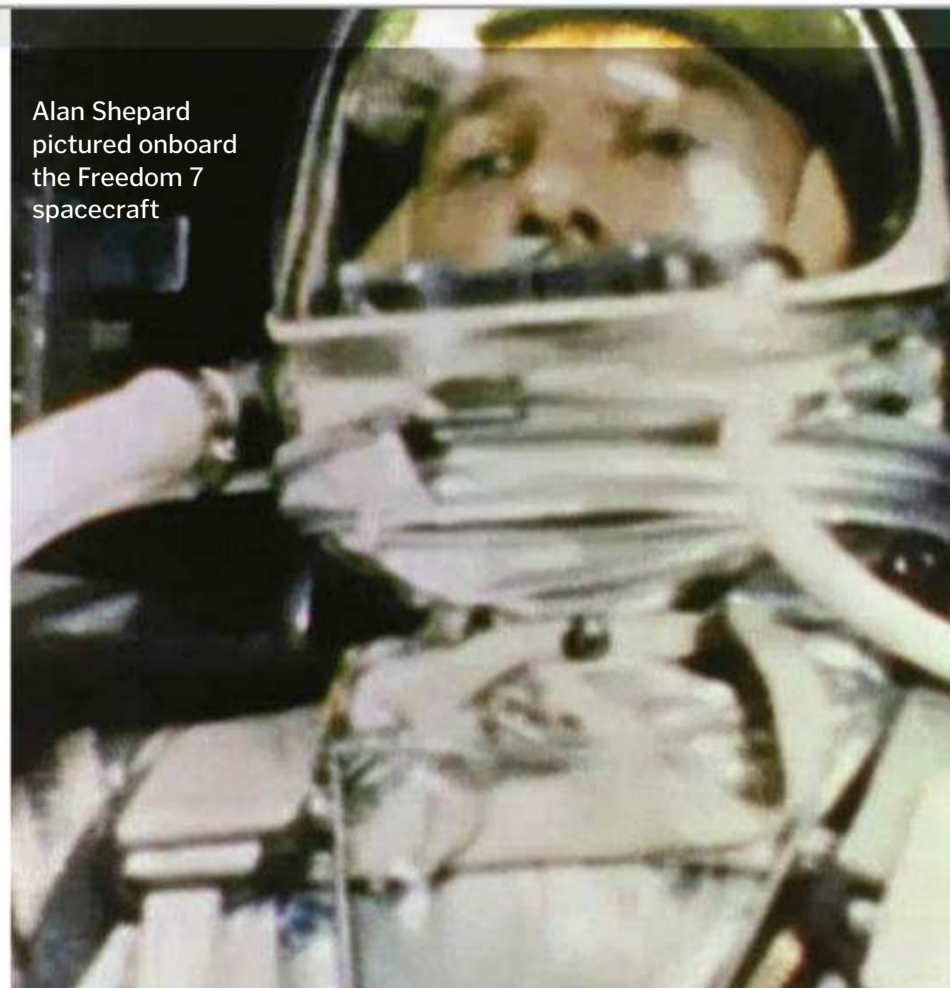
NASA began with 8,000 employees and an annual budget of \$100 million. Today it boasts more than 17,000 and a budget of over \$19 billion (£14.6 billion). And thanks to the early work of people fighting the corner for a peaceful space agency, NASA has grown to become the leading advocate of space science and exploration in the world. It has explored all the major planets, landed on the Moon, study Earth's climate, visited Pluto, and even sent spacecraft beyond the Solar System.

11 October 1958

02 NASA launches its first spacecraft, Pioneer 1, on top of a Thor-Able rocket. The spacecraft had an ambitious goal of reaching the Moon, but a programming error meant the probe fell back to Earth less than two days after launch.



Pioneer was also designed to measure cosmic radiation



Alan Shepard pictured onboard the Freedom 7 spacecraft

3 March 1959

03 Pioneer 4 launches, the first US spacecraft to pass by the Moon.

28 May 1959

04 Able and Baker become the first monkeys to survive a spaceflight.

5 May 1961

05 Alan Shepard becomes the first American in space (and the second human after Soviet Yuri Gagarin weeks prior) on the Freedom 7 spacecraft. During the 15-minute flight he reached an altitude of 187.5 kilometres before returning to Earth.

1950s

1960s

20 February 1962

06 John Glenn becomes the first American to orbit the Earth.

10 July 1962

07 First communications satellite launched, Telstar 1.

23 March 1965

08 First two US astronauts in space simultaneously, on Gemini 3.

15 July 1965

09 Mariner 4 returns the first close-up images of Mars.

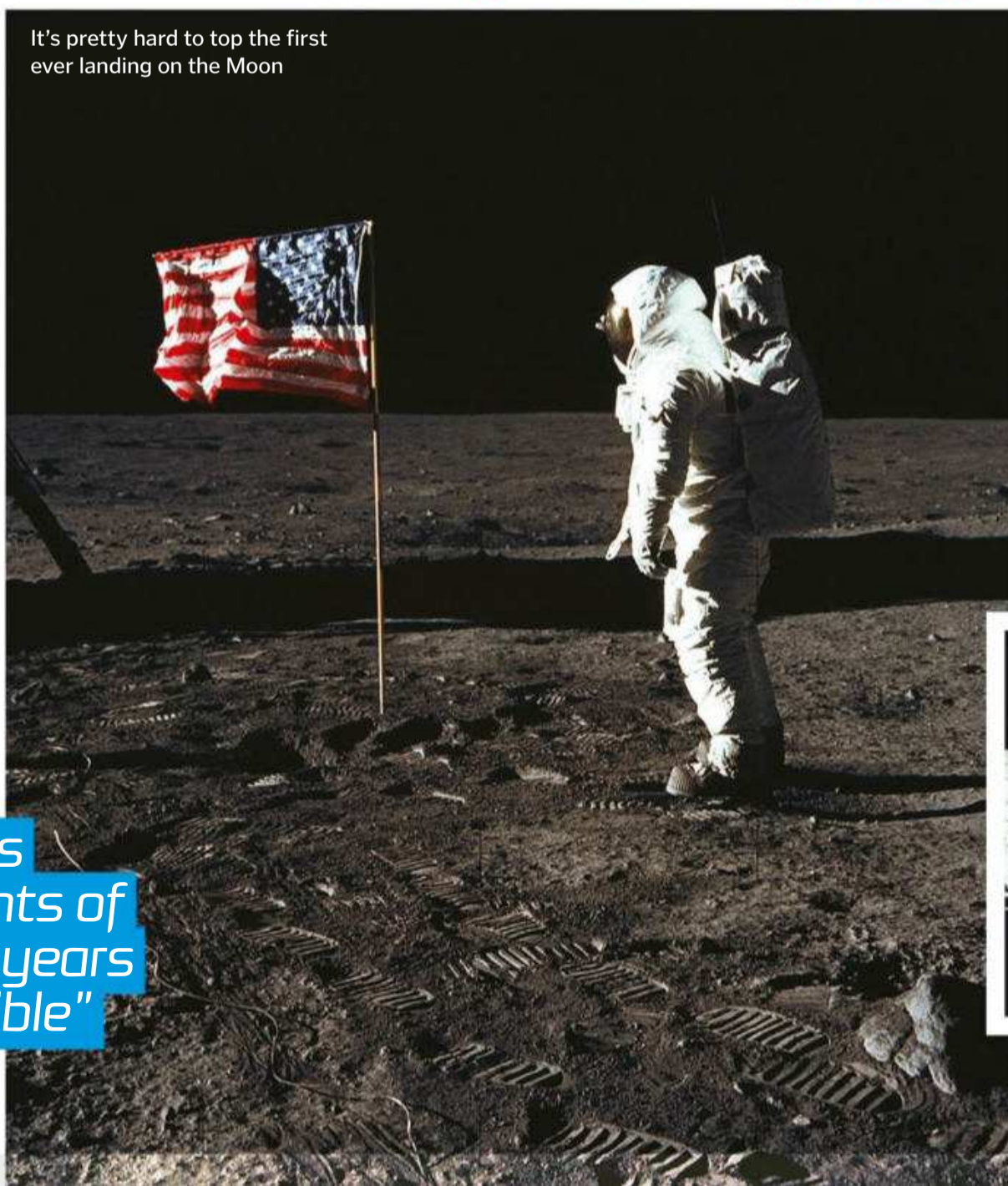
2 June 1966

10 First uncrewed US spacecraft, Surveyor 1, lands on the Moon.

21-27 December 1968

11 The first humans orbit the Moon, on the Apollo 8 mission.

It's pretty hard to top the first ever landing on the Moon



21 July 1969

12 Apollo 11 astronauts Neil Armstrong and Buzz Aldrin become the first humans to set foot on the surface of another world. This monumental event in human history ended the space race between the US and the Soviet Union, who had both set their sites on landing humans on the Moon.

Armstrong and Aldrin's lunar lander, called Eagle, touched down on the lunar surface in the afternoon on 20 July, although Armstrong would not take the first steps on the surface until the early hours of the morning of 21 July. Aldrin followed after, and the two conducted experiments, scooped up Moon rock, took pictures and left a plaque on the surface before returning home. It remains one of humanity's greatest ever achievements, let alone NASA's, watched by an audience in the hundreds of millions around the world.



© NASA

"NASA's achievements of the past 60 years are incredible"



11-17 April 1970

13 Recovery of Apollo 13 after disaster strikes the mission.

26 July-7 August 1971

14 Apollo 15, the first long-duration Moon mission with a rover.

14 November 1971

15 Mariner 9 becomes the first spacecraft to orbit another planet (Mars).

3 March 1972-6 April 1973

16 Pioneer 10 and 11 launch to visit Jupiter and Saturn.

7-19 December 1972

17 Final crewed mission to the Moon, Apollo 17.

14 May 1973

18 Skylab, the first US space station, is launched.

15-24 July 1975

19 Joint mission with the Soviet Union, the Apollo-Soyuz Test Project.

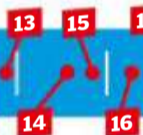


Viking 1 and 2 were the first successful Mars landers and returned some amazing images

20 July 1976

20 The Viking 1 spacecraft becomes the first to ever land successfully on the surface of Mars. It remains operational for more than six years, searching for signs of life on the Red Planet and taking stunning images of the Martian surface.

1970s



1980s



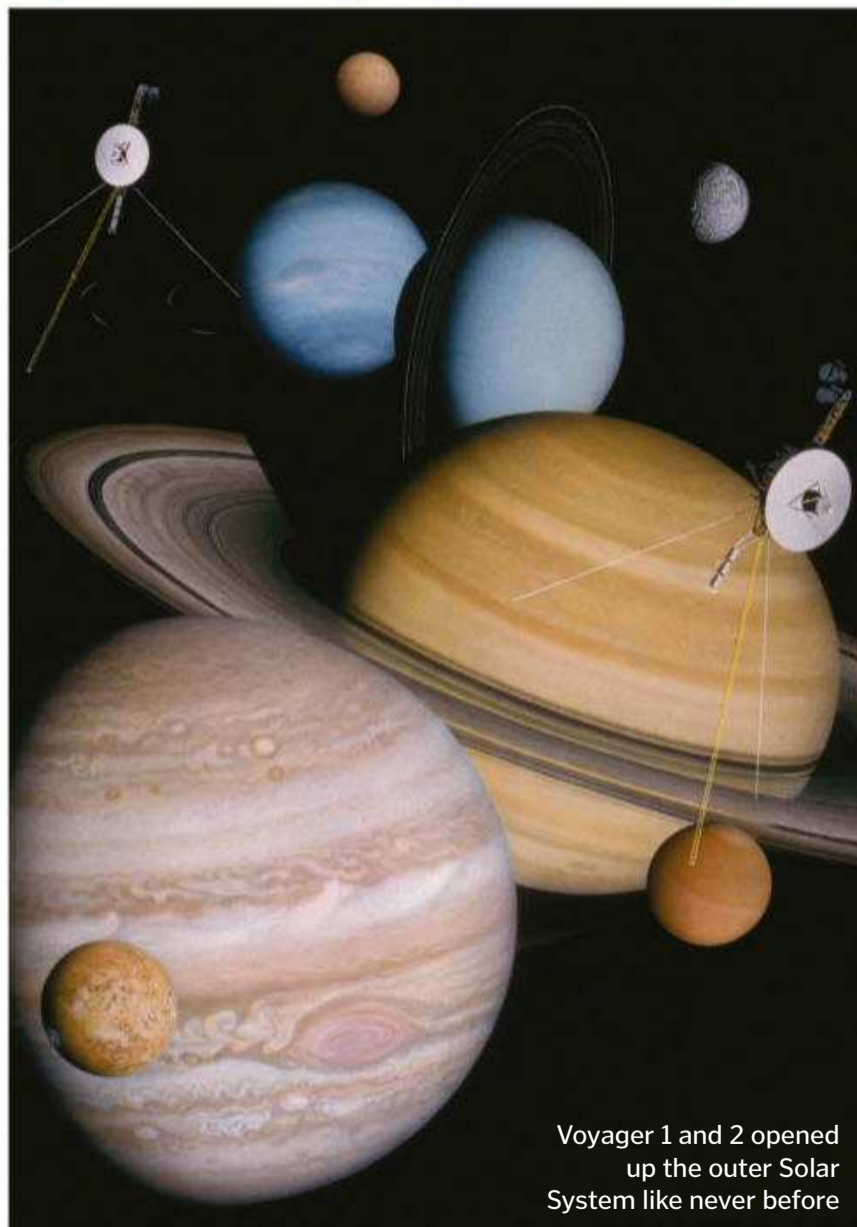
3 September 1976

21 Viking 2 successfully lands on Mars.

20 August 1977

22 In the summer of 1965, NASA scientists discover that a rare alignment of the planets occurs once every 176 years, making possible a 'Grand Tour' of the four outer planets: Jupiter, Saturn, Uranus and Neptune. The culmination of this discovery was the Voyager mission, consisting of two spacecraft, Voyager 1 and 2, the former launched on 5 September 1977, the latter on 20 August 1977.

The two spacecraft returned the first ever images of the four giant planets and imaged dozens of their moons. We saw up close for the first time the rings of Saturn, the band of Jupiter, and much more. As the faster of the two, Voyager 1 also became the first human spacecraft ever to leave the Solar System. Both still continue to transmit as they make their way into interstellar space.



Voyager 1 and 2 opened up the outer Solar System like never before

4 December 1978

23 The Pioneer Venus Orbiter enters orbit around Venus.

12 April 1981

24 The Space Shuttle takes flight for the first time, with astronauts John Young and Robert Crippen onboard. The launch of Columbia heralded the world's first reusable space plane, with the main orbiter detaching from the external tank once in space and able to spend weeks in orbit before returning to land on a runway on Earth. This was the first US human spaceflight since 1975 and was lauded as one of the greatest aviation achievements in NASA's history.

The programme would go on to be wildly successful, if costly, with five orbiters completing 133 missions. Two flights would end in tragedy as Challenger exploded in 1986 after lift-off, killing its crew of seven, and Columbia broke apart on re-entry in 2003, also killing seven.

18-24 June 1983

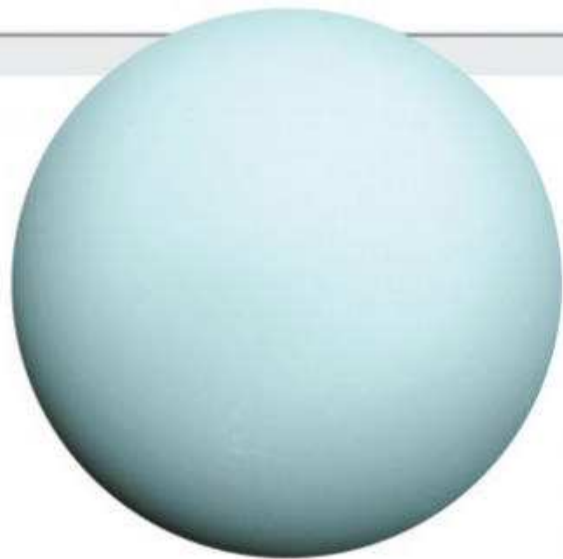
25 Sally Ride becomes the first US woman in space.

6-13 April 1984

26 First satellite orbital repair mission, by Space Shuttle Challenger.

NASA stopped painting the Shuttle's external tank white after the second launch, as it was found that the paint increased the tank's weight by over 270kg





24 January 1986–25 August 1989

27 The Voyager 2 spacecraft returns the first ever close-up images of Uranus and later Neptune, revealing these ice giants in all their glory. The probe captured amazing images of both planets and their moons and to this day remains the only spacecraft to ever visit these worlds.

24 January 1986

28 Voyager 2 performs the first and only Uranus flyby.

4 May 1989

29 Magellan spacecraft launches to map Venus' surface.

25 August 1989

30 First and only flyby of Neptune, by Voyager 2.

18 October 1989

31 Galileo spacecraft launches on mission to orbit Jupiter.



Hubble has been one of the greatest space observatories ever launched

24 April 1990

32 The Hubble Space Telescope is launched, the crowning achievement of NASA's astronomy programme and its most ambitious telescope at the time. Measuring 13.2 metres long and weighing nearly 11,000 kilograms, Hubble was lofted into orbit by Space Shuttle Discovery. However, shortly after launching a severe fault was found in its primary mirror, rendering all the telescope's images of the distant universe blurry. It wasn't until a complicated servicing mission in December 1993 was completed by the crew on Space Shuttle Endeavour that the telescope was up and running. It quickly began to completely redefine our view of the universe.

Hubble has snapped everything from glorious nebulae to distant galaxies, has helped us determine the age of the universe and even discovered new moons around Pluto. Today it is still going strong, with no end in sight.

"Hubble has snapped everything from glorious nebulae to distant galaxies"

1990s

32
33

2000s

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29 October 1991

33 Galileo performs the first ever asteroid flyby.

27 June–7 July 1995

34 Space Shuttle Atlantis docks to Russian space station Mir.

7 December 1995

35 Galileo releases a probe into the atmosphere of Jupiter.

20 February 1997

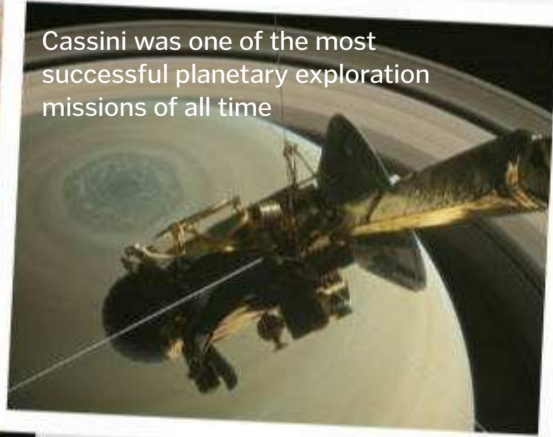
36 Galileo finds evidence for a subsurface ocean on Jupiter's moon Europa.

4 July 1997

37 Mars Pathfinder becomes the first rover on Mars.

15 October 1997

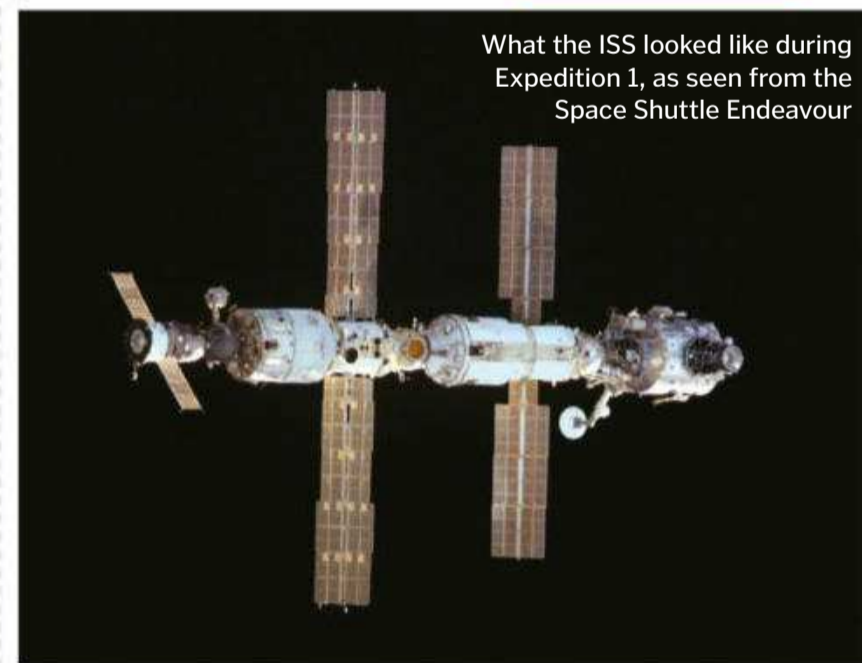
38 The Cassini probe launches, a bold mission to explore Saturn like never before. It would enter orbit in 2004, beginning a 13-year mission of multiple discoveries. It also deployed an ESA lander – Huygens – onto the moon Titan.



Cassini was one of the most successful planetary exploration missions of all time

4 December 1998

39 First US component of ISS launched, called Unity.



What the ISS looked like during Expedition 1, as seen from the Space Shuttle Endeavour

2 November 2000

40 The first crew arrives at the fledgling International Space Station (ISS), consisting of just a few modules. Composed of NASA astronaut Bill Shepherd and Russian cosmonauts Sergei Krikalev and Yuri Gidzenko, the Expedition 1 mission began the continuous presence of humans in space that is still ongoing today.

The ISS was a monumental achievement for NASA, Russia and their other international partners, working together on a global mission like never before. The station's design was born out of a previous NASA project, called Space Station Freedom, but they realised it was too ambitious to undertake alone so they enlisted the help of others. Impressively, just decades after the Cold War, one of these partners happened to be America's former arch rival, a partnership in space that doesn't look like it's ending any time soon.

© NASA/JPL-Caltech/Don Davis/Roe van der Hoorn



12 February 2001

41 NEAR Shoemaker becomes the first spacecraft ever to land on an asteroid.

28 May 2002

42 Mars Odyssey spacecraft finds signs of water ice deposits on Mars.

4-25 January 2004

43 Spirit and Opportunity rovers land on Mars.

1 July 2004

44 Cassini-Huygens enters orbit around Saturn.

4 July 2005

45 Deep Impact probe smashes crater on the comet Tempel 1.

15 January 2006

46 Stardust mission returns first dust from a comet.

9 March 2006

47 Cassini finds geysers of water on Enceladus.

25 May 2008

48 Phoenix lander touches down on Mars.

7 March 2009

49 NASA's Kepler space telescope launches, the first space telescope designed to hunt for worlds outside the Solar System – exoplanets. The mission was a resounding success, discovering thousands of other planets and completely redefining our view of the galaxy.

"NASA hopes to return samples from the surface of Mars"

8 September 2016

60 OSIRIS-REx launches on a mission to asteroid Benu.

15 September 2017

61 Cassini mission ends with plunge into Saturn's atmosphere.

18 April 2018

62 Transiting Exoplanet Survey Satellite (TESS) launches to find more exoplanets.

5 May 2018

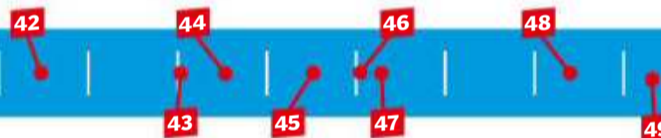
63 InSight lander launches to Mars.

12 August 2018

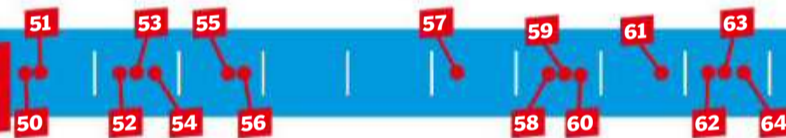
64 The Parker Solar Probe launches on a mission to the Sun.

The Kepler telescope has found the vast majority of known exoplanets to date

2000s



2010s



4 January 2010

50 Kepler detects its first planets beyond the Solar System.

11 February 2010

51 The Solar Dynamics Observatory launches to study the Sun.

18 March 2011

52 MESSENGER spacecraft enters orbit around Mercury.

16 July 2011

53 Dawn spacecraft enters orbit around Vesta.

21 July 2011

54 Final flight of the Space Shuttle as Atlantis touches down.

6 August 2012

55 The Curiosity rover lands on Mars, NASA's most advanced rover ever sent to another world. Results from the rover, still going strong today, have suggested evidence for ancient water on Mars and the possibility it was once habitable.

25 August 2012

56 Voyager 1 reaches interstellar space.

6 March 2015

57 Dawn orbits Ceres – the first spacecraft to orbit two celestial bodies.

5 July 2016

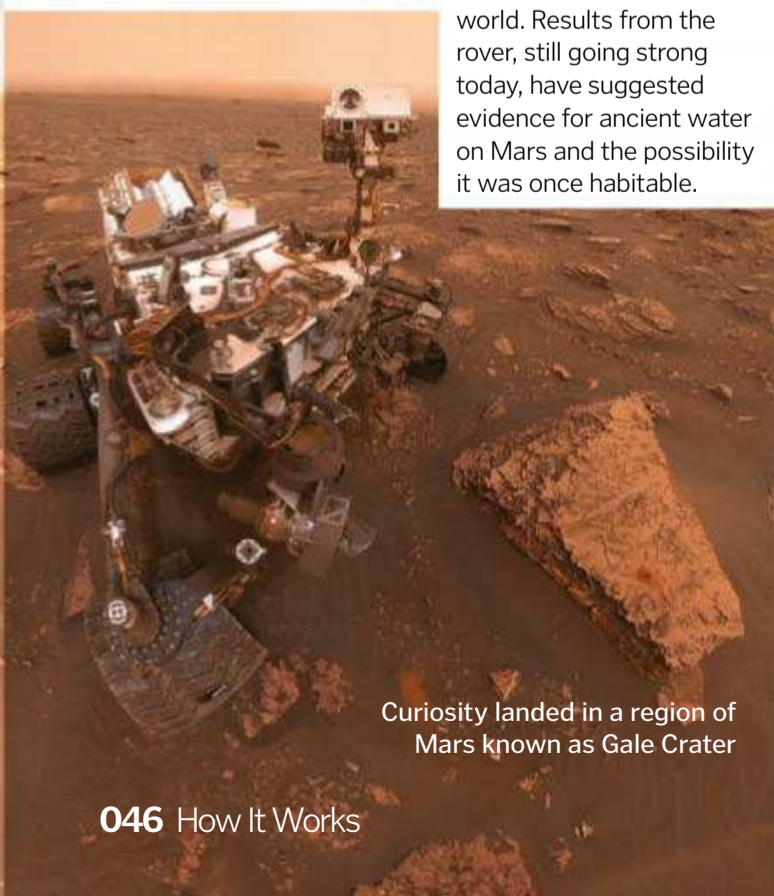
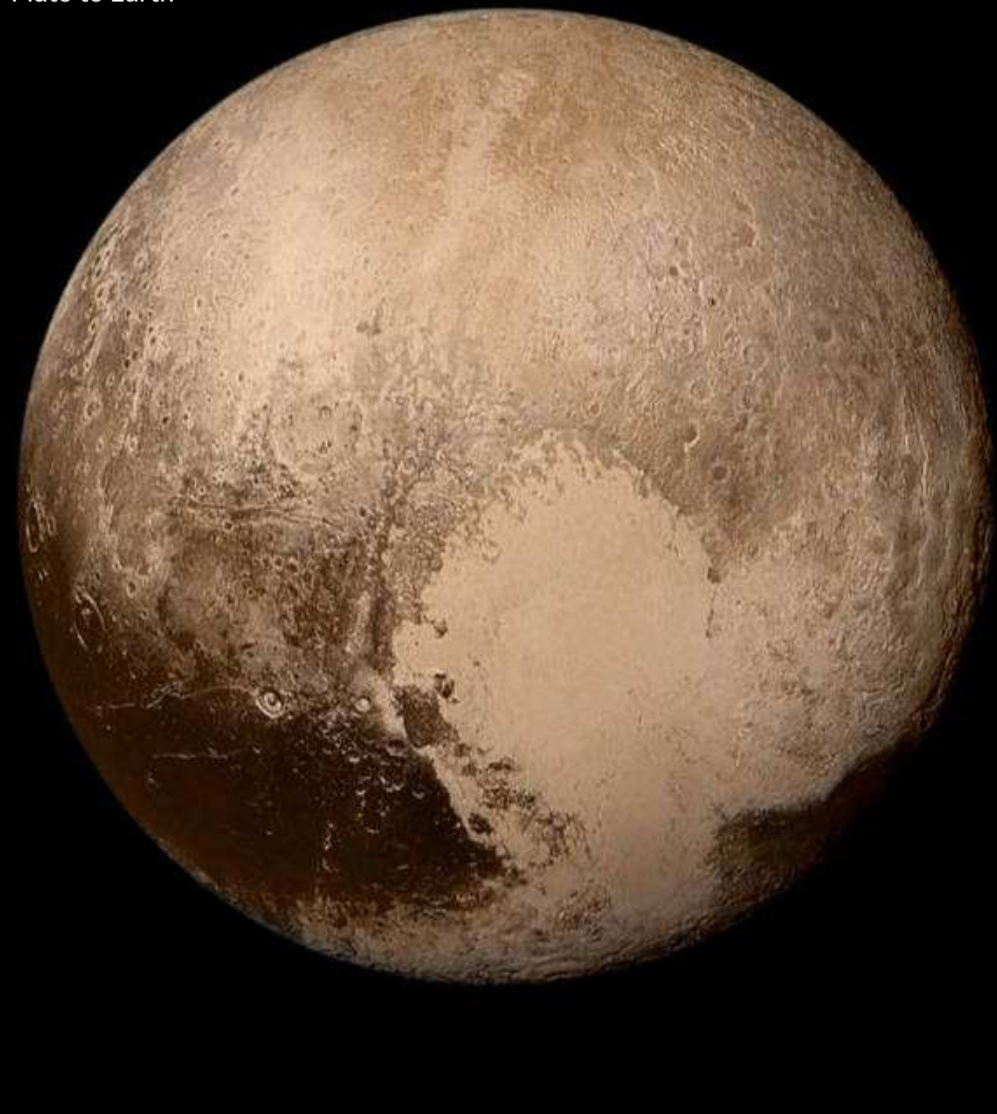
58 The solar-powered Juno spacecraft enters orbit around Jupiter.

14 July 2015

59 NASA's New Horizons spacecraft flies past Pluto, returning our first ever close up images of this distant world. It had launched into space on an Atlas V rocket on 19 January 2006, shooting into space at a speed of 58,536 kilometres per hour – the fastest spacecraft ever to leave Earth orbit. The journey to Pluto would take over nine years and cover a distance of 4.7 billion kilometres of space. New Horizons eventually flew past on 14 July 2015, sending back amazing images of the surface of Pluto and its largest moon Charon.

New Horizons is continuing on its way out of the Solar System today, and on 1 January 2019 it will reach its next target, a small object in the distant Kuiper Belt far beyond Neptune called 2014 MU69, believed to be a remnant of the early Solar System.

New Horizons returned stunning images of Pluto to Earth



Curiosity landed in a region of Mars known as Gale Crater

WHAT'S NEXT FOR NASA?

First private spacecraft

In mid-2019 at the earliest, the first private spacecraft in NASA's Commercial Crew Program – built by SpaceX and Boeing – will lift off. These spacecraft will finally return crewed launches to US soil.



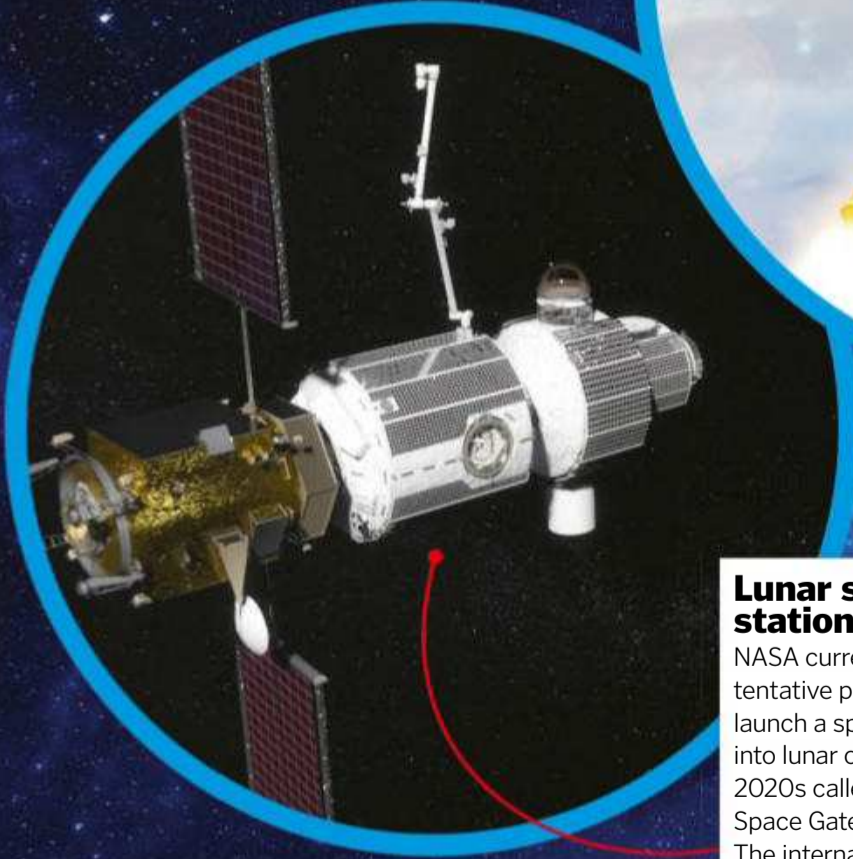
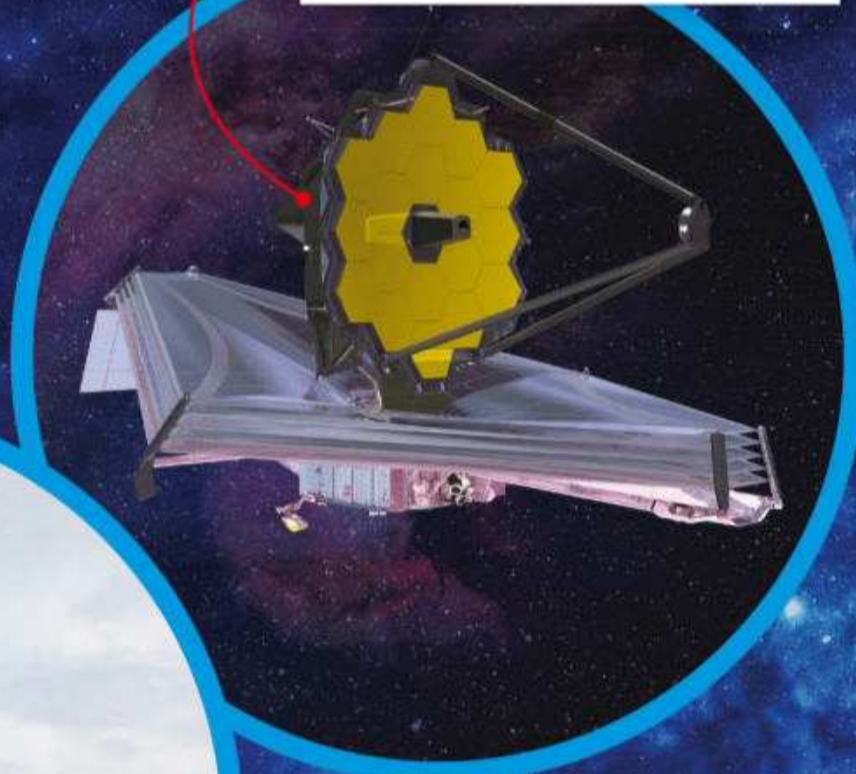
Space Launch System

NASA hopes to launch its huge new Space Launch System (SLS) rocket for the first time by 2020. This will be used to take astronauts back to the Moon and maybe on to Mars.



James Webb Space Telescope

The much-delayed James Webb Space Telescope (JWST) is planned to launch in March 2021. The successor to Hubble, it will give us a glorious new view of the universe.



Lunar space station

NASA currently has tentative plans to launch a space station into lunar orbit in the 2020s called the Deep Space Gateway (DSG). The international collaboration will replace the ISS.

Missions to Mars

In the late 2020s NASA hopes to return samples from the surface of Mars with robotic probes. They still hope to send humans there in the 2030s.





Creepy cosmos

The universe is a weird and wonderful place, but some of the strange new worlds we've discovered are far from welcoming...

In October 2014, our own Sun's active regions gave it the appearance of a jack-o'-lantern

Eternal darkness

Planet: TrES-2b

Discovered: 2006

Distance from Earth: 750 lightyears

This alien gas giant reflects less than one per cent of the sunlight that falls on it, making it blacker than coal and the darkest known exoplanet. It orbits just 4.8 million kilometres from its parent star, heating its atmosphere to over 980 degrees Celsius – too hot for reflective clouds like those on Jupiter to exist. Instead, its atmosphere consists of light-absorbing chemicals like titanium oxide gas and vaporised sodium and potassium.

This deadly blue planet is around the size of Jupiter but orbits its star as close as Mercury orbits our Sun

TrES-2b is not 100 per cent pitch black – it's so hot that it emits a faint, eerie red glow

Wasp-12b is being warped into an egg shape from the intense gravitational forces of its parent star

Deadly rain

Planet: HD 189733 b

Discovered: 2005

Distance from Earth: 63 lightyears

If the barefoot scene from *Die Hard* makes you wince, you wouldn't like life on this exoplanet. It rains shards of glass in over 7,000-kilometre-per-hour winds. This world may be blue like ours, but it's nothing like Earth. Its colour comes from silicate particles condensing into glass in the superheated atmosphere. These glass raindrops scatter more blue light than red, resulting in swirls of cobalt clouds.

Doomed planet

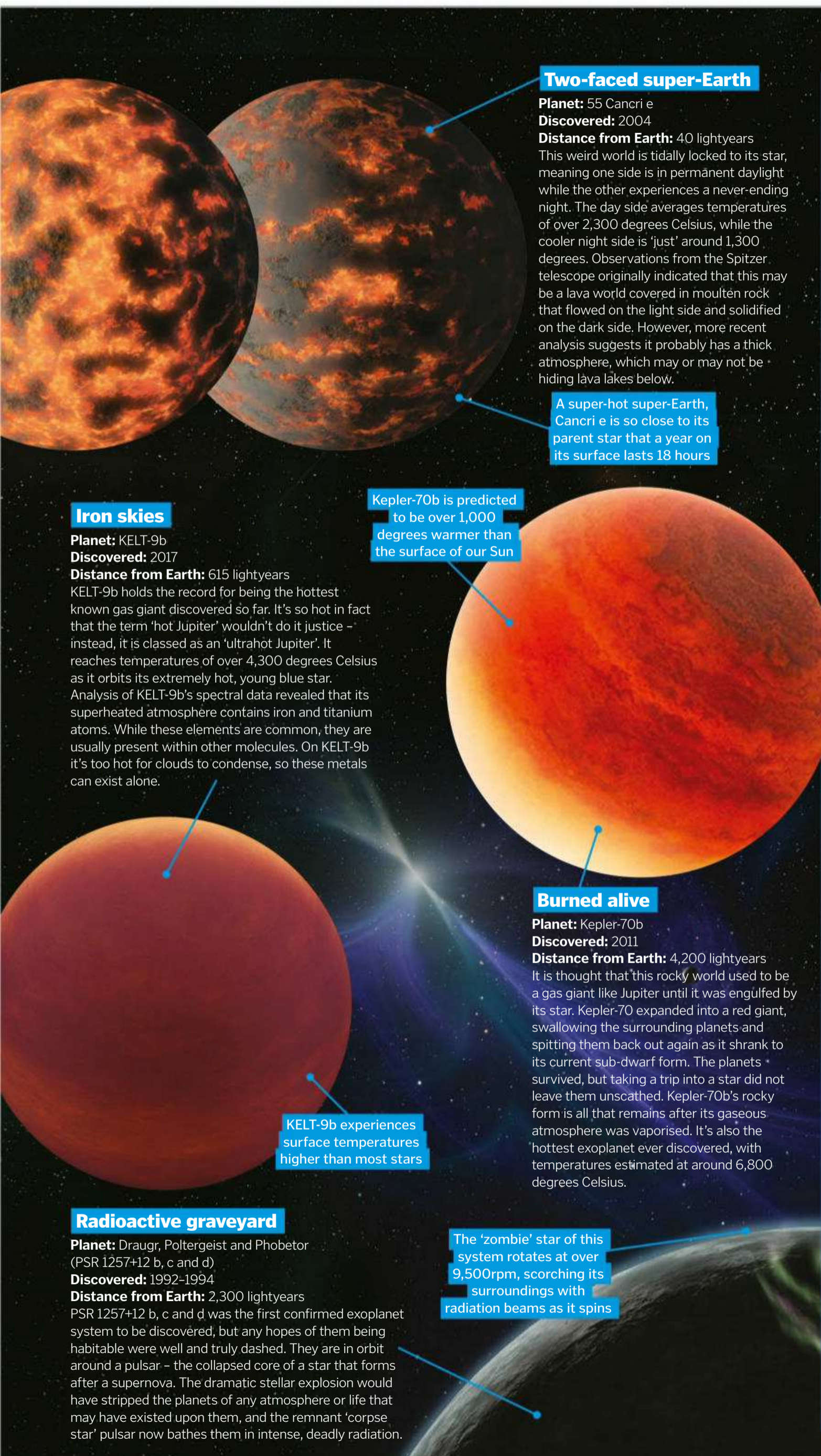
Planet: Wasp-12b

Discovered: 2008

Distance from Earth: 1,400 lightyears

Similar to TrES-2b, Wasp-12b is another hot, Jupiter-like world that reflects very little light. If this wasn't bad enough, the planet itself is slowly being 'eaten' as its atmosphere is escaping into the grasp of its parent star. It's estimated that Wasp-12b will be fully consumed within the next 10 million years.

"The exoplanet KELT-9b is classed as an 'ultrahot Jupiter' – it reaches temperatures of over 4,300°C"



Two-faced super-Earth

Planet: 55 Cancri e
Discovered: 2004
Distance from Earth: 40 lightyears
 This weird world is tidally locked to its star, meaning one side is in permanent daylight while the other experiences a never-ending night. The day side averages temperatures of over 2,300 degrees Celsius, while the cooler night side is 'just' around 1,300 degrees. Observations from the Spitzer telescope originally indicated that this may be a lava world covered in molten rock that flowed on the light side and solidified on the dark side. However, more recent analysis suggests it probably has a thick atmosphere, which may or may not be hiding lava lakes below.

A super-hot super-Earth, Cancri e is so close to its parent star that a year on its surface lasts 18 hours

Iron skies

Planet: KELT-9b
Discovered: 2017
Distance from Earth: 615 lightyears
 KELT-9b holds the record for being the hottest known gas giant discovered so far. It's so hot in fact that the term 'hot Jupiter' wouldn't do it justice – instead, it is classed as an 'ultrahot Jupiter'. It reaches temperatures of over 4,300 degrees Celsius as it orbits its extremely hot, young blue star. Analysis of KELT-9b's spectral data revealed that its superheated atmosphere contains iron and titanium atoms. While these elements are common, they are usually present within other molecules. On KELT-9b it's too hot for clouds to condense, so these metals can exist alone.

Kepler-70b is predicted to be over 1,000 degrees warmer than the surface of our Sun

Burned alive

Planet: Kepler-70b
Discovered: 2011
Distance from Earth: 4,200 lightyears
 It is thought that this rocky world used to be a gas giant like Jupiter until it was engulfed by its star. Kepler-70 expanded into a red giant, swallowing the surrounding planets and spitting them back out again as it shrank to its current sub-dwarf form. The planets survived, but taking a trip into a star did not leave them unscathed. Kepler-70b's rocky form is all that remains after its gaseous atmosphere was vaporised. It's also the hottest exoplanet ever discovered, with temperatures estimated at around 6,800 degrees Celsius.

KELT-9b experiences surface temperatures higher than most stars

Radioactive graveyard

Planet: Draugr, Poltergeist and Phobetor (PSR 1257+12 b, c and d)
Discovered: 1992-1994
Distance from Earth: 2,300 lightyears
 PSR 1257+12 b, c and d was the first confirmed exoplanet system to be discovered, but any hopes of them being habitable were well and truly dashed. They are in orbit around a pulsar – the collapsed core of a star that forms after a supernova. The dramatic stellar explosion would have stripped the planets of any atmosphere or life that may have existed upon them, and the remnant 'corpse star' pulsar now bathes them in intense, deadly radiation.

The 'zombie' star of this system rotates at over 9,500rpm, scorching its surroundings with radiation beams as it spins

Five phenomenally freaky nebulas



The Eye of Sauron (NGC 7293)

In infrared light, the Helix Nebula looks eerily similar to the all-seeing Eye of Sauron from *The Lord of the Rings* films.



Galactic Ghoul (DR 6)

Also known as the 'screaming monkey', this star cluster gets its nicknames thanks to the wide cavity regions that resemble eyes and a mouth.



Witch Head Nebula (IC 2118)

This faint reflection nebula in the constellation of Orion bears a spooky similarity to a wicked witch's face in profile.



Ghost Nebula (Sh2-136)

The billowing clouds of this nebula look strangely like small human-like figures fleeing in terror from a foreboding phantom.



Ghost Head Nebula (NGC 2080)

The two bright white 'eyes' of the Ghost Head Nebula are actually searingly hot regions of glowing hydrogen and oxygen.



Life WITHOUT the Sun

What sort of chaotic consequences would arise if the Sun was to disappear tomorrow? Could humanity survive? Follow this timeline to find out...

EIGHT MINUTES

Plunged into darkness

As light travels at a finite speed, people on Earth wouldn't notice the Sun's disappearance for the first eight minutes. At this point, all sunlight would vanish, making it night-time all the time.

MILLIONS OF YEARS

Stumbling across a replacement star

Depending on the initial trajectory of Earth, it is possible that the rogue planet could eventually come across a distant star and its atmosphere and oceans could thaw, possibly bringing back some of Earth's ancient habitable characteristics.

EIGHT MINUTES

Loss of attraction

Imagine Earth flies around the Sun like a ball is swung around on a string – if the defining, central mass were to vanish, it would be as if the string was cut. Earth and all the other objects in our Solar System would no longer orbit anything and would continue along a straight trajectory.

EIGHT MINUTES

Losing sight of the Moon

The Moon would become invisible to us as there would be no sunlight reflecting off it. The same concept would apply to other objects in the Solar System, including planets, meaning only distant stars would be visible with the naked eye.

ONE WEEK

Freezing temperatures

Within a week temperatures would fall to -18 degrees Celsius without the external heat source of the Sun. This would continuously drop and the majority of life could not be supported.

FEW WEEKS

Killing of plant life

Sunlight is key for photosynthesis, the process that generates breathable oxygen. Although the current supply of oxygen is enough to last a thousand years or so, plant life will not be able to survive in these dark conditions.

FEW WEEKS

Survival of the fittest

The complications that all these effects would have on animals would be extremely noticeable. It is predicted that the food chain would change, with weaker animals dying off first and natural scavengers lasting a little longer.

ONE MONTH

Humanity's escape plan

At this point, it would be make or break for humanity. The only options for survival are to build bunkers as close to the core as possible – surviving off internal radiated heat – or head to a different planet with more habitable conditions.

1,000 YEARS

Atmospheric collapse

At these outrageously cold temperatures it is most likely that our atmosphere will freeze as well and collapse to the surface, opening Earth up to the harmful rays of the cosmos and, most likely, meteor impacts.

1,000 YEARS

Insulated oceans

The large majority of the oceans would continue to freeze over as temperatures begin to stabilise at -240 degrees Celsius. Ironically, the ice layer provides valuable insulation that can keep the deeper ocean from freezing over for hundreds of thousands of years.

DECADES

Large trees left

A lack of sunlight will have wiped out all smaller plants by now, but the larger trees would still survive for a few decades without the need to photosynthesise. This is due to their slower metabolisms and large sugar storage capacities.

TWO MONTHS

Oceans freeze over

The temperature drop would eventually cause all global water to freeze over, turning Earth's seas into ice rinks. While the ocean surfaces would freeze, the depths could remain liquid due to the internal heat of the rogue Earth's core.

EIGHT MINUTES

A solar eclipse provides a momentary example of a Sun-less sky



1,000 YEARS



TWO MONTHS



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THE TERRIBLE TRUE STORIES OF THE TOWER OF LONDON

Murdered children, decapitated queens
and the world's largest diamond – over 900
years of Britain's most famous fortress

Words by **Jodie Tyley**



After his conquest of England in 1066, William of Normandy set about securing his throne by sending a clear message that he was here to stay – a message written in stone. The king built castles all over the country to stamp his authority, and the biggest and most imposing of them all was London's White Tower.

To construct the Tower, William shipped stone over from Caen in France, while Anglo-Saxons provided most of the labour. It took around 20 years to complete and when it was finished it stood at 27 metres tall with walls 4.5 metres thick; walls designed to intimidate the defeated Londoners and act as a defence against them.

The second and third floors – the most secure parts of the keep – were reserved for royalty and nobles. This also includes St John's Chapel, one of the earliest Norman chapels in the country. The first floor was used by domestic staff, and the cellar stored provisions and wine racks. Years later it would house a different kind of rack – one designed for stretching limbs and breaking bones.

The original entrance was on the first floor. Now accessible via a wooden staircase, in Norman times this would have been a ladder that could be quickly withdrawn to prevent intruders. If enemies did gain access, the spiral

staircase would have put them at a disadvantage. Right-handed attackers wouldn't have been able to swing their swords as effectively as the defenders – the wall would have got in the way. What's more, the steps vary in size, so anyone unfamiliar with the layout could lose their footing if they weren't careful, often fatal in a sword fight.

First and foremost, the Tower of London was a palace, not a prison. However, the first inmate was also the first escapee! Ranulf Flambard, Bishop of Durham, was imprisoned in 1100. A year later his friends smuggled in a rope inside a wine casket, which the guards heartily

consumed. As they slept, Ranulf is said to have used the rope to abseil to freedom.

The Tower of London continued as a royal residence for William the Conqueror's descendants, who made their own mark on the fortress. Henry III (1216–72) and his son Edward I (1272–1307) added royal

apartments and built not one but two concentric walls of defence and a 50-metre-wide moat – further than an archer could shoot accurately. However, in 1843 this moat was drained when sewage, carcasses and the bodies of plague victims turned it into a stinking pit of disease encircling the 2,500 people living in the Tower.

"First and foremost, the Tower of London was a palace, not a prison"

Protecting the Crown Jewels

For over 600 years the Tower has housed precious royal items, but it was also where the original Crown Jewels were destroyed following the execution of King Charles I in 1649. Among the irreplaceable historical artefacts was the 11th-century crown of the saint-king Edward the Confessor, which was dropped into the Mint melting pot and turned into coins.

The medieval coronation spoon was one of the few items that survived, and this 800-year-old object can be seen in the Tower's Jewel House today. This is also where the coronation regalia are displayed, created after the restoration of the monarchy in 1661. The most important item is the coronation crown itself, named St Edward's Crown in memory of its medieval predecessor. This is only worn when a monarch is crowned, so for the past 65 years it has been unused.

These sacred and ceremonial objects were once stored over 80 metres below ground in a fortified bunker but were transferred upstairs in 1994. In their present, more

accessible location in the Waterloo Barracks they are protected by bombproof display cases and over 100 hidden cameras. Massive vault doors with thick bolts secure entry into the room, and a control room where the security devices are located is strictly off-limits. The sentry, along with Yeoman Warders and the Jewel House wardens, also stand guard to protect the Crown Jewels.



The Crown Jewels feature the Koh-i-Noor, the largest diamond in the world

© Getty



Another of the defensive features are the portcullises. French for 'sliding door', these heavy metal gates could be lowered and raised by a pulley. The most infamous of these lies at the bottom of St Thomas' Tower. Originally, this was used as the water-gate entrance for Edward I's royal barge. Later it became known as the trader's gate, where supplies were delivered, but then things took a dark turn. In the 16th century this same entrance became known as Traitors' Gate, and it was through here that prisoners were brought to the Tower to be tried. The route to the gate took the accused along the River Thames and under London Bridge, where the heads of executed prisoners gazed down at them from spikes.

In 1279, Edward I moved the Royal Mint to the Tower. This was where the coins of the realm were manufactured under the close scrutiny of guards. Medieval coins were made of silver,

which was easy to bend and break, meaning criminals could flood the market with fake coins. When an enraged Edward learned of this ploy he placed the blame on England's small Jewish community. Many were consequently hanged and 600 were imprisoned in the Tower.

Bloody stories such as this earned the fortress a grisly reputation, and no one dared challenge its power until 1381 during the

Peasants' Revolt. On 14 June that year, an angry mob of militant rebels breached the Tower walls. One of their targets, the Archbishop of Canterbury and the king's chancellor, was saying his last prayers in

A tour of the Tower

The medieval castle has served many purposes over the centuries

Tower Green

Only high-ranking prisoners were beheaded inside the Tower. Seven nobles were executed on Tower Green, including two wives of Henry VIII.

Queen's House

Henry VIII built these apartments for his second queen, Anne Boleyn. She stayed here before her coronation and again years later before her execution in 1536.

Chapel Royal of St Peter ad Vincula

There has been a place of worship on this site for over 1,000 years. However, the chapel that stands today dates from the reign of Henry VIII (1509-1547).

Wakefield Tower

These were the royal lodgings of Henry III (Edward I's father). They were originally on the river's edge so that he could arrive by boat.

Traitors' Gate

The water gate was originally an entrance for Edward I to arrive by barge. It later became the entrance for prisoners condemned to the Tower.

St Thomas' Tower

This was built by Edward I between 1275 and 1279 as royal accommodation with views of the river.

Timeline of the Tower

1070s Following the Norman invasion in 1066, William the Conqueror began building the fortress to control the city of London.	1241 Henry III had the castle keep whitewashed. It then became known as the White Tower.	Mid-1300s The formal locking and unlocking of the Tower began on King Edward III's orders.	1381 The only time the Tower's defences failed was during the Peasants' Revolt when rebels ran through the gates.	1471 King Henry VI was murdered here during the Wars of the Roses. He was the last Lancastrian king.	1669 During the reign of Charles II paying members of the public were permitted to visit the Tower.	1674 The remains of small children were discovered, believed to be the 'Princes in the Tower', who went missing in 1483.	1835 The Royal Menagerie was closed and the animals were moved to Regent's Park.	1952 Notorious East End gangsters the Kray twins were among the last prisoners to be held at the Tower.	1994 The Crown Jewels were moved up to the Jewel House, which was opened by Queen Elizabeth II.
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White Tower

The foreboding castle keep was built by William the Conqueror between 1078 and 1097 to deter any would-be rebels and invaders.

Waterloo Block

As constable of the Tower, the Duke of Wellington ordered this block to be built in 1845 as barracks for some 1,000 men. It was named after his famous victory.

Martin Tower

The former prison later housed the Crown Jewels from 1669 to 1841. It was here that Thomas Blood made an attempt to steal them.

The first London zoo

Long before humans were held captive in the Tower, wild beasts once paced the fortress. The Royal Menagerie was founded by King John in the early 1200s, as exotic creatures were seen as status symbols. His son, Henry III, honoured this strange tradition and the number of animals at the Tower grew. In 1235, the Holy Roman Emperor Frederick II sent three lions, and in 1252 the King of Norway sent a polar bear.

The Royal Menagerie opened its doors to the public in the 18th century – the price of admission was three half-pence or a cat or dog to be fed to the lions! However, at the beginning of the 19th century animal welfare became a priority and the RSPCA was founded. The Menagerie closed and 150 animals were moved to Regent's Park, establishing London Zoo.



Fanny Howe, *whelp'd in the Tower*, 1794. Fanny was a female tiger housed in the Royal Menagerie

Edward I's bedchamber has been re-created using replicas of 13th-century furnishings

© Getty-Alamy



Lanthorn Tower

This tower was part of Henry III's queen's lodgings. It was also built to reinforce defences.



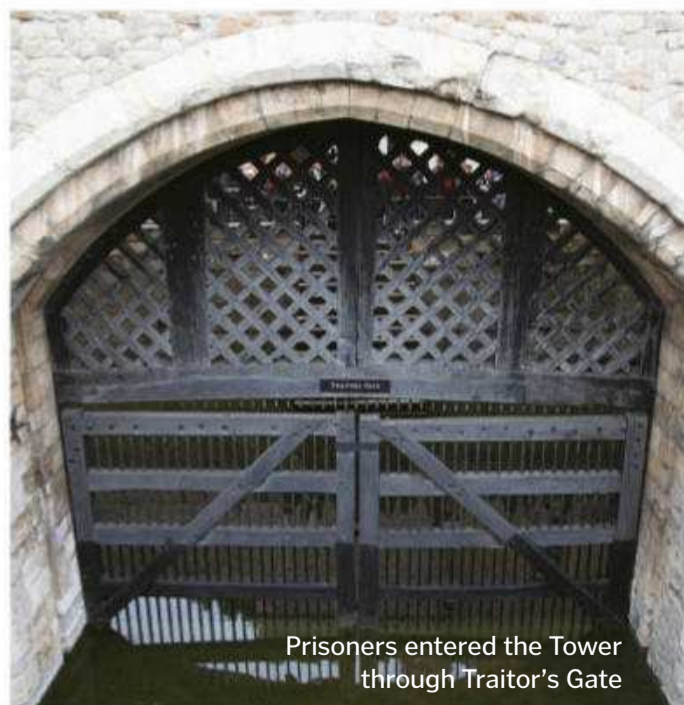
the chapel when they seized him. He was dragged to Tower Hill and promptly beheaded.

Clearly being a resident of the castle did not always guarantee your safety. During the Wars of the Roses, Henry VI was murdered while at prayer in the King's Private Chapel in the Wakefield Tower. Years later, the children of his Yorkist enemy, Edward IV, mysteriously disappeared within the fortress.

It was 1483, and 12-year-old Edward V was awaiting his coronation. He was taken there, as was tradition, along with his nine-year-old brother. Better known as 'the Princes in the Tower', the boys became prisoners when their uncle Richard (who later became King Richard III) declared them illegitimate and took the crown for himself. Months later the princes vanished. Rumours of their murder saw the Garden Tower where they were kept renamed as the Bloody Tower. For centuries no one knew what happened, until renovation work in 1674 uncovered the skeletons of two children under a staircase in the White Tower.

Yet more royal blood would be spilled during the reign of King Henry VIII. This time, however, the executions were ordered by the state and carried out in full view of the public. The Tudor tyrant signed the death warrants of two of his wives, Anne Boleyn and Catherine Howard, and some of his closest friends, including Sir Thomas More. While most of these executions took place on the nearby Tower Hill, seven nobles were executed within the walls of the Tower in relative privacy.

A temporary wooden scaffold was erected on Tower Green – an open space by the Chapel Royal of St Peter ad Vincula – to give the onlookers a better view. The condemned would climb the stairs onto the platform and give the executioner a purse of gold and silver as a final act of forgiveness. They would then utter their last words before laying their head on the chopping block to await the blow of the



Prisoners entered the Tower through Traitor's Gate

Guardians of the Tower

Yeoman Warders, nicknamed Beefeaters, have protected the fortress since Tudor times

Tudor bonnet

Known as the Tudor bonnet, this large hat adds height to the wearer, making them appear more intimidating to any would-be attackers.

Tudor state dress

The 'red and gilt' uniform has been worn since 1549 and was originally designed to be worn under armour. Today it is only worn when the monarch visits the Tower or during state occasions.

Medals

Today's Yeoman Warders must have completed at least 22 years' military service. They also need to have reached the rank of warrant officer and have been awarded the Long Service and Good Conduct Medal.



Undress uniform

This daily working uniform was granted to the Yeoman Warders by Queen Victoria in 1858. The frock coat features the initials of the current monarch.

Belt

The state dress is almost identical to the uniform of the Yeoman of the Guard – the bodyguards of the British monarch. However, the Warders wear a belt around their waist while the Guards wear cross-belts from the left shoulder.

Emblems

The Tudor state dress has an embroidered thistle, rose and shamrock – the emblems of Scotland, England and Ireland. It was designed to be worn under armour, hence the tights.

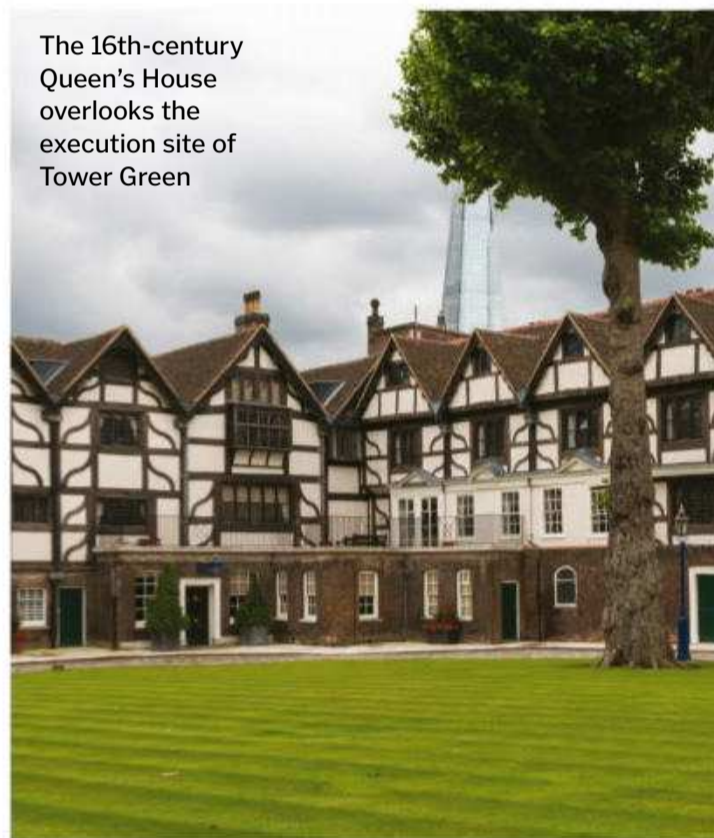
executioner's axe. In the case of Margaret Pole, Countess of Salisbury, it took several blows to finish the deed. The nobles who died here were buried in the grounds, and a memorial stands on the scaffold site today.

The Tower had become Henry VIII's personal prison, and he believed it should be protected by part of the royal bodyguard. The Yeoman Warders were created in 1485 and have guarded the castle ever since. It is said that they gained the nickname of 'Beefeater' because they were originally paid in food, in particular beef as it was a luxury item. It was a coveted position and one that could be sold for 250 guineas until the Duke of Wellington abolished this purchase system in 1826.

In his role as Constable of the Tower he made other changes, such as getting rid of the Royal Menagerie – a collection of exotic animals that had been there since the 13th century. He wanted to keep the Tower as a strictly military stronghold and even constructed the Waterloo Barracks for 1,000 soldiers.

The Iron Duke didn't entirely get his wish though, as today the Tower of London is one of the most-visited tourist attractions in the world. It continues the tradition of housing the Crown Jewels, and Yeoman Warders still stand on ceremonial guard, but their duties now include giving guided tours. But the Tower doesn't shut down when the visitors leave. The 37 Warders live on the premises with their families, the Resident Governor and a garrison of soldiers. There's an onsite doctor and chaplain and even a secret pub. Over 900 years on, the castle that was built to inspire awe and fear in Londoners is now one of the city's most treasured landmarks.

The Beauchamp Tower bears the graffiti of prisoners from the 16th and 17th centuries



The 16th-century Queen's House overlooks the execution site of Tower Green

Raven mad

Legend has it that if the Tower has fewer than six ravens in it the fortress and kingdom will fall. That's why there are seven ravens in the Tower today – one extra just in case! There is even a Ravenmaster who looks after their wellbeing and keeps their feathers trimmed to prevent them from flying too far away.

It's said that Charles II ordered that the ravens were protected upon hearing the grim prophecy. This was much to the annoyance of astronomer John Flamsteed, who complained that the birds were hampering his work in the observatory in the White Tower.

The ravens have since become known as guardians of the Tower, but over the years some have gone absent without leave and others have been dismissed for bad behaviour.



The ravens are fed raw meat and biscuits soaked in blood

Famous prisoners

Many well-known people spent time in the Tower



Anne Boleyn
2 May 1536–
19 May 1536

When Henry VIII's second queen did not give birth to a son she was arrested – and later executed – on trumped-up charges of treason, adultery and incest.



Lady Jane Grey
19 July 1553–
12 February 1554

The 'Nine Day Queen' was already at the Tower preparing for her coronation when her claim to power was overruled. She was imprisoned then executed.



Guy Fawkes
5 November 1605–31
January 1606

The head of the Gunpowder Plot was tortured in the Tower. Sentenced to be hung, drawn and quartered, he was spared this fate by breaking his neck.



Sir Walter Raleigh
1603–1616

Once the favourite of Elizabeth I, Raleigh was unpopular with her successor, James I. Accused of plotting against the king, he was imprisoned for 13 years before being executed.



The Princes in the Tower
June 1483

Edward and Richard York were held in what became known as the Bloody Tower before they mysteriously disappeared after their uncle usurped the throne.



Rudolf Hess
17–20 May 1941

Winston Churchill briefly imprisoned the Deputy Führer of Nazi Germany after Hess' plane crashed in Scotland. He claimed to have been travelling on a mission to broker peace.



Carnotaurus

Meet one of the weirdest dinosaurs to have walked the Earth

The Carnotaurus was one of the Late Cretaceous period's most feared predators. It once stalked across the land with its bright, beady eyes, box-shaped head and distinctive bull-like horns. Standing around four metres tall and nine metres long, these unusual-looking giant theropods were the distant South American cousins of the T-rex.

The Carnotaurus' most distinctive feature, however, is its comical – and probably useless – tiny arms. While these wouldn't have made it any less ferocious if you were confronted with one, they do pose an evolutionary puzzle for palaeontologists today (see boxout opposite).

Only one Carnotaurus fossil has ever been discovered, unearthed in Argentina by palaeontologist Jose Bonaparte in 1985. However, it is almost a full skeleton and impressively detailed – including fossilised

impressions of its skin in the surrounding Earth – making it a very rare find indeed. The remains have given palaeontologists a remarkable insight into the Carnotaurus' anatomy, posture, habitat and diet.

It's not hard to see why palaeontologists chose the name Carnotaurus, meaning 'meat-eating bull'. Its distinctive horns are thought to have been used by males to fight one another, literally butting heads when competing for territory or to impress females.

Like many other large theropods, Carnotaurus were carnivores and so had the sharp teeth to match. If their terrifying backwards-curving, flesh-tearing teeth were not enough to scare you, researchers suspect that the crafty Carnotaurus was also one of the most intelligent theropods – it could definitely outrun you, and it may have even been able to outsmart you.

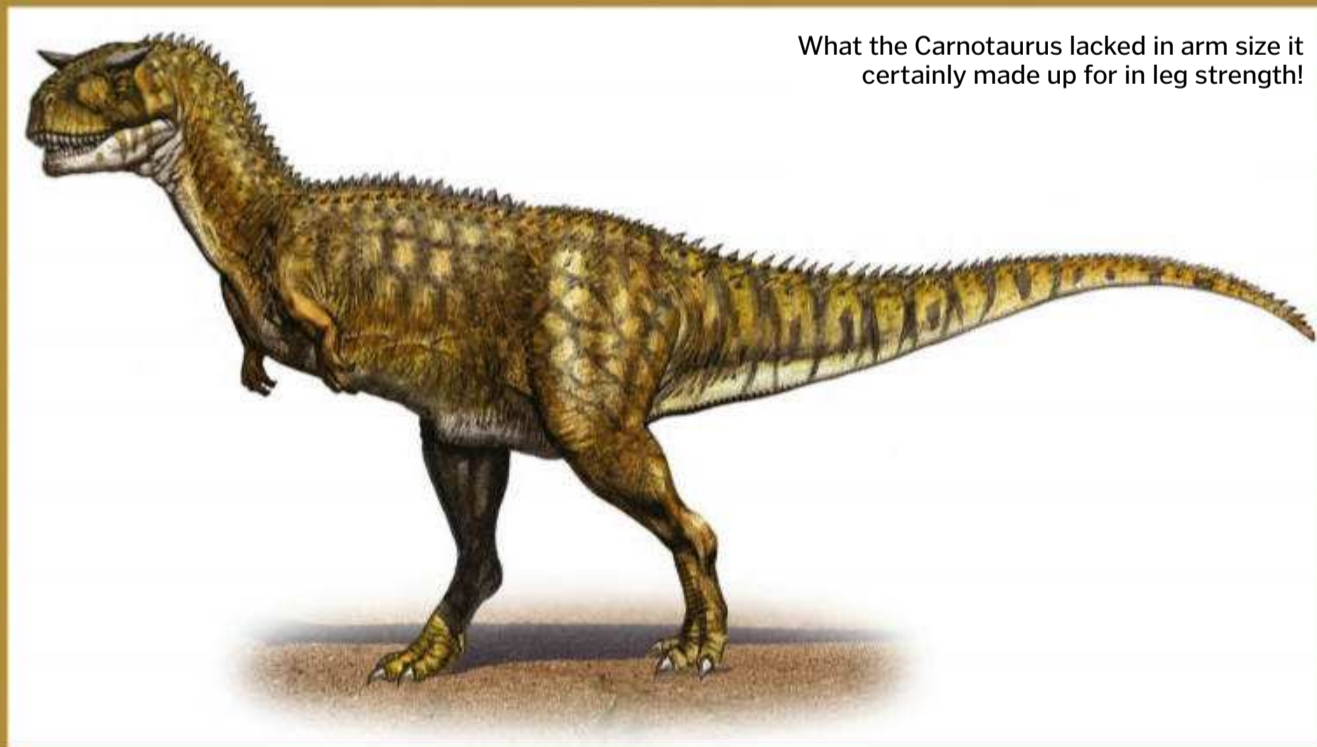
Roarsome sprinter

Carnotaurus was a champion sprinter, capable of reaching speeds of 40 kilometres per hour. Two of the most striking pieces of evidence for this come from analysing the leg and tail of the fossil specimen. Its thigh bones were adapted to withstand bending movements when running, while bulky muscles in its tail also provided power.

The caudofemoralis (a pair of muscles that ran either side of the tail) attached to a prominent ridge on the thigh bone to pull the leg backwards when contracted. The

muscles were anchored to the tail bones, which, in the case of the Carnotaurus, were not T-shaped like slower-moving animals but instead formed a V-shape. This adaptation created more space for bigger caudofemoralis muscles, which made up some 15 per cent of the Carnotaurus' entire body mass – larger than any other theropod.

Because of this super sprinting ability it's thought that Carnotaurus would have been ambush predators, employing bursts of speed to catch their prey.



What the Carnotaurus lacked in arm size it certainly made up for in leg strength!

Carnotaurus anatomy

Sharp teeth, powerful jaws, muscular legs and teeny-tiny arms. This formidable predator almost had it all...

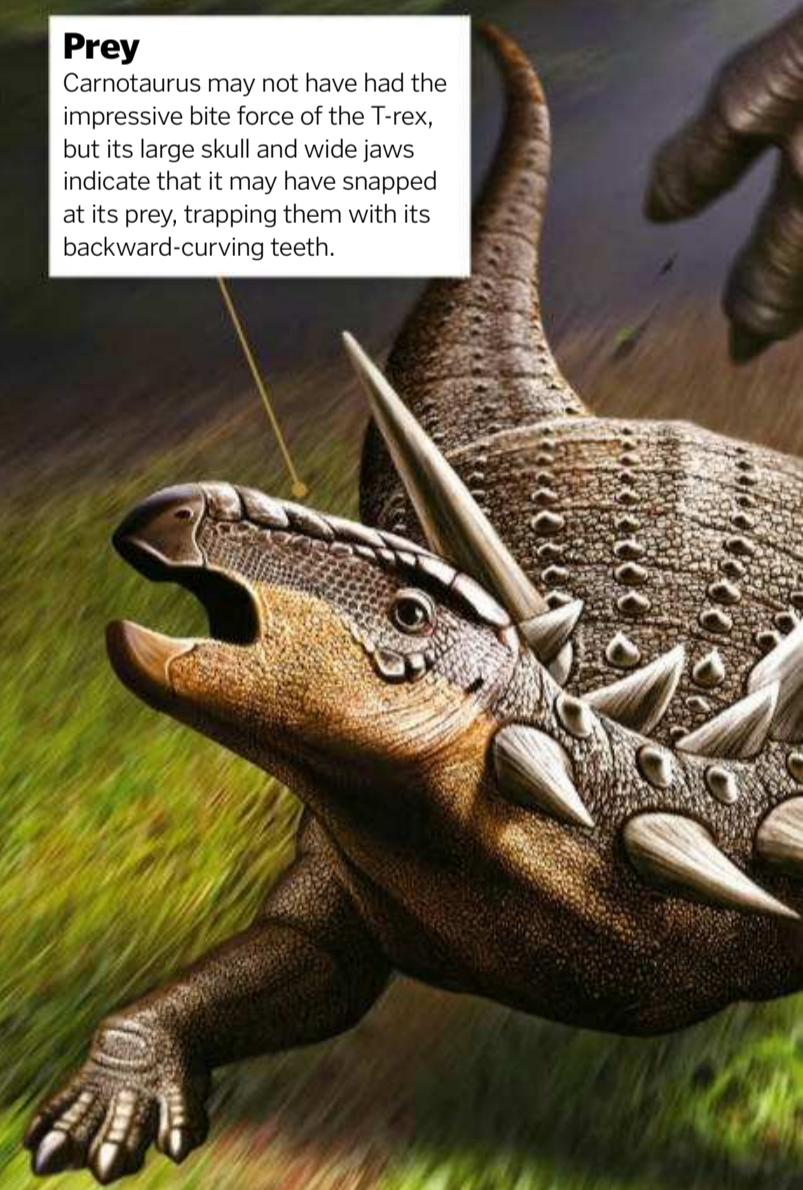
Heavy and huge

Based on the single specimen discovered so far, palaeontologists estimate that Carnotaurus weighed about 2tn and measured 4m tall and 9m long.

"Carnotaurus' horns may have been used to fight one another, literally butting heads when competing for territory"

Prey

Carnotaurus may not have had the impressive bite force of the T-rex, but its large skull and wide jaws indicate that it may have snapped at its prey, trapping them with its backward-curving teeth.



Fast-moving

The speedy Carnotaurus could outrun a T-rex. Thanks to powerful muscles in its tail it could sprint at speeds of up to 40kph.

Scaly skin

Analysis of the Carnotaurus' fossilised skin samples has revealed that their bodies were covered in pebble-like scales, with conical scutes (bony plates) along their sides that would have acted like armour.

Head and horns

Carnotaurus had 15cm-long bull-like horns on its head that were used to fight rivals for territories and mates.

Senses

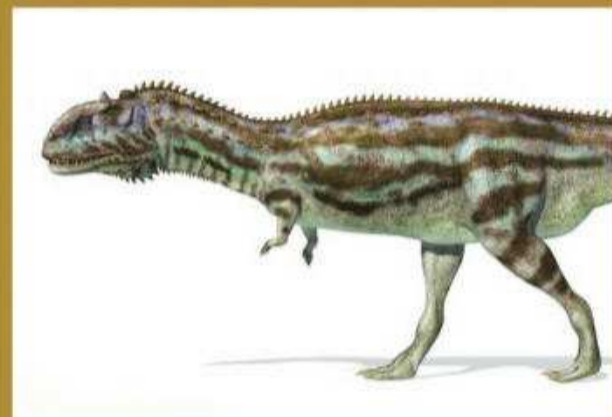
Like other dinosaurs, the Carnotaurus is thought to have had a powerful sense of smell to compensate for poor eyesight.

So why the small arms?

One of the first things that you'll notice about the ferocious Carnotaurus is its disproportionately tiny arms. They're so small that they're little more than wrists. And if you're thinking they look too tiny to be useful, you're probably right. Though the radius and ulna bones that make up the lower arm are actually stronger and more robust than expected, their hands were certainly weak, particularly when you consider the strength of the rest of its titanic body.

However, the presence of the four fingers on their hands suggests that their arms must have either had some evolutionary purpose or they had only recently (in evolutionary terms) become so ridiculously small and useless.

Regardless of their unknown purpose (it has been hypothesised that perhaps the juvenile Carnotaurus were better proportioned and the arms only became useless in adulthood) the trend of smaller arms in carnivorous dinosaurs of the Cretaceous is well documented. The strong and powerful arms of Jurassic dinosaurs become mostly weak and useless in the Cretaceous, though there is little evidence suggesting why.



Many members of the Abelisaurid family, including the Majungasaurus (pictured), had small arms

© Getty



Though smaller than the T-rex, the Carnotaurus was a formidable predator and used its tough skin and armoured head in battle against competing animals



Killer colours

From poisonous greens to gruesome browns, the art world has a long history of deadly and disgusting paint pigments



Bone black

Created from the charcoal remains of burned animal bones, this deep blue-black pigment has been used since ancient times and was popular with the Dutch master portrait artist Rembrandt (1606-1669).



Orpiment

This vivid yellow hue derives from naturally occurring arsenic sulphide, a mineral that even in small doses is deadly to humans. It was used as early as 1200 BCE in Egypt and later the Persian Empire.



Realgar

Another extremely deadly arsenic-based pigment, for centuries this was the closest colour to orange that medieval artists could get their brushes on. The name derives from the Arabic *rahj al ghar*, meaning 'powder of the mine'.



Lead white

Popular in ancient Greek and Roman makeup routines, this pigment was considered the purest white available to artists until the 19th century. It was created by combining metallic lead and vinegar and was therefore highly toxic.



Vermilion/cinnabar

Created by combining mercury and sulphur, this compound's Arabic name, cinnabar, or *zinjafr*, translates as 'dragon's blood'. It was widely used in China since the 8th century CE, and its mercury content made it incredibly toxic.



Naples yellow

Examples of this mysterious colour have been found in ancient Egyptian, Greek and Roman art. Despite its highly hazardous lead content it was also used during the Italian Renaissance and was popular for its warm, subtle tone.



Indian yellow

The source of this bright hue certainly put the 'p' in portraiture. It was traditionally extracted from the urine of Indian cattle fed on mango leaves. Despite this the pigment was widely used by European painters until the 19th century.



Mummy brown

As its name suggests, this tone is made of Egyptian corpses. A gruesome method of grinding up these bodies was found to create a pleasant flesh-brown hue. The macabre substance was also used as a cure for a range of illnesses.



Scheele's green

Swedish chemist Carl Scheele lent his name to this pigment, which he created by combining copper sulphate with arsenic. Used to dye wallpaper and clothes, when the deadly effects of arsenic became known its popularity waned.



Emerald green (aka Paris green)

Created to supplant the popularity of Scheele's Green, this copper-arsenic compound was, like its rival, highly poisonous. It's thought the presence of one of these pigments in Napoleon's wallpaper contributed to his death.



Radium green

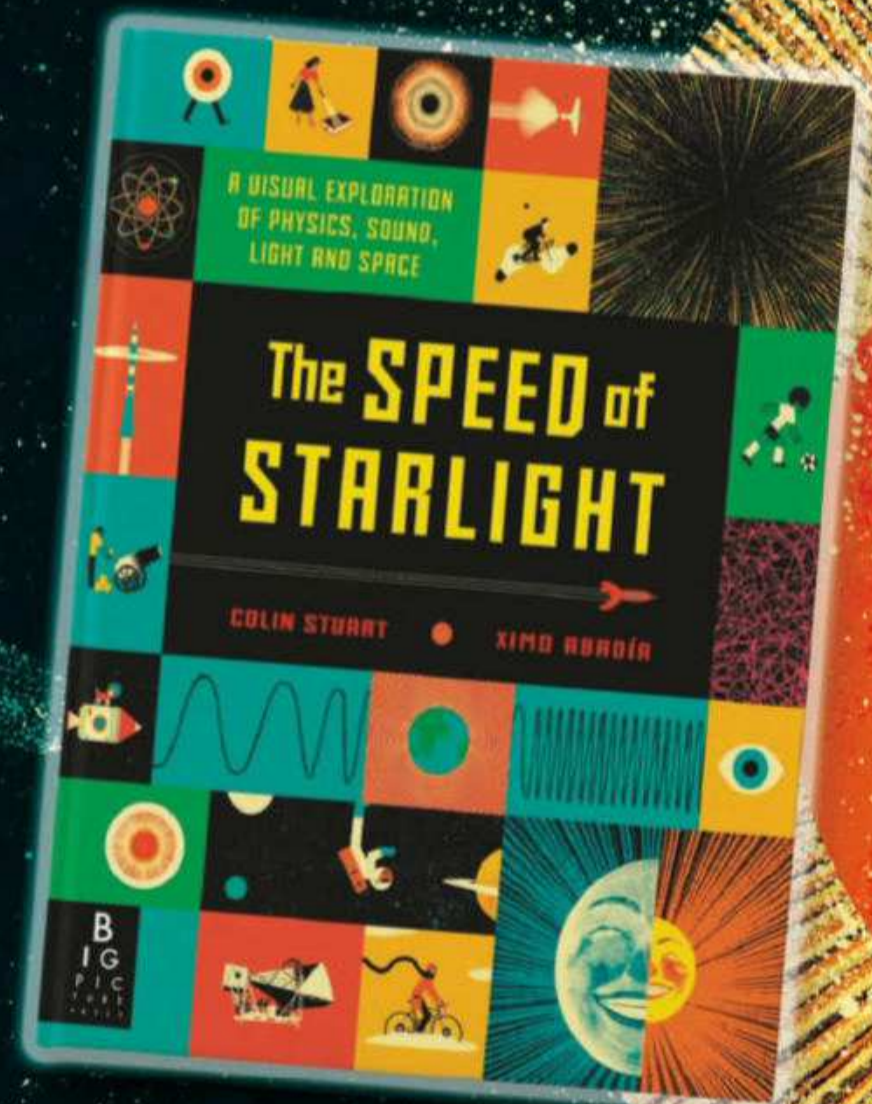
It may seem ludicrous now, but 100 years ago radium paint was considered the latest wonder material. From makeup to dye, in the early 20th century this radioactive substance was even thought to have health benefits.



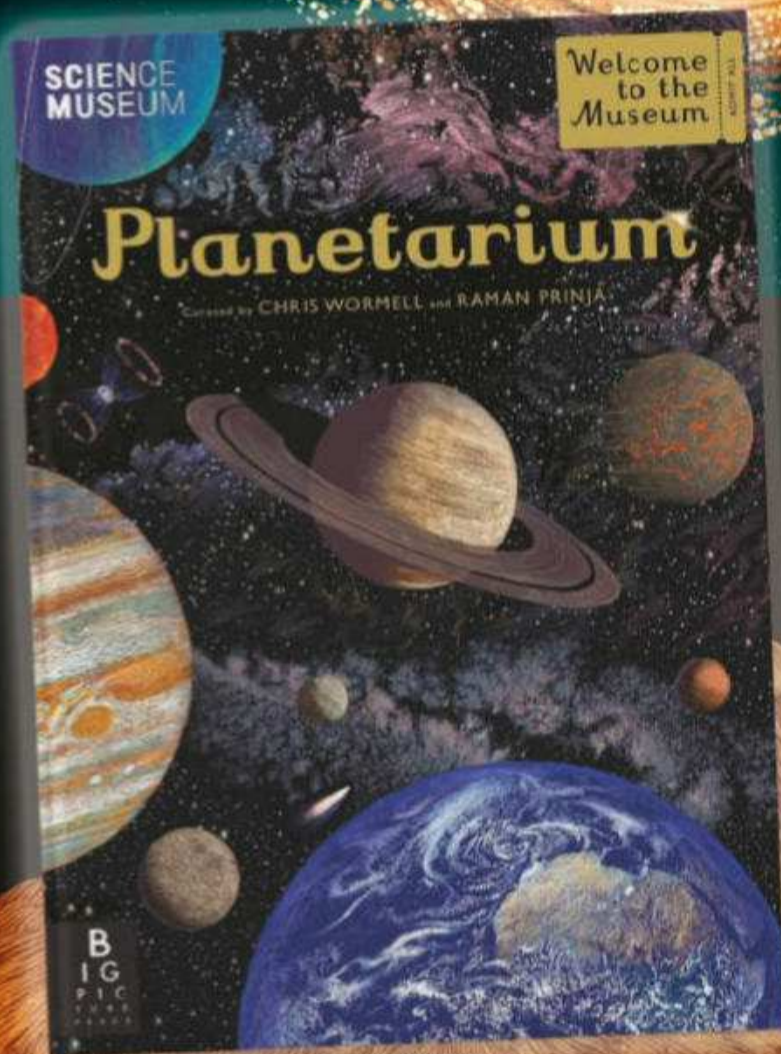
Uranium oxide

Fiesta dinnerware was popular in the 20th century, but its red-orange finish was achieved by using hazardous uranium compounds during the glazing process. Depleted uranium cells from nuclear tests were even used in the glaze!

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Cryptocurrencies

How do people make Bitcoin, and why is blockchain changing how we work online?

Words by **Stephen Ashby**

You've probably heard of Bitcoin. At the end of 2017, a boom in the market made a lot of people very rich. In a matter of weeks the value of a single Bitcoin shot up from around £2,300 to almost £15,000 (\$3,000 to \$19,300). Some people who already owned Bitcoins became millionaires. Others scraped together savings to try and make a quick profit. But what is a Bitcoin?

It certainly isn't something you can hold or keep in your purse. You can't use it in a supermarket, and nobody is minting physical Bitcoins. That's because it's a digital currency, and one that can be 'mined' by using computers to solve mathematical puzzles. It's all possible thanks to a technology called blockchain, which is

changing the way businesses and people around the world work. Bitcoin might be getting the headlines, but the cryptocurrency only exists thanks to blockchain. Let's find out how it all works.

BUILDING BLOCKS

We'll start with blockchain, because it's the basis upon which cryptocurrencies are built. There are all kinds of different uses for blockchain, and cryptocurrencies like Bitcoin are just one.

A blockchain is basically a digital ledger. It lets people and businesses record transactions and track assets, and the records are all stored securely across multiple devices. An 'asset' could be anything from a

car or a house to a patent or a copyrighted logo. The blockchain itself is shared between multiple users, and when a new transaction takes place it updates for everyone at the same time. Every transaction is logged and tracked across the whole network of connected users, so you can't adjust anything later; the information is recorded for good.

But why is this useful? To understand, let's look at blockchain being used in the context of buying a house. The process involves lots of people. It starts with the builder, who buys the land from someone. The builder gets planning permission, puts a house on the site and registers the address to be connected to the water, gas and electricity supplies, as well as the phone line. Then, when it's finished,

the builder finds a buyer. The ownership is transferred in exchange for money.

Without blockchain, all of this information, from the land ownership details to the final price and utility information, would have to be recorded by separate companies – the electricity, gas and water companies, for example. It would therefore all be in different places, and for the buyer, getting hold of it all could be difficult and time-consuming. Plus, if there are any mistakes along the way it could cause problems later as everyone tries to work out where an error was made.

Now, let's think about how blockchain could improve the process. At each point in the chain a new block would be created in the blockchain and added to the previous blocks. The builder could add land registry information, planning documents and utility details. They could also add useful legal information, like who is responsible for fixing a fence if it falls down. Then, when the house is finished, the buyer could get access to the blockchain and see all of the information that they need about the house in one secure place.

In this way, one single chain of data can be created and shared easily with those that need it. If the buyer decides to sell the house later they have all the information they need, and the person buying it from them knows for a fact that all of the information is correct and legal because the blockchain cannot be edited or changed. It's secure, and it makes every step of the process quicker and easier.

This is just one small example, but when you think about what this can mean for big businesses, where ordering parts or selling electronic products are an everyday occurrence, you can see why it's changing the way people work.

WHAT ABOUT BITCOIN?

While blockchain makes transactions like the one above safer, limits on currencies like dollars and pounds can still slow down the process of buying and selling. It costs money to transfer funds and it can take time for transfers to be approved. In business, wasted time is wasted money.

Cryptocurrencies like Bitcoin aren't like normal currencies. There's no central bank that controls them. Instead, powerful computers can solve complex mathematical puzzles to 'mine' coins over time. And, unlike normal currencies (which banks can just

How is cryptocurrency different from normal money?

NORMAL		CRYPTOCURRENCY
The economy of the country that issues the currency, as well as products and services	What backs it up?	A consensus of all users, as well as products and services
A central bank (such as the Bank of England)	Who or what governs it?	Mathematics and computers around the world
Up to several days	How long can international transfers take?	A matter of minutes
Up to two or three per cent of the total transfer	What's the cost of an international transfer?	Less than 1p
A chargeback can be made if a payment is disputed	Can it be charged back?	Once the transaction is complete you can't edit or reverse it. Every part of it is recorded securely
Yes, cash is printed and banks can choose to print more if they want more in circulation	Is it a physical item?	No, it is a digital currency and there is only a limited amount of it – no more will be made

"The blockchain is shared between multiple users across the world"



Blockchain has the potential to change how businesses work and how we live

What is Bitcoin 'mining'?

We've already mentioned that Bitcoins can be obtained by 'mining', but what does that mean? Well, mining is just a way of saying a computer is using its power to help create information on the blockchain.

Let's say that ten Bitcoin transactions are happening across the world at once. All of those transactions need to be checked against the blockchain, the identity needs to be confirmed, and then the whole blockchain needs to be updated across every computer in the network. That takes a lot of computational power. Bitcoin 'miners' lend their computing

power to this task to help the network function, and when they do they also work towards unlocking a new Bitcoin, which is added to their account. This can take a while, and you need a powerful computer or a customised mining rig to be able to earn a lot of Bitcoins.

Mining rigs are designed to get the most power without overheating any of the components





print more of), there's a limited number of Bitcoin that can ever be produced. Only 21 million will ever exist, and only a small number of new coins can be mined every hour. The rate at which they appear will reduce slowly until no more can be mined.

It's all possible thanks to blockchain. The Bitcoin chain logs how much any person has and this is securely shared across the world. You can't just change your records to say you have more Bitcoin than you do - the blockchain keeps a clear record that's constantly updated.

In the house example above, a private blockchain would be used. Only users that have been invited to join the chain would have access to the blocks and be able to see the data. Some people in the chain, such as the estate agent, would only be granted permission to see a limited amount of information in the chain.

The Bitcoin network is open, so the integrity of transactions can be easily monitored. It also keeps transfers more private because there is no need for identity checks. When someone submits a transaction, the network protocol looks back through the previous transactions for that currency to confirm the sender has enough Bitcoin and the authority to send them. If they do, the transaction can go through.

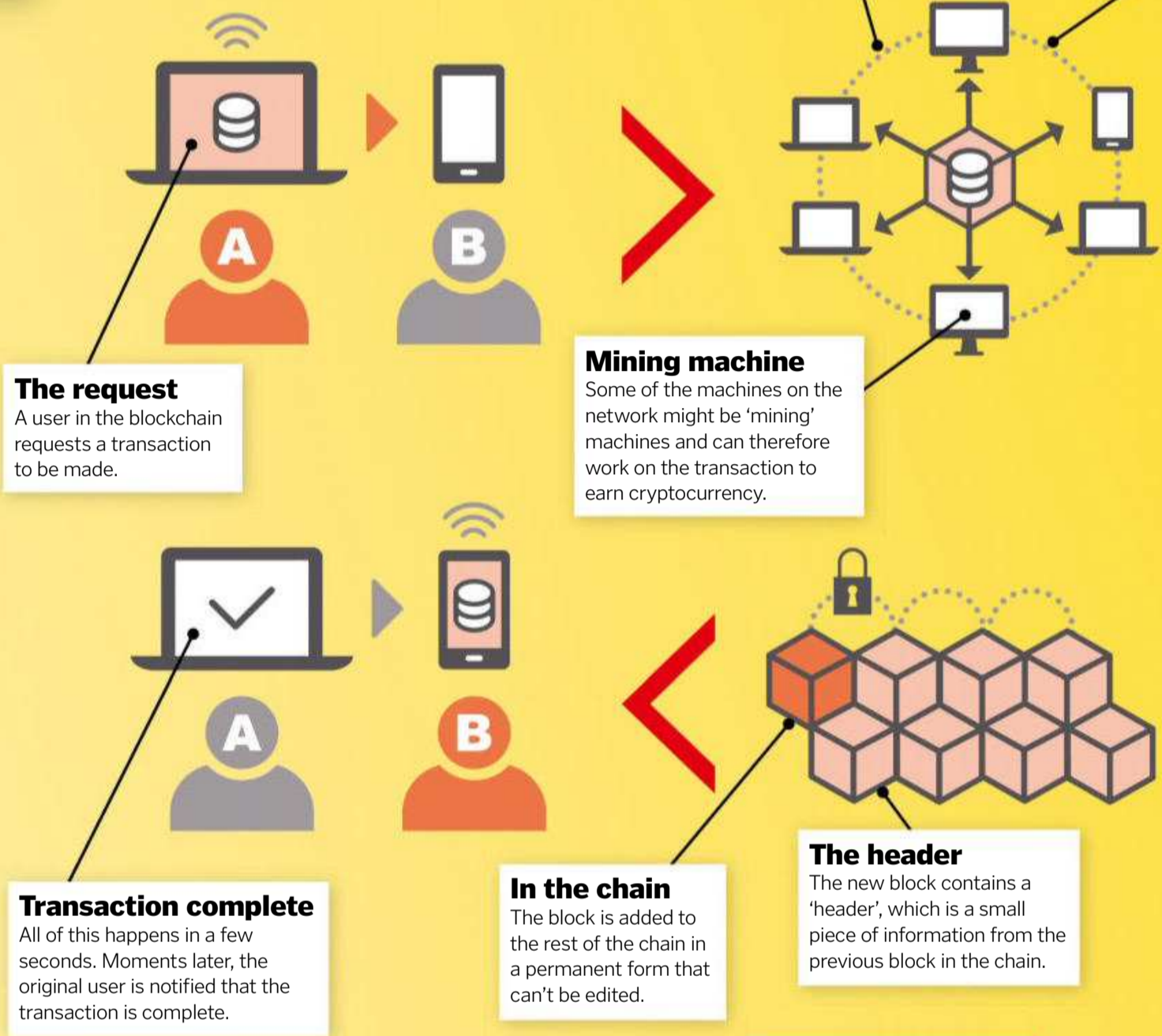
This might sound shady, but in reality, a unique wallet helps to identify users, and law enforcement can use this ID to track users if needed. Plus, most transactions need to have an identifier logged with the transfer by law, and because this is recorded on an open network it makes Bitcoin a less-than-ideal currency for criminals.

Finally, like all transfers that are made through blockchain, it is not possible to edit or reverse a transaction once it is completed. In fact, the only way to undo a transaction is to fulfil the identical transaction in the opposite direction. In that case, both transactions would be fully tracked in the chain for everyone to see. It makes cryptocurrencies like Bitcoin an extremely secure way to trade.

There are lots of types of cryptocurrency, but Bitcoin is certainly the biggest, and while it isn't the only use for blockchain, it's definitely the most well known. However, blockchain technology has huge potential, and many businesses are already using it to make fast, secure transactions. Whether it will become something that normal people use every day remains to be seen, but it certainly has the potential to change the way we live.

How does a blockchain transaction work?

The process behind a transfer is more complex than it might appear



Anyone can invest in a rig to mine Bitcoin - the more powerful the rig, the more you'll mine!

"The Bitcoin network is open, so it's easy to monitor the integrity of transactions"

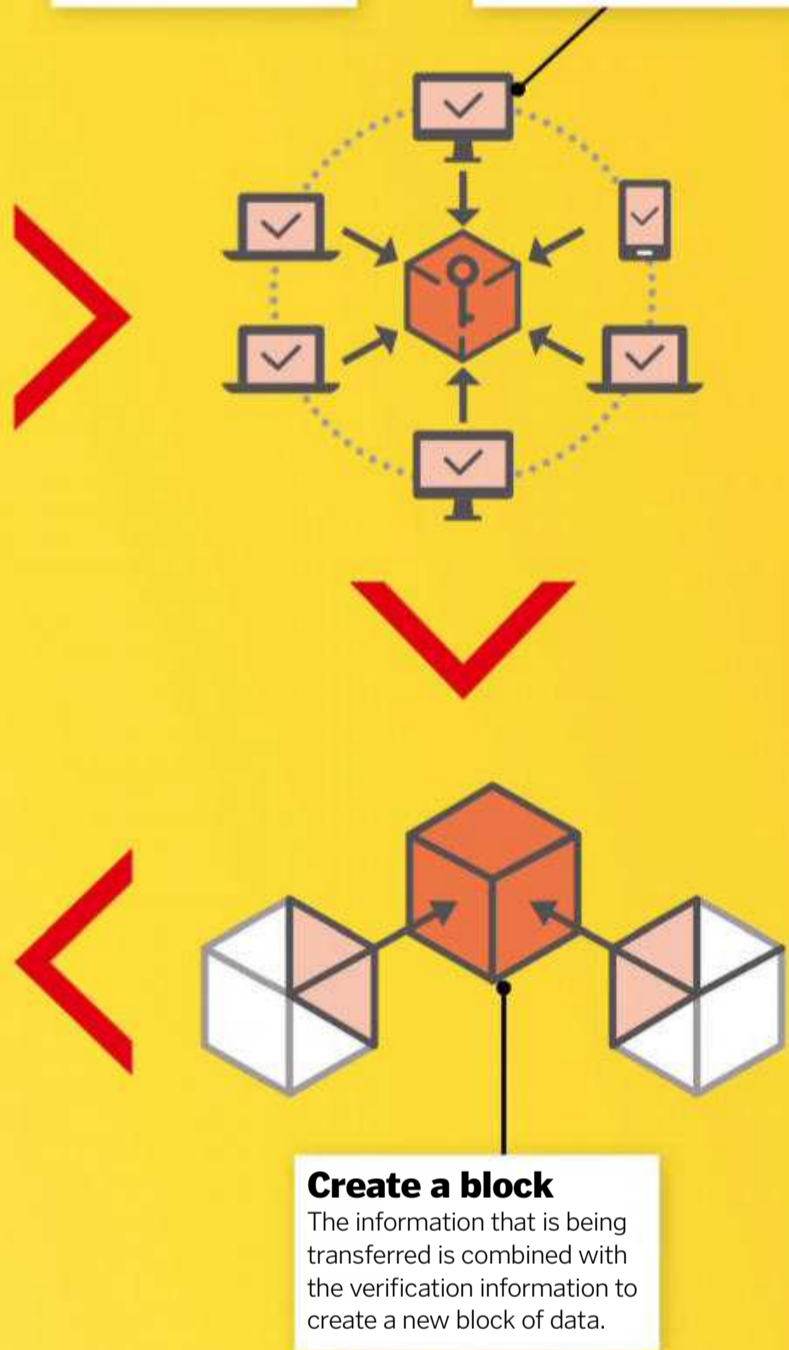


Validation

When the network nodes have checked the user's status they'll validate the transaction.

Verification

A verified transaction can involve all kinds of data, from cryptocurrency like Bitcoin to contracts or other important information.

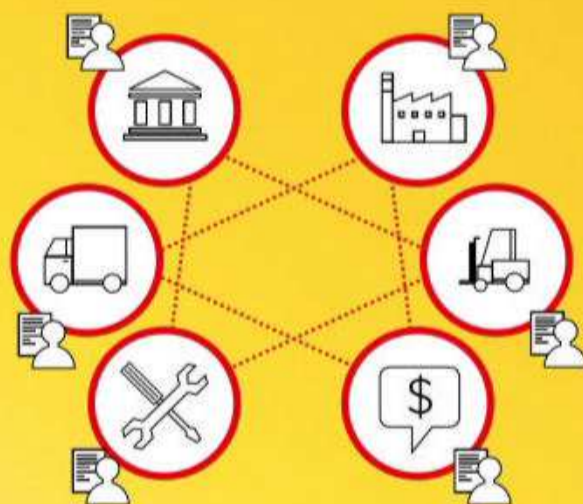


Create a block

The information that is being transferred is combined with the verification information to create a new block of data.

Hey big sender!

Could blockchain make the world go round?



Broken links

Currently, the information relating to business transactions is often stored in numerous places by different parties.



Information chain

Blockchain has the potential to change the way information is stored by keeping it in a secure, centralised location.

THE PROS & CONS OF BLOCKCHAIN



Secure transfers

It's a safe and confidential way to transfer data that can't be edited.



Hacks still happen

Some system hacks can still cause major problems, such as an attack that blocks a node from accessing the network.



Irreversible transactions

Transfers are safer because a buyer can't take information then claim back the money.



Irreversible transactions!

When mistakes are made it can be more difficult to organise refunds or redistribution.



The potential

Blockchain technology could make it easier for us to pay for things, access our medical records and even vote.



No regulators

Because Bitcoin is digital it has no official regulator. If the creator decided to split it, or change it, it could have major effects.



Cryptocurrencies can't be frozen

If there's a financial crisis, banks often freeze bank accounts. That can't happen with cryptocurrencies.



New tech can scare people

People don't really understand blockchain or cryptocurrency, so making them mainstream will be a tough ask.

The nodes in a blockchain network can be anything from normal computers to large, powerful servers in an office



Cryptocurrency ATMs enable people to buy and/or sell digital currencies



How does a CT scanner work?

These 3D X-rays can create detailed pictures of the inside of your body

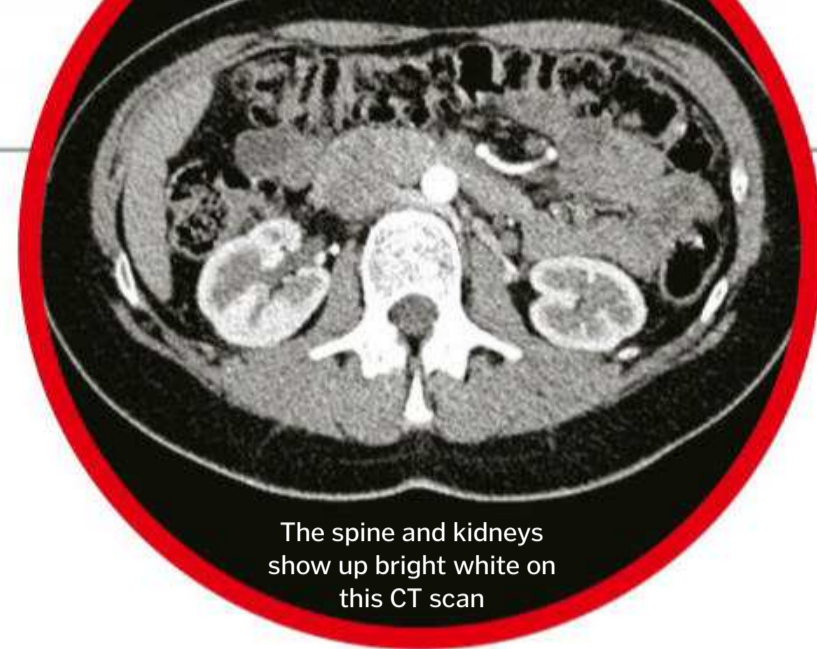
At the end of the 19th century, Wilhelm Röntgen discovered X-rays and changed medicine forever. As X-rays pass through the body, different tissues absorb different amounts of energy, leaving shadows on photographic film. For the first time, doctors could see inside their patients without having to cut them open. But the story didn't stop there.

If you capture one X-ray image you see a snapshot of the body, but with the organs piled on top of one another it's hard to make out what's going on. In 1972, Godfrey Hounsfield found a solution when he invented computerised tomography (CT) scans, thereby revolutionising medicine again.

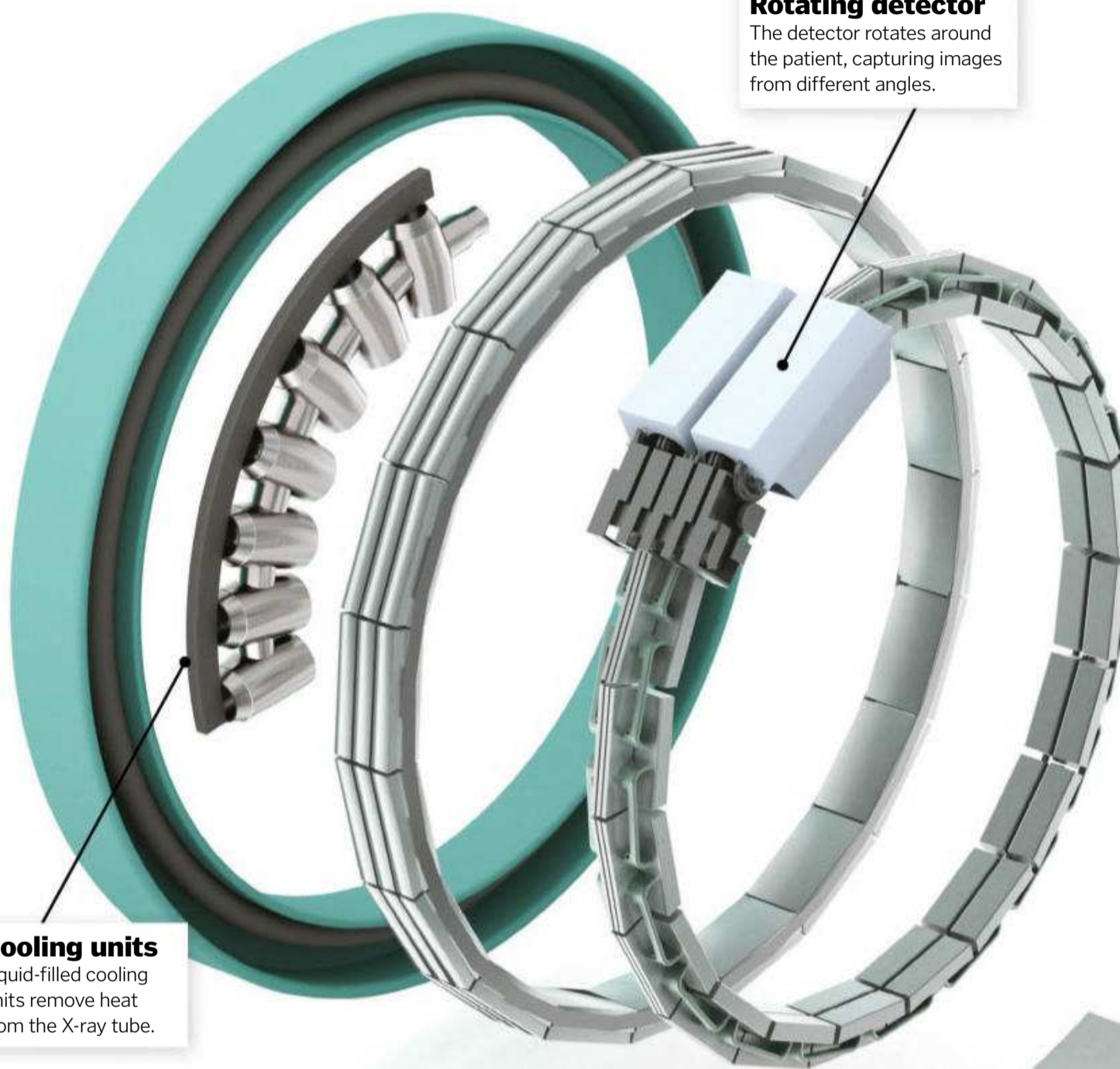
CT scanners use a rotating ring to take X-ray images from all angles. A computer then combines these images to separate out the signals from different bones, organs and blood vessels. This creates image slices between one and ten millimetres thick, showing the inside of the body in cross-section. During the scan, a table slides the patient through the ring, capturing more and more image slices. Then the computer stacks them together to make 3D pictures of the internal organs.

The result is a much higher-resolution picture of the inside of the body. The outlines of the tissues are clearer than a normal X-ray, and the 3D shapes allow medical professionals to see abnormalities. X-ray-absorbing chemicals called contrast agents can make the pictures even clearer. For example, iodine injected into the blood can reveal the outline of the blood vessels, showing up clots. Barium swallowed in a meal or drink can highlight the outline of the digestive system, revealing tumours.

Though X-rays do deliver small amounts of ionising radiation, which can damage cells, the benefits far outweigh the risks.



The spine and kidneys show up bright white on this CT scan



Rotating detector

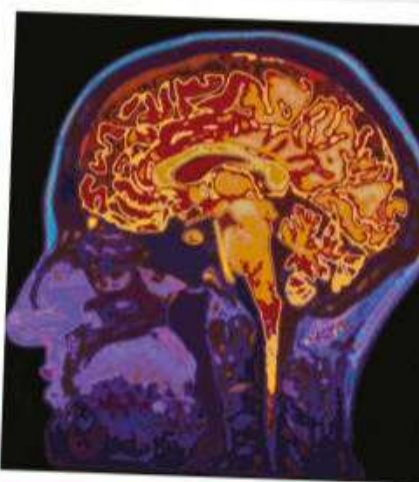
The detector rotates around the patient, capturing images from different angles.

Cooling units

Liquid-filled cooling units remove heat from the X-ray tube.

Inside a CT scanner

Patients slide through a rotating ring stuffed with X-ray technology



MRI scans offer a higher-resolution picture of the body's soft tissues

CT vs MRI

CT scans are good for showing up bones, blood vessels and organs, but they can't capture the fine detail of soft tissues. To do this we need Magnetic Resonance Imaging (MRI). These scans use a combination of radio waves and powerful magnets to make 3D pictures. The magnets pull on the hydrogen atoms in the water molecules inside the body, rotating them so they all point in the same direction. Radio waves then knock them temporarily out of line; when they snap back in line they release energy. Detectors pick this energy up, creating a picture of where the water molecules are. Different tissues contain different amounts of water, giving a clearer view of the internal organs.

PET and SPECT

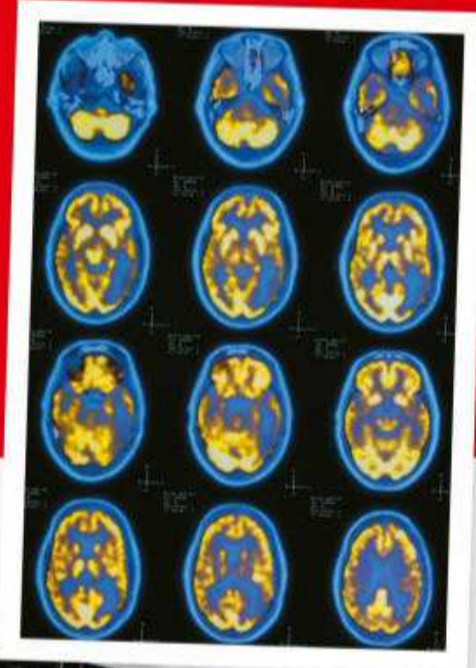
Doctors can zone in on specific parts of the body using nuclear medicine. This involves injecting, inhaling or swallowing small amounts of radioactive material to light up different tissues.

Doctors sometimes need to highlight the blood vessels to look for circulation problems. To do this they can use Single Photon Emission Computed Tomography (SPECT) scans. Patients receive an injection containing radioactive atoms, which enter the blood and release gamma rays as they

circulate. When a gamma camera detects the rays, it reveals the outline of the blood vessels.

Another option is a Positron Emission Tomography, or PET scan. These use radioactive tracers that produce positrons instead of gamma rays. Positrons interact with electrons inside the body, sending bursts of energy to the detectors. PET tracers attached to sugar molecules can light up tissues using lots of energy, like active areas of the brain or growing tumours.

The yellow areas of the brain on this PET scan are using the most energy



X-ray source

Different tissues absorb different amounts of energy as X-rays pass through.

Fan

A fan pumps warm air out of the gantry, keeping the equipment cool.

Gantry

The circular opening in the machine is known as the ring tunnel, or gantry.

Monitor

The computer assembles the images into slices, which appear on a monitor ready for analysis.

Drive unit

Motors inside the gantry rotate the ring and slide the patient table.

Table

The table slides through the detector ring as it captures each image slice.

"CT scanners use a rotating ring to take X-ray images"



Inside the Magic Leap One

Check out the latest AR headset aiming to change the world

The future of visual technology isn't only about VR – augmented reality (AR) is also advancing quickly, and soon 'mixed reality' headsets may become a common sight. These headsets project images onto small, translucent lenses in front of the wearer's eyes, meaning they can see the world around them through the lenses but can also see other digital creations projected on top of their surroundings.

AR has already started to take off – right now you can download all kinds of AR apps to your phone that use the camera on the back to show the world with new, digital creations appearing onscreen. However, so far no manufacturer has quite managed to pull off the effect in a headset. Until now, that is.

Magic Leap has finished their first version of the One headset. The device makes this incredibly complex technology lightweight and wearable, and it does so without the need for a separate computer.

That's because the brains and battery for the headset sit in a small, puck-like device that clips onto your trouser pocket. A cable runs up your back and into the headset... and that's it. So you can move freely around a room without worrying about tripping over cables on the floor.

It's a remarkable achievement, but don't get too excited yet – this is still an early version of the hardware, designed so creators can make and test new ideas on the headset. Oh, and it costs \$2,295 (around £1,800). Let's take a look inside one to find out why it's so costly...



A wireless controller can be used to navigate through the interface or play games

Outer lenses

Outer lenses

The holes in this outer casing are for the cameras that capture an image of the room around you. And, of course, you can see out of the lenses.

Waveguides

This magnesium frame holds six separate pieces of glass called waveguides. Light is projected into these and then reflected into the eye of the wearer.



Eye tracking

The tiny square camera at the bottom of this ring houses the eye-tracking camera. It helps the computer to know where you're looking.

Mini board

On this cable are a number of small chips that analyse the data sent from the computer and work out how to display it through the light projectors.

Light projectors

At each side of the headband are two light projectors. They emit red, blue and green light, which is projected into the waveguides and reflected into your eye, creating a perfect image.

IR cameras

One of these small camera units sits near each temple. An IR dot blaster fires IR light, and a camera sees where it bounces so the computer can create a digital image of your surroundings.

"The device makes this incredibly complex technology lightweight and wearable"

Behind the Magic

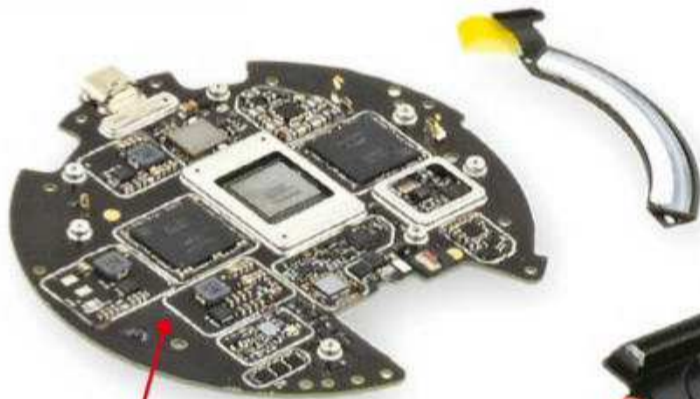
We lift the lid on the highly anticipated Magic Leap One AR headset

Headband

The headband is adjustable and features built-in speakers near each ear. You can use headphones if you prefer.



The headset can make 3D creations appear on flat surfaces in front of you, and you can move around them to explore



The brains

This board is where the main computing power happens. It clips onto your pocket, so you can be almost completely wireless.

Fan

All that computing power makes the motherboard warm! This fan helps dissipate the heat to keep everything running smoothly.

Battery

The battery has a similar capacity to that of the most recent iPad. By clipping to your pocket it reduces the weight of the headset.

In focus

Your eyes have an amazing ability to focus on things close to you or far away. However, this makes it hard for the Magic Leap One to keep its images in focus, because they're so close to your eyes. That's why each lens has six separate glass waveguides. There's an individual waveguide for each colour channel - red, green and blue - across two focal planes. So whether you're looking at something close to you or at a distance, the projected image will always appear sharp to your eyes.





EIGHT-LEGGED ALIENS?

Octopuses certainly don't look like earthlings, but could these brainy, blue-blooded creatures really be from another planet?

Words by **Ella Carter**

There's no denying that the octopus looks like something straight out of science fiction. Its eight-limbed, sucker-covered, slimy, colour-and-texture-changing body is as unfamiliar to us as can be. Add in the fact that they are capable of accomplishing surprisingly intelligent tasks and we are immediately suspicious. Many of the octopus' creepier features have been borrowed over the years by writers and directors to illustrate life from other planets, and there are even theories that our own earthly cephalopods came from outer space. However, octopuses are simply an incredible feat of earthling evolution.

The recent theory proposed by 33 authors in a paper published in the journal *Progress in Biophysics and Molecular Biology* suggests the Cambrian Explosion (a period in the fossil record where biodiversity boomed around 540 million years ago) was brought about by viruses crashing to Earth aboard extraterrestrial meteors, altering the genetic codes of species here. The authors highlighted the octopus as a specific example, which led to a flurry of outlandish headlines in the press.

This idea is furthering a controversial theory from the 1970s known as the panspermia hypothesis, which challenges the origins of life and suggests that instead of evolving on Earth,

much of life was 'seeded' and brought to our planet on asteroids. Although an imaginative idea, this theory has been examined by many leading evolutionary biologists, and despite the octopus looking pretty alien, the evidence is overwhelming in favour of earthly evolution.

Our last common ancestor with the octopus lived around 750 million years ago and was most likely an aquatic worm-like critter.

Cephalopods are molluscs, part of the same family as slugs and snails, yet given their higher intellect compared to their molluscan cousins it's fair to wonder how they became so advanced. However, the octopus genome was mapped in 2015 and showed that these eight-legged critters share DNA not only with their closest relatives but also with many other species, including humans.

Despite their blue blood (caused by the presence of haemocyanin), three hearts (one for each gill, one to pump blood around the organs), amazingly

advanced eyesight, keen minds and otherworldly body shape, octopuses are very much of this Earth, even if they are wonderfully weird inhabitants of it.

Octopus vs squid

These cephalopod cousins have very similar bodies types but are also wildly different. Here's how they match up head-to-head...

Octopus	Squid
---------	-------

LIMBS

Eight long, flexible, sucker-covered arms surround the mouth.

Squid have eight sucker-covered arms, plus two extra-long feeding tentacles that they use to catch prey.

BEAK

Yes

Yes

INTERNAL PEN

The octopus doesn't have any hard parts apart from its beak.

As an evolutionary remnant of a shell, the squid has a feather-shaped 'pen' in its mantle.

FINS

Sometimes

Yes

EYES

Exceptional eyesight, with rectangular pupils that help with depth perception for spotting both predators and prey.

Large, circular pupils help the squid to see all around its body with no blind spots.

SIPHON

Used to force water out of the mantle at speed, allowing for a fast getaway.

All cephalopods have a siphon, which is perfect for escaping predators or chasing prey.

CAMOUFLAGE

Yes

Yes

INK

Cephalopod ink is blackened by melanin. It's produced in the ink gland within the ink sac.

All cephalopods produce ink to deter predators and make a quick getaway.

"Despite the octopus looking pretty alien, the evidence is overwhelming in favour of earthly evolution"



Squid have an elongated body, with mouths surrounded by both arms and tentacles



The octopus has an instantly recognisable body shape with eight long arms



Octo physiology

Super senses, big brains, colour-changing bodies... Octopuses are some of the most fascinating underwater beings

Octopuses are cephalopods, which means 'head-foot'. Their eight arms (technically not tentacles) surround the mouth and are full of strong muscles. They also contain two-thirds of the octopus' neurons, which means they can quite literally think for themselves.

Each arm is equipped with over 250 suction cups, each able to be manipulated independently. They are also a sensory organ capable of smell and taste, ideal for seeking out food. But eight arms are a lot to keep track of, so what stops octopuses getting tied in knots?

Amazingly, its skin has a coating that prevents the suckers from sticking to itself. Arms can also be dismembered at will as a last-ditch attempt to escape a predator. They can then regrow the lost limb, a process that takes roughly two months.

These arms are also essential for swimming, but crawling over the seafloor is preferred. This is because when it swims, the octopus' third heart, which pumps blood to its organs, stops beating, so swimming is an exhausting activity.

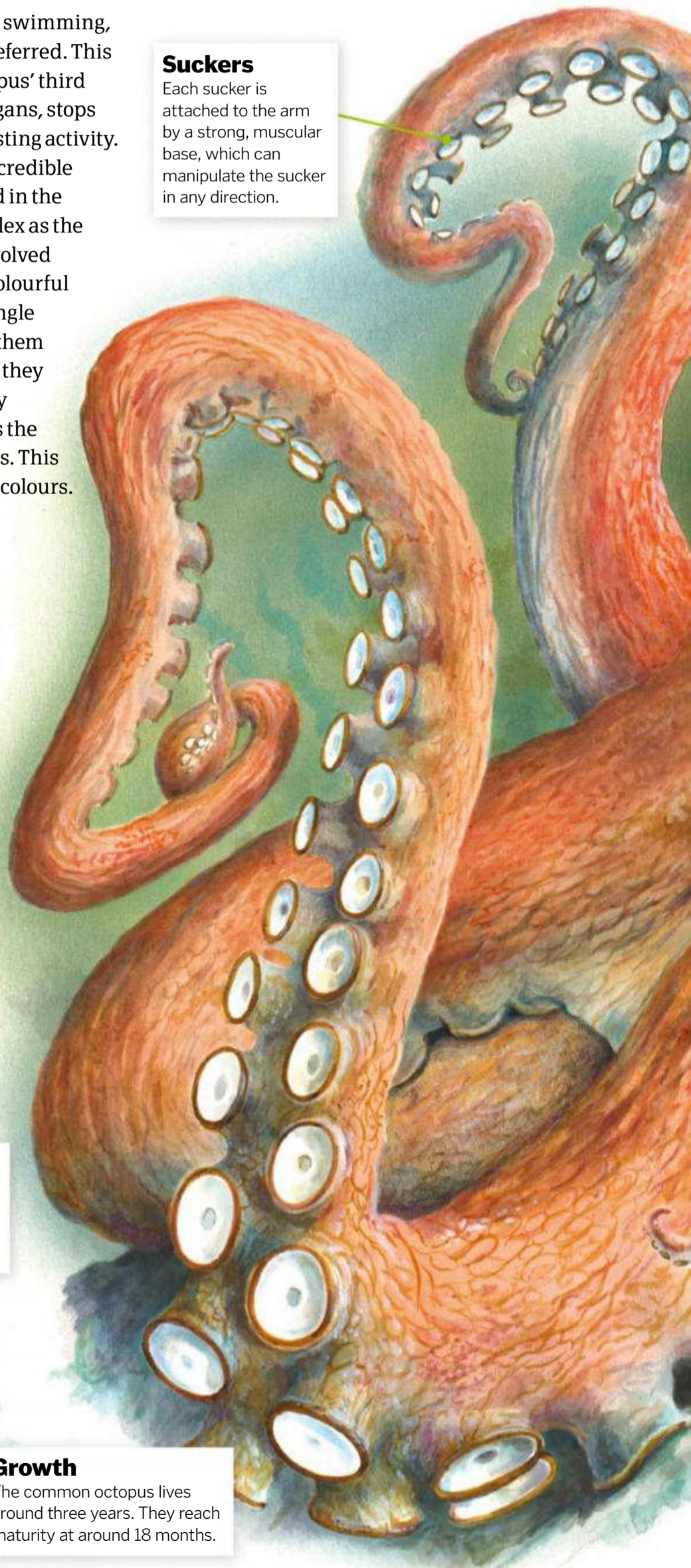
The octopus' eyes are another incredible feature. Some of the most advanced in the animal kingdom, they are as complex as the vertebrate eye even though they evolved independently. Yet despite being colourful creatures, their eyes only have a single photoreceptor cell, which renders them technically colour-blind. However, they can pick out wavelengths of light by altering the shape of their lenses as the light enters their rectangular pupils. This allows them to focus on individual colours.

Octopus anatomy

Inside one of the strangest body types in the animal world is a very simple anatomical structure that performs complex tasks

Suckers

Each sucker is attached to the arm by a strong, muscular base, which can manipulate the sucker in any direction.



Development

Females will often care for the eggs throughout their development, warding off hungry predators and ensuring eggs are oxygenated.

Egg laying

Female octopuses stitch their eggs together into braids and secure them in sheltered surroundings.

Hatching

The mother octopus gives the hatched babies a helping hand by wafting them out of the den. They are perfect miniatures of her.

The circle of life

With short lifespans, 'live fast, die young' is an apt octopus motto

Mating

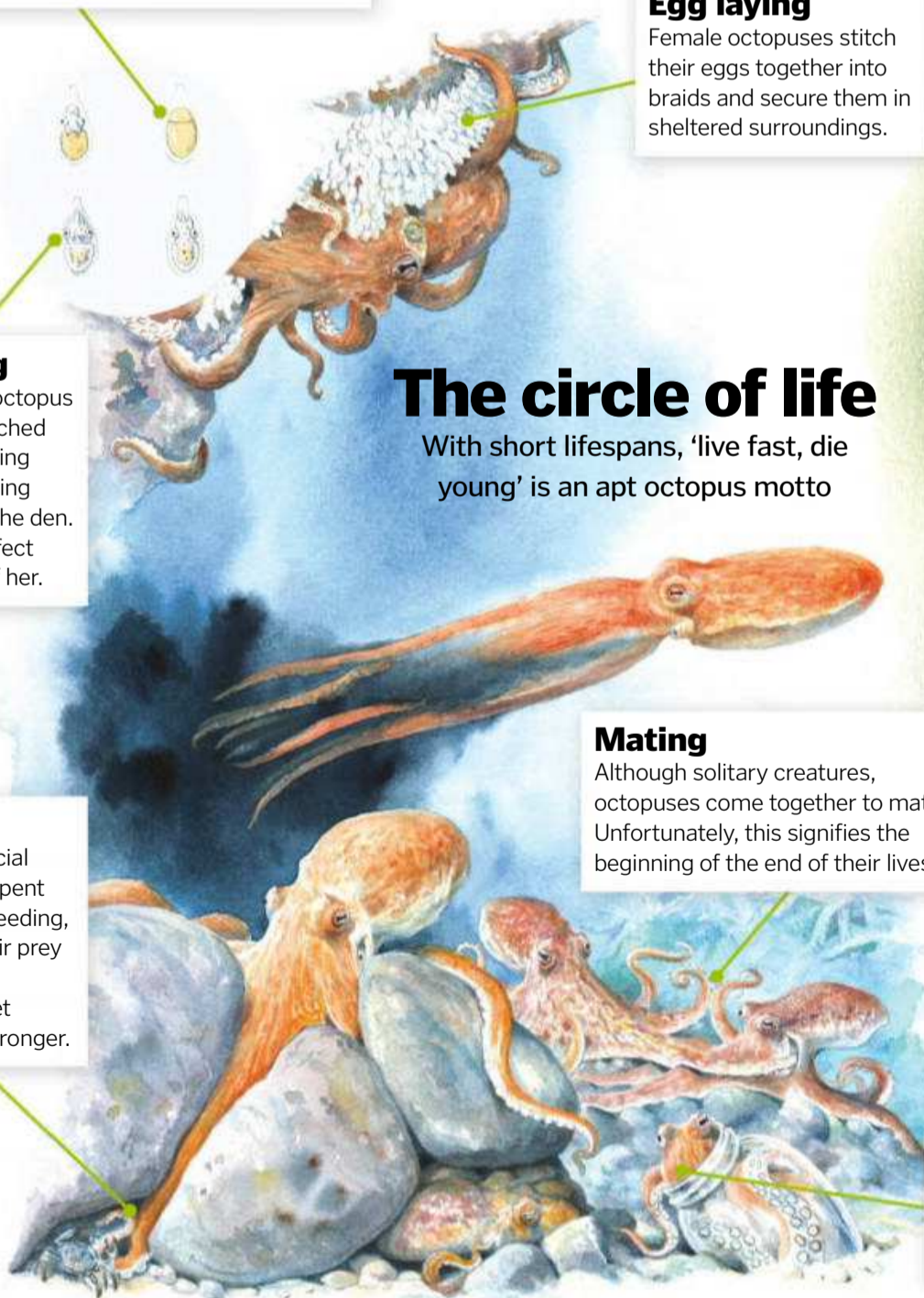
Although solitary creatures, octopuses come together to mate. Unfortunately, this signifies the beginning of the end of their lives.

Feeding

The next crucial months are spent voraciously feeding, changing their prey as the young octopuses get bigger and stronger.

Growth

The common octopus lives around three years. They reach maturity at around 18 months.



"Octopus arms can be dismembered at will and regrow in just two months"

Beak

Looking much like a parrot's beak, this is the only hard part of the octopus' body.

Brain

Although this is a concentrated 'brain' area, almost two-thirds of the octopus' neurons are contained elsewhere.

Neurons

Many neurons are contained in the arms, allowing for particularly efficient hunting.

Mantle

Composed of incredibly strong musculature, the mantle keeps all of the octopus' internal organs safe within its soft body.

Hearts

Octopuses have three hearts; two pump blood through the gills and the third pumps blood through the body.

Siphon

Jet propulsion at its finest, octopuses draw water into their mantle then express it quickly for a speedy getaway.

Gills

Water is pushed over the gills, where oxygen is extracted and absorbed into the blood.

Ink sac

Sitting within the body cavity, ink produced in the sac is then expelled via the siphon.



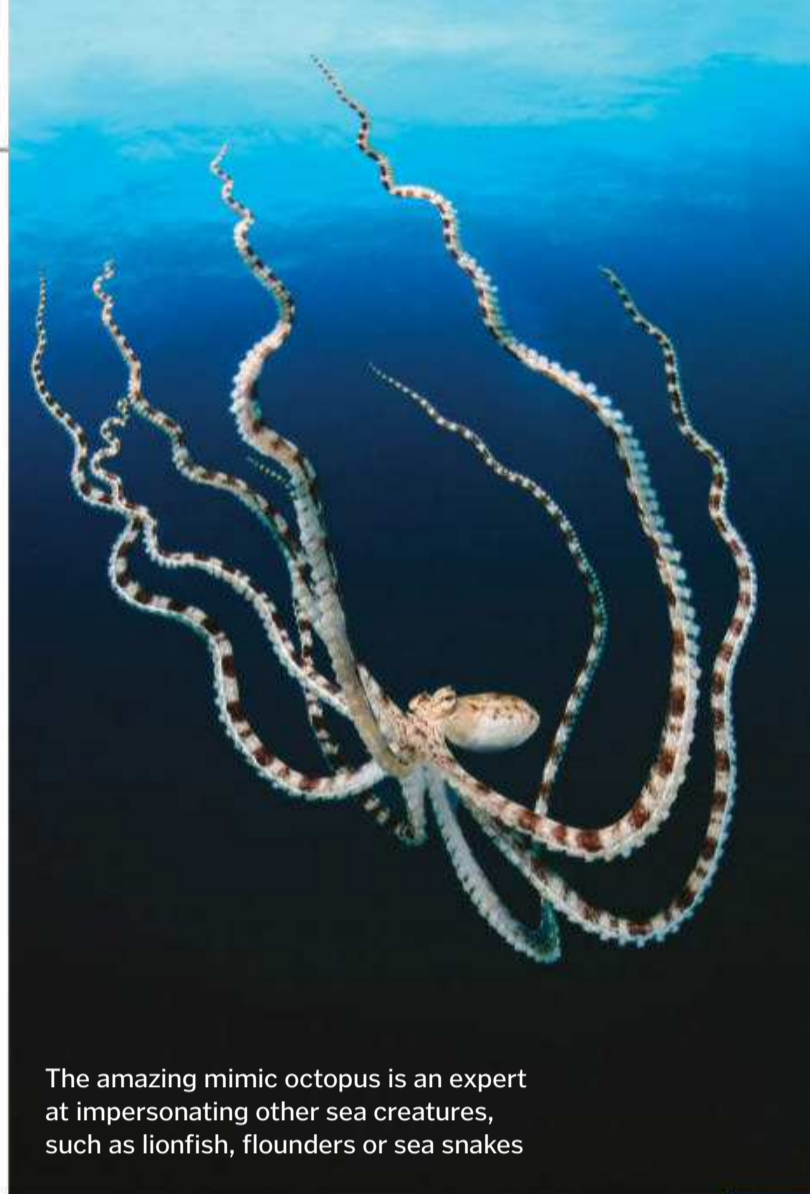
Subsea smarts

From escaping captivity to targeting people with jets of water, octopuses are nothing if not crafty

It's no secret that cephalopods are clever. With large brains (especially for creatures without backbones), octopuses are able to solve problems, learn from their encounters and even experience sleep and play. These have all been tested in laboratories across the globe, with octopuses obliging by navigating mazes, solving puzzles to gain access to food and using their elaborate arms to mischievously play with items in their tanks. One octopus even flooded the Santa Monica Pier Aquarium by tampering with a valve in her tank. There are also anecdotes of octopuses sneaking out of their tanks at night to feed on other aquarium residents.

This is all possible due in part to their eight dexterous appendages that contain the majority of their neurons, allowing them to work independently without input from the brain. With 500 million neurons present, this places octopuses close to the realm of dogs, although the amount of neurons isn't necessarily an indicator of intelligence.

Like dogs, however, those who have spent time with octopuses will attest to their various different personalities and how some octopuses in aquariums will squirt water at specific employees when they approach, testament to their powers of recognition.



The amazing mimic octopus is an expert at impersonating other sea creatures, such as lionfish, flounders or sea snakes

Masters of masquerade

Octopuses can change colour and texture at will. Colour changes are controlled by tiny cells in the octopus' skin called chromatophores, which are manipulated by muscles that cause the cells to expand or contract. These cells are connected to the nervous system, allowing these critters to easily match their surroundings.

Texture changes are controlled by organs known as papillae. They allow raised bumps to appear on the skin, blurring the octopus' outline into the background for an extra layer of protection.

Thanks to highly specialised skin cells and excellent eyesight, the octopus can seamlessly blend into the background



Voracious hunters

Like the rest of the soft-bodied cephalopods, octopuses are both predator and prey. They have to be able to hunt quickly and efficiently, as if they hang around there is the possibility of becoming dinner for someone else.

Octopuses hunt with a variety of tactics. Their favourite foods are crabs and other crustaceans, but they also eat fish and other cephalopods. Ambush predation is a key component of the hunt; the octopus assumes the colour and texture of its surroundings before seizing its unsuspecting prey.

Once it has stuck, the strong, muscular arms will bring the prey to the octopus' mouth, where a dose of neurotoxin-laden saliva is administered to paralyse it. This is how the octopus can subdue crabs, as their claws can be dangerous obstacles to overcome. Enzymes in the saliva break down the soft tissue inside the crab, which the octopus can then slurp up like a milkshake for a tasty meal.

Extraordinary members of the octopus family



Giant Pacific octopus

Found in temperate Pacific waters, these octopuses are the largest species out there; their arms can span up to around five metres.



Blue ringed octopus

At the size of a golf ball, this octopus may look adorable, but it contains enough venom – 1,000 times more powerful than cyanide – to kill 26 humans!



Dumbo octopus

So named for their large 'fins', which resemble the Disney elephant's ears, these critters live in the deep ocean at around 4,800 metres below the surface.

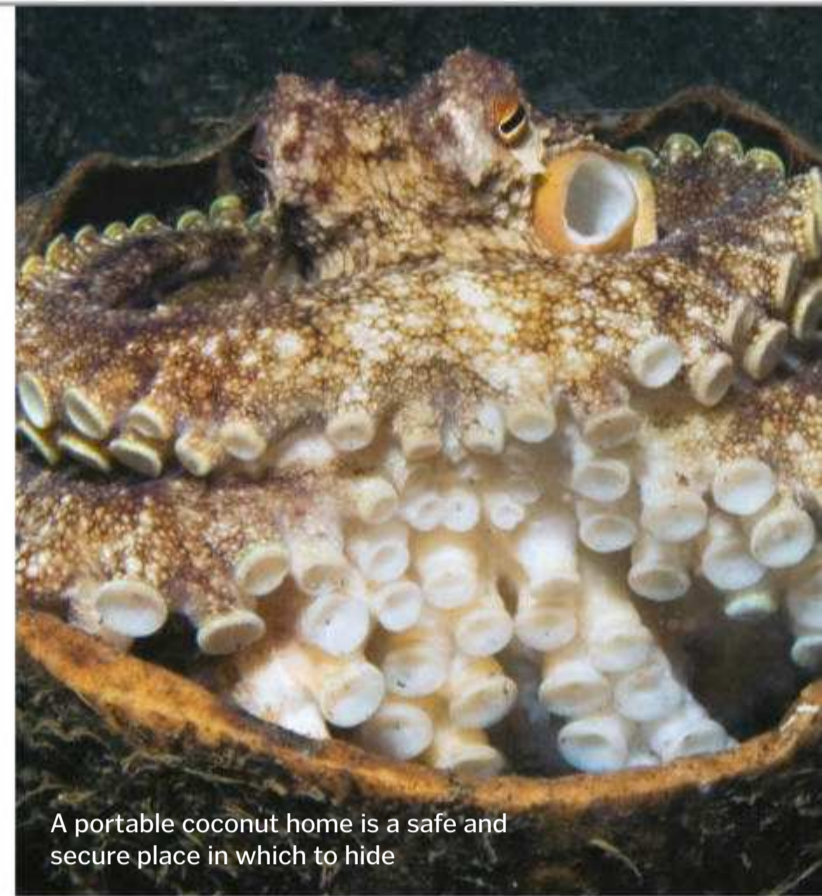
Smokescreen escapes

Like all cephalopods, octopuses have an extra trick up their sleeve with their inking abilities. Their siphon is used to shoot out a jet water for quick escapes, expel waste and secrete ink from within the mantle. When an octopus is startled or threatened it can contract the siphon to release the ink, which mixes with mucous to form a sticky, confusing smokescreen.

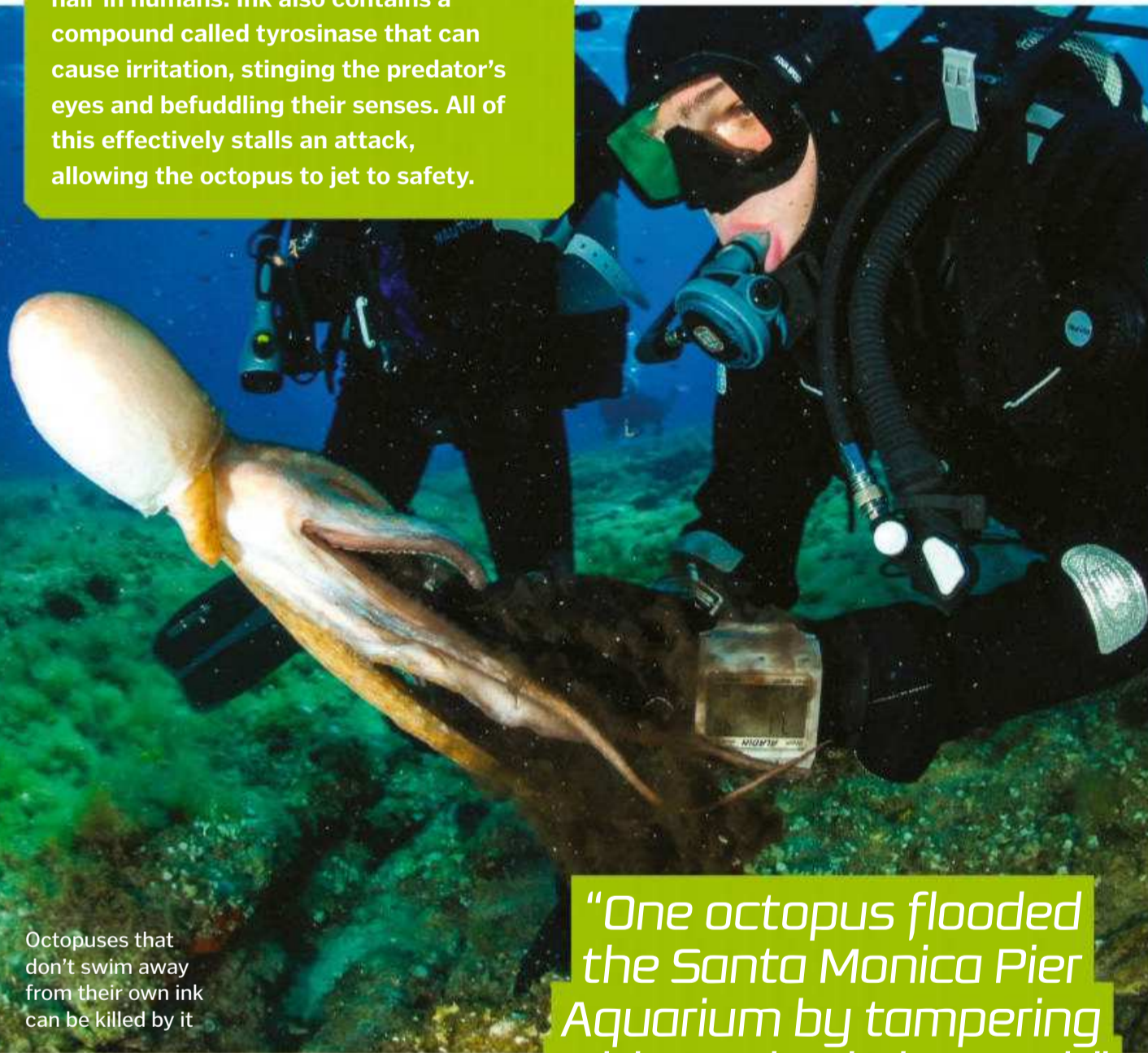
Ink is black thanks to melanin – the substance responsible for dark skin and hair in humans. Ink also contains a compound called tyrosinase that can cause irritation, stinging the predator's eyes and befuddling their senses. All of this effectively stalls an attack, allowing the octopus to jet to safety.

Tools for the job

Another aspect of octopus intelligence is the use of tools. Previously only witnessed in primates, dolphins and some birds, octopuses in Indonesian waters have been witnessed carrying two halves of a coconut shell as they traverse the seafloor. The octopuses used these halves as a whole protective 'case', squeezing into the coconut in areas where dens, nooks and crannies were hard to find in order to escape predators. Tool use has long been a benchmark of animal intelligence, but there is some debate among biologists as to whether this is classed as 'tool usage'.



A portable coconut home is a safe and secure place in which to hide



Octopuses that don't swim away from their own ink can be killed by it

"One octopus flooded the Santa Monica Pier Aquarium by tampering with a valve in her tank"

Suckers on land

Thanks to their amazing limbs, swimming and moving along the ocean floor aren't the only hunting strategies open to certain species of octopus. The rocky shore offers a cornucopia of prey, and one species located on Australian beaches is exploiting its skills in order to clean up.

Known as the only 'land' octopus, the *Abdopus octopus* (*Abdopus aculeatus*) has been witnessed crawling out of its rock pool home to comb the beach in search of tasty morsels trapped in pools at low tide. It can do this using the strong, sucker-covered arms that it expertly manipulates in order to pull itself across the shore. Nipping from pool to pool, this specially evolved octopus has the edge thanks to its land-roving ability.

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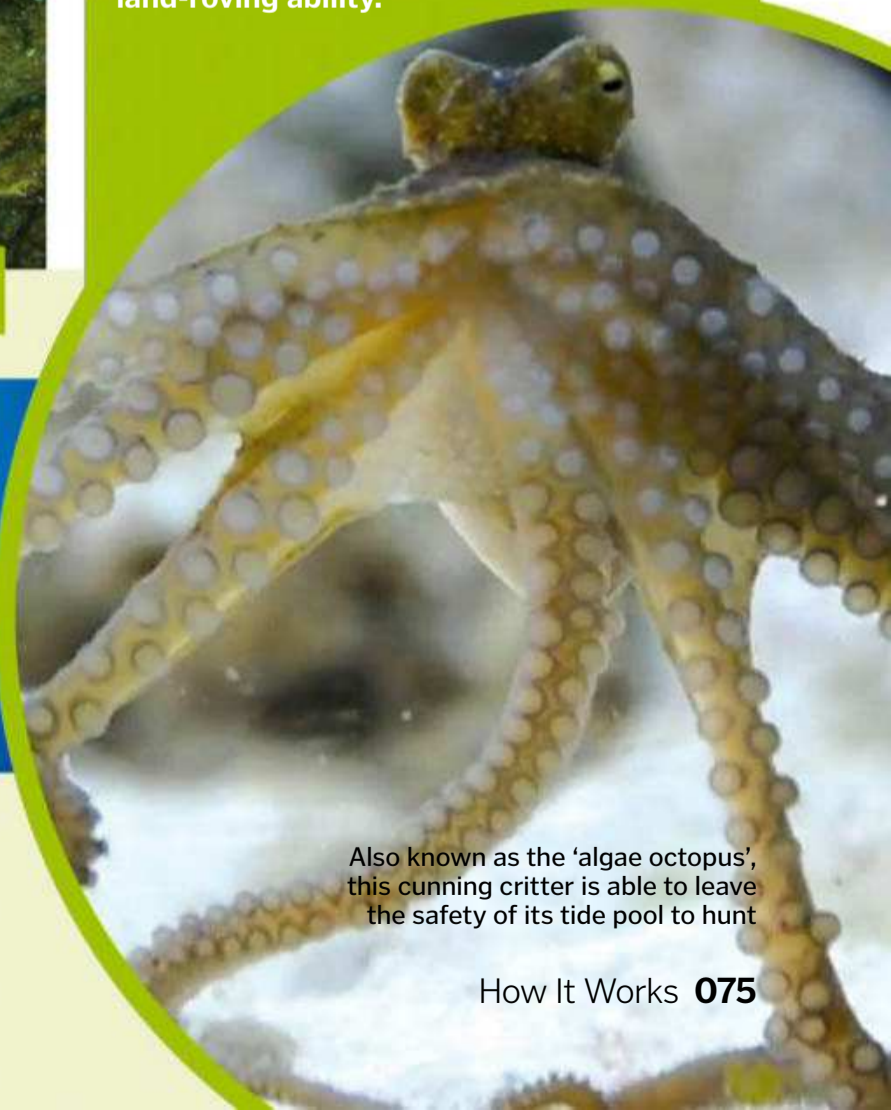
Star-sucker pygmy

Reaching just two centimetres in length and weighing just one gram, this tiny critter is the smallest octopus species known to science.



Blanket octopus

Females of this species sport long blankets of flesh between their arms, which can splay out to deter predators. Males are just a tiny fraction of their size.



Also known as the 'algae octopus', this cunning critter is able to leave the safety of its tide pool to hunt



The island effect

Cut off from the rest of the world, island inhabitants undergo strange transformations

When young biologist J Bristol Foster compared the body sizes of 116 island species with their closest relatives on the mainland, he noticed a trend; these isolated animals had become considerably larger or smaller than their continental counterparts.

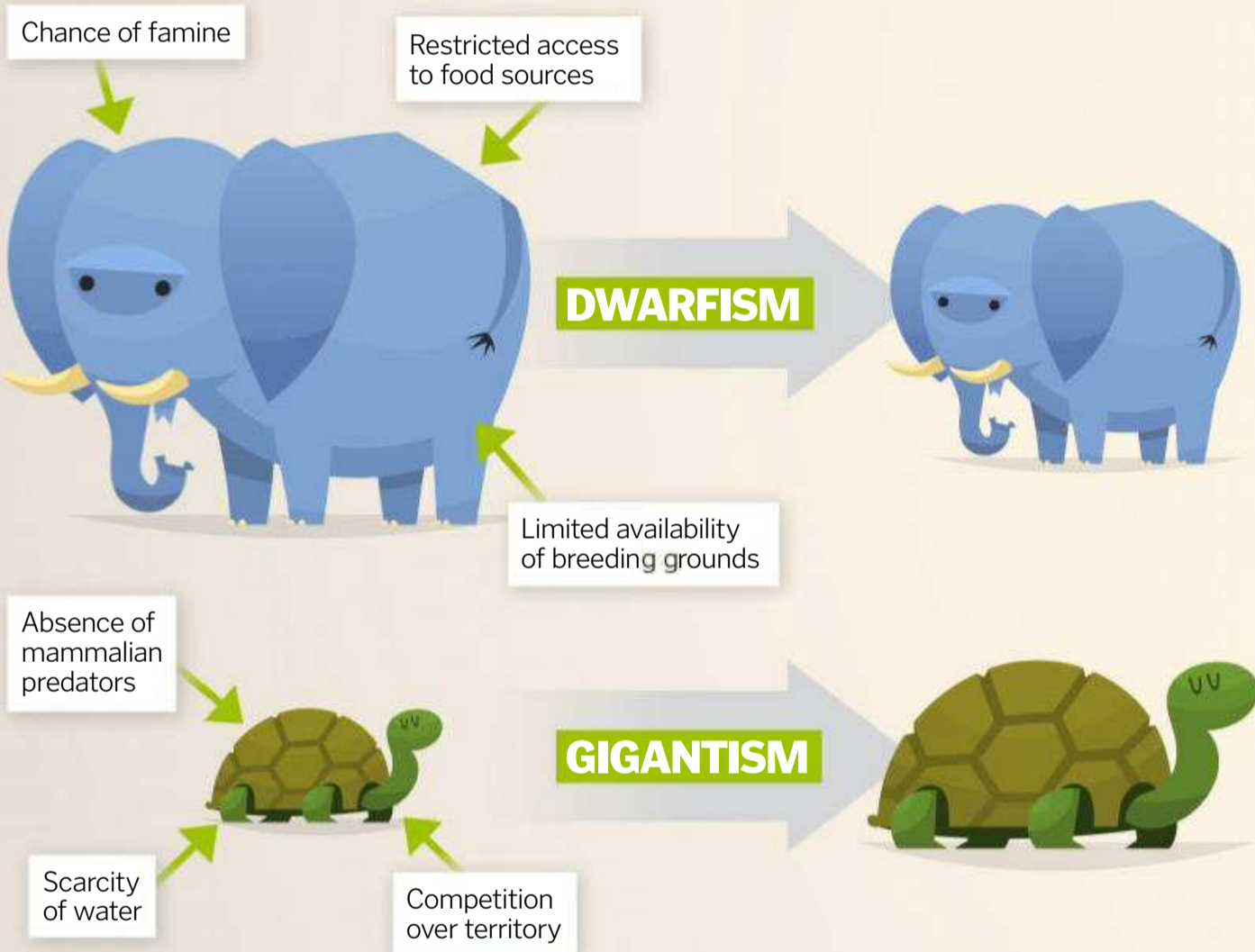
In 1964, he proposed a theory that became known as Foster's Rule. He suggested that small species on islands would become bigger than usual because of the reduced predation

pressure, while large animals would shrink over time due to the limited food. The concept has since been expanded to include additional factors like competition and temperature and to reflect the fact that these pressures affect certain animal groups more than others, but Foster was on the right track. It all seems to come down to efficiency; evolution moves species towards forms best able to obtain energy and survive, and on islands this often means a change in size.

Island dwarfism and gigantism have taken place on islands all over the world, creating huge flightless birds and elephants just a metre tall. Growing and shrinking have also been observed in populations on the mainland isolated in oases, caves and valleys, but islands surrounded by ocean often present settlers with conditions most different to those their ancestors evolved under. Many of the giants and dwarfs have gone extinct – some, like the 3.6-metre-tall flightless moa of New Zealand, were hunted to extinction by humans – but set foot on an island today and you may still be met with a host of creatures of surprising sizes.

Under pressure

The unique conditions on islands can cause animals to change size over the generations



Many island giants are now extinct, like the famous dodo

"Evolution moves species towards forms best able to obtain energy and survive in their habitat"

Island inhabitants

Isolated life comes in many sizes



Fossa
Madagascar's apex predator belongs to the mongoose family but can grow to a length of about 1.5m, which includes a 66cm tail.

Madagascar hissing cockroach

Another Madagascan giant, hissing cockroaches can reach almost 8cm at maturity.



Kakapo
New Zealand's kakapo is a nocturnal, flightless parrot that weighs up to 4kg.

Gran Canaria giant lizard

At 80cm long, this sturdy lizard is among the largest of the world's true lizard species.



Dwarfs vs giants

Life is a challenge for prodigious predators and pocket-sized prey alike

Dwarfism

Less waiting

Smaller animals have shorter gestation times, allowing them to reproduce faster.

Cool down

On tropical islands, smaller animals are better able to lose heat and keep their bodies at a safe temperature.

Snack size

Dwarf animals are in much greater danger should a new predator arrive on the island.

No backup

Small bodies have less space for storing reserves of energy.

GIGANTISM

Sturdy stuff

Larger animals can often survive longer without water and food and can travel further to find them.

Ready for battle

Bigger bodies are better equipped to fight off other animals when competing over food or territory.

Staying grounded

Giant birds often become too heavy and cumbersome to fly.

No escape

Larger animals find it much harder to hide from danger.

Hobbits and pygmies

The Indonesian island of Flores made headlines in 2003 when small human-like skeletons were discovered in a cave. Analysis revealed that they had once belonged to hominins all standing around a metre tall, members of an extinct species known as *Homo floresiensis*.

The modern-day inhabitants of Flores are still much smaller than the average person, and there had long been speculation that *Homo floresiensis* had met *Homo sapiens*

and passed on some of the genes for short stature. A new study has now ruled out that theory as no trace of Flores 'Hobbit' DNA was found when scientists studied the genes of the living pygmy people, and the original residents are thought to have died out tens of thousands of years ago.

With no relation between the two populations, small body size must have evolved twice on Flores in response to the extreme conditions on the island.



Small stature helps the people of Flores to survive the challenges of the island

© Getty-Wiki/Shutterstock



Nosy Hara chameleon

The island of Nosy Hara is home to the world's smallest chameleon, which measures just 29mm!



Island fox

Native to six of the Californian Channel Islands, the island fox is much smaller than the mainland gray fox.

Tamaraw

This critically endangered buffalo from the Filipino island of Mindoro is just 1m tall.



Pygmy three-toed sloth

The pygmy sloth, endemic to a tiny island off the coast of Panama, is the smallest of all the sloths.





Sturmpanzerwagen A7V tank

Germany's first operational tank, the Sturmpanzerwagen A7V made its combat debut during the desperate Spring Offensive in 1918

The appearance of British tanks on the World War I battlefield of the Somme in 1916 came as a shock to the German military establishment. Although tank development had been of interest prior to the outbreak of war – as early as 1911 in fact – other priorities had shunted the development of armoured fighting vehicles to low importance prior to the rude awakening.

The only operational German tank of World War I was the product of a hurried development programme that began with the formation within the War Ministry of the Allgemeines Kriegsdepartement Abteilung 7 Verkehrswesen – which translates as General War Department Section 7, Transportation – in the autumn of 1916. The newly established department also contributed a part of its name to its first production vehicle, the Sturmpanzerwagen A7V, or Armoured Assault Vehicle A7V, a 33-ton tank.

Specifications were issued for a monolithic, heavily armed and armoured beast that could sweep aside Allied tanks – both British and French – and destroy any soft targets, such as infantry concentrations and machine gun nests, that impeded the progress of infantry.

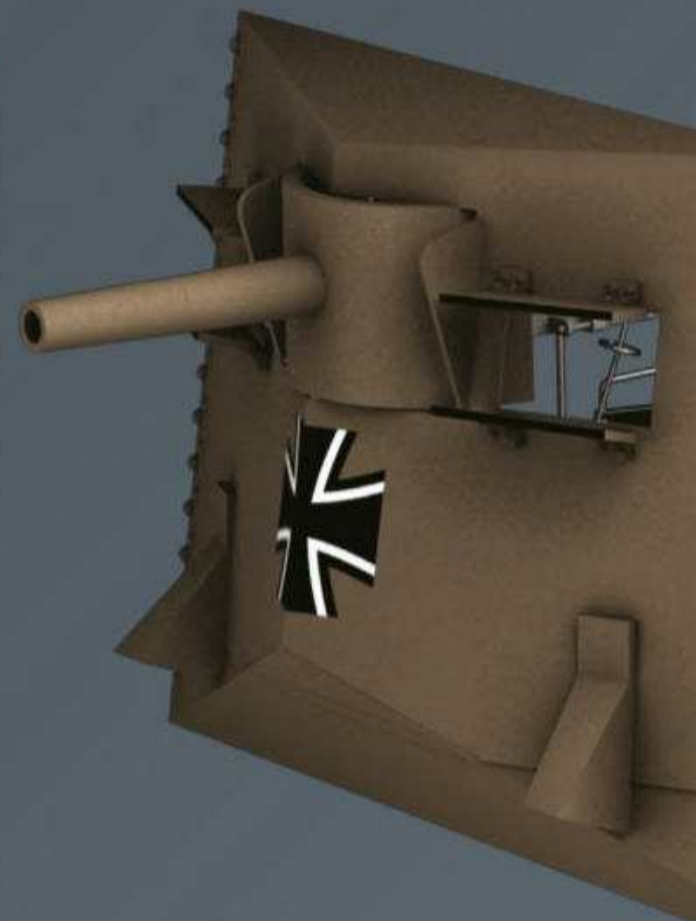
Specifications were also issued for a pair of light tanks built for speed and manoeuvrability to rapidly exploit any offensive breakthroughs.

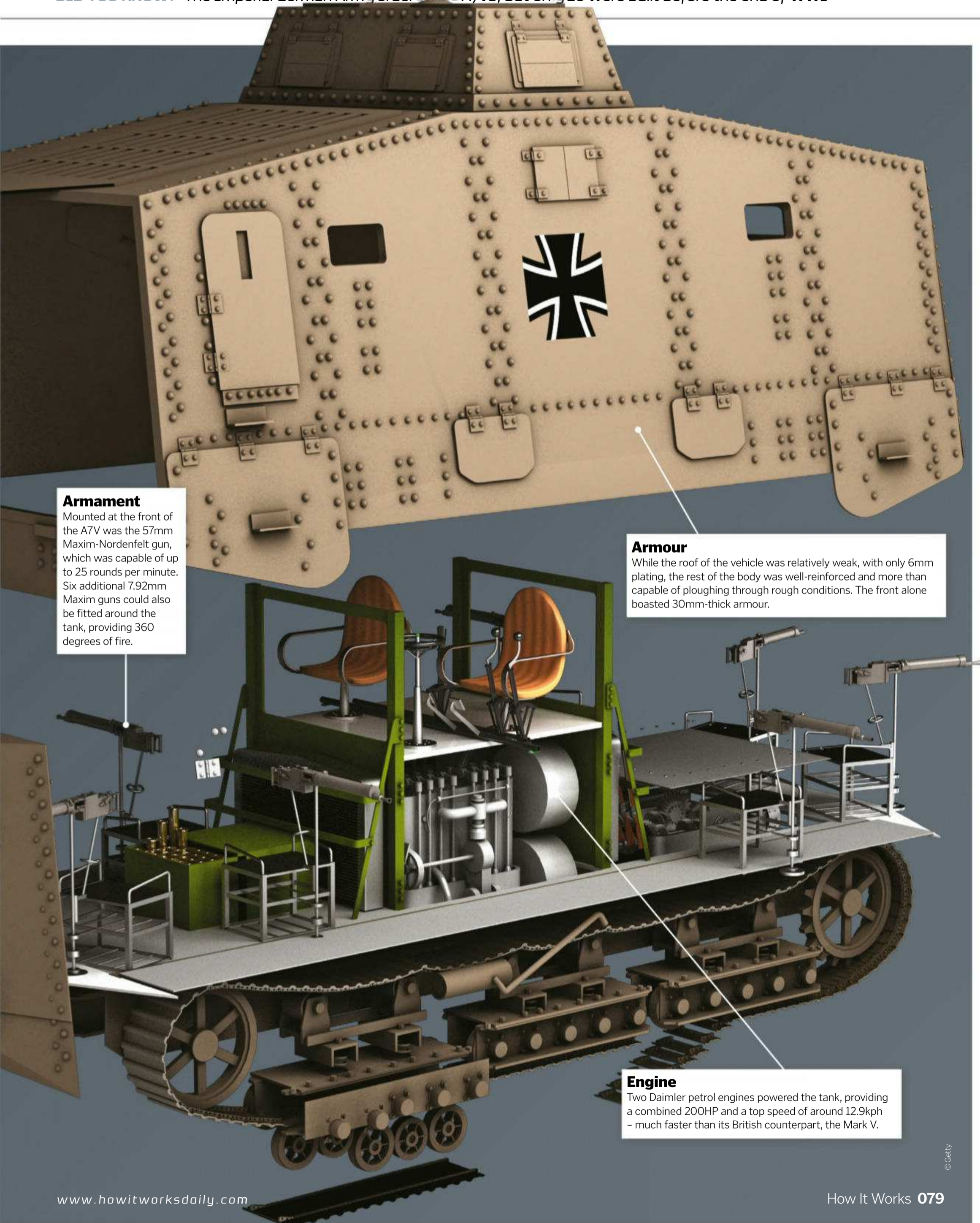
Three prototype tanks were built but never progressed beyond preliminary evaluation, either due to the coming of the Armistice in November 1918 or their obvious design flaws. The massive 120-ton Grosskampfwagen, or K-Wagen, was dropped with the end of the war; the light seven- and eight-ton LK I and LK II tanks were conceived in early 1918. The German army ordered 580 LK IIs, but none were completed. A commitment was made to limited production of the A7V in November 1916, mere weeks after the unnerving encounter with British armour on the Somme.

“Specifications were issued for a monolithic, heavily armed and armoured beast that could sweep aside Allied tanks”



Left: An A7V named 'Wotan' in active service in 1918





Armament

Mounted at the front of the A7V was the 57mm Maxim-Nordenfelt gun, which was capable of up to 25 rounds per minute. Six additional 7.92mm Maxim guns could also be fitted around the tank, providing 360 degrees of fire.

Armour

While the roof of the vehicle was relatively weak, with only 6mm plating, the rest of the body was well-reinforced and more than capable of ploughing through rough conditions. The front alone boasted 30mm-thick armour.

Engine

Two Daimler petrol engines powered the tank, providing a combined 200HP and a top speed of around 12.9kph – much faster than its British counterpart, the Mark V.

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What is aquaplaning?

How a seemingly harmless downpour can cause of the biggest dangers on the roads

Aquaplaning, also known as hydroplaning, is a problem that can transform a drive in the rain into a terrifying experience. This dangerous phenomenon occurs when rain starts to settle on a road, creating a layer of water between the tarmac and the tyres of cars. This loss of traction can quickly cause drivers to lose control of a vehicle as they are unable to steer or brake; the tyres cannot grip the road and this could cause the car to spin or skid across the road.

If you are unlucky enough to catch all of your wheels in water deeper than 2.5 millimetres, and you are driving at a speed in excess of 70 kilometres per hour, the water might become wedged between the tyres and road, pushing the wheels out of the water and causing them to skate on the surface rather than grip the road.

This happens because either the tyre has been worn down or poor drainage has left a lot of

water on the road, which means the wheels can't move the water out of the way fast enough for the rubber to make contact with the road surface – good quality tyres can clear around a bucket of water from the road every seven seconds.



2,918 people were killed or seriously injured on the UK's roads during wet conditions in 2015

How to handle a slide

A driver will realise that their car is aquaplaning because it will suddenly start acting strangely. The engine will start to roar louder, the steering will become light and the back end of the car will start to drift. It's easy to panic. Your instincts tell you to hit the brakes, but doing that will only make things worse.

Instead, you must gently ease off the accelerator and keep holding your steering wheel straight until your vehicle can grip the road again. If you want to reduce your risks of aquaplaning be careful of your speed in wet weather conditions and make sure your tyres are kept in good condition.



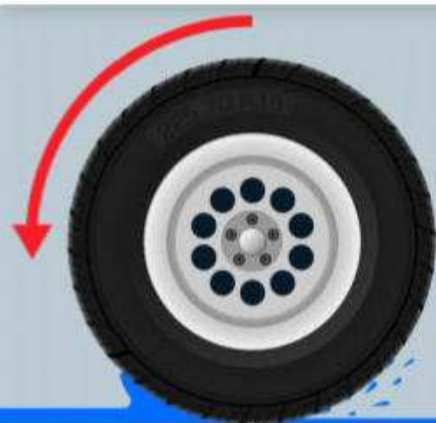
It's important for drivers to be aware of puddles on the road as they might be an aquaplaning risk

The science behind aquaplaning

This dangerous skidding is caused by the action (or inaction) of key forces

Slow speed

At slower speeds the tyres are able to shift the water away from the surface of the road and the surface of the wheel.



Full road contact

At slower speeds the tyres manage to keep in full contact with the road so the driver can manoeuvre safely through the wet conditions.

Moderate speed

At moderate speeds the tyres are still able to move most of the water and, while traction is reduced, grip remains.



Reduced road contact

Reduced road contact can result in some loss of control and may cause a vehicle to slide around a bit.

Higher speed

At higher speeds the treads on tyres are unable to shift the water between the tyre and the road, causing the tyres to lose all traction and the driver to lose control of the vehicle.



Aquaplaning

When the water isn't removed by the tyres the pressure increases in front of the tyres as it gathers there instead. Eventually the water wedges underneath the tyre, lifting the vehicle and causing it to glide along the road.



© Shutterstock: Getty

Marvel's Spider-Man

Could this be the greatest superhero game yet?

- Developer: Insomniac Games
- Publisher: Sony Interactive Entertainment
- Format: PlayStation 4 exclusive
- Rating: PEGI 16 / ESRB Teen
- RRP: £54.99 / \$59.99
- Release date: Out now

Swinging between skyscrapers, webbing up the bad guys and protecting the city... it's all in a day's work for Spider-Man.

Insomniac Games took on the daunting task of immersing players in the world of the web-slinging wonder, and the results pay off. Combining stunning visuals, a masterful combat system and engaging story, they've produced one of the best games of the year.

To get into the swing of things (literally) you start the game by making your way across Manhattan. Web-swinging around, over and between buildings is seamless – not to mention great fun – and there's a convincing sense of gravity with every dive and swoop. Even after you unlock the fast travel option between key locations, you may still find yourself preferring to take the swinging scenic route instead.

Soon enough, vigilante duty calls and Spidey has to take on the bad guys. The game takes place eight years after Peter acquires his powers, so – unlike an origin story – you're already an experienced crime fighter, and as such combat is fast-paced, fluid and intricate. This is not a game you can sail through by absentmindedly smashing X. The list of moves may be daunting at first, but once you've familiarised yourself with it, taking out a crowd of goons with perfectly executed combos becomes incredibly satisfying. Encounters also encourage you to consider different tactics; some situations call for stealth, others brute force or special moves. A range of different suits, skills and gadgets (which you can acquire and upgrade throughout the game) grant new benefits and abilities.

When you're not saving the day as Spider-Man, you'll also juggle Peter Parker's other responsibilities, including his day job at a



Take out the bad guys with slick combat sequences

biotech laboratory. Peter is a genius scientist and inventor, after all, so it's only fitting that the game highlights his intellectual abilities. Being **HIW**, we particularly enjoyed the scientific angle of the in-game puzzles, which include fixing electronic circuits and analysing spectrographs of mystery compounds.

There are a variety of optional sidequests available to fulfil your role as the friendly neighbourhood Spider-Man. These range from

"Taking out a crowd of goons becomes incredibly satisfying"

stopping crimes in progress to scoping out the city's landmarks and conducting scientific research projects to combat environmental health hazards. Some tasks can be a bit repetitive if you commit to completing them all at once; it may be better to tackle them sporadically between main story missions. That said, not only do these tasks earn you collectibles for gear upgrades, they also lead you to areas of the city that you wouldn't necessarily visit just by sticking to the main story.

As the game takes place in Marvel's New York, when exploring the city you'll uncover Easter eggs from the Marvel Universe. This will delight dedicated Marvel aficionados, but casual fans may find these references go over their heads. These moments won't detract from your



Swinging through Marvel's New York is a joy

enjoyment though, as many such hints are hidden in sidequests or (seemingly) throwaway comments in conversation.

The dialogue and voice acting are natural and entertaining, packed with Spidey's characteristic humour. Whereas in other games secondary characters can feel incidental or two-dimensional, here the supporting cast is well developed. Some characters, such as Mary Jane, take on larger roles and have their own playable chapters, adding greater depth.

Visually, the game is outstanding. The city is stunning and character animations and facial expressions in cutscenes are authentic. Combat animations are superb – particularly when performing special 'finishing moves' that take down enemies in cinematic style.

The main story takes around 20-25 hours to complete, but will soon be expanded with the upcoming three-part DLC series *The City That Never Sleeps* (available separately – £15.99 / \$24.99). The first instalment, *The Heist*, will be released on 23 October, with *Turf Wars* and *Silver Lining* following in November and December respectively. Each will include new missions, challenges and gear, as well as introducing new allies and adversaries.



How It Works received a code to review Marvel's Spider-Man courtesy of PlayStation. Opinions are our own. We achieved 96% completion on the 'Amazing' (normal) difficulty setting before writing this review.

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Could we power the world with solar energy alone?

Chelsea Casey

■ More energy from the Sun hits the world in a single hour than humanity uses in an entire year, so yes, we could theoretically power the whole world with solar energy alone. However, we'd first need to make some changes and build new infrastructure. We'd need better batteries to store power, so solar could be used

in vehicles and when the Sun wasn't shining. New electricity lines would also be needed to carry power from sunny places to dark places. Experts estimate that we'd need between 100,000 and 500,000 square kilometres of solar panels (the latter being an area as big as Spain) to power the Earth. TL



How do disc brakes on a car work?

Henry Hunter

■ Attached to the back of a car wheel is a metal disc called a rotor with a brake pad on either side. Applying the brakes pushes the pads together, squeezing the rotor between them and slowing the rotor and wheel as their kinetic energy is converted into thermal energy through friction. TL

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Why is it so hard to remember our dreams?

Lianne Durley

■ To remember things we need to transfer experiences from short-term storage into long-term storage, but most of the time we don't do this with dreams. Researchers at Caltech recorded neuron activity in the brains of sleeping rats to find out why. They discovered that during REM sleep, when we dream, the neurons in the hippocampus (which makes memories) stop talking to the neurons of the neocortex (which stores them). **LM**



We hold our dreams in our short-term memories and forget them when we wake

Who invented the waistcoat?

Mike Doyle

■ The waistcoat has a royal heritage, having been invented by none other than King Charles II in the 17th century. He would later insist that it should become part of every English gentleman's attire. **JH**



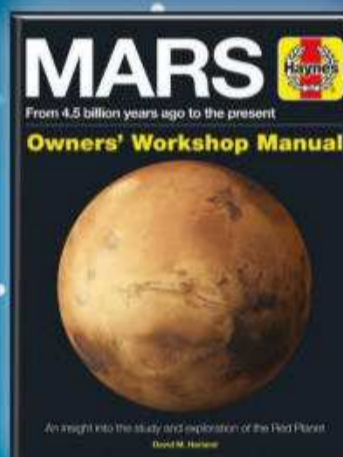
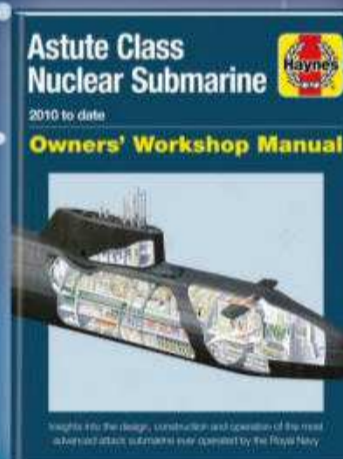
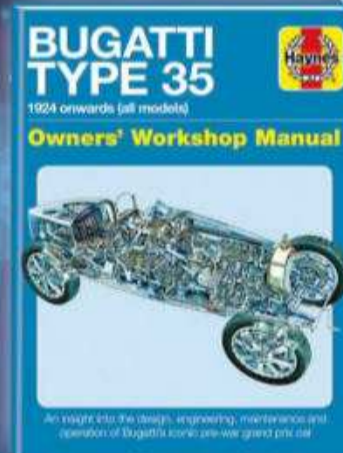
Do identical twins have identical fingerprints?

Tomas Steffensen

■ Identical twins don't have identical fingerprints because fingerprints are not determined by genes. Their formation is influenced by random changes in hormone levels as the foetus develops in the womb. **JS**



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Haynes shows you how

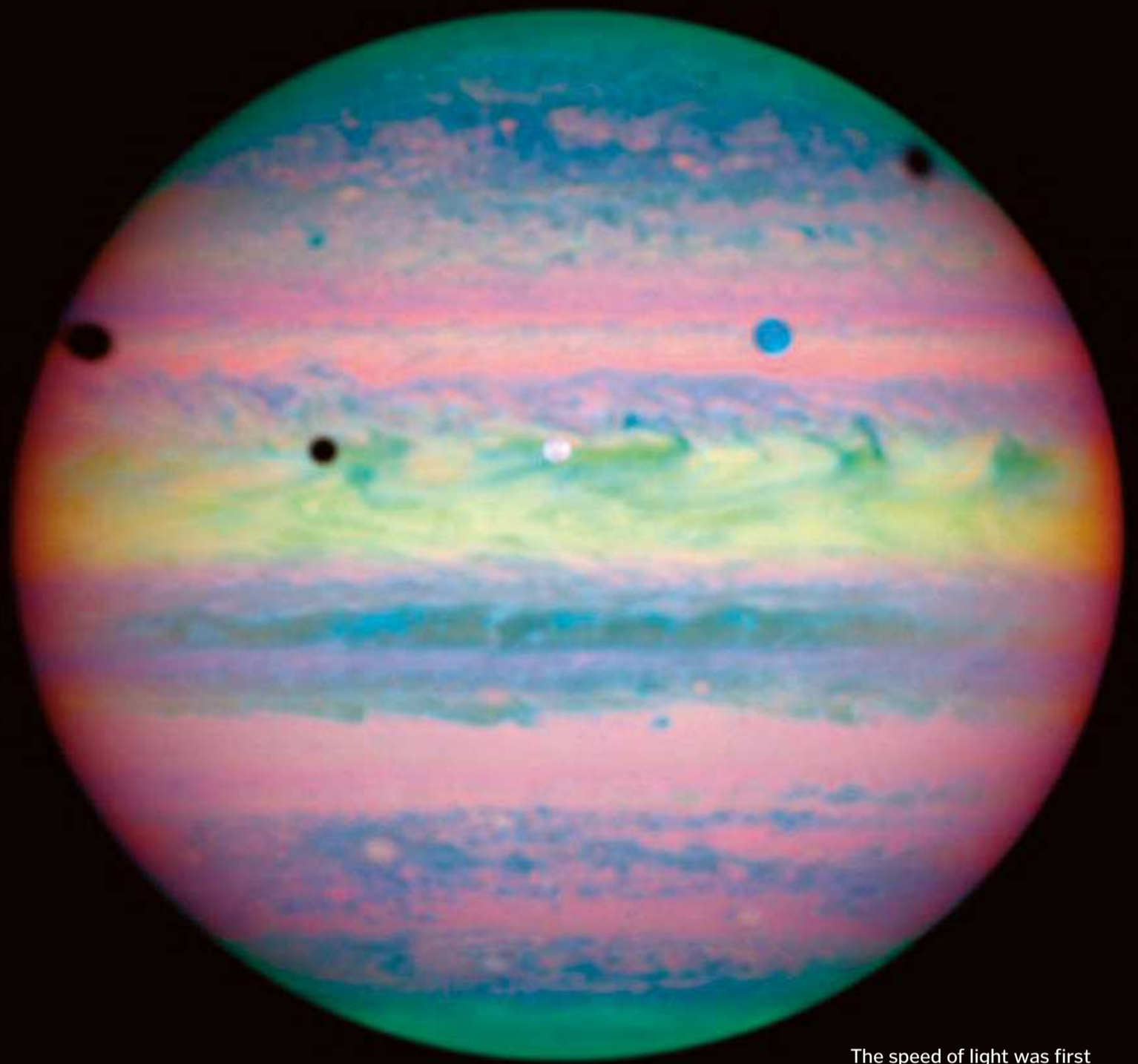


www.haynes.com

Who first calculated the speed of light?

Ed Clarke

■ A fairly accurate calculation for the speed of light was derived by Danish astronomer Olaus Roemer all the way back in 1676. Roemer was monitoring the eclipses of the moons of Jupiter and noticed that when the Earth was moving further away from the gas giant, the time interval between successive eclipses seemed to increase. He surmised that this must be because the light had further to travel when the Earth was further away and so it was taking longer to reach his observatory. From this he was able to estimate the speed of light and arrived at a respectable 225,000 kilometres per second. Others would later refine his estimate to reach the accurate 299,792.458 kilometres per second value. **JH**



The speed of light was first calculated based on Jovian eclipses nearly 350 years ago

How do we know Pangea existed?

Naomi Paulson

■ German meteorologist Alfred Wegener first presented the concept of the Pangea supercontinent in 1912, giving three reasons for his theory. The first was how well the continents' coastlines could fit together. The second was the similarity in the geology and climate of regions that could once have been joined. The third was the fossils of identical plants and animals found on different continents with no obvious route for them to have travelled between them. It wasn't until after his death that geologists could prove him right thanks to progress in rock and mineral dating, sonar and geophysics. **JS**



Pangea existed for around 99 million years and broke up around 200 million years ago



Is it true that the Olympic flame never goes out?

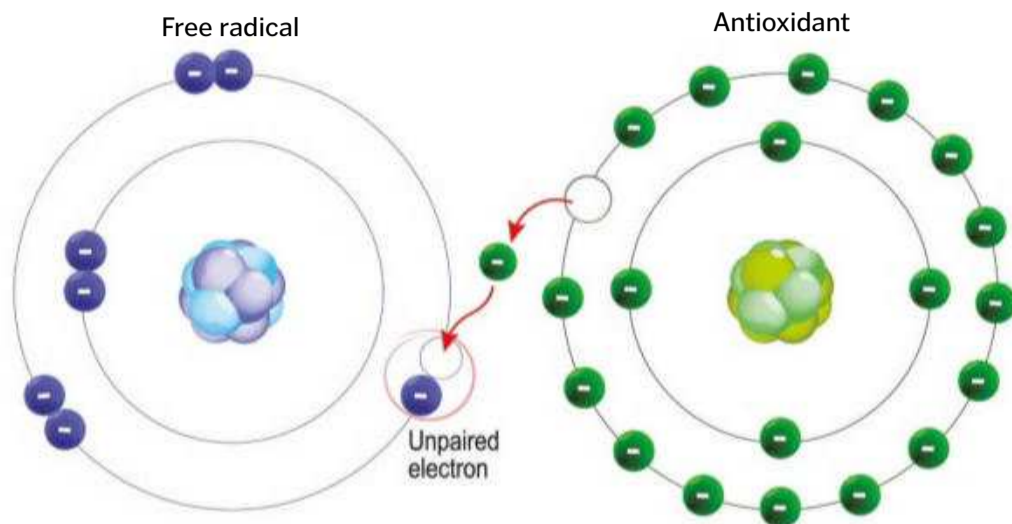
Debbie Myles

■ A new flame is lit before each Olympics and burns for the duration of that year's games. The organisers have spare flames in case it goes out before the closing ceremony! **TL**

What are antioxidants?

Dave Matterson

Free radicals are molecules with unpaired electrons. They are highly reactive and can damage vital components of our cells. Antioxidants either break down free radicals or block their reactions. **LM**



Why does coffee never taste as good as it smells?

Max Jones

Scientists have found that when we eat or drink, we smell in reverse. The aroma travels from the throat to the nose and is interpreted in a different part of the brain, which is less receptive to flavour. On top of that, our saliva destroys nearly half of the coffee chemicals and changes the taste. **JT**



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Why is it called a 'Mexican' wave?

Pierre Thomas

The rippling wave effect – made by stadium crowds throwing their arms in the air – is believed to have originated in the US in the early 1980s. But it was at the football World Cup finals in Mexico City in 1986 where the move was fully embraced and showcased to the world, entrenching the Mexican wave in the global consciousness. **JH**



Is there a difference between a school and a shoal of fish?

Lorraine Brown

A shoal is a disorderly group of fish staying together for social reasons. The shoal becomes a school when the fish start moving in unison, which can confuse predators. **JT**



Is the aluminium in deodorant bad for you?

Ruth O'Brien

Aluminium salts plug sweat glands, helping to stop perspiration, but some people have concerns about their safety. In 2014, a team of scientists reviewed all the studies linking aluminium and breast cancer and found no clear evidence of any danger. **LM**



Why does hot weather make it hard to sleep?

Jake Taylor

When you're ready to go to sleep, your body releases a hormone called melatonin that drops your core temperature to help you drift off. But if your body temperature is too high, melatonin can't be produced, making it more difficult to fall asleep. **JS**



The Cornish spaceport will be used for horizontal launches, which will lift off from a runway

What will the UK's new spaceports be used for?

Robert Weston

■ The UK spaceports are set to open at the earliest in 2021 in Cornwall, England, and Sutherland, Scotland, where they will host the first space launches from UK soil. The UK

Government has teamed up with Virgin Orbit for horizontal launches from its Cornwall site (where the rocket is lifted to altitude by a plane before firing), and the Sutherland site will be used for traditional vertical launches.

This technology will enable the UK to place small payloads weighing approximately 150 kilograms – including observation and communication satellites – into orbit. **JH**



The GDPR helps to protect your personal data and privacy

What is GDPR?

Peggy Spencer

■ GDPR stands for General Data Protection Regulation. It's a new Europe-wide law that regulates how companies and other organisations protect the personal information that they have stored about people. Among other things, GDPR means that organisations that hold personal data have to respect your privacy, keep your data secure and can't sell it to other people or use it for things that you haven't agreed to. Companies that break the rules can be very heavily fined. **TL**



Horses like to graze on grass and hay throughout the day

Why do horses eat hay?

Jermaine York

■ Horses are herbivores and need to regularly eat small amounts of high-fibre vegetation. Their natural diet consists mainly of grass, as it contains most of the nutrients they need to stay healthy. However, when a field of luscious grass isn't available, hay is the next best thing. Hay is dried grass that can be stored for when fresh grass isn't available. Many horses will also be fed grains that make up for the nutrients hay can't provide. **JS**

What is NATO?

Amelia Torres

■ The North Atlantic Treaty Organization (NATO) was founded in 1949, and as of 2018 it is made up of 29 member states. In the aftermath of WWII, Western nations saw the need for a defensive pact against any external threats. Historically, the main threat was perceived as the Soviet Union. There were 12 founding members, including France, the United Kingdom and the United States. If any one member of NATO were attacked, then all the other member states would be obliged by the Treaty to act in their defence through political and military means. **JT**



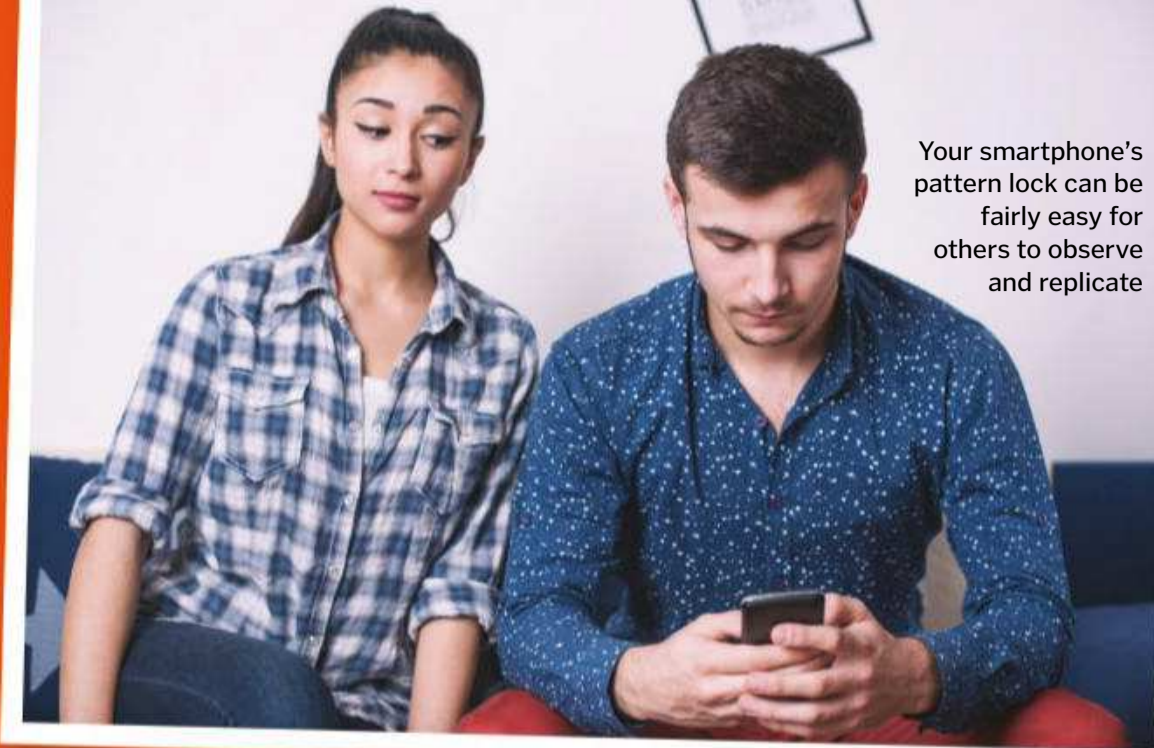
What do nerve agents do?

Thea Winters

■ Nerve agents are organophosphorus chemical weapons. They work fastest when they get into the blood through the lining of the lungs, but they can also infiltrate the body via the skin. They interact with an enzyme called acetylcholinesterase, stopping it breaking down a chemical called acetylcholine. Nerve cells use acetylcholine to send messages, and without the enzyme they can't turn the messages off. At low doses, this causes a runny nose, headache and slurred speech. At higher doses, it becomes hard to breathe. Nerve agents paralyse muscles and interfere with the respiratory centres in the brain. Treatments try to reverse the damage by reactivating the enzyme and blocking the acetylcholine signals. **LM**

Nerve agents interfere with the chemical signals that pass between nerve cells

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Your smartphone's pattern lock can be fairly easy for others to observe and replicate

Are pattern locks secure?

Kevin Ballard

■ Unlock patterns are much less secure than numbered passcodes or biometric scanners. A study found that two out of three observers could replicate a six-point unlock pattern, even from a distance of nearly two metres. Researchers think it could be due to how well our brains remember patterns. Another study found that thieves could crack a pattern lock within five attempts by covertly videoing the owner unlocking their device and using software that tracks their fingertip movements. **JT**

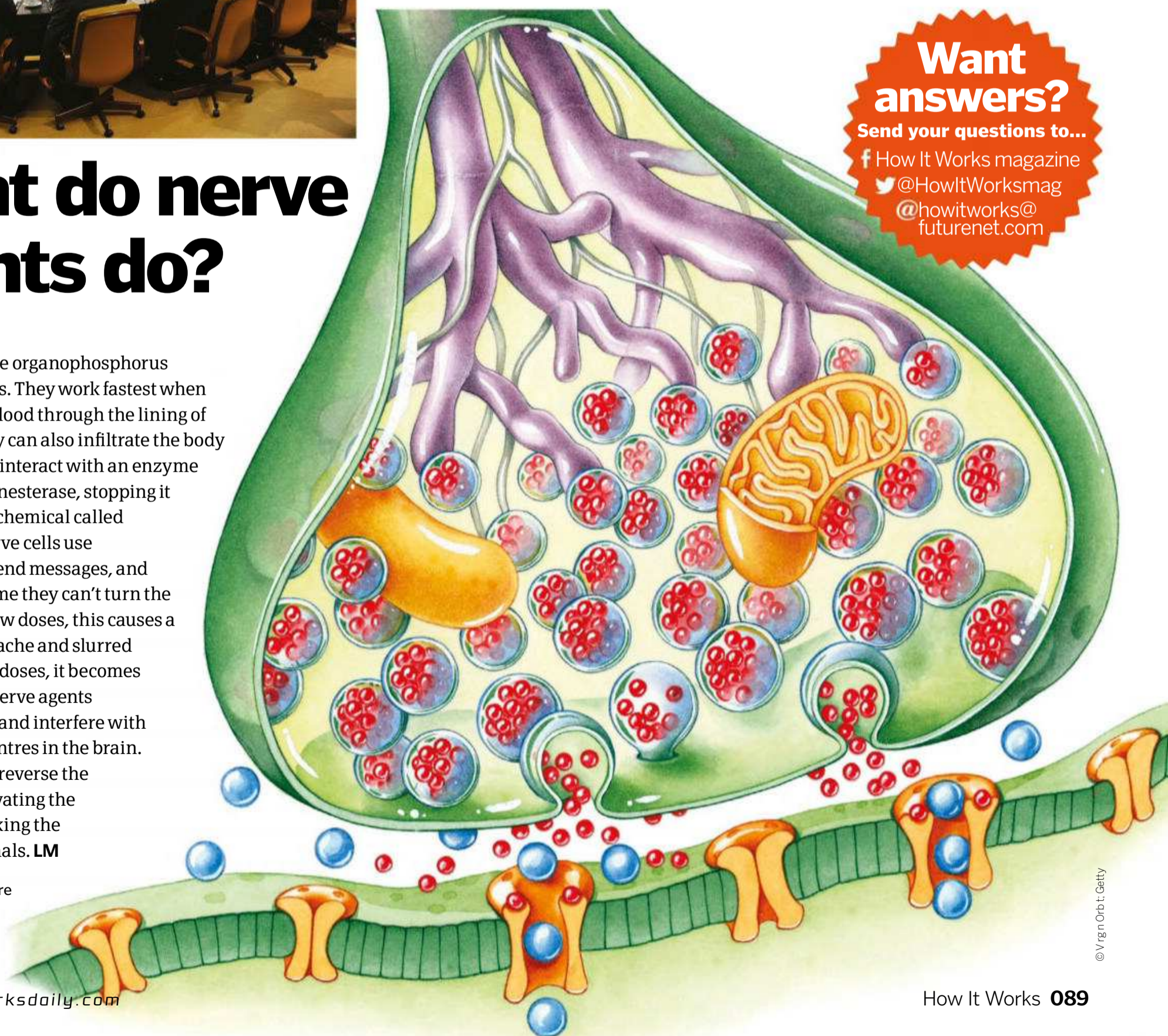
Want answers?

Send your questions to...

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BOOK REVIEWS

The latest releases for curious minds

How to Speak Science

Entertainment meets education, from the brain of a YouTube scientist

- Author: **Bruce Benamran**
- Publisher: **Virgin Books UK / The Experiment US**
- Price: **£12.99 / \$15.95**
- Release date: **Out now**

Often, for more casual readers of science titles like this, the success or failure of the book comes down to the quality of the writing. Do you like a conversational tone alongside your facts, or do you prefer something drier but more authoritative? If it's the former, you're in luck.

As you might expect from a YouTuber whose success depends on being exciting, engaging and entertaining, Bruce Benamran's title is full of character. The Frenchman has over 1 million subscribers to his channel (which he name-drops early), and once you start reading it's plain to see why.

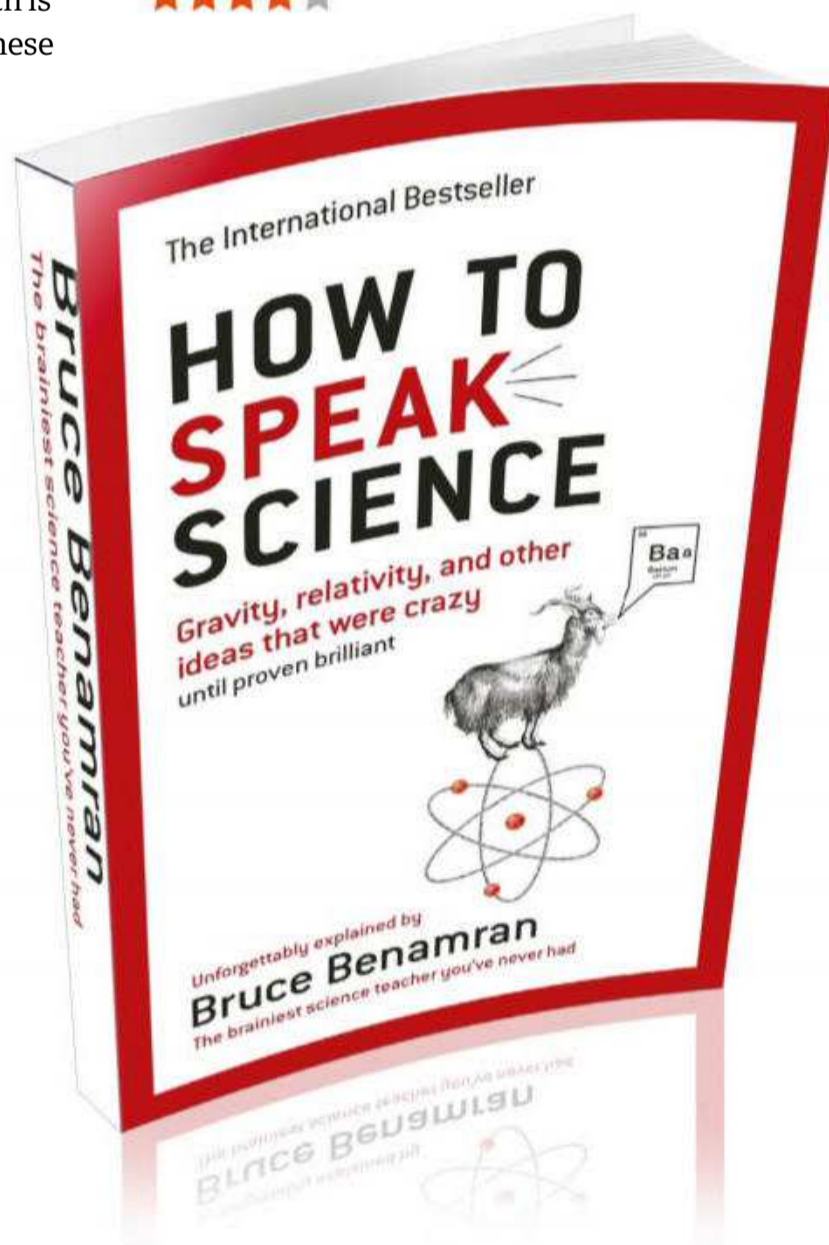
His writing is full of charm, and Benamran certainly isn't afraid to share an opinion. Within the first 20 pages he's called Aristotle an idiot, and explained – in bullet points – why he believes this to be the case. It's a bold opening and sets the tone for the book, which flows along nicely. There's the odd Focus Frame, which is Benamran's name for a digression, and these usually do a lovely job of expanding on a subject or giving more detail to a topic that deserves it. It's all digestible thanks to the way he writes, and the whole thing is very readable indeed.

However, there are points at which the structure feels a little haphazard. In recent months, we've reviewed books that discussed science, theories and experiments through the lenses of history. That is, they travelled chronologically from ancient times

through to modern discoveries and ideas, with everyone from Archimedes to Stephen Hawking getting a mention. The historical lens works well, because it shows the progress of understanding. Here, the topics are divided by their overall area. The book opens, for example, by talking about matter. It makes sense – begin with the atom and make your way up. But as a result the flow isn't quite as neat, and you're constantly zipping back and forth in time as you discuss the evolution of each theory.

To be fair, we're being a little picky here – the structure does work, and thousands of other books follow a similar format. Perhaps it is a matter of taste.

What we're sure everyone will agree on, however, is that Benamran's writing is brilliantly balanced, and it makes for an exceptionally educational, enlightening and entertaining book.



The Universe in Bite-Sized Chunks

Want to know what's out there?

- Author: **Colin Stuart**
- Publisher: **Michael O'Mara Books**
- Price: **£9.99 (approx. \$13)**
- Release date: **Out now**

We've lost count of the times we've wished for a book that talks about space, the cosmos and beyond in a concise and accessible manner. Now, with Colin Stuart's *The Universe in Bite-Sized Chunks*, it looks like we've finally got what we've been asking for.

Taking us on a journey of discovery, Stuart starts right at the beginning, from the earliest time-recording devices built by our ancestors and Eratosthenes' discovery that the world wasn't flat, to further examinations of the Big Bang theory and black holes, to what possibly awaits us in the distant future.

Along the way he also poses frequent questions and hypotheses. Is it possible that alternate realities exist? Is time travel possible? What about alien life? Some of the answers may well surprise you; they certainly did us. Throw in profiles of the planets and objects like comets and asteroids, as well as sections covering important figures like Stephen Hawking and the theories he postulated, and a lot of ground is covered.

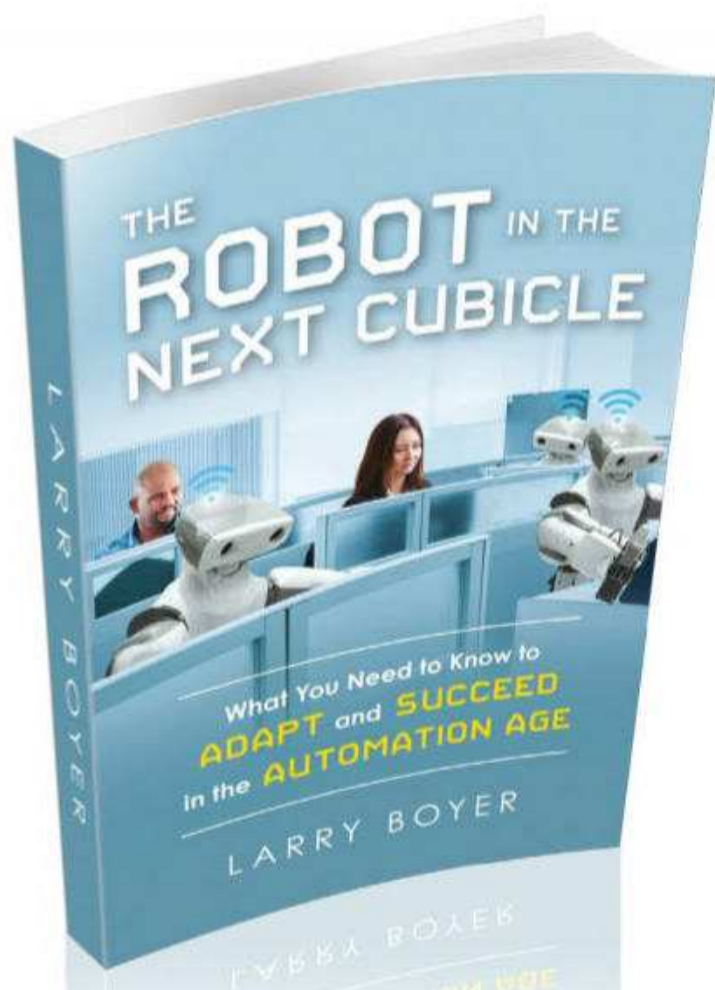
One of the strengths of this book is that it does indeed cover the best of both worlds, so to speak. The information contained within is never presented in a confusing manner, while at the same time, to our mind, it doesn't feel like anything important is missed out.

So at least until the Big Rip (want to know what that is? Read this book to find out...), what we have here is something equally worthwhile both to newcomers and those brushing up on the subject. In other words, this comes highly recommended.



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"Within the first 20 pages he has called Aristotle an idiot..."



The Robot in the Next Cubicle

Or: how to survive the AI uprising

- Author: **Larry Boyer**
- Publisher: **Prometheus Books**
- Price: **£15.99 / \$19**
- Release date: **Out now**

Techno fear. With the abilities of robots developing all the time, and with it the warnings of the potential quandaries that AI brings, it's just one on our ever-growing list of worries, although many apparently don't consider it to be a pressing one. After all, robots aren't that advanced yet, right?

Maybe not, but as part of the so-called 'Fourth Industrial Revolution', the prospect of competing with robots for a place in the workplace is looking like an ever more likely reality, and one we would be foolish not to react to. Rather than having us all become Luddites, however, Larry Boyer offers a different solution, one that involves us marketing ourselves apart from our potential future robot colleagues and developing skills that will allow us to stay relevant in the workplace.

Starting off by looking at the previous three industrial revolutions, the prospect of what he suggests is likely to become a reality doesn't initially sound

particularly welcoming. While these events changed the face of the Earth and greatly improved quality of life for many, their impact on those who lost their jobs as a result was initially catastrophic, and we still haven't got a handle on the environmental damage currently being wreaked on the world.

As you might expect, this kind of book is more enjoyable to read as a theory rather than a genuine practical guide. Sections on how the increased presence of robotics may impact career fields such as law and construction are undeniably interesting, but other sections will be less useful to the casual reader. After all, not everyone will possess the skills and resources that are suggested as a means of getting around the robot issue.

Still, there's a lot of food for thought for those searching for something robot-related to munch on. It perhaps shouldn't be taken too seriously, but considering it's title, maybe it isn't trying to be.



GIFT GUIDE

It's not too early to start thinking of some stocking fillers...

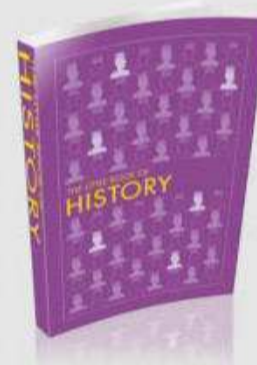


Science: A Children's Encyclopedia

- Author: **Various**
- Publisher: **DK**
- Price: **£19.99 / \$29.99**
- Release date: **Out now**

PERFECT FOR...
LITTLE EINSTEINS

This fact-filled encyclopedia is the perfect guide for any budding scientists in the family. Principles are explained clearly with bite-sized chunks of text and easy-to-follow diagrams. Suitable for ages eight and up.



Big Ideas: The Little Book of...

- Author: **Various**
- Publisher: **DK**
- Price: **£8.99 / \$12.99 each**
- Release date: **Out now**

PERFECT FOR...
CURIOUS POLYMATHS

These pocket-sized guides are ideal gifts for anyone whose thirst for knowledge knows no bounds. Each title provides a comprehensive overview of its subject, from psychology to Shakespeare and history to philosophy.



Large Hadron Collider Owners' Workshop Manual

- Author: **Gemma Lavender**
- Publisher: **Haynes**
- Price: **£22.99 / \$36.95**
- Release date: **Out now**

PERFECT FOR...
PHYSICS FANS

Find out what goes on at the world's largest and most powerful particle accelerator with this in-depth manual, covering everything from the project's construction to its groundbreaking discoveries and future upgrades.



Columbus in Space

- Author: **The European Space Agency**
- Publisher: **Century**
- Price: **£8.99 / \$16.95**
- Release date: **Out now**

PERFECT FOR...
FUTURE ASTRONAUTS

Discover the cutting-edge, out-of-this-world research taking place aboard the ISS's Columbus module. Packed with diagrams and photos, this stunning book celebrates the tenth anniversary of Europe's first space lab.

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Quickfire questions

Wordsearch

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

FIND THE FOLLOWING WORDS...

- AQUAPLANING
- BLOCKCHAIN
- CAROUSEL
- CTSCAN
- CRYPTOCURRENCY
- DAREDEVIL
- HALLOWEEN
- HOUDINI
- ISLANDS
- NASA
- OCTOPUS
- PIGMENT
- SPACETIME
- STUNT
- TARDIS
- THE DOCTOR
- TOWER
- VAMPIRE
- WELLS
- ZOMBIE

Q1 What are carved pumpkins known as?

- Jack-o'-lanterns
- Jackanackanories
- Jack-of-all-trades
- Jack-in-the-box

Q2 Which of these is a collective noun for a group of peacocks?

- An ostentation
- A pride
- A muster
- All of the above

Q3 Who painted the *Mona Lisa*?

- Michelangelo
- Da Vinci
- Monet
- Picasso

Q4 Which group has the Roman numerals in ascending order?

- V, X, I, L, D, M, C
- I, V, X, C, D, L, M
- I, V, X, L, C, D, M
- V, I, X, L, C, D, M

Spot the difference

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



Sudoku

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

EASY

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

DIFFICULT

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

What is it?

Hint:

Super-sensitive detectors



A

For more brain teasers and to test your problem-solving abilities, enjoy our *Mensa Puzzle Book*, which is packed with challenging problems and puzzles designed by experts.

Available from myfavouritemagazines.co.uk



Spot the difference



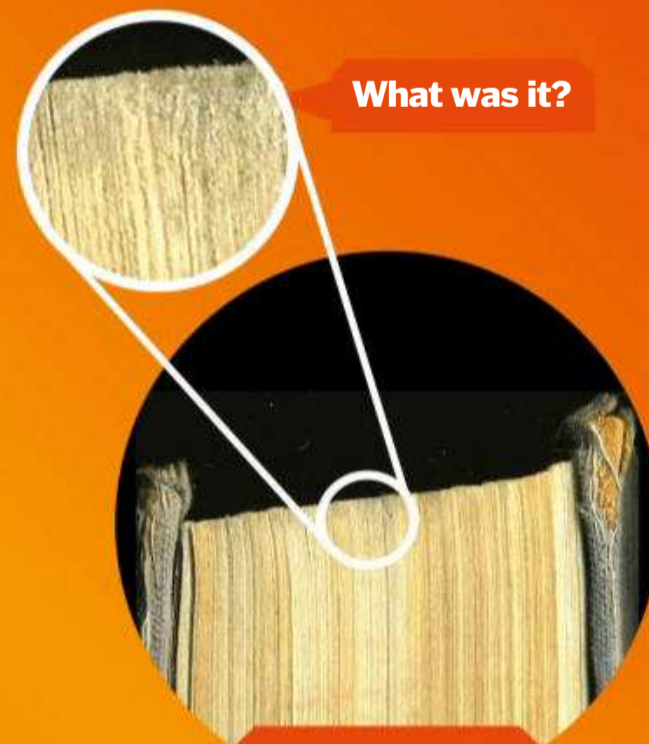
Check your answers

Find the solutions to last issue's puzzle pages

Quickfire questions

- Q1 1877
- Q2 Benjamin Franklin
- Q3 = $6.67 \times 10^{-11} \text{m}^3 \text{kg}^{-1} \text{s}^{-2}$
- Q4 Eukaryotic

What was it?



Book pages

HOW TO...

Practical projects to try at home

Create cosmic space eggs

Make eggs into colourful and weird planet-like creations

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU



1 Egg-cellent preparation

First, you need a hard-boiled egg. Ask an adult to help you boil an egg, let it cool, then put it in a bowl and completely cover it with vinegar. Leave it for five minutes.



2 Fill your tray

Next, you need to take a shallow container, like a tray, and fill it with whipped cream – the spray version is easiest. Then use a spoon to flatten the cream to a smooth surface.



3 Add some colour

Drizzle some food colouring – preferably in bright, neon colours – into the cream. Try a mix of little drops and big splashes. You can use more than one colour if you like.



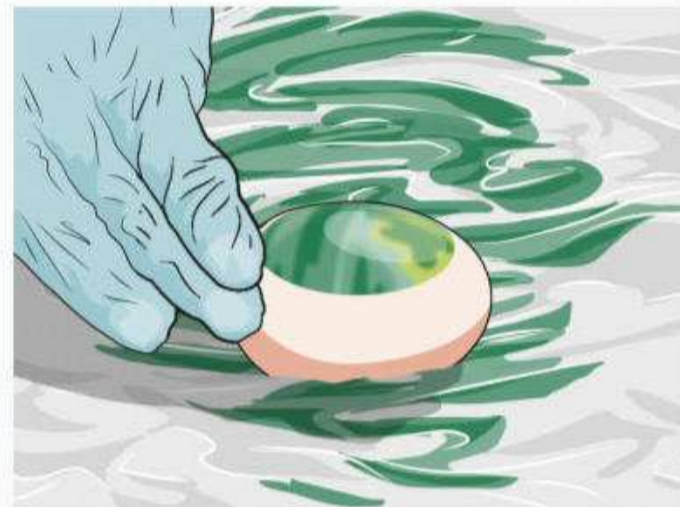
4 Spread and expand

Now take a toothpick or chopstick and swirl the food colouring so that the colours mix a little and the surface of the cream is covered. Try to make some cool, sweeping patterns!



5 De-shelling

Use a spoon to lift the egg (or eggs) out of the vinegar. Gently rub them with a paper towel and you'll see that the outer layer of the shell comes off. Keep going until it's all gone.



6 Roll it out

Now roll your white eggs through the colour mixture in the cream, making sure the whole surface is covered. Use plastic gloves for this part to keep the colouring off your hands!



7 Dry it off

Leave your eggs on a plate so that the colouring can dry. Once they're done you should be left with an egg that looks more like an amazing, colourful planet!

HOW IT WORKS...

Egg shells are made mostly of calcium carbonate, which dissolves when it reacts with the acidic vinegar. Food colouring relies on acid to help it stick to surfaces, and because there's a thin coating of acid left on the outside of the egg, the food colouring sticks to it. Dyeing clothes works in the same way.

Had a go? Let us know!

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

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NEXT ISSUE
MAKE LAVA IN A CUP

COMPETITION

WIN

A NINTENDO SWITCH AND LABO BUNDLE!

This month we're giving away a Nintendo Switch – the fantastic console-handheld hybrid – plus a Nintendo Labo Variety Kit. As well as enjoying games, with Labo kit you can use your Switch to build five different interactive projects, including a motorbike, piano and remote-controlled car!

To enter, just answer the following question on our website:

In *Doctor Who*, what is the 'catchphrase' of the Daleks?

- a) **Exfoliate!**
- b) **Extrapolate!**
- c) **Exterminate!**



► Enter online at howitworksdaily.com and one lucky reader will win!

In 2017, the world's first gene editing in a human body was attempted to correct a DNA defect causing Hunter's syndrome



Letter of the Month

Editing genes

Dear HIW,

Professor Robert Winston gave a talk at our school and talked about genetically modified mice – it was very fascinating! I was wondering how scientists modify animals' genes and how they know which genes to modify?

Thanks,
Charlie Lewis

Genetic engineering, or genome editing, has been around since the 1970s, but in recent years the discovery of the CRISPR-Cas9 system has opened up the possibility of editing genes more directly. CRISPR refers to DNA sequences found in bacteria that are involved in defending against invading viruses. Viruses inject their DNA into a

cell so that the viral DNA will reproduce within the host cell, creating a virus factory. The bacteria's immune response, however, is to copy that DNA and insert it into its DNA sequence at matching base pairs, achieved by using a protein called Cas9 and guide RNA.

To do this, Cas9 cuts a slot for the new DNA, slots it in and stitches it back up. It's this process that inspired gene editing in other organisms. Thanks to genetic sequencing, scientists know which sequence of a gene codes for different traits, such as hair and eye colour or a mutation that can cause diseases such as leukaemia. With the help of a virus, engineered DNA and Cas9 can be inserted into a cell to replace individual DNA sequences or mutations.

WIN!
AMAZING PRIZE FOR LETTER OF THE MONTH!
ENDURANCE
It was a year in space, but a lifetime of discovery for astronaut Scott Kelly who has experienced things very few of us ever will



Seeing red

Dear HIW,

How do red-leaved trees photosynthesise when chlorophyll is green?

Thanks,
Amy Clark-Want

You raise an interesting point, Amy. We are taught in school that chlorophyll is a green pigment in plants and the fuel for their life-sustaining process of photosynthesis. Trees with leaves that appear red are not missing any chlorophyll but have an extra water-soluble pigment called anthocyanins. It's more a question of physics and light; chlorophyll reflects wavelengths of green light, and therefore we see it as such. Anthocyanins, on the other hand, reflect wavelengths of red/purple light instead. When the anthocyanin levels are higher than the chlorophyll the red colour dominates, so that's what we see in the leaves of Japanese red maple trees, for example.



Chlorophyll are pigments where light is converted into chemical energy and released as fuel for plants

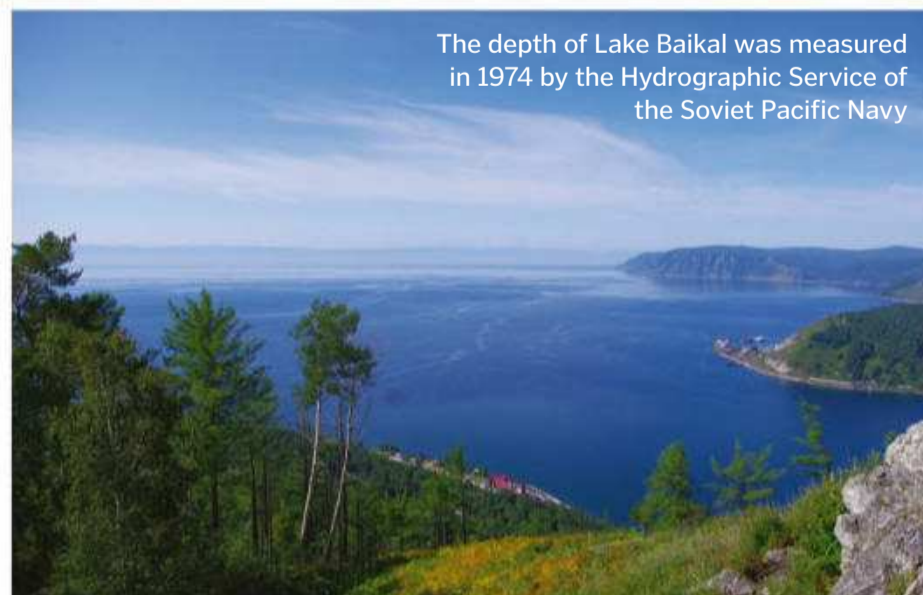
Into the deep

Hi How it Works,

I've been reading your magazine for a while now and love the environment section, but I've been wondering, what's the deepest lake in the world?

Matthew Simenoidis

Well, Matthew, according to the Guinness World Records, the world's deepest lake is Lake Baikal in southeastern Siberia, Russia. It is 636 kilometres long, 48 kilometres wide and the lake's Olkhon Crevice reaches depths of 1,637 metres.



The depth of Lake Baikal was measured in 1974 by the Hydrographic Service of the Soviet Pacific Navy

"Cas9 cuts a slot for the new DNA, slots it in and stitches it up. It's this process that inspired gene editing in other organisms"

You can look out for the Moon in the day by checking its phase and rising times



Day Moon

Hi **How it Works**,

I love your magazine and read it every month. I have a question I'm hoping you can answer: why can we sometimes see the Moon when it's broad daylight?

Thanks,

Debbie Horton

Due to the way the Earth rotates, the Moon is above the horizon for about 12 hours each day. Of those 12 hours there is only a six-hour window on average to view it during daylight. When the Moon is within a week or so of its full Moon phase, and when its apparent position in the sky is fairly far away from the Sun's, it's bright enough to be seen during the day.

We become less sensitive to bitter tastes as we get older



A matter of taste

Hi **HIW**,

Why do our taste buds change as we grow older?

Thanks,

Jess Castle

Our sense of taste develops in the womb. On the surface of the tongue there are bumps called papillae. How many you have is down to genetics, but the more papillae you have, the more sensitive you are to intense flavours such as spices. As we age, however, papillae do not regenerate very well and stop at around the age of 40, along with a decreased sense of smell, so our perception of taste changes.

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What's happening on...

social media?



This month, we asked you if you could time travel like #DrWho when & where would you go?

"I would go to the cretaceous period and extract dinosaur DNA [to bring dinosaurs back]"
@dwdwdan0510

"Outer Space 13.8 billion years ago. :]"
@FlookJamie

"To the Victorian era to see the beautiful costumes and buildings"
@OracleMackenzie

"The Tudor court so I could witness all the political scheming!"
@TheOriginalCath

"I'd love to visit the swinging sixties. I love the music, fashion and lifestyle - I'm pretty sure I was born in the wrong decade!"
@mrsangelapagan

"My son says we should not mess with time. It will change the past or future!!!!"
@mikeywinner



Highlights from the Twitterverse

"One of the best ways to learn is to do something you've never done before"
@richardbranson

"A ground-breaking new project in Bangladesh could help reduce the life-long health problems that come from childhood malnourishment - by focusing on the gut"
@royalsociety

"Two years of planning. Two months of climbing and a lifetime of dreaming. I poured my heart and soul into my new book, UP, Published October 18th"
@Benfogle

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1 Nov 2018

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

Editorial

Editor **Jackie Snowden**
Senior Art Editor **Duncan Crook**
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Production Editor **Charlie Ginger**
Staff Writer **Charlotte Evans**
Staff Writer **Scott Dutfield**
Group Editor in Chief **James Hoare**
Photographer **James Sheppard**

Contributors

Adrian Mann, Ed Crooks, Ella Carter, James Horton, Joanna Stass, Jodie Tyley, Jonathan O'Callaghan, Laura Mears, Lee Cavendish, Stephen Ashby, Steve Wright, The Art Agency, Tim Williamson, Tom Lean, Victoria Williams

Cover images

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Photography

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Advertising

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

International

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International Licensing Director **Matt Ellis**
matt.ellis@futurenet.com

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Production Manager **Vivienne Calvert**

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Editorial Director **Paul Newman**
Head of Art & Design **Greg Whittaker**

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Chief executive **Zillah Byng-Thorne**
Non-executive chairman **Richard Huntingford**
Chief financial officer **Penny Ladkin-Brand**

Tel +44 (0)1225 442 244

FAST FACTS

Amazing trivia to blow your mind

DOCTOR WHO IS THE LONGEST-RUNNING SCIENCE FICTION TV SERIES OF ALL TIME

THE DEEPEST WE HAVE EVER DRILLED INTO EARTH'S CRUST IS

12,262 M

AT THE KOLA SUPERDEEP BOREHOLE IN RUSSIA

OCTOPUSES HAVE
3 HEARTS
AND BLUE BLOOD

IF THE SUN SOMEHOW WENT OUT, EARTH'S TEMPERATURE WOULD DROP TO

-18°C WITHIN A WEEK

-73°C WITHIN A YEAR

-240°C WITHIN A FEW MILLION YEARS

OVER
2.8 MILLION
PEOPLE VISITED THE TOWER OF LONDON IN 2017

BORNEO PYGMY ELEPHANTS ARE NEARLY

3x

SMALLER THAN AFRICAN ELEPHANTS

THE REVOLUTION CT SCANNER BY GE CAN CAPTURE INCREDIBLY DETAILED IMAGES OF WHOLE ORGANS IN LESS THAN 1 SECOND

THERE ARE OVER
1,600
DIFFERENT CRYPTOCURRENCIES

AS OF 2015, KANSAI INTERNATIONAL AIRPORT IN JAPAN HAD NOT LOST A SINGLE ITEM OF LUGGAGE SINCE OPENING IN 1994

50 million

OF YOUR CELLS HAVE DIED AND BEEN REPLACED IN THE TIME IT'S TAKEN YOU TO READ THIS

CARNOTAURUS' LOWER ARMS WERE JUST A QUARTER THE LENGTH OF ITS UPPER ARMS

BEFORE THE DANGERS OF RADIOACTIVITY WERE DISCOVERED, RADIUM WAS USED IN MANY DIFFERENT PRODUCTS INCLUDING GROCERIES, BEAUTY PRODUCTS AND CLOTHING

1st

BY THE TIME NASA CELEBRATES ITS 65TH ANNIVERSARY IN 2023 IT IS HOPED THAT ASTRONAUTS WILL HAVE COMPLETED THE FIRST MANNED ORION FLIGHT

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© Mr. Bean

and BRILLIANT*
The beloved ~~oddball~~ Mr Bean famously drives a 1976 British Leyland Mini 1000 on his adventures. The 'Citron' lime green coloured car is fitted with numerous GENIUS ~~bizarre~~ security features including a bolted latch and padlock on the driver's door and a removable steering wheel.

* NB: This product description has been skilfully corrected by Mr Bean (of London)



CC82110 Mr Bean's Mini



Visit our website at **corgi.co.uk** or your local model shop

@corgi /corgidiecast



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