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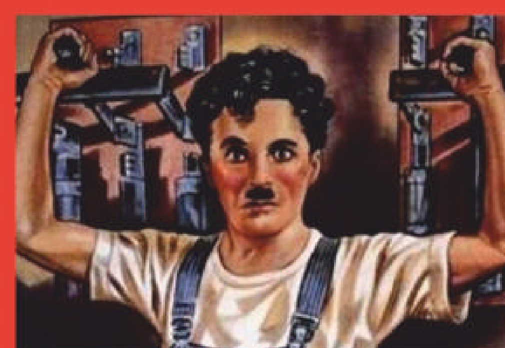

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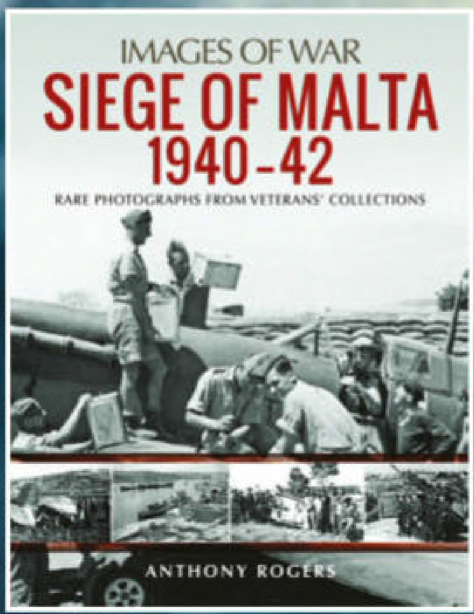

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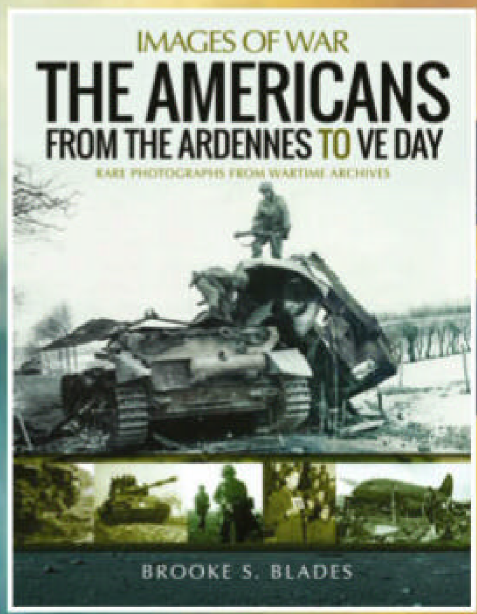

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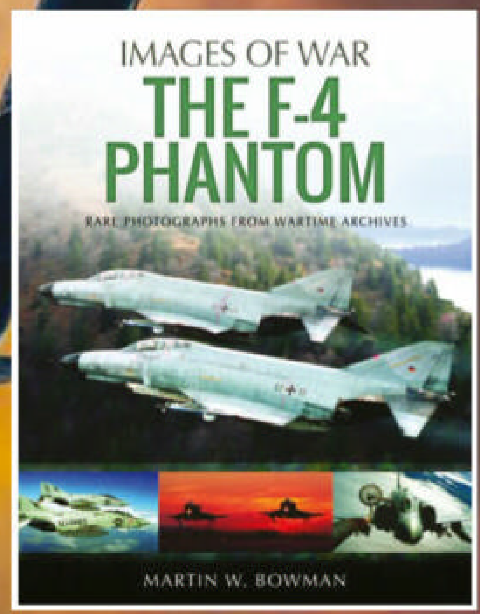

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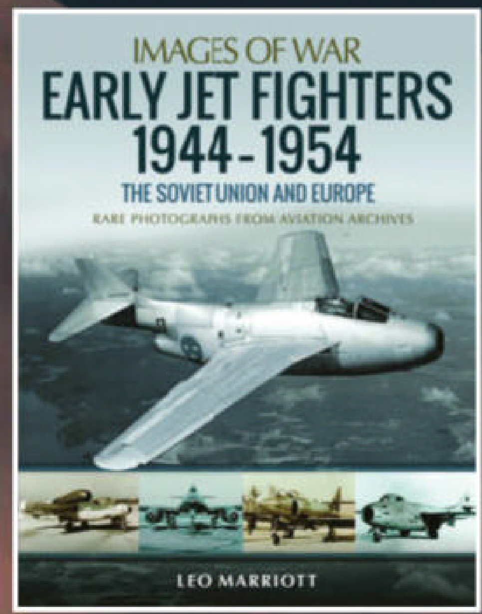

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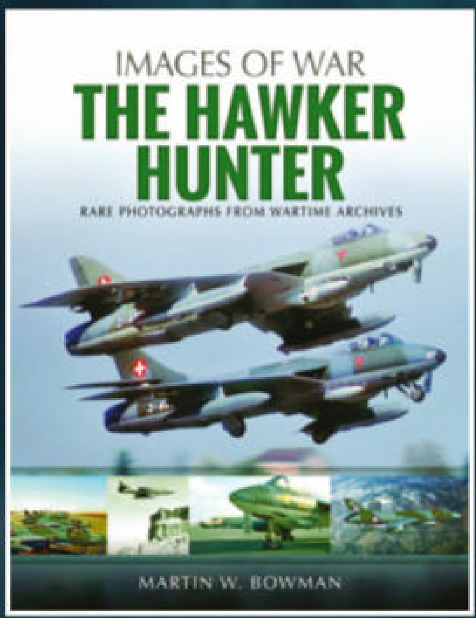

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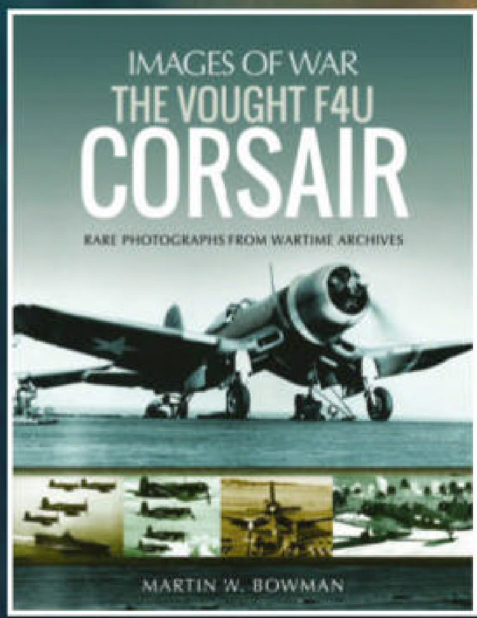

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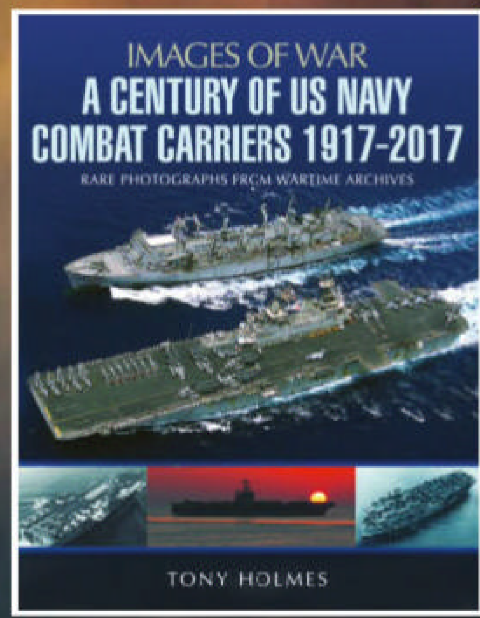

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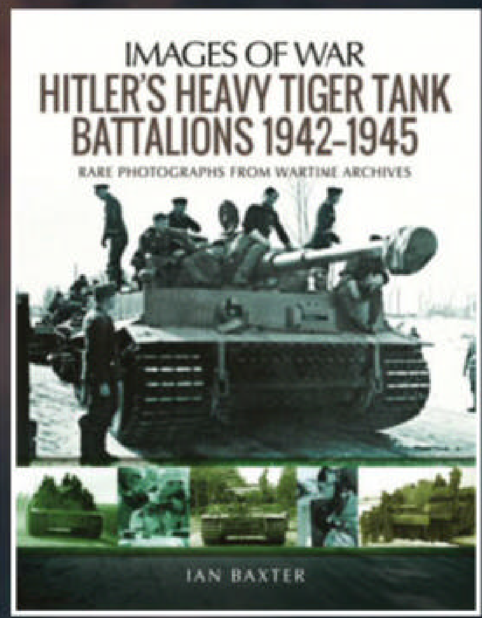

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ISSUE 135

WELCOME

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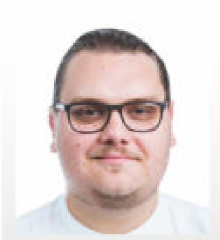
"The ecosystem in our intestines is essential for our survival"

Body bugs, page 22

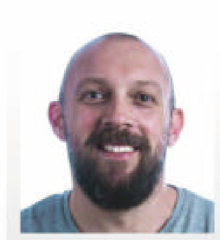
Meet the team…

Nikole
Production Editor
How did movies pull off their magic before CGI? Turn to page 58 to see the secrets behind the silver screen's special effects.



Scott
Staff Writer
Discover the molecular interactions that keep fire ablaze, as well as its destructive power, on page 32.

Baljeet
Research Editor
Have spacecraft gotten easier to fly since the days of Apollo? And what does it take to pilot one? Find out on page 50.



Duncan
Senior Art Editor
The London Eye has looked out over the Thames for 20 years now. Learn about its design and construction on page 78.

Ailsa
Staff Writer
Ever watched your cat and wondered what's going on inside their head? Learn to understand your feline friend on page 44.

It wasn't so long ago I learned that every cell in the human body is replaced at least once every ten years. That means you are literally not the same person you were a decade ago. Now, in this issue of **How It Works**, I've discovered that a large percentage of a human's total body weight – possibly more than half of it – is microbiota: bacteria, fungi and other families of microorganisms. So only half of what I thought was me is actually human, and hasn't even been around for half the time I thought it had! Not to detract from all those friendly bugs in our bodies though: find out how important they are on page 22. Enjoy the issue!

Ben Editor

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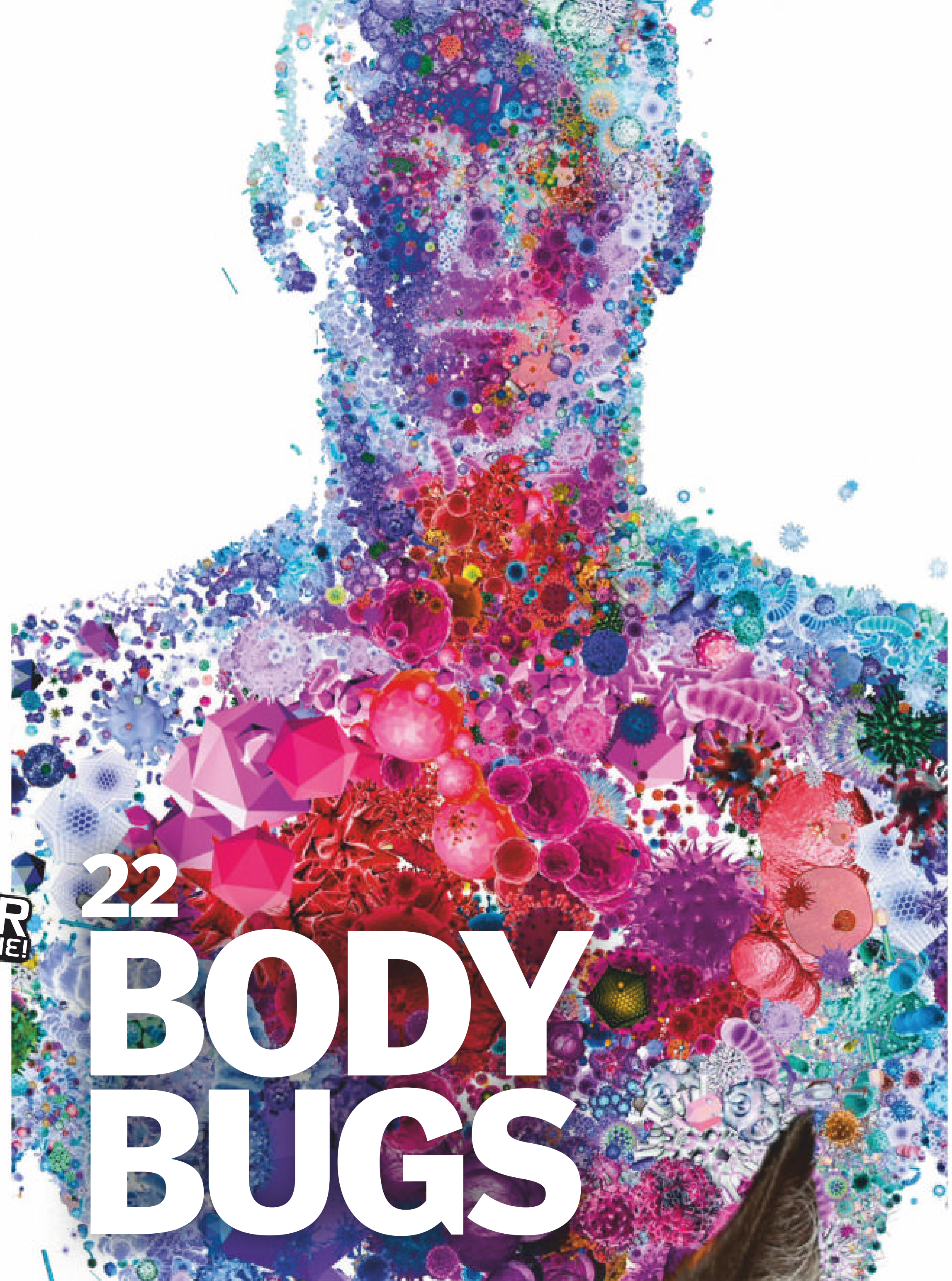
CONTENTS




58 Secrets of the silver screen


78 Ride the London Eye


44 How to tell what a cat is thinking

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MEET THIS ISSUE'S EXPERTS...

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

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

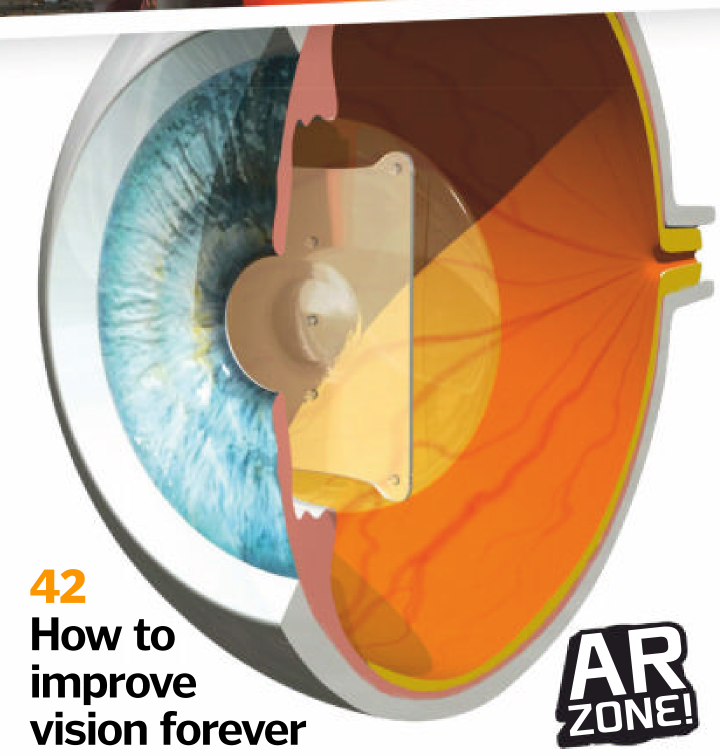
Andy Extance
Andy is a freelance science writer based in Exeter, UK. He previously worked in early stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.

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

75 TV tech explained

32 How to tame fire

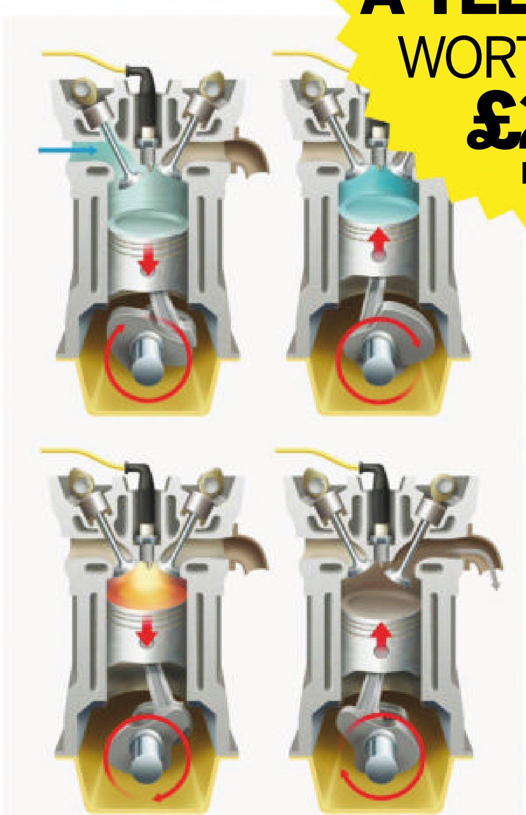
38 Killer chemicals



42 How to improve vision forever

WIN A TELESCOPE WORTH OVER £200

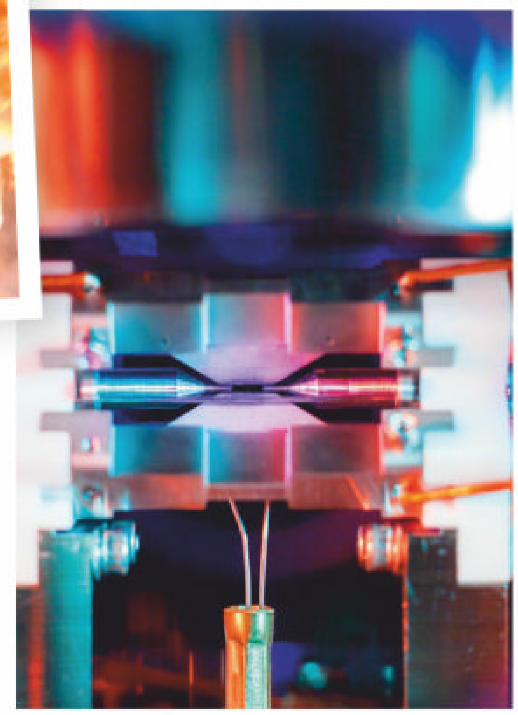
Page 82



80 How petrol engines drive a car

50 How to fly a spacecraft

REGULARS



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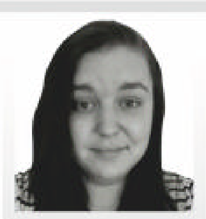
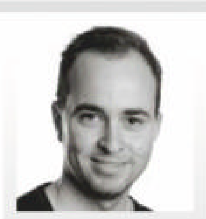
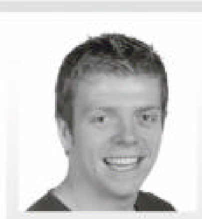


Amy Grisdale
Volunteer animal worker Amy has an enormous breadth of experience on animal conservation projects. She specialises in writing about environmental topics.

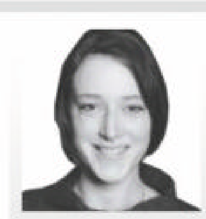


Steve Wright
Steve has worked as an editor on various publications. He particularly enjoys history feature writing and regularly writes literature and film reviews.

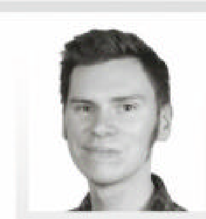
Stephen Ashby
Stephen is a writer and editor with video games and computer tech expertise. He is endlessly intrigued by Earth science.



Jonny O'Callaghan
With a background in astrophysics, science writer Jonny enjoys delving into the natural wonders of the universe and space missions.



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

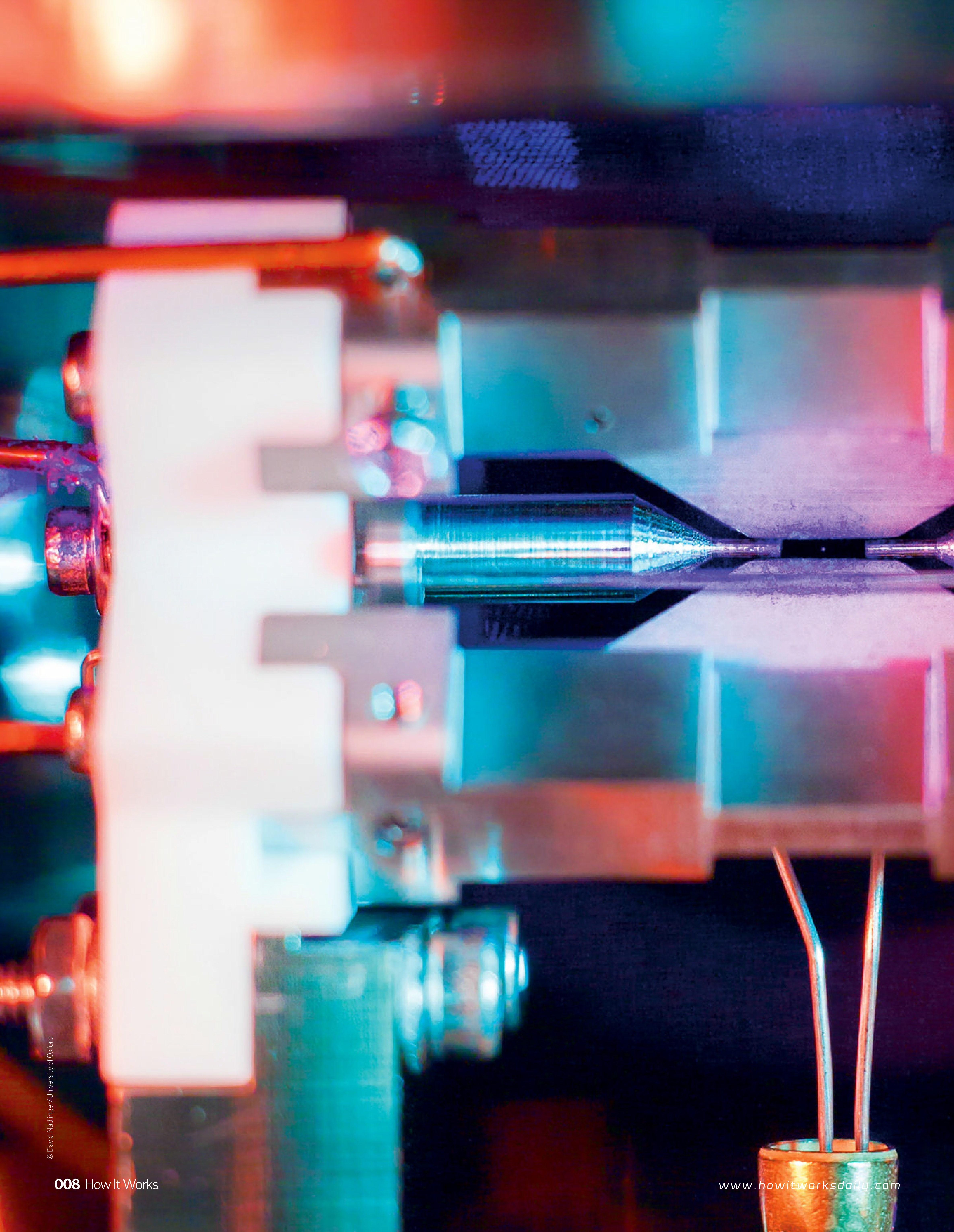


Jack Parsons
A self-confessed technophile, Jack has a keen interest in gadgets and wearable tech, but also loves to write about projects with much grander ambitions.

© David Spears

Garden mini-beast

Found feasting on the flesh of rotting vegetation and avoiding the predatory advances of spiders, beetles and hedgehogs, the common woodlouse (*Oniscus asellus*) is one of nature's robust invertebrates. There are around 30 species of woodlouse in the UK alone, all of which sport smooth segments of armour to form a protective exoskeleton. Spending the majority of their time beneath rocks and between the crevices of decaying wood, woodlice have an average life span of around two years, with some reaching as old as four years. This woodlouse was captured and digitally coloured by David Spears for The Royal Photographic Society's 2019 science photography competition. You can find out more about this year's entries at **rps.org**.



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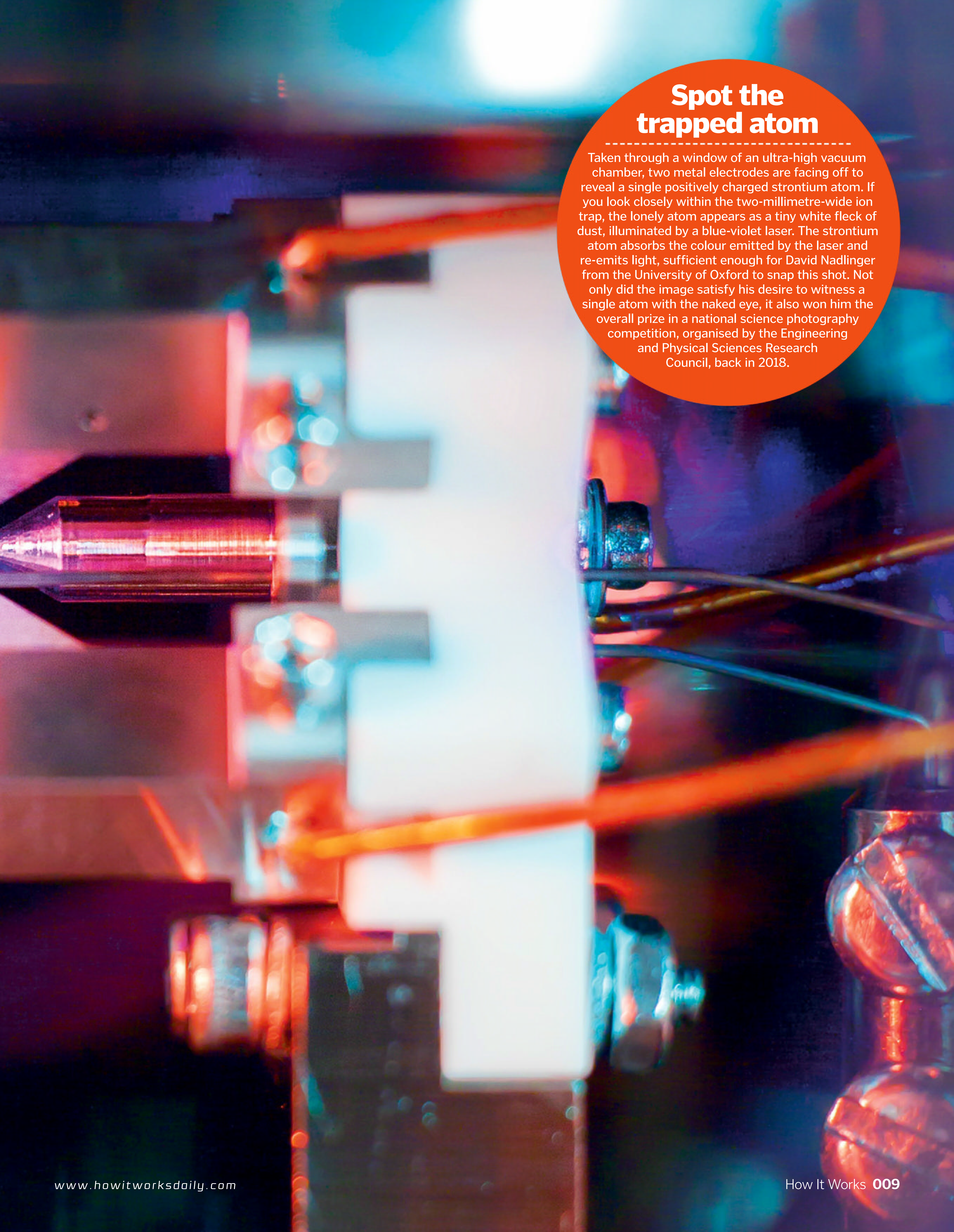
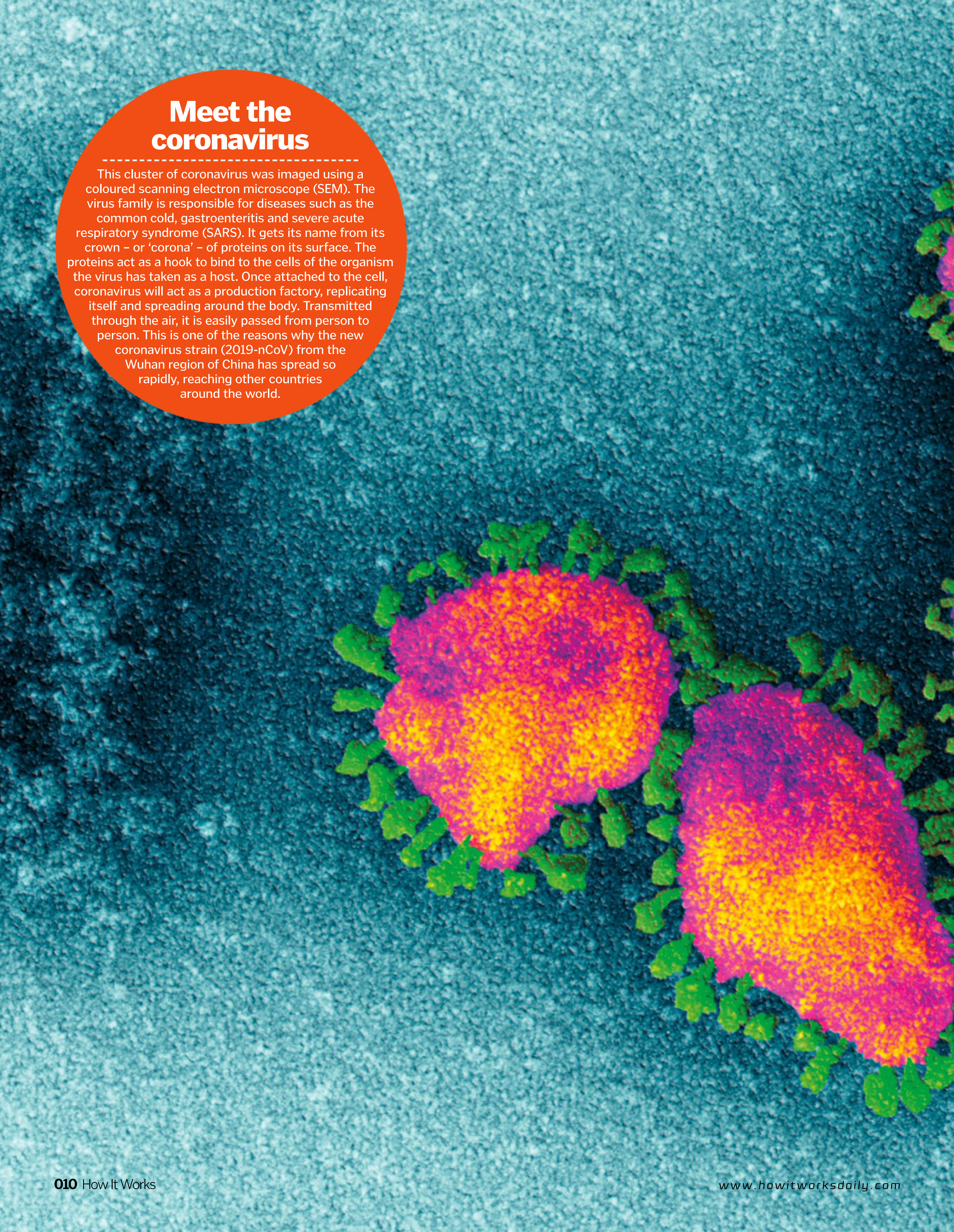


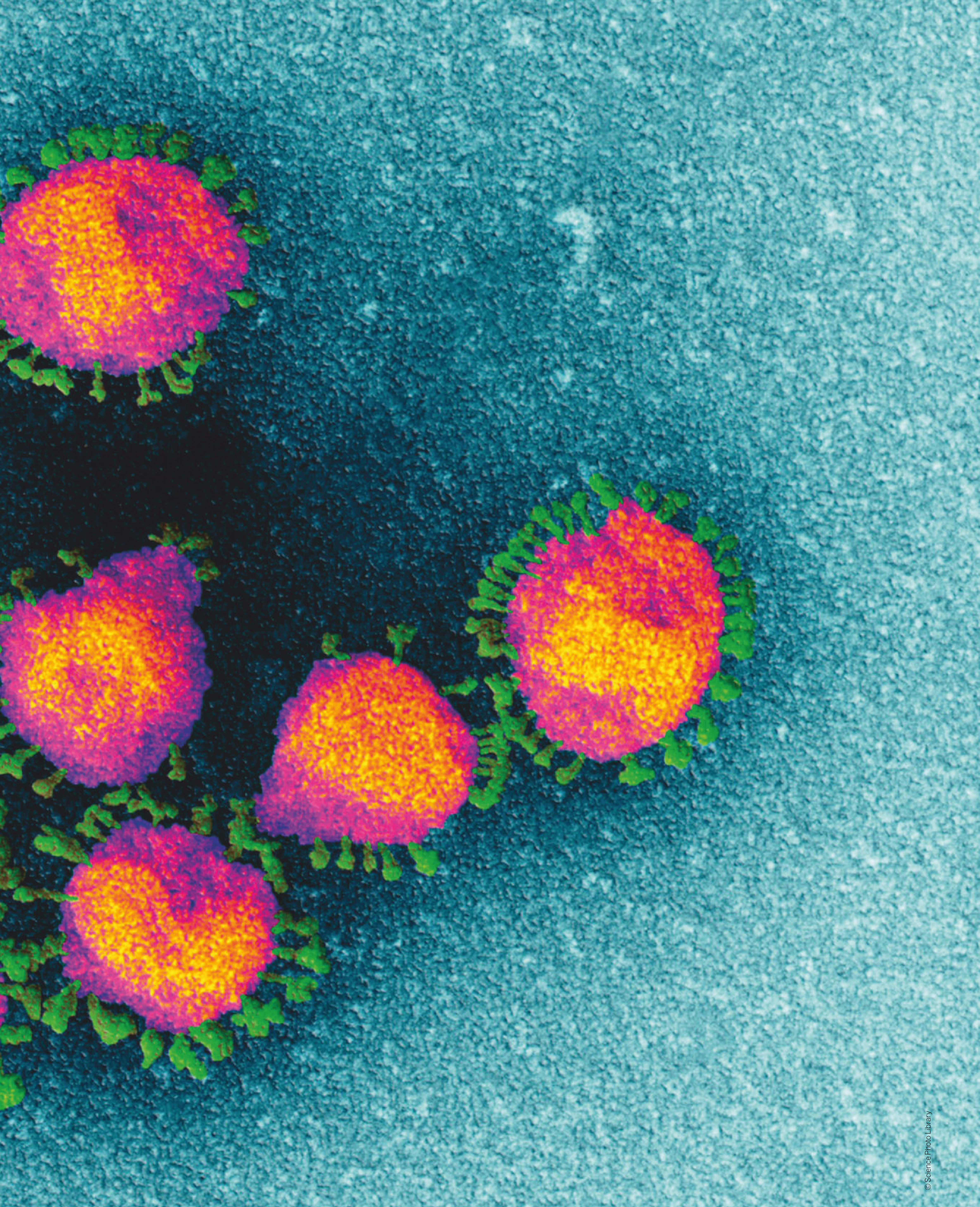
Spot the trapped atom

Taken through a window of an ultra-high vacuum chamber, two metal electrodes are facing off to reveal a single positively charged strontium atom. If you look closely within the two-millimetre-wide ion trap, the lonely atom appears as a tiny white fleck of dust, illuminated by a blue-violet laser. The strontium atom absorbs the colour emitted by the laser and re-emits light, sufficient enough for David Nadlinger from the University of Oxford to snap this shot. Not only did the image satisfy his desire to witness a single atom with the naked eye, it also won him the overall prize in a national science photography competition, organised by the Engineering and Physical Sciences Research Council, back in 2018.



Meet the coronavirus

This cluster of coronavirus was imaged using a coloured scanning electron microscope (SEM). The virus family is responsible for diseases such as the common cold, gastroenteritis and severe acute respiratory syndrome (SARS). It gets its name from its crown – or 'corona' – of proteins on its surface. The proteins act as a hook to bind to the cells of the organism the virus has taken as a host. Once attached to the cell, coronavirus will act as a production factory, replicating itself and spreading around the body. Transmitted through the air, it is easily passed from person to person. This is one of the reasons why the new coronavirus strain (2019-nCoV) from the Wuhan region of China has spread so rapidly, reaching other countries around the world.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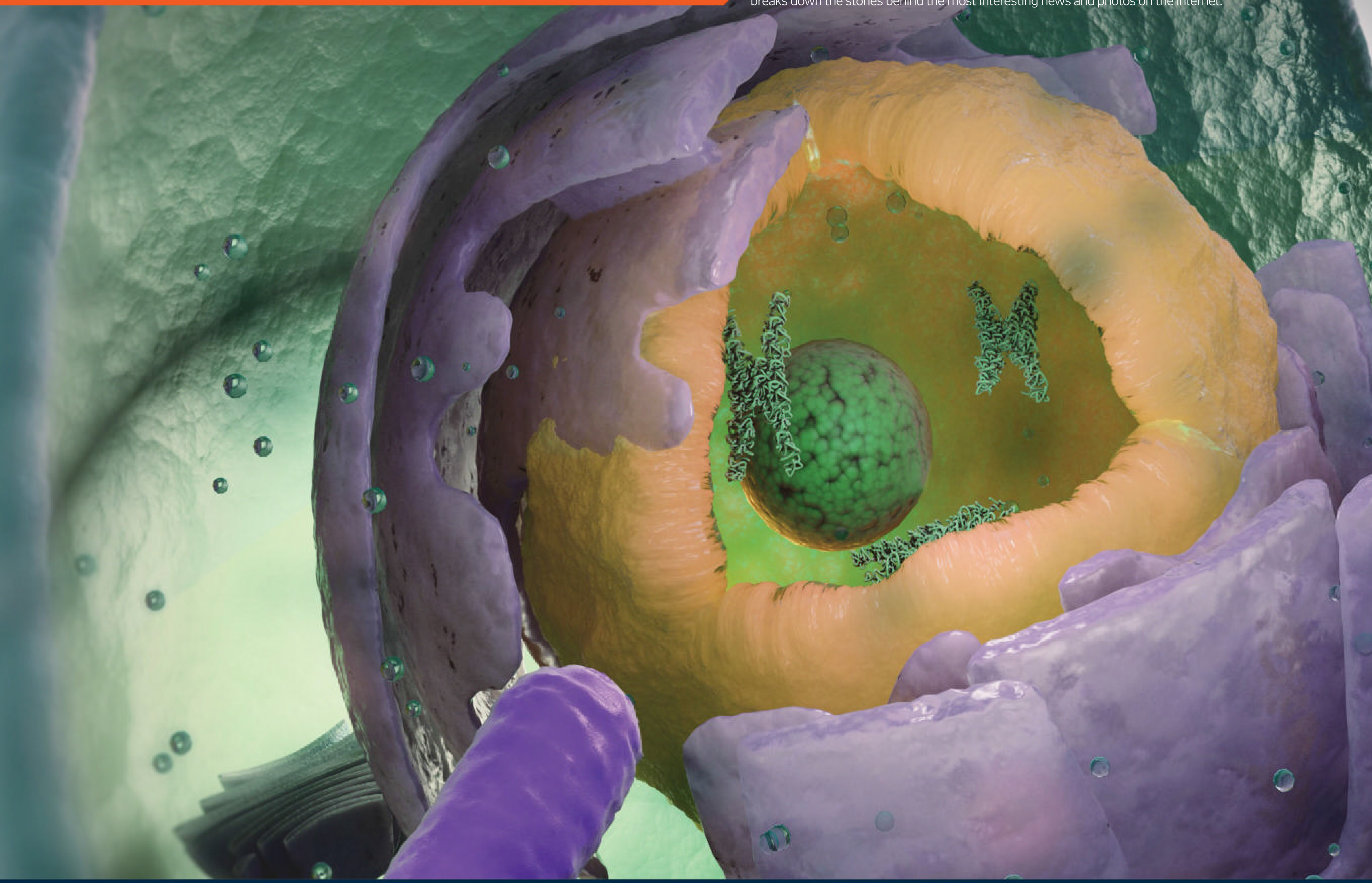


PLANET EARTH

Deep-sea blob's secrets to life's origins

Words by **Yasemin Saplakoglu**

A microbe found in the muddy depths of the Pacific Ocean that looks like a blob with tentacles may hold the secrets to how the first multicellular life forms evolved.

Long before complex organisms existed, the world was home to simple single-celled organisms, archaea and bacteria. Between 2 and 1.8 billion years ago, these began to evolve, leading to the emergence of more complex life forms called eukaryotes, a group that includes humans, animals, plants and fungi. But this incredible journey over which life transitioned from swimming blobs to walking animals is still poorly understood.

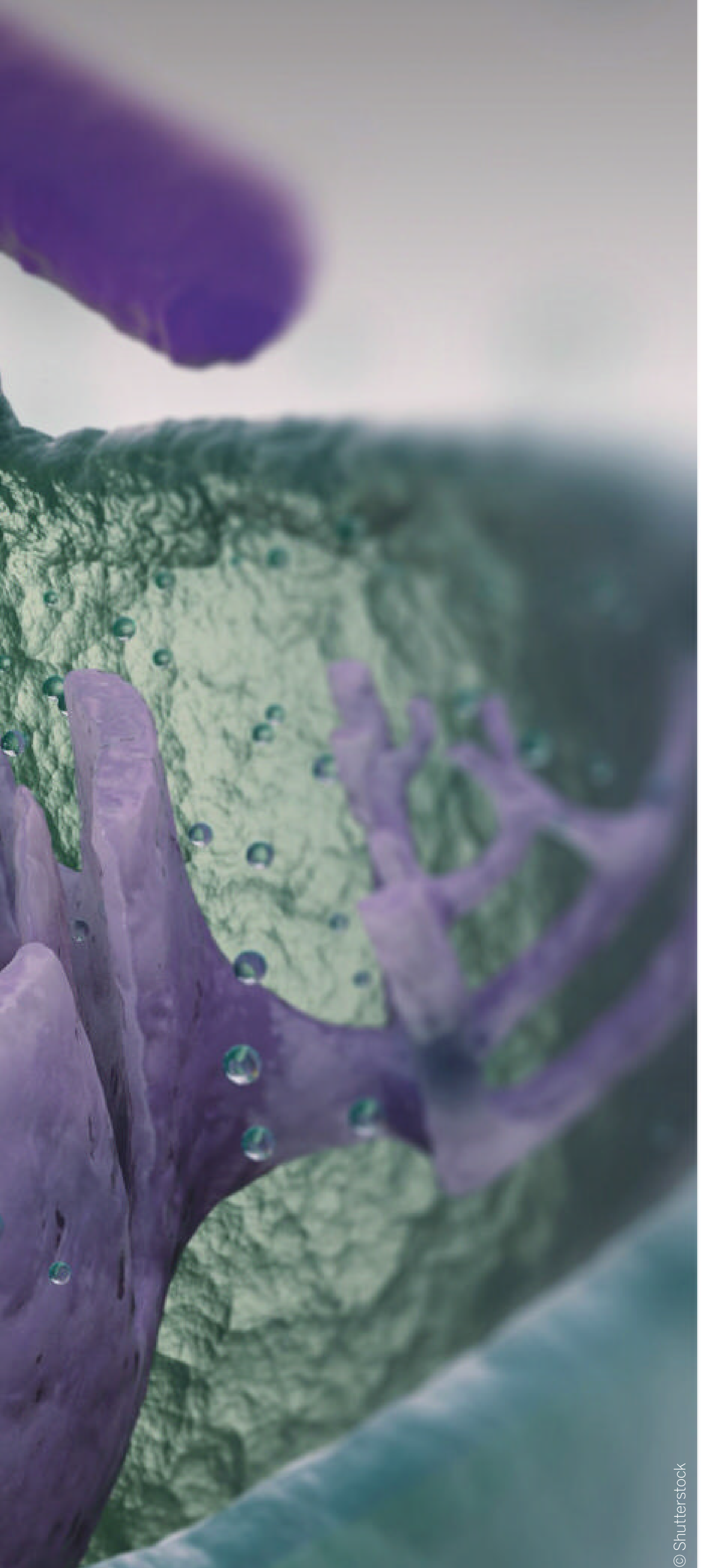
Scientists had previously hypothesised that a group of microbes called Asgard archaea were the ancestors of eukaryotes, because they contain similar genes to their complex counterparts. To analyse what these microbes looked like and how this transition might have happened, a group of researchers in Japan spent a decade collecting and analysing mud from the bottom of the Omine Ridge off the coast of Japan.

The team kept the mud samples – and the microorganisms in them – in a special bioreactor in the lab that mimicked conditions of the deep sea in which they were found. Years later, they began to isolate the microorganisms within the samples. The initial purpose was to find microbes that eat methane that might be able to clean up sewage. But when they discovered that their samples contained a previously unknown strain of Asgard archaea, they decided to analyse it and grow it in the lab.

They named the newly found strain *Prometheoarchaeum syntrophicum* after the Greek god Prometheus, who is said to have created humans from mud. They found that these archaea were relatively slow growers, only doubling in number every 14 to 25 days.

Analysis confirmed that *P. syntrophicum* had a great number of genes that resembled those of eukaryotes. These genes held the instructions for creating certain proteins found inside these microbes, but the proteins did not create any organelle-like structures like the ones found inside eukaryotes.

The authors propose the hypothesis that around 2.7 billion years ago, oxygen began to



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Eukaryotic cells, as illustrated here, evolved from single-celled organisms around 2 billion years ago

accumulate on our planet. Having lived in a world without oxygen for so long, this would prove toxic to *P. syntrophicum*, so it may have developed a new adaptation: a way to form partnerships with bacteria that were oxygen-tolerant. These bacteria would give *P. syntrophicum* the necessary vitamins and compounds to live, while in turn feeding on the archaea's waste.

As oxygen levels increased even further, *P. syntrophicum* might have become more aggressive, snatching passer-by bacteria with its long tentacle-like structures and internalising it. Inside *P. syntrophicum*, this bacteria might have eventually evolved into an energy-producing organelle key to eukaryote survival: the mitochondria.

HISTORY

Volcanic eruption turned man's brain to glass

Words by **Nicoletta Lanese**

When Mount Vesuvius erupted in the year 79 CE, the volcano unleashed an avalanche of gas and rock hot enough to boil blood, vaporise flesh and even transform bits of brain tissue into glass, according to a new study.

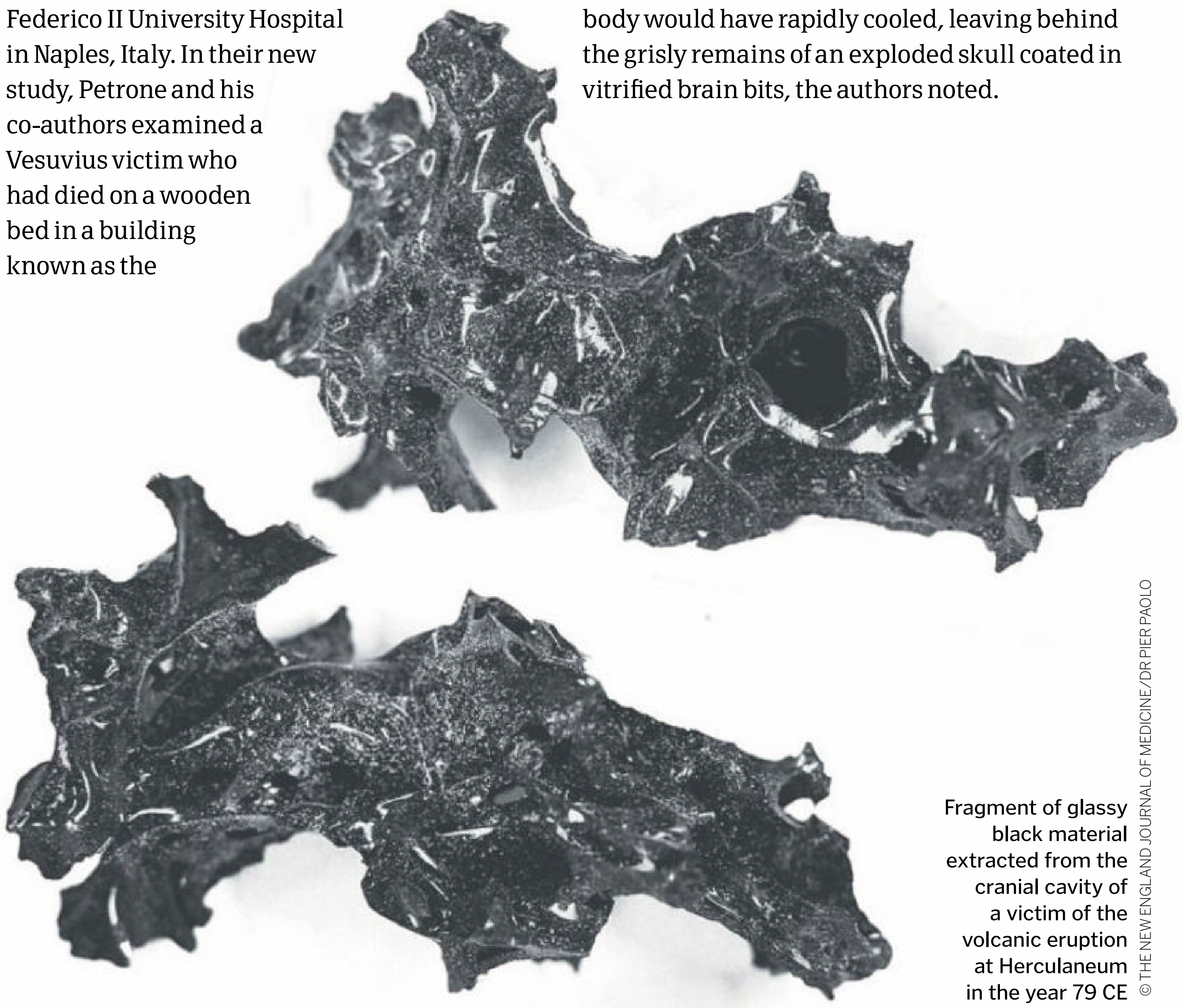
Archaeologists rarely uncover human brains during their digs, and if they do, the organs feel soap-like and smooth. During a process called saponification, triglycerides in the fatty brain tissue react with charged particles in the surrounding environment, transforming into soap over time. Scientists found something very different, however, when they examined the remains of a man who perished in Herculaneum during the Vesuvius eruption.

Enveloped in a surge of hot ash, the victim's brain had been burned to twisted black bits through a process called vitrification. The glassy material 'encrusted' the surface of the man's skull.

The unusual discovery was made by Dr Pier Paolo Petrone, a professor of human osteobiology and forensic anthropology at the Federico II University Hospital in Naples, Italy. In their new study, Petrone and his co-authors examined a Vesuvius victim who had died on a wooden bed in a building known as the Collegium Augustalium. The corpse was found in the 1960s, buried within a mound of volcanic ash. Like other victims, the charred skeleton bears the sparse remnants of a skull that burst during the eruption.

The team spotted shards of glassy black material lodged within remnants of the exploded skull and scattered among the remains of the cranial cavity. The analysis revealed proteins known to be found in different areas of the human brain, including the wrinkled cerebral cortex, which is responsible for higher brain functions like decision-making; the amygdala, which is important to emotional processing, and the substantia nigra, which helps control movement and our response to rewards.

Based on analysis of the charred wood found near the corpse, the team determined that the room likely reached a maximum temperature of 520 degrees Celsius. The extreme temperature would have been hot enough to "vaporise soft tissues" in the victim's body and burn every last trace of fat. Following the brief blast of heat, the body would have rapidly cooled, leaving behind the grisly remains of an exploded skull coated in vitrified brain bits, the authors noted.



Fragment of glassy black material extracted from the cranial cavity of a victim of the volcanic eruption at Herculaneum in the year 79 CE

© THE NEW ENGLAND JOURNAL OF MEDICINE/DR PIER PAOLO

A scientist collects gas samples at the newly discovered Soda Springs in the Philippines

PLANET EARTH

Bubbling vent discovered on Philippines seafloor

Words by **Yasemin Saplakoglu**

Diving hundreds of metres below the surface of the ocean off the coast of the Philippines, scientists came across a bubbling hotspot of carbon dioxide. And their research suggests that this newly discovered vent might help us predict how coral reefs will deal with climate change.

Bayani Cardenas, a professor in the department of geological sciences at the University of Texas at Austin, accidentally discovered this carbon dioxide fountain while researching the effect of groundwater run-off into the ocean environment in the Philippines's Verde Island Passage.

This strait that runs between the Luzon and Mindoro islands, connecting the South China Sea with the Tayabas Bay, is busy on its surface, serving as a prominent shipping route. It's also busy below the surface, where it harbours one of the most diverse marine ecosystems in the world. And the reefs in this passage, unlike bleached reefs elsewhere, are thriving.

The researchers named the new hotspot Soda Springs and said that it could have been releasing these bubbles for decades or even millennia. Soda Springs is a result of an underwater volcano, which vents gas and acidic water through cracks in the ocean floor. The researchers found carbon dioxide concentrations as high as 95,000 parts per million (ppm) near the springs, which is over 200 times the concentration present in the atmosphere.

The levels quickly fell as the gas flowed into the massive ocean, but the seafloor released enough gas to create elevated levels of 400 to 600 ppm and enough acidic water to lower the pH for the nearby coastline. This might be an ideal spot for studying how other coral reefs around the world may cope with climate change as it brings more carbon dioxide into their environments.

What's more, by tracing levels of radon-222, a naturally occurring radioactive isotope found in groundwater local to the area, the team discovered hotspots on the seafloor where groundwater was being discharged into the ocean. "Groundwater flow from land to sea could have important coastal impacts, but it is usually unrecognised," the authors wrote in the study. "Delicate reefs may be particularly sensitive to groundwater inputs."

The researchers found that groundwater and seawater appeared in different relative amounts in different areas of Soda Springs. This variable mixing means that "the groundwater flow could be contributing to the evolution and functioning of the ecosystem," the authors wrote.

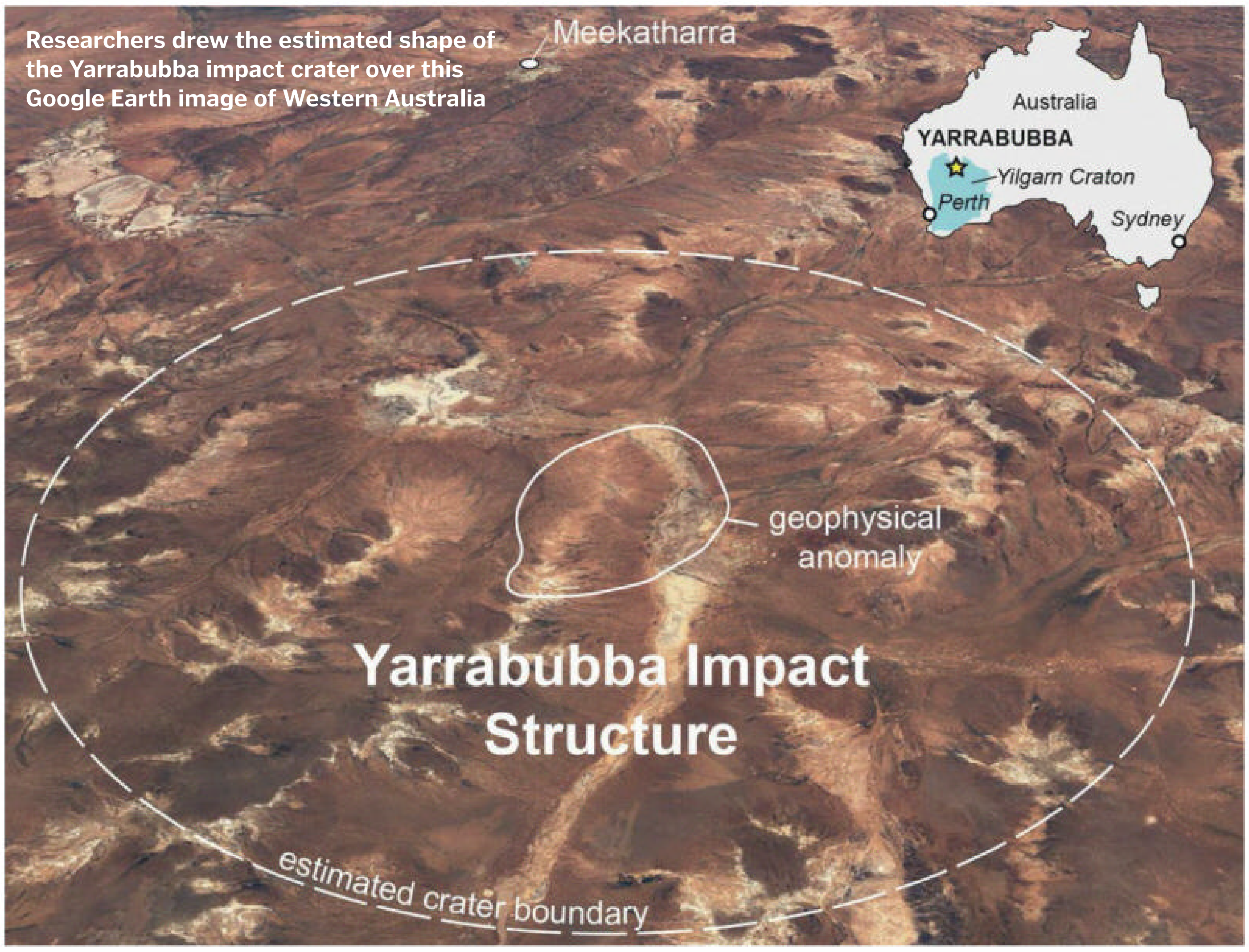
However, the presence of these passageways might also mean that there is a way for pollutants from the island to make it into the coral reef. In the Philippines, where coastal development has surged, people are using septic tanks instead of modern sewage systems, which can easily pump waste into the reefs.

It's not clear how these reefs thrive in a carbon-dioxide-rich environment, but then again, not much is known about this area. "It's really a big part of the ocean that is left unexplored," Cardenes said. "It's too shallow for remotely operated vehicles and is too deep for regular divers."

PLANET EARTH

Oldest meteorite crater found in Australia

Words by **Brandon Specktor**



Researchers drew the estimated shape of the Yarrabubba impact crater over this Google Earth image of Western Australia

Despite Earth's long history of getting smacked by space rocks, evidence of those collisions can be very hard to find; even the largest impact craters vanish over time due to erosion and tectonic activity, taking the best reminders of Earth's past with them. Now, however, researchers in Western Australia believe they've found the single oldest impact crater ever detected, dating to roughly 2.2 billion years ago.

In a recent study, published in the journal *Nature Communications*, researchers studied a 70-kilometre impact site in the Australian Outback known as Yarrabubba. Today all that's visible of the once-enormous crater is a small red hill at the area's centre, known as Barlangi Hill. According to the researchers, the minerals inside that hill hold valuable information about the impact's age.

"[Barlangi Hill] has been interpreted as an impact-generated melt rock," the researchers wrote. That means its rocky innards hold mineral grains that were smashed, melted and eventually recrystallised by the ancient impact. Narrowing down the ages of those crystal inclusions, known as neoblasts, could reveal the date of the impact itself.

To do that, the study authors looked for neoblasts in a sample of grains containing two minerals, monazite and zircon, collected from Barlangi. Using a method called uranium-lead dating, which can reveal a mineral's age based on how many uranium atoms have decayed into lead, the team determined that the crater was formed roughly 2.229 billion years ago, making it 200 million years older than any other known crater on Earth.

SPACE

Exoplanet's atmosphere is melting before our eyes

Words by **Brandon Specktor**

KELT-9b, a hot Jupiter, orbits its sun so closely that a year there lasts just one-and-a-half Earth days. With a surface temperature of 4,300 degrees Celsius, KELT-9b is hotter than any other exoplanet, as well as some stars.

Astronomers discovered this supremely sweltering world orbiting a star some 670 light years from Earth in 2017, and are still learning details about just how unhabitable it is. For example, KELT-9b is so hot that its atmosphere seems to be constantly melting on one side, a new study suggests.

In a recent study published in the *Astrophysical Journal Letters*, researchers watched KELT-9b through NASA's Spitzer space telescope, which observes space in infrared light. This allowed the team to record subtle variations in the planet's heat as it whizzed around its home star.

Because the planet is tidally locked – meaning the 'dayside' always faces the sun while the other side always points away in perpetual night – the team saw remarkable differences in temperature on either side of the planet. Using computer models, the researchers determined that gas and heat were being cycled across the two halves of the globe, resulting in a dramatic circle of atomic destruction and rebirth.

On the dayside, the heat of the sun was so intense that hydrogen molecules in KELT-9b's atmosphere were literally being ripped to shreds and blown across the planet, a process known as dissociation. While the nightside was still extremely hot at 2,300 degrees Celsius, it appeared to be just cool enough for loose atoms from the dayside to recombine into hydrogen molecules. Eventually, though, those molecules flowed back to the dayside, where they were ripped apart again.

SPACE

Astronomers baffled as gravitational wave hits Earth

Words by **Yasemin Saplakoglu**

A mysterious cosmic event might have ever so slightly stretched and squeezed our planet. On 14 January, astronomers detected a split-second burst of gravitational waves, distortions in space-time, but researchers don't know where this burst came from.

The gravitational-wave signal, picked up by the Laser Interferometer Gravitational-Wave Observatory (LIGO) and the Virgo interferometer, lasted only 14 milliseconds, and astronomers haven't yet been able to pinpoint the burst's cause or determine whether it was just a blip in the detectors.

Gravitational waves can be caused by the collision of massive objects, such as two black holes or two neutron stars. Astronomers detected such gravitational waves from a neutron star collision in 2017 and from one in April of 2019, according to new findings that were presented at the meeting of the American Astronomical Society last month.

But gravitational waves from collisions of such massive objects typically last longer and manifest in the data as a series of waves that change in frequency over time as the two orbiting objects move closer to each other, said Andy Howell, a staff scientist at Las Cumbres Observatory Global Telescope Network and an adjunct faculty member in physics at the University of California, Santa Barbara, who was not part of the LIGO research.

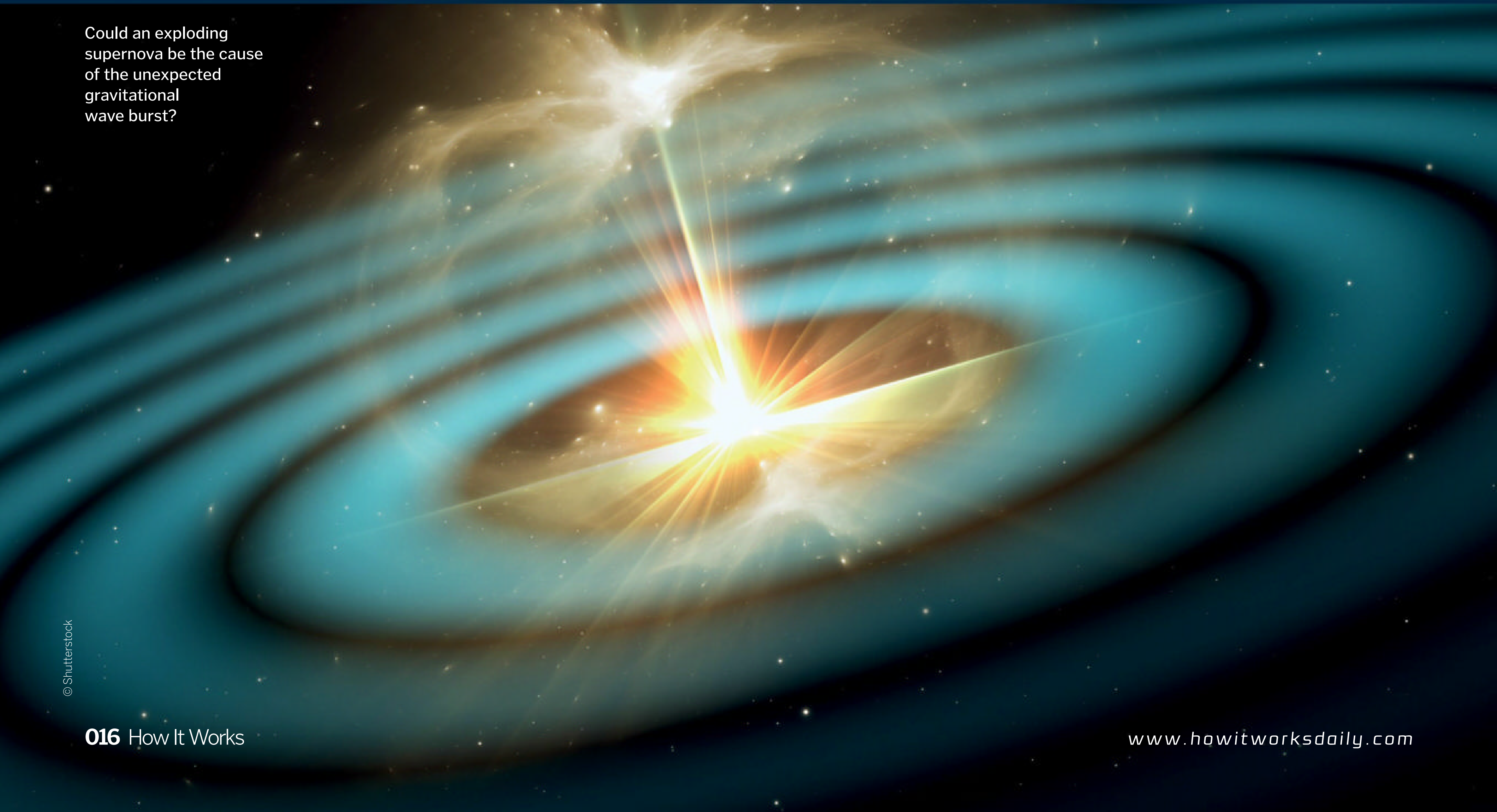
This new signal was not a series of waves but a burst, Howell said. One more likely possibility is that this short-lived burst of waves comes from a more transient event, such as a supernova explosion, the catastrophic ending to a star's life.

Indeed, some astronomers have hypothesised that this could have been a signal from Betelgeuse, which mysteriously dimmed recently and is expected to undergo a supernova explosion. But Betelgeuse is still there, so it's not that scenario, Howell said. It's also unlikely to be another supernova because they happen in our galaxy only about once every 100 years, he added.

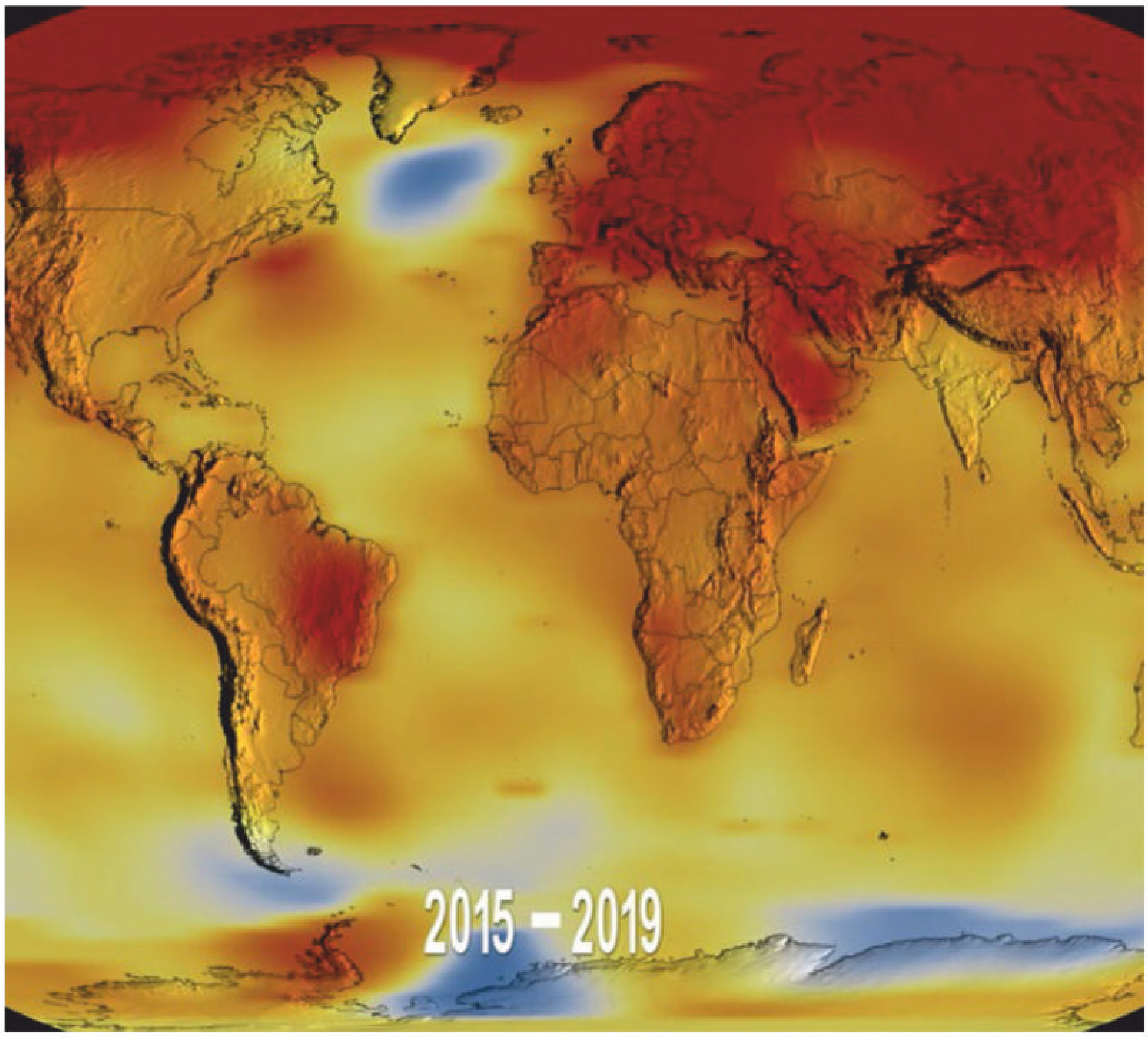
What's more, the burst still "seems a little too short for what we expect from the collapse of a massive star," he said. "On the other hand, we've never seen a star blowing up in gravitational waves before, so we don't really know what it would look like." In addition, the astronomers didn't detect any neutrinos, tiny subatomic particles that carry no charge, which supernovae are known to release.

It's also possible that this signal was just noise in the data from the detector, Howell said. But this burst of gravitational waves was found by all three LIGO detectors: one in Washington state, one in Louisiana and one in Italy. The probability of the LIGO detectors finding this signal by chance – meaning it's a false alarm – is once every 25.84 years, which "gives us some indication that this is a pretty good signal," Howell said.

Astronomers are now pointing their telescopes to that region to try to pinpoint the source of the waves."The universe always surprises us," he added. "There could be totally new astronomical events out there that produce gravitational waves that we haven't really thought about."



Could an exploding supernova be the cause of the unexpected gravitational wave burst?



© NASA's Scientific Visualization Studio/Data provided by Robert B. Schmunk (NASA/GSFC GISS)

A graphic produced by NASA shows how 2019 temperatures compare with historical averages

PLANET EARTH

2019 was the second-hottest year on record

Words by **Meghan Bartels**

It's the award no one wanted to win: 2019 was the second-hottest year on record, government scientists have confirmed.

That's according to two separate analyses: one conducted by NASA and one by the National Oceanic and Atmospheric Administration (NOAA). Each study compared 2019 Earth temperature data with scientists' historical records, which begin in 1880. Of those 140 years, only 2016 was warmer than last year. The analyses also show that the five hottest years on record have been the five years beginning in 2015.

"The decade that just ended is clearly the warmest decade on record," Gavin Schmidt, director of NASA's Goddard Institute for Space Studies in New York, said in a statement. "Every decade since the 1960s clearly has been warmer than the one before."

According to NOAA's temperature report, 2019 was also the 43rd year in a row that saw above-average global land and ocean temperatures. That analysis, like the similar one conducted by NASA, is based on data gathered by more than 20,000 stations around the world.

The connections between severe-weather events and broader climate changes are complex, but the findings speak to the increasing extremity of weather on Earth. Temperature changes, including average global surface temperature increases, are just one facet of these changes, and the most easily tied to a cause.

"We crossed over into more than 2 degrees Fahrenheit [over 1.1 degrees Celsius] warming territory in 2015 and we are unlikely to go back," Schmidt said in the statement. "This shows that what's happening is persistent, not a fluke due to some weather phenomenon. We know that the long-term trends are being driven by the increasing levels of greenhouse gases in the atmosphere."

TECH

Google creates the most detailed image of a brain yet

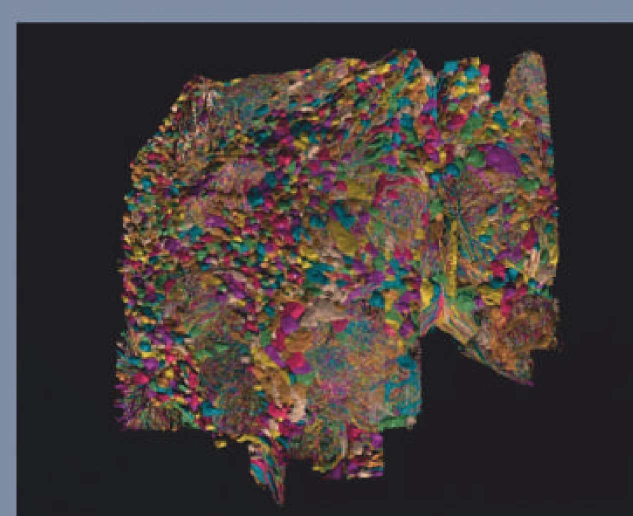
Words by Yasemin Saplakoglu

The mesmerising threads of blue, yellow, purple and green represent thousands of brain cells and millions of connections found inside the brain of a fruit fly.

This high-resolution map, known as a 'connectome', only makes up one-third of a fruit fly's brain, but includes a large region involved in learning, navigation, smell and vision. Scientists found over 4,000 different types of neurons, including those involved in the fly's circadian rhythm – or internal clock – that might help researchers learn a bit more about how the insect sleeps.

This map, a collaboration between scientists at Google and the Janelia Research Campus in Virginia, took two years to create. The team started out by cutting a fruit fly brain into extremely thin slices using a hot knife and then imaging each slice under an electron microscope. Afterwards they stitched the images together to create a large map, tracing the paths of the neurons through the brain.

The point of such maps is to reveal something about how specific physical connections in the brain are linked to distinct behaviours. But following each individual neuron in a journey across the brain is painstaking work – and critics note that such maps have not yet led to a major discovery.


© FlyEM/Janelia Research Campus

This connectome depicts the neurons and synapses present in one-third of a fruit fly's brain

STRANGE NEWS

Restored 15th-century painting gives art lovers the creeps

Words by **Brandon Specktor**

The restored lamb from Jan and Hubert van Eyck's Ghent Altarpiece gazes into your soul

© Getty

The Adoration of the Mystic Lamb, a 15th-century masterwork by the brothers Jan and Hubert van Eyck, has finally been restored after three painstaking years of work – and people are freaked out. What's made spectators go baa-listic? Apparently it's the titular lamb's weirdly humanoid face post-restoration.

Don't worry, this is not another 'monkey Jesus' screw-up. The lamb's mannish face is actually part of the original painting, long lost to history, the restorers told *The Art Newspaper*.

"[The discovery was] a shock for everybody – for us, for the church, for all the scholars, for the international committee following this project," Hélène Dubois, who led the restoration for the Royal Institute for Cultural Heritage since 2016, told *The Art Newspaper*.

A bit of background: *The Adoration of the Mystic Lamb* is the centrepiece in a series of 12 panels known as the Ghent Altarpiece, painted for the altar of St Bavo's Cathedral in Ghent, Belgium. The lamb in the painting's forefront symbolises Jesus. It bears a wound on its breast, similar to the one Jesus received during his crucifixion, and is bleeding into a nearby chalice as crowds of adoring angels look on. The lamb's face, meanwhile, remains perfectly stoic as its human-like eyes stare directly out of the painting toward the viewer.

The details all fit with the van Eyck brothers' vision – before the lamb's face was painted over by two other artists during a major restoration in 1550, anyway. Perhaps cathedral visitors at the time shared the opinions of modern critics who find the lamb's human eyes weird and overly 'confrontational', as the restorers gave the sheep a more naturalistic animal's face.

While the recent restoration to the van Eycks' original vision has jarred many observers, those behind the project said they could not be happier. "When I saw the lamb for the first time as van Eyck painted it, I had to catch my breath," Dubois told the Flemish newspaper *De Standaard*. "It is of a shocking beauty." The man-faced lamb panel will join several others from the Ghent Altarpiece on display at St Bavo's Cathedral in February.

Grey whales might need good solar weather in order to stay on track when migrating

© Getty

ANIMALS

Solar storms may lead whales astray

Words by **Kimberly Hickok**

Recent research shows that healthy grey whales are nearly five times more likely to strand when there is a high prevalence of sunspots, and therefore high levels of radio waves emitted from solar storms.

From March to June, grey whales swim north from the coast of Baja California, Mexico, to the cool, food-rich waters of the Bering and Chukchi seas, north of Alaska. Whales begin their return trip south in November. Occasionally, a seemingly healthy grey whale strands while en route. Although there are many reasons why a whale might strand, one possibility is that the whale made a navigational error when something was disrupting Earth's magnetic field or the whale's ability to detect it – like a solar storm.

Lead author Jesse Granger and her colleagues reviewed grey whale stranding data from the US West Coast between 1985 and 2018 and found that otherwise healthy grey whales were stranding far more often when there were a high number of sunspots.

But that finding alone doesn't explain how a sunspot could cause a grey whale to get lost. Although sunspots cause a large increase in electromagnetic radiation, most of that radiation doesn't make it to our planet's surface because that light is blocked or scattered by Earth's atmosphere. "However, there's a huge chunk in the radio frequency (RF) wave range that does make it all the way to Earth," Granger said. "It's been shown in several species that RF noise can disrupt a magnetic orientation ability."

The researchers found there was a 4.3-fold increase in the likelihood that a whale would strand on days when there was high RF noise. This suggests that the whale's magnetic receptor, or ability to read its map of the area, could be what's causing the whale to take a detour – not that the map is incorrect.

But scientists still don't know for sure if whales even have a magnetoreceptive sense or not. All we know, Granger said, is that "whales are stranding a lot more often when the Sun is doing crazy stuff."

ANIMALS

Pacific Ocean acid found dissolving crab shells

Words by **Brandon Specktor**

Humans have pumped about 1.8 trillion tonnes of carbon dioxide into the atmosphere since the start of the Industrial Revolution, and the ocean has absorbed about 25 per cent of it. This glut of greenhouse gases not only warms the ocean, but also changes the water's chemistry, slowly acidifying it and reducing the concentration of molecular building blocks that shellfish, corals and other marine life use to craft their hard outer shells. According to a new study, that molecular mix-up is already having harmful effects on the development of some baby crabs.

Marine scientists funded by the National Oceanic and Atmospheric Administration (NOAA) studied 50 larval Dungeness crabs (*Metacarcinus magister*) collected from ten sites near the Pacific coast of the United States and Canada. Overall, crabs collected closer to the coastline, where oceans tend to be more acidic, were in much worse shape than crabs collected farther out at sea. The acidification of this coastal water corroded the larvae's shells, stunted their growth and in some cases damaged or destroyed the animals' tiny sensory organs known as mechanoreceptors. All in all, the researchers wrote, acidification left the larvae smaller, weaker and much less likely to survive into maturity.

The condition of these crabs – which are an important source of food for both humans and other marine creatures – should be a wake-up call to the dangers of acidification. Lead study author and senior scientist with the Southern California Coastal Water Research Project, Nina Bednarsek, told **cnn.com**, "If the crabs are affected already, we really need to make sure we pay much more attention to various components of the food chain before it is too late."

Bednarsek and her colleagues investigated each larval crab using a variety of methods and recorded their findings. These methods included microscopy and X-ray spectroscopy. The team noticed clear 'structural deformities' in the shells of crab larvae gathered from the most acidic habitats. Those deformities could make the larvae less protected against predators. These same crabs from acidic locations also tended to be smaller than those from less acidic environments, and some were missing some of their hair-like mechanoreceptors, which crabs use to navigate the sea.

The effects were most severe in crabs who had spent more than a month living in acidic coastal waters. The reason for this, the researchers wrote, is that more acidic waters have fewer carbonate ions, the molecular bricks that shellfish and corals use to build their exoskeletons. Other marine animals, like clams and oysters, rely on the same ions to thrive.

If those animals are being similarly impaired by the acidifying ocean, it could make for a problem spanning the food chain, the researchers said. Either way, the only solution is to reduce carbon emissions as much and as fast as possible.

© Getty

Crabs living in acidic coastal waters are smaller, weaker and their shells melt away

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WISH LIST

The latest **stargazing** tech

Stellina

■ Price: **€3,999 (approx. £3,400 / $4,400)**
www.vaonis.com

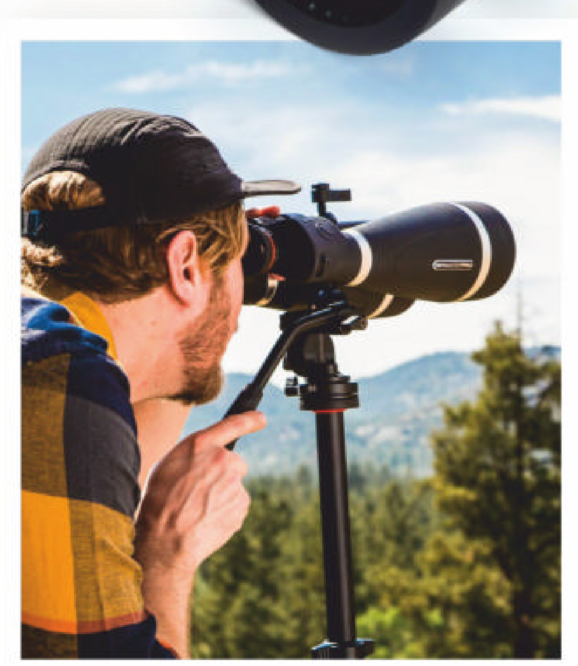
Bring the power of a stellar observatory to your back garden with Stellina by Vaonis. This next-generation telescope allows stargazers to select a planet, star or nebula, and Stellina will locate its position and begin imaging. As a highly sophisticated piece of technology, this compact telescope comes equipped with a rain sensor and will power down when weather conditions become harsh. This allows you to leave Stellina outside for long-exposure shots and mesmerising timelapse videos. Stellina also makes stargazing a social experience by removing eyepieces and sending observation images straight to your smartphone or computer for you to share on social platforms.

© Vaonis

Skymaster Pro 20X80 Binoculars

■ Price: **£230 / $379.95**
www.celestron.co.uk

You don't always need a giant telescope and a tripod to view the stars. The Skymaster Pro binoculars by Celestron can be a great handheld way to observe the cosmos with its 80-millimetre lens. Made for all weather conditions, these polycarbonate and aluminium binoculars are lightweight and can be easily transported in a backpack. The Skymaster Pro is also equipped with a red-dot finder to bring astronomical objects into view.



© Celestron

Altair Hypercam 183C PRO TEC

■ Price: **£865 (approx. $1,125)**
www.altairastro.com

Document your astronomical observations with this astronomy imaging camera by Altair. Using the built-in 20 megapixel Sony IMX183 sensor, this telescope attachment can display the stars straight to your computer screen as detailed images. Offering a 4K mode and amplifier glow reduction, the Hypercam is a great way to capture clear images of the Solar System and deep-sky targets. Its internal 4GB RAM memory also means you can store your images and view them later.

Meade Green Laser Pointer

■ Price: **$39.99 (approx. £30)**
www.meade.com

Stargazing can be a great hobby, not just as a solo pastime but also one to enjoy with friends and family. However, when you've caught a glimpse of something exciting in the sky, it's often hard to communicate where you've trained your telescope. This compact pen is capable of generating a bright green dot at a distance of around 7,600 metres to easily identify constellations and planetary locations.

© Meade

© Meade

Meade Infinity 70AZ refractor

■ Price: **£89 / $99.95**
www.meade.com

Finding the right telescope can be tricky, especially if you're just starting out as an astronomer. Meade Instruments has a wide range of telescopes to select from, but its Infinity is a great starting point. These refracting telescopes are a straightforward way to stargaze, with interchangeable eyepieces for varying magnifications. Models with an aperture of 60 millimetres and above come equipped with a red dot viewfinder, making it easier for you to find your favourite planet or star.

© Sega Toys

Homestar Flux

■ Price: **£149 (approx. $195)**
www.segatoys.space

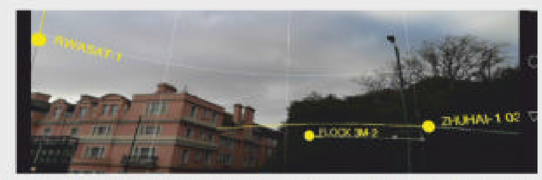
Bring the night sky indoors with the Homestar Flux by Sega Toys. This home planetarium can project more than 60,000 high-definition stars straight onto your ceiling. The Homestar Flux also lets you explore different regions of the universe with interchangeable scenic discs. Simply place a disc of the Northern or Southern Hemisphere into the Homestar Flux and watch as the ceiling comes alive with stars and celestial bodies. However, the Flux is not restricted to your living room thanks to its USB power outlet, allowing the planetarium to be portable.

APPS & GAMES

Satellite AR

■ Developer: **Analytical Graphics, Inc.**
■ Price: **Free / Google Play / App Store**

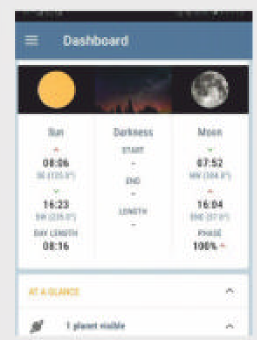
Keep track of more than stars and planets: Satellite AR shows all the satellites visible in the sky. Follow the movements of your favourite orbiter.



NightShift

■ Developer: **Waddensky**
■ Price: **Free / Google Play**

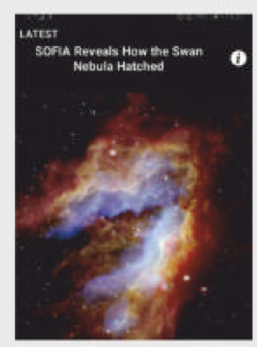
Whether you're an experienced astronomer or an amateur stargazer, this app is a great tool to let you know when and where to get the best views.



Space Images

■ Developer: **Jet Propulsion Laboratory**
■ Price: **Free / Google Play / App Store**

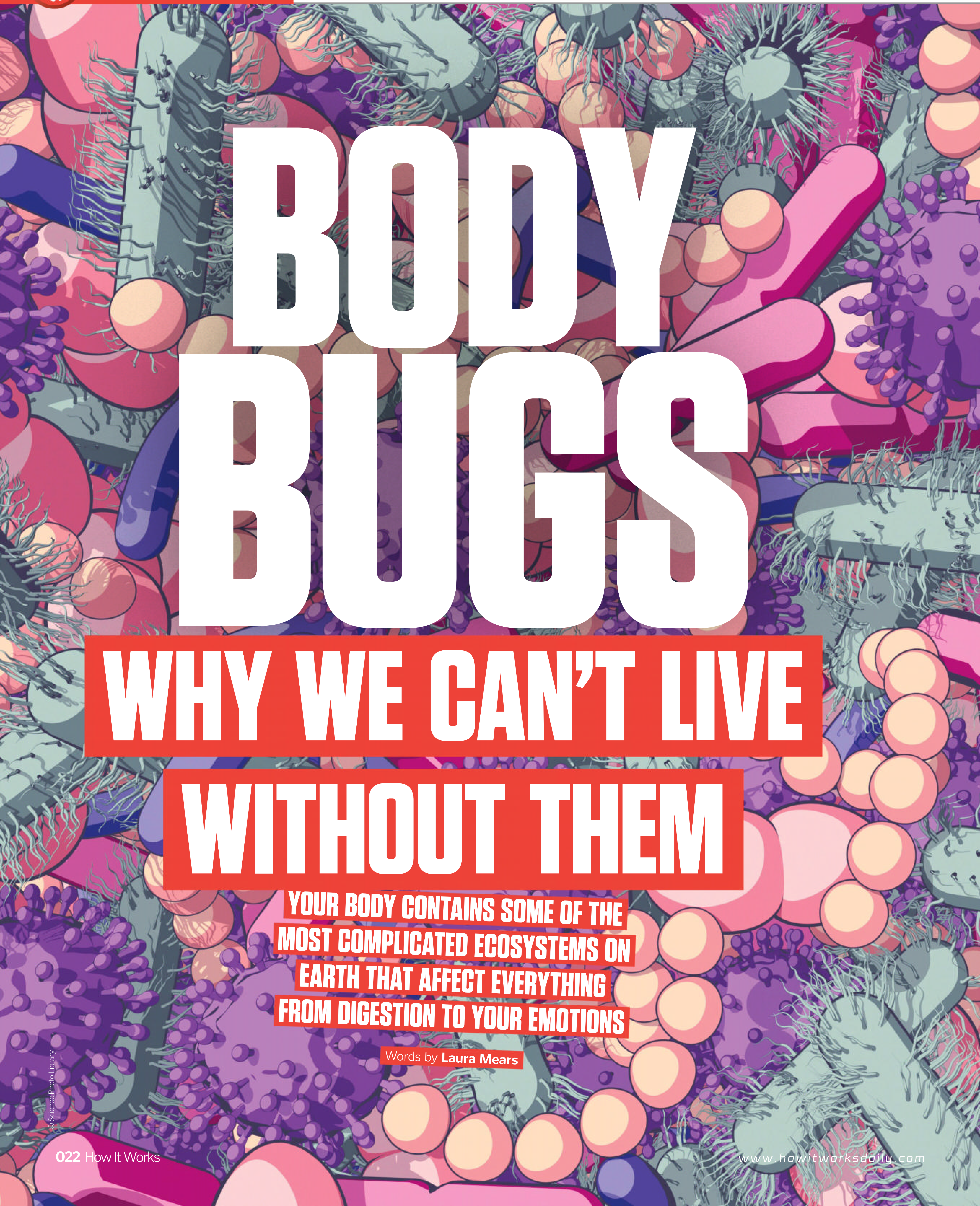
Keep up to date with the latest images and videos from NASA/JPL or search through its catalogue of confounding interstellar photos.



Star Walk 2

■ Developer: **Vito Technology**
■ Price: **Free / Google Play / App Store**

Identify all the stars with this visual guide to the cosmos. Learn about constellations, planets, comets and so much more by simply pointing your phone at the sky.



BODY BUGS

WHY WE CAN'T LIVE WITHOUT THEM

YOUR BODY CONTAINS SOME OF THE MOST COMPLICATED ECOSYSTEMS ON EARTH THAT AFFECT EVERYTHING FROM DIGESTION TO YOUR EMOTIONS

Words by **Laura Mears**

© Science Photo Library

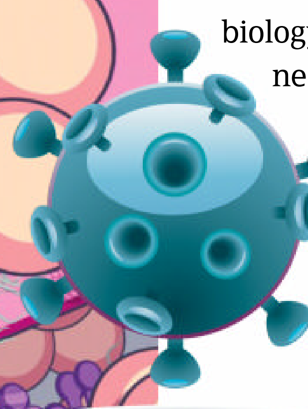
DID YOU KNOW? *If you counted up all the unique genes in human gut microbes, you'd find more than 3.3 million*

Your body is teeming with life. In every nook and cranny, there are miniature ecosystems bursting with bacteria, archaea, fungi, protists and viruses. They form a vital part of your biology, digesting your food, interacting with your immune system and even affecting your mood. Just as different plants and animals live in different habitats on Earth, different species of microbe colonise different parts of your body. The skin on your arms and legs is dry and the temperature is unpredictable, like a desert, so few species are hardy enough to make it their home. But the lining of your gut is warm, wet and full of nutrients, like the tropics, supporting a vast diversity of microscopic life. The microbe communities found in each tiny body ecosystem are known as 'microbiota', and their genomes as 'microbiomes'.

Analysing these miniature ecosystems can be tricky, but techniques have advanced rapidly in recent years. One way to understand body bugs is to take swabs and samples and grow them in petri dishes. But this doesn't show the whole story. Many microbes that live happily inside our bodies cannot survive on a dish in a lab, so we never see them. Now, with modern gene-sequencing techniques, it's possible to detect the signatures of these hidden body bugs, and the results are astonishing. As it turns out, we're more microbe than human, and our microbiomes are more unique than our genes.

Old estimates suggested that bacterial cells outnumbered our own cells ten to one. But recent science is a bit more conservative. It's likely that there are between 30 and 50 trillion bacterial cells inside you right now, compared to just 30 trillion human cells. That means that we are only half human at best. What's more, while we humans share around 99.9 per cent of our DNA with each other, our internal ecosystems are nowhere near as similar. Compare our gut microbes and we only share between 80 and 90 per cent of the same genes.

Some scientists think that we should stop thinking of ourselves as individuals and start thinking of ourselves as ecosystems called 'holobionts' – a word that literally means 'whole organism'. This approach helps to make sense of the massive impact our body bugs have on our health. Our microbes don't just ride around inside us, they form an integral part of our biology; we need them as much as they need us.



Take the gut, for example. It's the richest ecosystem in your body, thanks to you. The food you eat provides a constant supply of nutrients, supporting well over three-quarters of the bacteria that call you home. But they aren't freeloading;

gut microbes are a vital part of your digestive system. Bacteria have genes that we don't, which allow them to do metabolic tricks that we can't. This means that they can digest food that our bodies wouldn't otherwise be able to break down. They can also make essential vitamins that we can't produce on our own.

Having microbes in our intestines lets us extract much more nutrition from the food that we eat. In Japan, for example, some people have a gut bacteria species called *Bacteroides plebeius*. It comes from the seaweed in their diet, and it makes an enzyme that can digest complex sugar found in red algae. Without the enzyme, the sugar would just pass straight through. Thanks to the bacteria, the sugar becomes a new source of energy.

Bacteria also seem to help keep the lining of our gut safe. Our intestines need to be able to absorb nutrients without allowing allergens, toxins and bad bacteria to get into the body. In mice, killing certain gut bacteria can trigger a peanut allergy. Restoring the bacteria reverses the effect. The bugs seem to be able to stop dangerous peanut proteins getting into the body.

The ecosystem in our intestines is essential for our survival. However, like any other ecosystem on the planet, maintaining a healthy community is a delicate balancing act. Our guts support hundreds of species, and if this complex mix gets out of balance, it can spell disaster. Problems with the microbiome have been linked to all kinds of diseases, from acne and diarrhoea to diabetes and cancer.

Helicobacter pylori bacteria have tails, called flagella, which help them swim around the stomach lining

"It turns out, we're more microbe than human"

Work to unpick the role microbes play in our health is still in its early stages, but there are some links that are starting to become clearer. Genetics and lifestyle both have important roles to play in how we interact with our gut microbes.

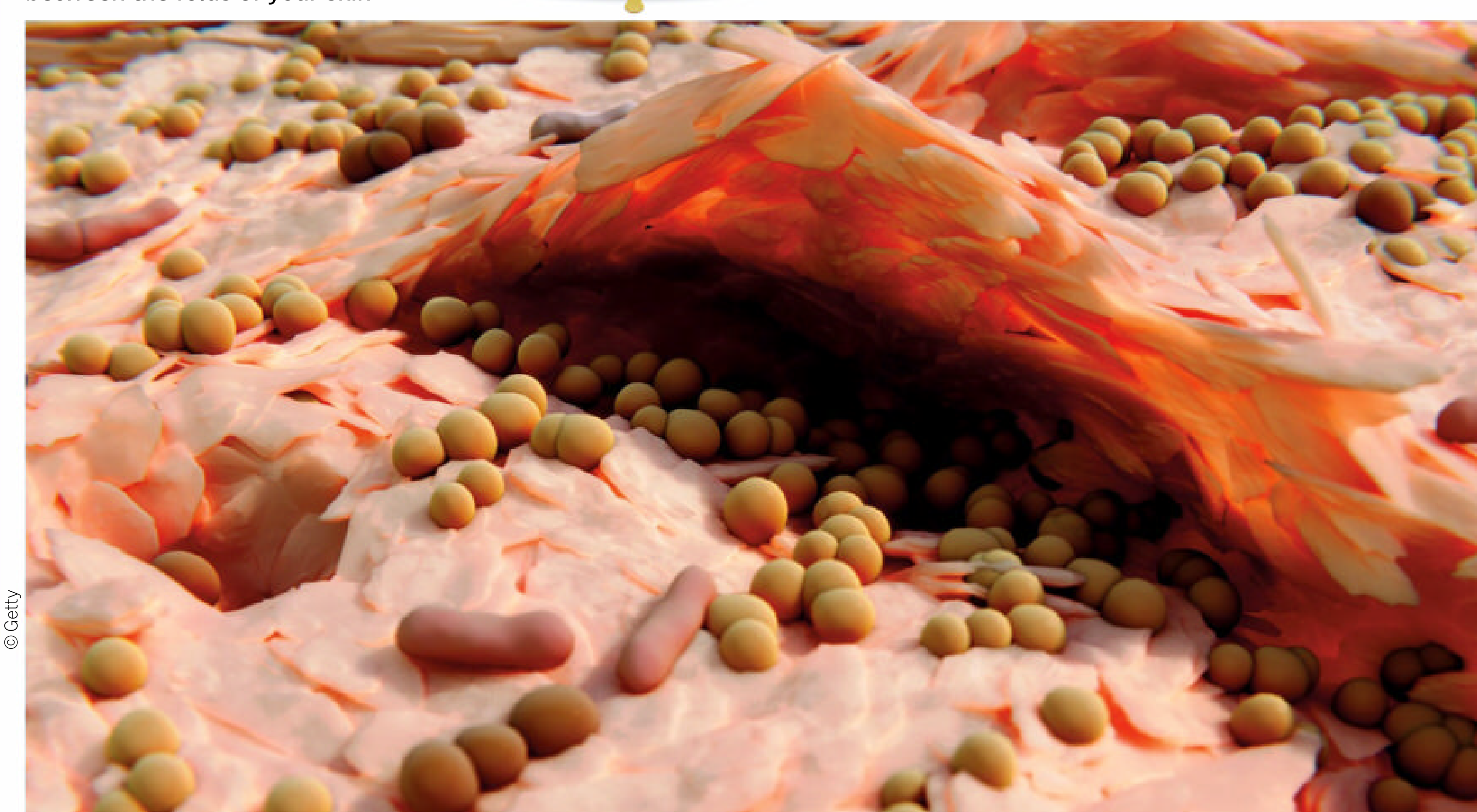
One way that scientists have been learning about this is by looking at mouse poo. Analysing the leftovers of a meal can tell us how much energy the mice have managed to extract from their diet. When mice have gene mutations linked to obesity, everything changes. Mice with one type of mutation were able to get more calories from the same amount of food. Mice with a different mutation wanted to eat more. In both cases, it seemed that their gut bacteria were partly to blame.

Gut bacteria are also in tune with our lifestyles. Eating lots of meat makes them switch on protein-digesting enzymes, while crunching through vegetables encourages them to turn on enzymes that break down complex carbohydrates. This is hugely beneficial for both us and the microbes.

We can't digest all the fibre from plant-based foods on our own, and without fibre, good bacteria can't survive. So we work together. The more fibre you eat, the more bacteria you can support, and there are benefits for you too. Fibre-eating bacteria make fatty acids, which nourish your gut cells, help to maintain your gut barrier and reduce inflammation.

So far, the focus has mostly been on the intestines. They tend to get all the attention when it comes to microbes because they're easily the richest ecosystem in your body. This is simply because the gut is full of nutrients. However, just because other parts of the body don't have as much food for the microbes to eat doesn't mean they don't have their own microscopic communities.

Take the skin, for example. Adults have around two square metres of skin, a huge habitat for microbes. Most of it is cool and slightly acidic, a tricky place for microbes to make their home, but there are



Staphylococcus aureus bacteria live between the folds of your skin

When good bugs turn bad

Around half of us carry *Staphylococcus aureus*, little round cells that clump together like bunches of grapes in the folds of our skin, inside our mouths and up our noses. They're mostly harmless, but like many good body bugs, these bacteria are opportunistic pathogens: if they manage to get inside our tissues or into our blood, they can turn nasty.

***Staphylococcus aureus* doesn't harm healthy skin, but if it gets into an open wound it can cause painful and dangerous infections. Normally these infections are easy to treat with a type of antibiotic called penicillin. However, every time we use antibiotics to treat infection, we give the bacteria in our bodies a chance to develop new defences.**

Lab tests can find out which antibiotics work best against which strains of bacteria

DID YOU KNOW? *Antonie van Leeuwenhoek – a pioneer of gut science – studied his own gut microbes in the 1600s*

havens among these deserts, especially in folds and crevices.

Warm, damp creases in the skin, like the belly button, attract bacteria like *Staphylococcus aureus*. Glands, like those on the face, attract species like *Propionibacterium acnes*, named after the spots it causes when it grows too fast. Each little crack forms a tiny ecosystem with its own unique community of body bugs.

Different sets of microbes live inside the ear, on the edge of the nose, up the nostril, in the armpit and in the crease of the elbow. They help to protect the skin from colonisation by more dangerous, disease-causing bacteria and fungi. They also coach the immune system, training it to prevent infections by parasites.

These microbes also form part of your unique body-bug fingerprint. The bacteria that colonise our hands leave telltale traces on everything we touch. The signatures they leave behind are so specific that not only can you tell which person touched an object, you can even tell which finger. Your miniature ecosystems are as unique as you, and without them, you wouldn't be here.

How do babies get their body bugs?

The microbes that inhabit our bodies change throughout our lives, but we get our first residents when we're still in the womb. The placenta has its own microbiome, including bacteria that help to convert chemicals into vital vitamins.

The next big dose of microbes comes during and shortly after birth, and different babies pick up different combinations of body bugs. Babies born by caesarean section pick up lots of skin bacteria, while babies born vaginally get a combination of bacteria from the skin, gut and birth canal. Babies born at home pick up a richer set of bacteria than those born in hospitals. Breast-fed babies get a gut microbe boost thanks to tiny bacteria-feeding sugar particles called human milk oligosaccharides.

When babies transition to solid foods, everything changes again as new bacteria enter their digestive system. If they catch an infection or take antibiotics, this can also change their body-bug mix.

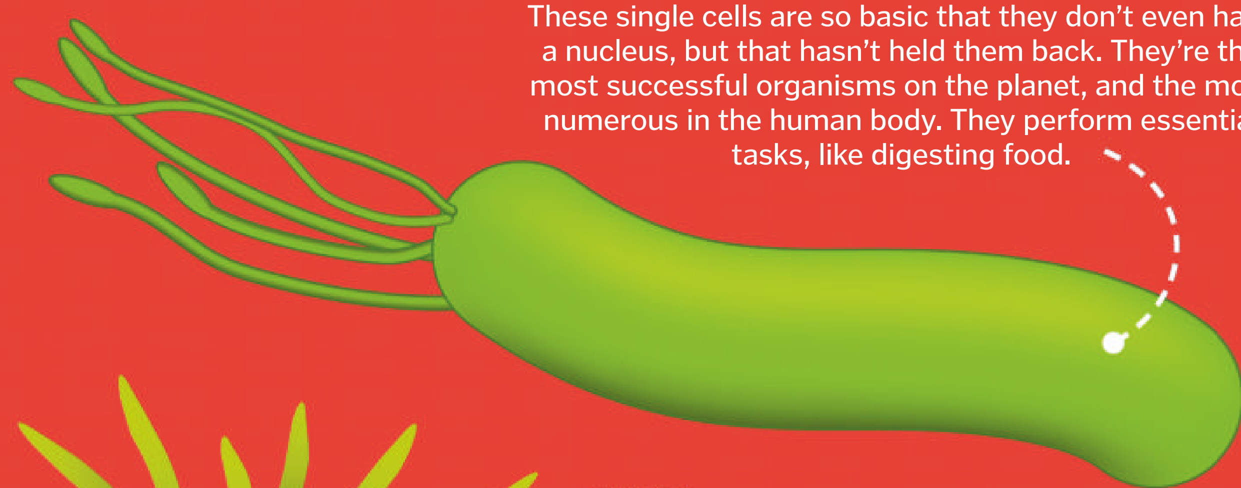
Newborn babies pick up microbes from their environment

MICROBES UNDER THE MICROSCOPE

YOUR BODY ECOSYSTEM IS TEEMING WITH DIFFERENT KINDS OF MICROSCOPIC LIFE

Bacteria

These single cells are so basic that they don't even have a nucleus, but that hasn't held them back. They're the most successful organisms on the planet, and the most numerous in the human body. They perform essential tasks, like digesting food.

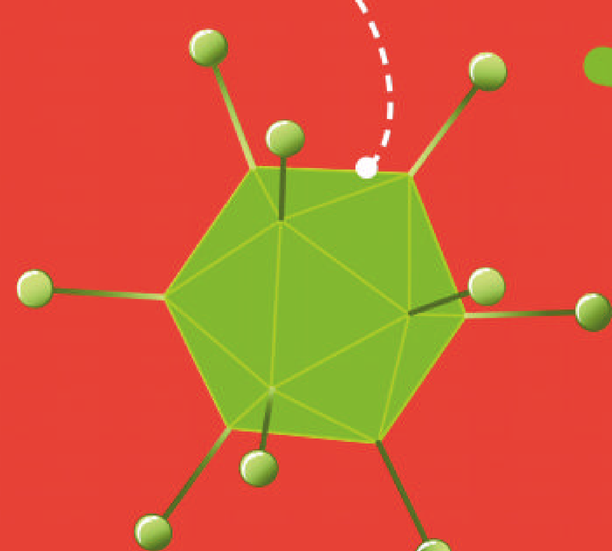


Archaea

These microbes look a bit like bacteria, but they have completely different chemistry. This allows them to do something special – make methane. It's a critical step in human digestion, and the source of some of our gut gas.

Viruses

These small bags of genetic code hijack cells and turn them into virus factories. Some infect us directly, while others attack the organisms that live inside us. This isn't always a bad thing; it helps to keep our microbes in balance.



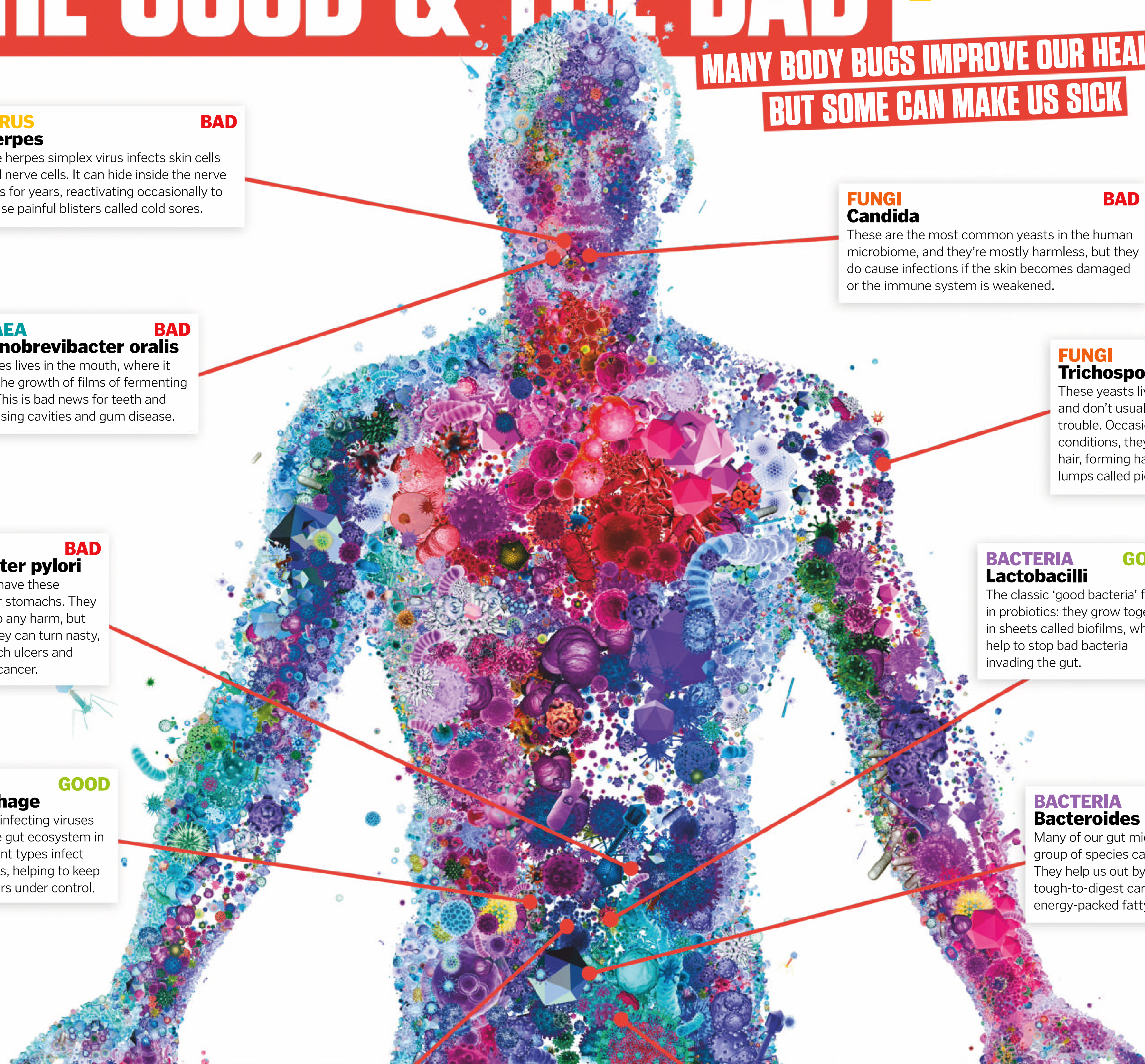
Fungi

There aren't many types of fungi inside our bodies. Those that do call the human ecosystem home are mainly yeasts. They fight with bacteria for space on our skin, and if an opportunity arises, they sometimes invade and cause disease.

THE GOOD & THE BAD

MANY BODY BUGS IMPROVE OUR HEALTH, BUT SOME CAN MAKE US SICK

- BACTERIA
- FUNGI
- ARCHAEA
- VIRUS



VIRUS — **BAD**
Herpes
The herpes simplex virus infects skin cells and nerve cells. It can hide inside the nerve cells for years, reactivating occasionally to cause painful blisters called cold sores.

FUNGI — **BAD**
Candida
These are the most common yeasts in the human microbiome, and they're mostly harmless, but they do cause infections if the skin becomes damaged or the immune system is weakened.

ARCHAEA — **BAD**
Methanobrevibacter oralis
This species lives in the mouth, where it supports the growth of films of fermenting bacteria. This is bad news for teeth and gums, causing cavities and gum disease.

FUNGI — **GOOD**
Trichosporon
These yeasts live on healthy skin and don't usually cause any trouble. Occasionally, in wet conditions, they can colonise the hair, forming harmless white lumps called piedra.

BACTERIA — **BAD**
Helicobacter pylori
Lots of people have these bacteria in their stomachs. They don't usually do any harm, but occasionally they can turn nasty, causing stomach ulcers and even stomach cancer.

BACTERIA — **GOOD**
Lactobacilli
The classic 'good bacteria' found in probiotics: they grow together in sheets called biofilms, which help to stop bad bacteria invading the gut.

VIRUS — **GOOD**
Bacteriophage
These bacteria-infecting viruses help to keep the gut ecosystem in balance. Different types infect different species, helping to keep bacteria numbers under control.

BACTERIA — **GOOD**
Bacteroides
Many of our gut microbes belong to a group of species called Bacteroides. They help us out by turning tough-to-digest carbohydrates into energy-packed fatty acids.

ARCHAEA **GOOD**

Methanobrevibacter smithii

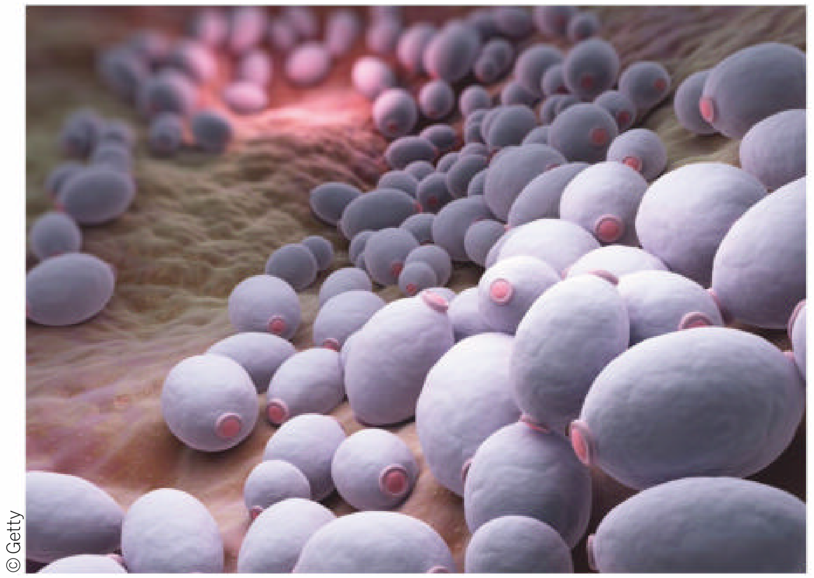
This species boosts digestion by turning hydrogen into methane. This helps good gut bacteria to make more energy, but can cause smelly wind.

VIRUS **GOOD**

Endogenous retroviruses

Known as 'fossil viruses', these are genes left over by ancient viral infections. Some now form vital parts of our biology, including helping to build the placenta.

© TVD&SUN



© Getty

These little ball-shaped bugs are the skin-infecting yeast, *Candida albicans*

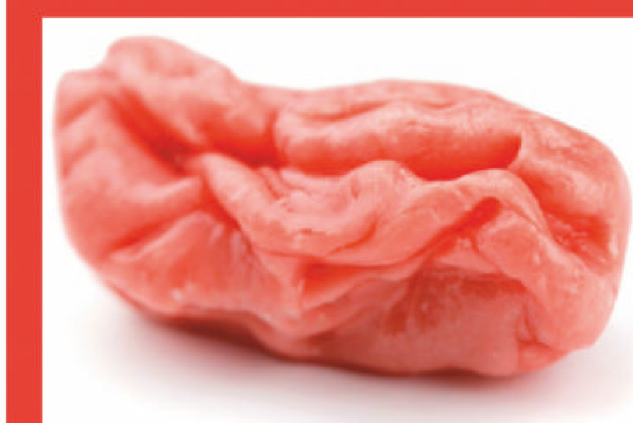
© Getty

Your intestines are full of bifidobacteria. These tiny bugs help to digest your food

"The ecosystem in our intestines is essential for our survival"

Ancient mouth microbes revealed

Thousands of years ago, Neolithic hunter-gatherers made sticky black chewing gum from birch tree tar. As they chewed, their saliva mixed with the gum, leaving behind traces of DNA. In 2019, scientists found a piece of this ancient gum, preserved for 5,700 years beneath the sand in Denmark. Human DNA in the sample revealed that the gum-chewer was a woman with dark skin, brown hair and blue eyes. Plant and animal DNA revealed that she'd recently eaten duck and hazelnuts, and bacterial DNA revealed that her mouth was full of similar bacteria to ours, including bugs that can cause gum disease.



© Getty

Chewed gum carries the DNA signatures of you, your food and your mouth microbes

AR ZONE! SCAN HERE

MICROBIOME BY NUMBERS

10:1

Viruses outnumber bacteria 10:1 in the intestines

1,000

1,000 species of bacteria can live in human intestines

0.1MM

Human eyes can't see anything smaller than 0.1mm

30%

of people have *Staphylococcus aureus* living in their noses

0.01MM

Body-infecting yeasts are smaller than 0.01mm

2KG

The weight of microbes in your gut

600

More than 600 species can live in the airways

40%

of people have *Helicobacter pylori* living in their stomach

0.002MM

Most gut bacteria are smaller than 0.002mm

23,000

The human genome has only 23,000 genes

1,000,000

The human microbiome has more than 1,000,000 genes

10%

of your gut microbes are bifidobacteria

1,000

1,000 species can live on the skin

95%

of your body bugs live in your intestines

25

25 species can live in the stomach

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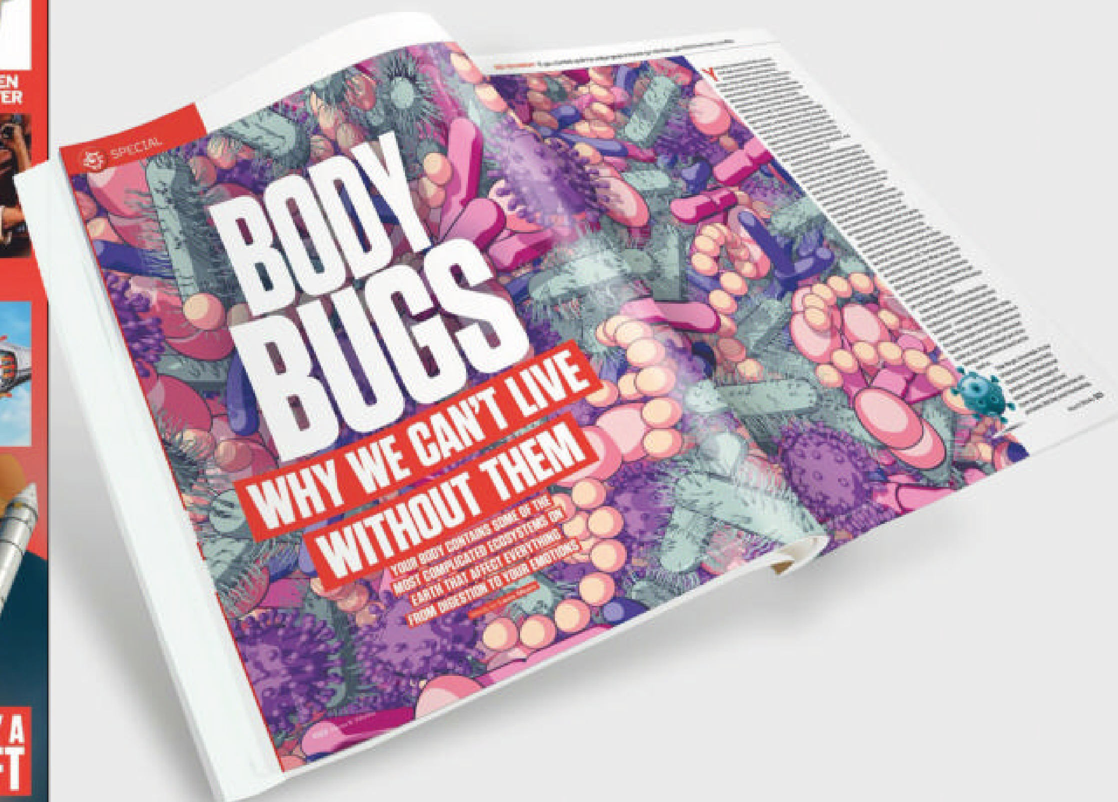

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HOW TO TAME FIR

From the chemistry of candles to flames in space, discover the science behind this hot topic

Words by **Scott Dutfield**

When striking a match, the flammable sulphur and red phosphorus head ignites by the spark created from friction

Ever since our caveman ancestors rubbed two sticks together to produce embers, humans have evolved a fascination with fire. In a relationship which has defined our modern-day selves, fire transformed the way humans eat, stay warm and build global civilisations. It was described in ancient Greece as one of Earth's 'natural elements' alongside water, air and earth. But what exactly is fire?

Fire is an interaction of particles that creates a hot, glowing plasma. Fundamentally, what we see when we strike a match is a series of chemical reactions that emit heat, light, gas and water as by-products. Every flicker and flare of a dancing flame is created by atoms releasing energy at different stages of being heated.

The recipe for fire is relatively simple. Add a dash of oxygen, a drizzle of fuel and a heap of heat, and hey presto, you've got fire. While all

Burning underwater

Some materials burn so furiously that not even water can put them out. Used in metal refineries and even bomb production, thermite is a human-made combination of powdered aluminium and a metal oxide, often iron. Once ignited this marriage of metals can burn at an alarmingly high temperature, around 2,400 degrees Celsius, spewing molten chunks of iron on the ground.

Back in 2015, a popular YouTube channel called 'TheBackyardScientist' wanted to see if the reaction could be halted when dipped in water. Sure enough, not even water could stop the thermite reaction from burning while submerged until the fire ran out of fuel.

three are required to create fire, the fuel source can be almost anything. The two most flammable elements on Earth are carbon and hydrogen, so fuels that are heavily comprised of these elements are a fire's favourite food. This is because carbon and hydrogen like to combine with oxygen in the air. With the initial release of heat energy such as a spark, a fuel source like wood needs to reach its own ignition temperature in order to burn. Once heated up, volatile gases such as carbon and hydrogen released from the fuel begin a chain reaction of oxidation called combustion. During this rapid oxidation, the chemical bonds that make up the fuel source are broken apart and reformed into the by-products of the fire, carbon dioxide and water. In this process of ripping molecules apart, energy is released in the form of heat and incandescent light.

However, not all fires are created equal when it comes to how hot they burn. A fire's temperature can vary wildly depending on the chemical composition of the fuel and the amount of oxygen available. For example, a wood fire may burn at around 1,100 degrees Celsius, whereas ethanol can burn at around 1,920 degrees Celsius. This is predominantly due to the higher proportion of carbon and hydrogen in ethanol compared to wood. Another important factor that can determine whether or not something catches fire is its size. Thicker and denser fuel sources, such as a tree trunk, take a great deal longer to reach a temperature where they might ignite than a smaller fuel such as kindling.

Fire is indiscriminate in its search for fuel, and this can lead to devastation. By the very nature of this chemical reaction, until a fuel source is completely depleted or a critical ingredient of the fire recipe is removed, flames will continue to rage, destroying everything in their path. One of the biggest examples of the untameable nature of fire are the recent bushfires in


Wildfires can be speedy, travelling up to around ten kilometres per hour in forests and 23 kilometres per hour in grasslands

"Add a dash of oxygen, a drizzle of fuel and a heap of heat, and hey presto, you've got fire"

Types of extinguishers

Using the wrong one can make things a lot worse

Wet chemical

- **Solid material (wood and paper)**
- **Cooking oils**

Due to the volatile reactions between water and hot oil an alternative wet chemical extinguisher is used to tackle these fires. These extinguishers disperse a mist of potassium salts which react with the burning oil to create a soapy film, cutting off oxygen supply.

Water

- **Solid material (wood and paper)**

Only suitable for solid material fires, such as wood and fabrics, water removes heat from the burning fire, cooling it down and preventing it from igniting again. Water extinguishers should never be used on electrical or burning fat or oil fires.

Carbon dioxide

- **Flammable liquids**
- **Electrical**

In fires where electricity is at play, using liquid extinguishers can spread the fire and make it worse. In these cases, carbon dioxide gas extinguishers are used to cut off air supply to the fire.

Dry powder

- **Solid material (wood and paper)**
- **Flammable liquids**
- **Gaseous fires**
- **Electrical**

As the most versatile type, a dry powder extinguisher sprays a mixture of sodium or potassium bicarbonate or monoammonium phosphate to coat and smother a variety of fire types.

Foam

- **Solid material (wood and paper)**
- **Flammable liquids**

By creating a seal over flaming liquid or burning wood, foam extinguishers prevent any flammable vapour from igniting surrounding oxygen, thus starving the fire into submission.

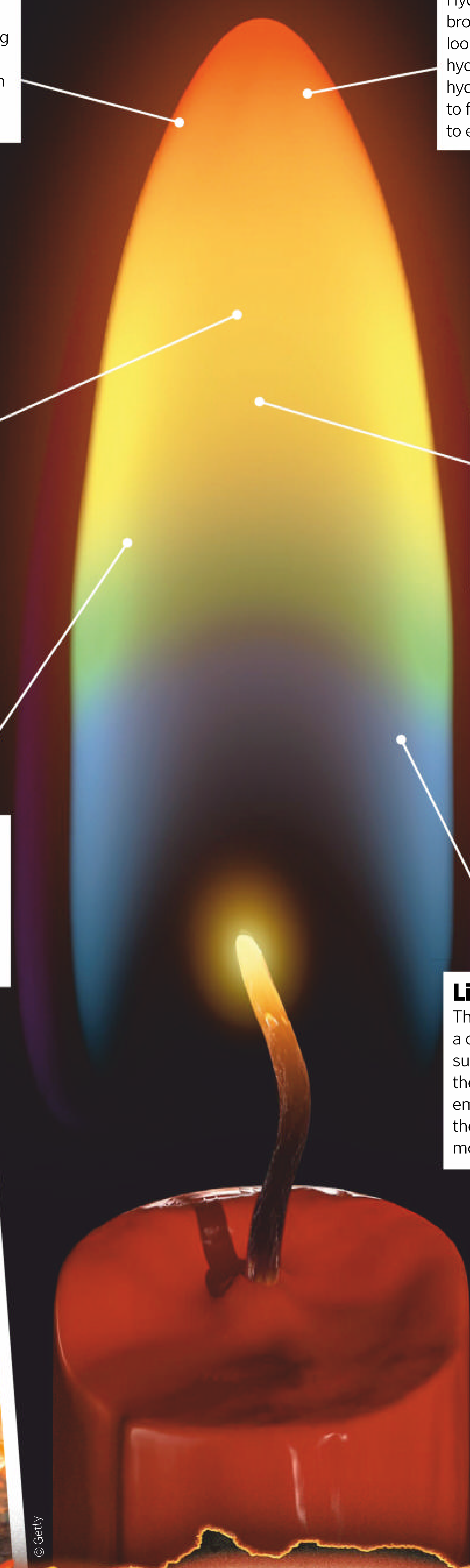
Hot rainbow

Changing the colour of fire might be an experiment you remember from school. When heated, different elements emitted an array of colours as light energy, a result of the elements' electrons 'jumping' from a normal to an excited state. As they fall back down to a normal state, they emit wavelengths of differing colours. For example, copper burns with a blue-green flame. Larger atoms such as strontium require less energy to excite their electrons, and so during their energy comedown emit a colour with a longer wavelength – red. However, smaller atoms such as sodium demand more heat energy to get excited, therefore having more energy to expel as colours with shorter wavelengths.

Fire extinguishers are designed to smother fires by removing one of three vital ingredients needed for their creation

Candle combustion

Fire isn't just destructive. It can light our homes or be used in celebration



Wax
As a candle's fuel source, melting wax is pulled up the wick when set alight, where its hydrocarbon molecules that meet the flame are vaporised and break apart.

Soot
Hydrogen and carbon that are broken apart are reformed as loop-like polycyclic aromatic hydrocarbons. These hydrocarbons clump together to form soot, rising up the flame to eventually become smoke.

Oxygen
Drawn in from the air, oxygen combines with free carbon atoms and is released as carbon dioxide.

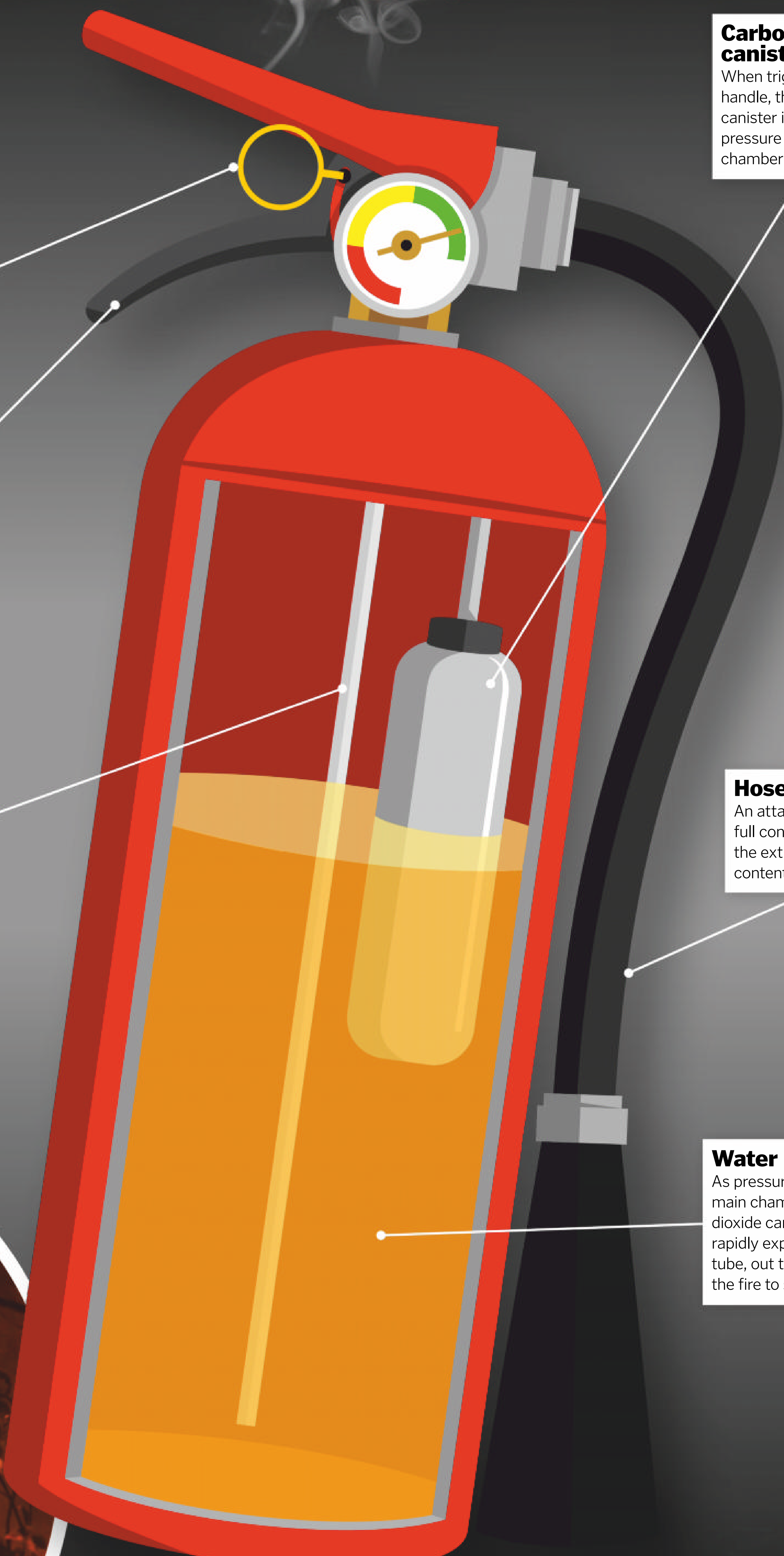
Water
In the same way that oxygen combines with a candle's carbon, oxygen also comes together with hydrogen to produce water as another by-product.

Heat
During the reactions between oxygen, carbon and hydrogen, energy is released as visible infrared and heat, with the hottest portion of the flame located at the base.

Light
The majority of light produced by a candle is emitted from the surface of the flame, rather than the hottest region. Visible light is emitted largely by the burning of the incandescent soot molecules moving up the flame.

Inside a fire extinguisher

How water extinguishers use pressure to put out fires



Safety pin
Ensuring the extinguisher doesn't go off unintentionally, a safety pin prevents the premature trigger of the handle.

Handle
To activate the extinguisher and release the water within, the handle needs to be squeezed together.

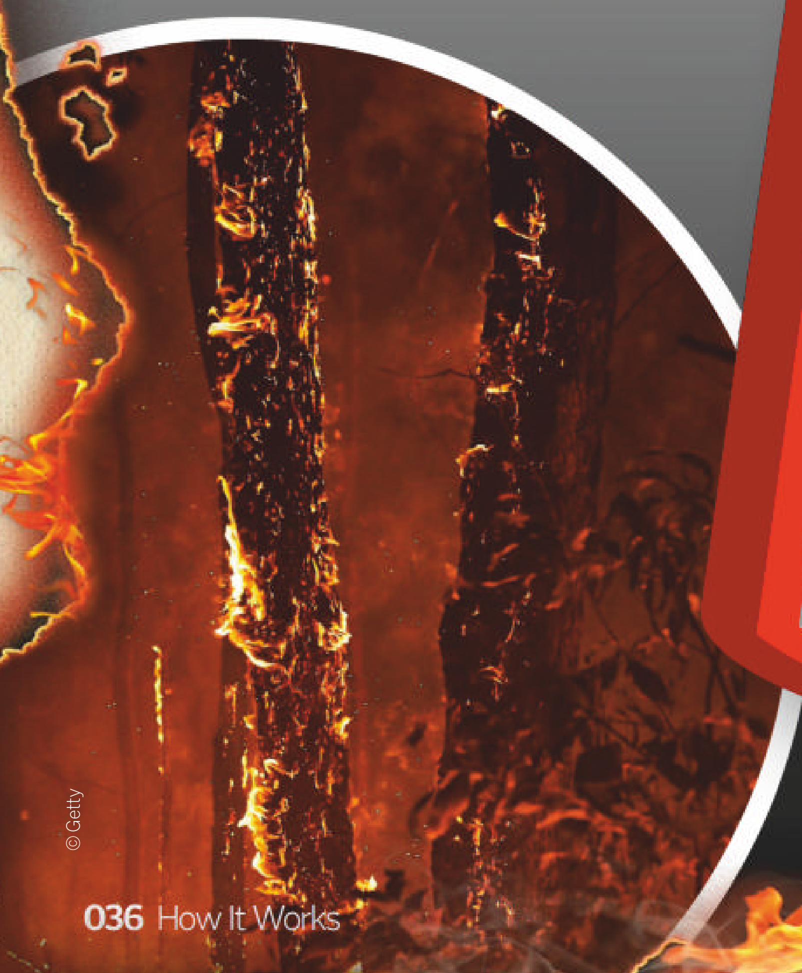
Siphon tube
When the carbon dioxide canister is activated, the extinguisher's water content is rapidly driven up the siphon tube for release.

Carbon dioxide canister
When triggered by the handle, the carbon dioxide canister is opened, releasing pressure into the main chamber of the extinguisher.

Hose
An attached hose allows full control over directing the extinguisher's contents towards the fire.

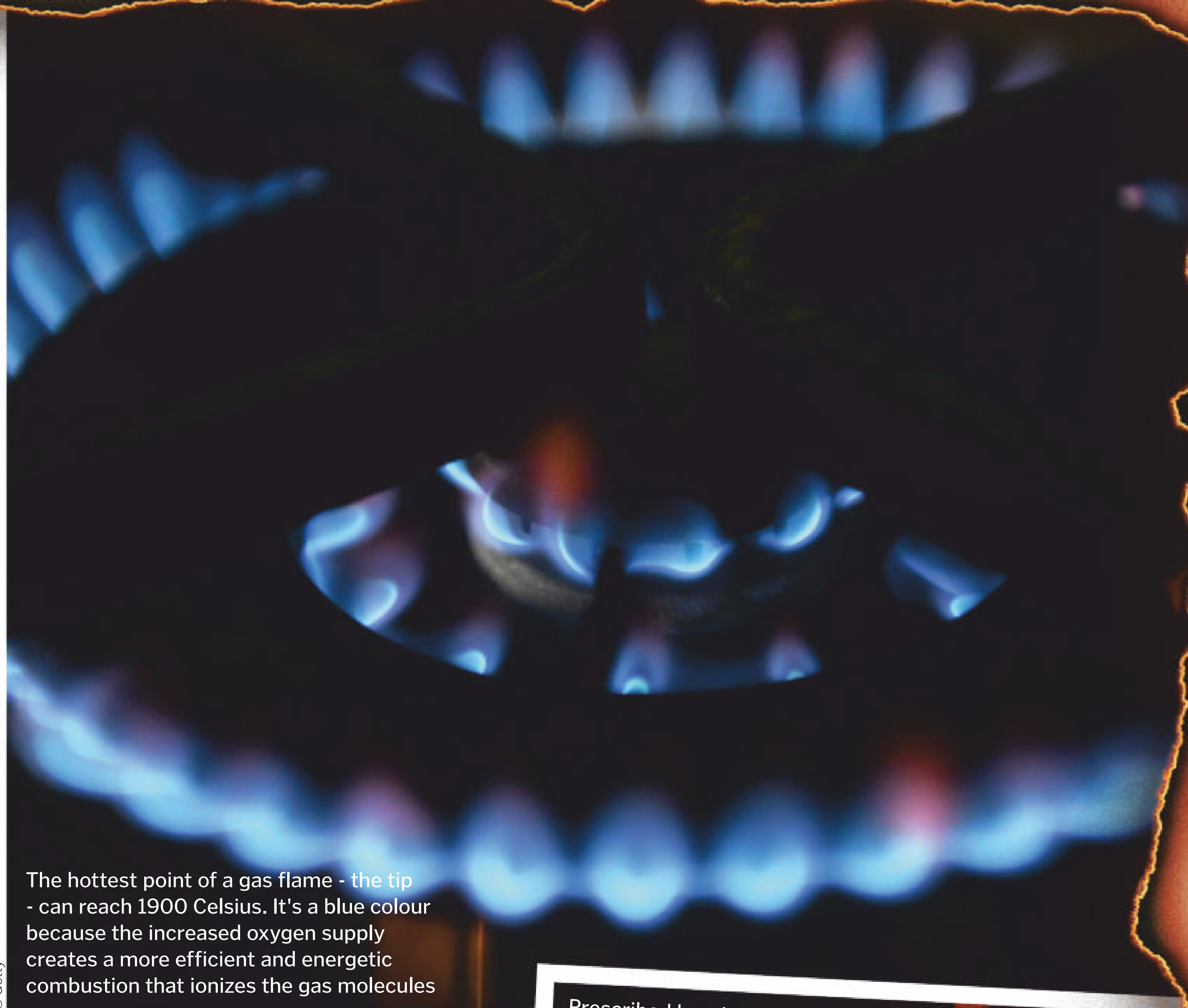
Water
As pressure builds within the main chamber by the carbon dioxide canister, water is rapidly expelled up the siphon tube, out the hose and onto the fire to smother it.

When heated to around 150 degrees Celsius, wood begins to decompose, releasing volatile chemicals as smoke



Australia. Raging for more than five months, more than 11 million hectares of Australian bush have been destroyed by wildfires. The ignition source could be a lightning strike or even arson. However, as to why these fires have raged so fiercely is down to the dry environmental conditions in Australia. Pointing the finger towards climate change and the extreme heat the country has experienced throughout the last year, Australia's forests and bush have become the perfect kindling for the fire to exploit.

As a forest fire rages, hot air rises upwards and cooler oxygen-rich air is dragged to the bottom, the same as when a candle flame burns. The air's motion is barely noticeable in the tiny flame of a candle, but when a fire is burning across hectares, this gaseous movement can generate winds of more than 160 kilometres per hour. With the assistance of strong wind speeds, embers produced by fires leap from one wildfire and fall to another area of forest, igniting a new blaze. Without widespread rainfall to extinguish the travelling flames, Australia has been experiencing the worst fire season on record.

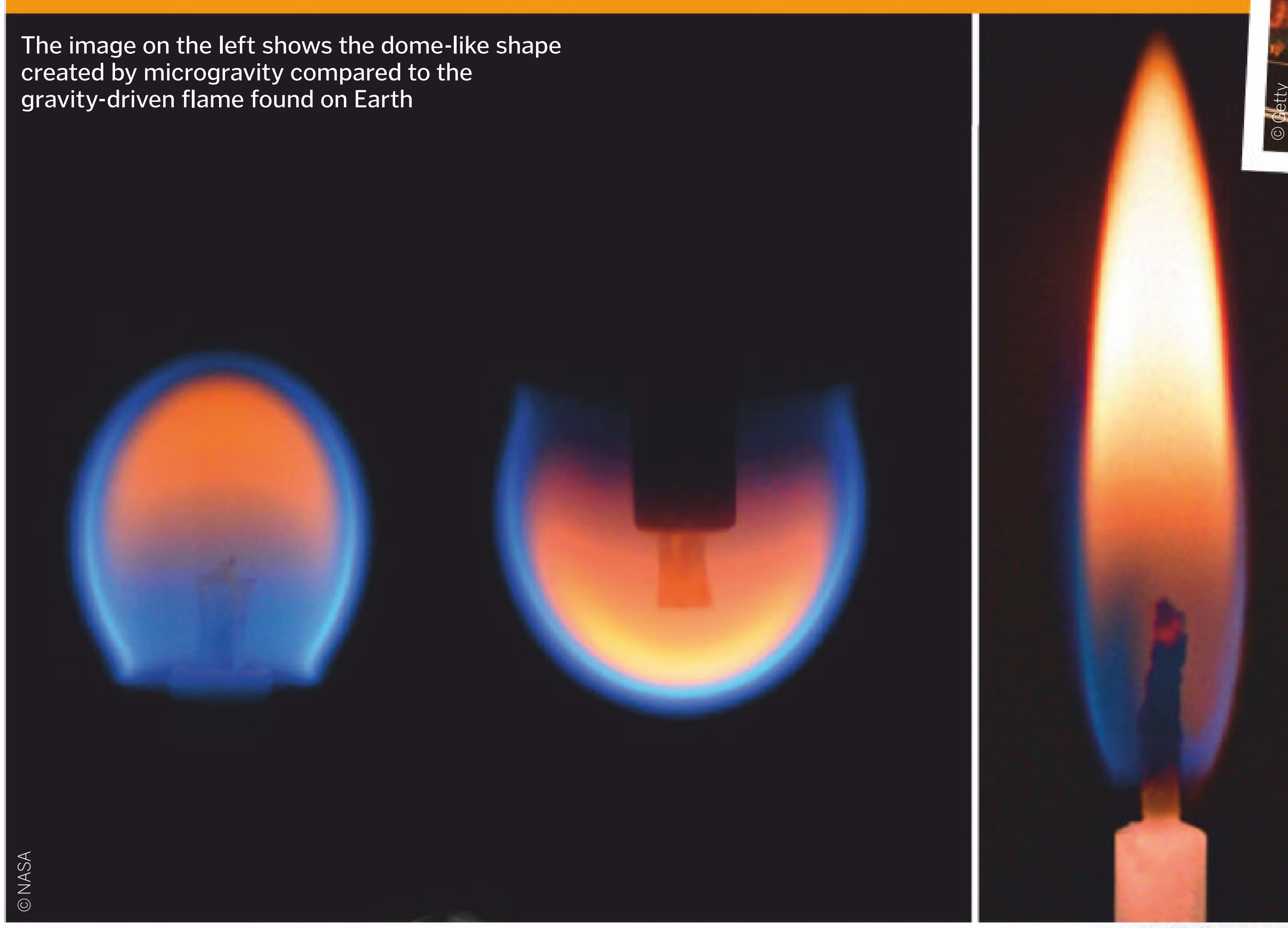


The hottest point of a gas flame - the tip - can reach 1900 Celsius. It's a blue colour because the increased oxygen supply creates a more efficient and energetic combustion that ionizes the gas molecules

© Getty

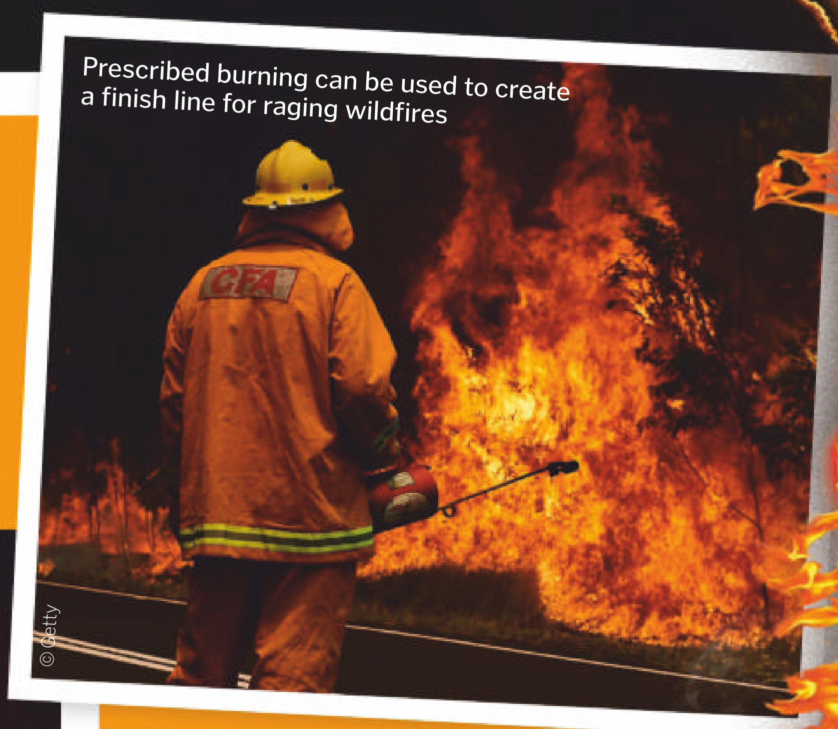
Fire in space

Lighting a match inside a giant, oxygen-filled research centre floating in space doesn't sound like the safest idea. However, in 2012, astronauts aboard the International Space Station (ISS) did just that. With a lack of oxygen throughout space, the only way to see how fire reacted in microgravity was to strike a match aboard the ISS. The teardrop shape of a flame on Earth is due to the uptake of oxygen as it burns. However, in microgravity, the same rules don't apply. Without an abundance of rising oxygen, space flames are shaped merely by the static air around them. This creates a spherical flame as the chemical reactions creating light occur all around the match.



The image on the left shows the dome-like shape created by microgravity compared to the gravity-driven flame found on Earth

© NASA



Prescribed burning can be used to create a finish line for raging wildfires

© Getty

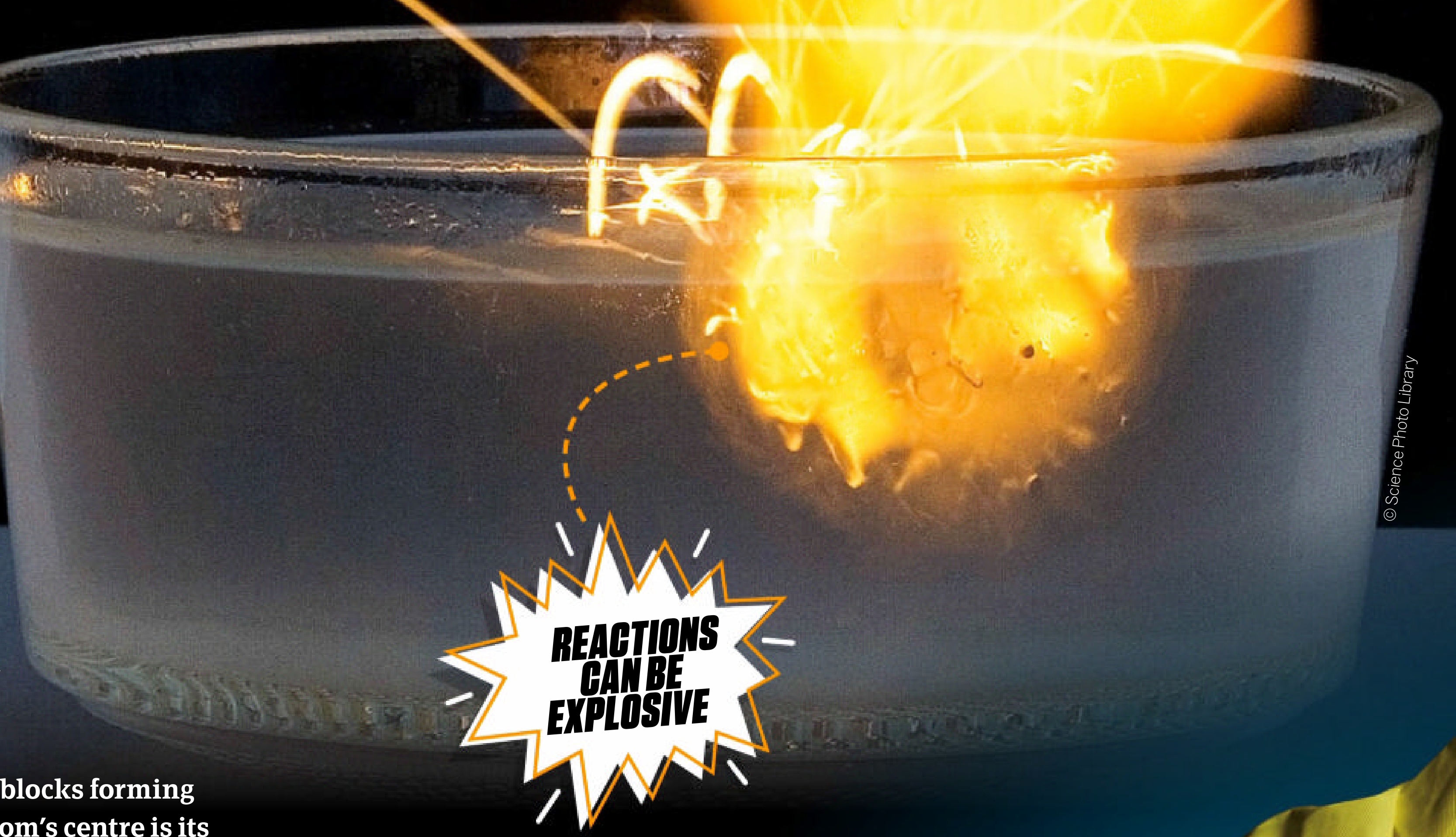
Fighting fire with fire

When battling blazing wildfires it might seem strange to introduce more fire in an attempt to quash the already-raging flames. However, prescribed burns may help to relieve the painful effects of wildfires. In a strategic endeavour to limit the advancement of wildfires, a human-made wall of fire can be drawn around them in the hopes of starving them of fuel. By purposely burning strips of woodland before wildfires can reach them, a prescribed fire could potentially stop the spread. This isn't a guarantee, and although controlled by firefighters, there is a risk that the prescribed fire could become uncontrollable, or floating embers could ignite new wildfires.

KILLER CHEMICALS

Nature has many gruesomely deadly substances, but understanding them keeps us safer

Words by **Andy Extance**



Marie Curie is one of few women to win science's highest honour, a Nobel Prize, but her work also brought her an early death. She and her husband Pierre spent years carefully grinding radioactive rocks and soaking the powder in acid. In 1898 they discovered the new element polonium, and a few months later, Marie would go on to discover radium too. But the Curies didn't know how risky their work was. Scientists had discovered radioactivity just a few years earlier. We now know that radioactivity is very dangerous. Worse still, polonium may be the most radioactive element.

The danger comes from the building blocks forming elements' atomic structures. At each atom's centre is its nucleus. In radioactive elements, the nucleus breaks apart, firing out smaller chunks that can harm people. Also, a cloud of electrons surrounds each atom's nucleus. The number of electrons an atom has and how the nucleus is built make all elements behave differently. From this chemistry emerge many different hazards.

Some hazards arise because elements are toxic or poisonous. Most often, such poisons work because two different elements are similar. We need many essential elements to live, powering the biological machines in our cells. Therefore we must take them in when we eat and drink. But consuming elements that mimic the essential ones stops the biological machines working.

Other hazards come from elements' reactivity. Usually this happens when elements strongly give electrons to other atoms, or take them away. If the chemical reactions this causes are fierce enough, they become fires or explosions. Yet these same properties mean that the substances produced are then very safe and stable. Chlorine's reactivity makes it poisonous, and sodium's makes it explosive in water. But together they make sodium chloride, which is so safe we eat it as table salt. And when atoms assemble into molecules like nitroglycerin, these properties can be even more complex.

But why would anyone want to understand these dangerous chemicals? It's not because scientists want to poison or kill people. Instead, knowing about these substances' bad effects helps everyone avoid being hurt.

The explosive that heals hearts

Nitroglycerine was the first explosive to be more powerful than gunpowder. Like many other explosives, such as trinitrotoluene (TNT), its power comes partly from the atoms responsible for the 'nitro' in its name. Nitro groups link together one nitrogen atom and two oxygen atoms. Nitroglycerine therefore has lots of oxygen atoms, along with carbon, hydrogen and nitrogen atoms. When it burns the high oxygen content means the atoms react explosively, as they seek to produce more stable substances.

Nitro groups also play important roles in the body. They break down to form chemical signals that tell blood vessels to widen. Nitroglycerine is used to help reduce the pain people experience when they have problems with their heart.

© Getty

Alfred Nobel made his fortune producing explosives, including some using nitroglycerine

The element that killed a Russian spy

In November 2006, former Russian secret agent Alexander Litvinenko became the first-ever person that we know to have been killed by polonium poisoning. This horrible death shows just how powerful his enemies were, in part down to the extreme rarity of the poison. Polonium itself is a rare element, found in rocks that also contain uranium. A gram of such a rock contains around one ten-billionth of a gram of polonium. There are also 42 different forms of the element, known as isotopes, all of which give off dangerous radiation. Litvinenko died from the powerful radiation of the polonium-210 isotope disrupting the working of his cells. He probably drank the substance three weeks earlier, in the form of dissolved polonium chloride. The radioactive polonium could then quickly pass from Litvinenko's stomach to his blood, and then to the rest of his body.

© Getty

Litvinenko was poisoned with polonium-210, which affects rapidly dividing cells the worst

EXPLOSIVES ON YOUR TABLE?

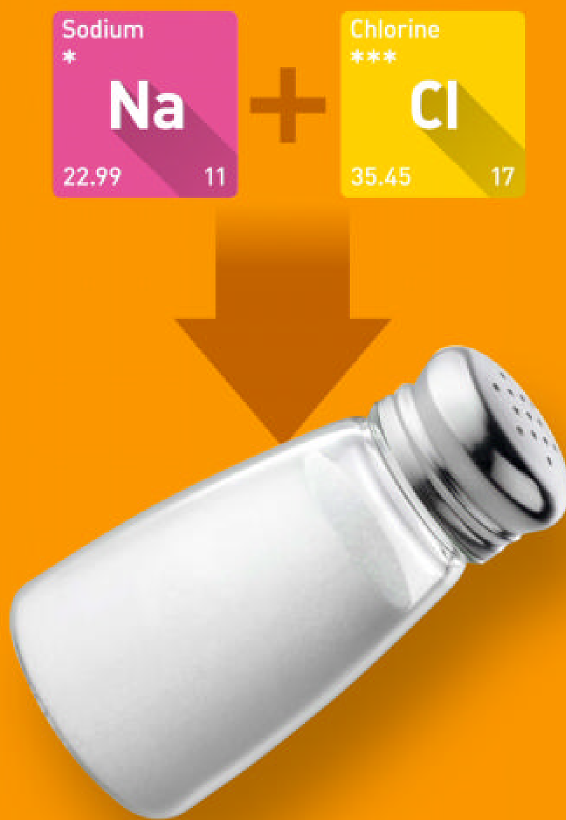
Sodium chloride is simple table salt, but has two very dangerous ingredients

Sodium (Na)

You rarely see sodium as a metal element because it's so reactive. This silvery metal is soft enough to cut with a sharp knife. But don't be deceived by its softness – drop it in water and it will explode!

Chlorine (Cl)

You really don't want to see the yellow-green gas that is pure chlorine, because breathing in very high levels can kill you. Chlorine's hunger for electrons means that tiny amounts can kill off bacteria.



Flashy but familiar chemistry

One way to make sodium chloride is dropping sodium metal into chlorine gas. Perhaps adding a little water, there would be a bright flash of a violent reaction. The white smoke that remains afterwards is much like table salt.

Table salt

In the flashy reaction between them, chlorine atoms steal electrons from sodium metal. The resulting sodium and chloride ions nestle together to produce crystals of table salt. These ions are very stable, so don't react further when we eat them.

© Getty

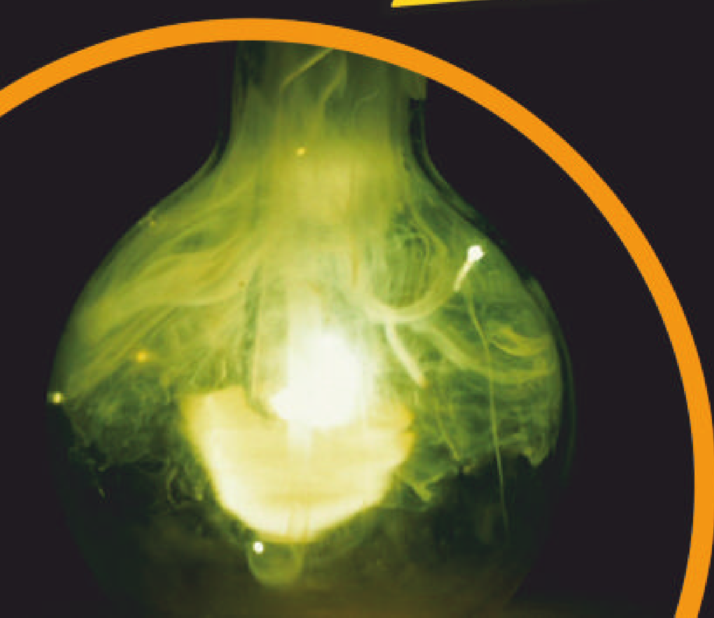
Hydrogen **Flammable**
If one-fifth of the air we breathe wasn't made up of oxygen, hydrogen might be relatively safe. But hydrogen and oxygen react rapidly, burning together to make water.

Chromium **Carcinogen**
Chromium metal that has reacted with air is stable and shiny, so is used in car parts. But removing six electrons from a metal chromium atom gives cancer-causing substances.

Hydrogen *** H 1.008 1									
Lithium * Li 6.941 3	Beryllium * Be 9.012 4								
Sodium * Na 22.99 11	Magnesium * Mg 24.31 12								
Potassium * K 39.10 19	Calcium * Ca 40.08 20	Scandium * Sc 44.96 21	Titanium * Ti 47.87 22	Vanadium * V 50.94 23	Chromium * Cr 52.00 24	Manganese * Mn 54.94 25	Iron * Fe 55.84 26	Cobalt * Co 58.93 27	Nickel * Ni 58.69 28
Rubidium * Rb 85.47 37	Strontium * Sr 87.62 38	Yttrium * Y 88.91 39	Zirconium * Zr 91.22 40	Niobium * Nb 92.91 41	Molybdenum * Mo 95.94 42	Technetium * Tc [98] 43	Ruthenium * Ru 101.07 44	Rhodium * Rh 102.91 45	Palladium * Pd 106.42 46
Caesium * Cs 132.91 55	Barium * Ba 137.33 56	LANTHANIDES	Hafnium * Hf 178.49 72	Tantalum * Ta 180.95 73	Tungsten * W 183.84 74	Rhenium * Re 186.21 75	Osmium * Os 190.23 76	Iridium * Ir 192.22 77	Platinum * Pt 195.08 78
Francium * Fr [223] 87	Radium * Ra [226] 88	ACTINIDES	Rutherfordium **** Rf [267] 104	Dubnium **** Db [268] 105	Seaborgium **** Sg [269] 106	Bohrium **** Bh [270] 107	Hassium **** Hs [269] 108	Meitnerium **** Mt [278] 109	Darmstadtium **** Ds [281] 110

Caesium **Explosive/flammable**
If you ever come across caesium, handle it with care! Left alone in air, caesium metal bursts into flames. Put in water, it explodes violently.

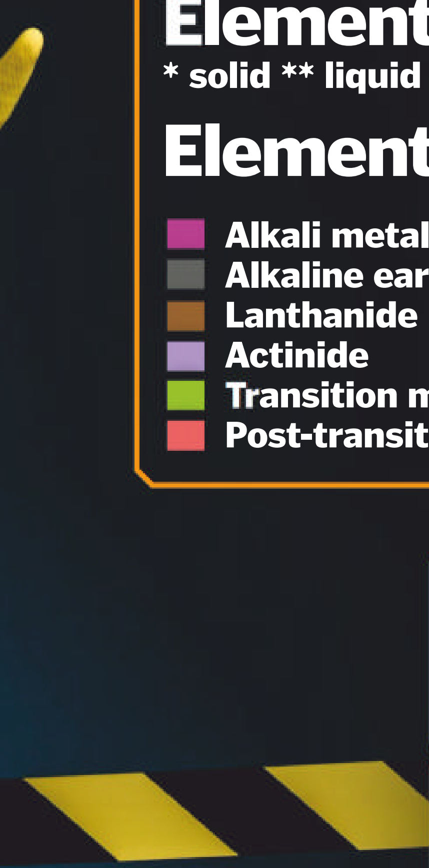
Lanthanum * La 138.91 57	Cerium * Ce 140.12 58	Praseodymium * Pr 140.91 59	Neodymium * Nd 144.24 60	Promethium * Pm [145] 61	Samarium * Sm 150.36 62	Europium * Eu 151.96 63	Gadolinium * Gd 157.25 64
Actinium * Ac [227] 89	Thorium * Th 232.04 90	Protactinium * Pa 231.04 91	Uranium * U 238.03 92	Neptunium * Np [237] 93	Plutonium * Pu [244] 94	Americium * Am [243] 95	Curium * Cm [247] 96



Sodium metal in chlorine gas reacts with a bright flash to make salt

Plutonium **Radioactive**
Plutonium's atomic structure enables nuclear weapons, and makes it highly radioactive. Being radioactive means that its atoms break down, spitting out chunks that can badly damage human cells.

DID YOU KNOW? *Thallium used to be sold as poison to kill rats and mice, but was withdrawn because it can also kill people*



Element state

* solid ** liquid *** gas **** unknown

Element group

- Alkali metal
- Alkaline earth metal
- Lanthanide
- Actinide
- Transition metal
- Post-transition metal
- Metalloid
- Other non-metal
- Halogen
- Noble gas
- Unknown chemical properties

							Helium *** He 4.003 2
		Boron * B 10.81 5	Carbon * C 12.01 6	Nitrogen *** N 14.01 7	Oxygen *** O 16.00 8	Fluorine *** F 19.00 9	Neon *** Ne 20.18 10
		Aluminium * Al 26.98 13	Silicon * Si 28.09 14	Phosphorus * P 30.97 15	Sulfur * S 32.07 16	Chlorine *** Cl 35.45 17	Argon *** Ar 39.95 18
Copper * Cu 63.55 29	Zinc * Zn 65.39 30	Gallium * Ga 69.72 31	Germanium * Ge 72.63 32	Arsenic * As 74.92 33	Selenium * Se 78.96 34	Bromine ** Br 79.90 35	Krypton *** Kr 83.80 36
Silver * Ag 107.87 47	Cadmium * Cd 112.41 48	Indium * In 114.82 49	Tin * Sn 118.71 50	Antimony * Sb 121.76 51	Tellurium * Te 127.60 52	Iodine * I 126.90 53	Xenon *** Xe 131.29 54
Gold * Au 196.97 79	Mercury ** Hg 200.59 80	Thallium * Tl 204.38 81	Lead * Pb 207.2 82	Bismuth * Bi 208.98 83	Polonium * Po [209] 84	Astatine * At [210] 85	Radon *** Rn [222] 86
Roentgenium **** Rg [281] 111	Copernicium **** Cn [285] 112	Ununtrium **** Uut [286] 113	Flerovium **** Fl [289] 114	Ununpentium **** Uup [289] 115	Livermorium **** Lv [293] 116	Ununseptium **** Uus [294] 117	Ununoctium **** Uuo [294] 118

Terbium * Tb 158.93 65	Dysprosium * Dy 162.50 66	Holmium * Ho 164.93 67	Erbium * Er 167.26 68	Thulium * Tm 168.93 69	Ytterbium * Yb 173.04 70	Lutetium * Lu 174.97 71
Berkelium * Bk [247] 97	Californium * Cf [251] 98	Einsteinium * Es [252] 99	Fermium * Fm [257] 100	Mendelevium * Md [258] 101	Nobelium * No [259] 102	Lawrencium * Lr [262] 103

Arsenic Poison
The well-known poison arsenic also confuses our cells. That's because its properties are similar to the essential element phosphorus, which is just above it in the periodic table.

Fluorine Corrosive
Fluorine's atomic structure makes it greedy for electrons from other atoms and therefore extremely reactive. It can corrode, degrade or modify nearly everything, making it very toxic and corrosive.

Antimony Poison
Antimony is below arsenic in the periodic table, and the two elements have similar poisoning effects. This is because both behave like phosphorus. Antimony damages people's livers and makes them vomit.

Cadmium Poison
A true heavy metal, cadmium can interfere with how calcium builds up bones in our bodies. Cadmium can also mimic zinc, which we need to live, but without its benefits.

Thallium Poison
Thallium is physically similar to another element, potassium, which keeps us alive. But thallium doesn't behave exactly the same way, so it confuses our cells and stops them working.

Lead Poison
Lead used to be very common in paint and petrol. However, we now know it damages the brain and kidneys. Today it is used much more carefully.

5 FACTS ABOUT
SOMETIMES DANGEROUS, SOMETIMES USEFUL

1 Painting a gloomy picture
Dutch artist Vincent van Gogh wanted to eat paint to try to kill himself. The yellow paint he used for his famous Sunflower pictures contained chromium, making it poisonous.

2 Hydrogen fuels cleaner heating
The natural gas many people use for heating their homes produces greenhouse gases that cause climate change when it burns. Because hydrogen burns easily, it might replace natural gas.

3 Friendly in low doses
To keep swimming pools clean without harming ourselves, we use very small amounts of chlorine. Usually swimming pools contain just one molecule of chlorine for every million water molecules.

4 Exceptionally bright hopes
Cadmium's poisonous nature means companies are removing it from most products, but there is one exception: some solar panels are made from a cadmium compound whose benefits outweigh their risks.

5 Drop-dead gorgeous
Poisonous antimony compounds were used in ancient Egypt as eye make-up in around 3100 BCE. The wearers had no idea just how unhealthy their vanity was!

Unlike regular contacts, lenses are fully contained, allowing use in activities such as water sports

How to improve vision forever

These contact lenses can be permanently embedded into your eyes with a clever bit of surgery

Being able to see our surroundings clearly enhances our lives and determines what we can do. For most it is a necessity, improving safety and allowing independence in daily activities.

Some people are blessed with perfect vision, taking for granted the ability to see well naturally. It can be something of an inconvenience and a daily reminder of poor vision when the first act of every morning is to fumble for your glasses just to see the end of your bed. So what if there was a way to emulate the eyesight you wish you had permanently? Would you consider a surgical implant to achieve this?

One option considered by many are implantable contact lenses. These invisible aids are mainly an option for those who suffer from myopia - meaning they are short-sighted. Sitting inside your eyes, they provide people with constant high-quality sight.

Called Implantable Collamer Lenses (ICL), they work next to your eyes' natural crystalline lenses to bend light rays onto the retina. In doing this, images presented in daily life become clearer. Wearers don't feel the embedded lenses against the eyelid as they would when wearing temporary and removable contacts.

Over 50 years since the manufacture of the first modern contact lenses began, these convenient optical aids and their applications continue to develop, allowing millions of people to retain their sight when nature has failed them.

How contact lenses are implanted

Permanent eyesight perfection may sound like a dream, but first there is a procedure to endure that involves cutting into these precious organs. These contact lenses are placed either between the cornea and the iris or just behind the iris. In this process, which can take around 20 minutes per eye, the natural eye lens remains intact.

Limiting the invasive aspect of the surgery, the contact lenses' material enables them to be folded for insertion. This reduces the size of the hole that needs to be cut into the eye. The total depth of the incision is about 2.5mm. Before the lens enters the eye, a gel is first applied to prevent any damage. Finally in place behind the iris, the lens is rotated to the correct position.

When the procedure is complete, it can take a couple of months to fully heal, but most people can return to daily activities in a matter of a few days. The implanted lens doesn't change over time, but the eye's natural lens can change. For this reason those with lens implants are recommended to attend check-ups.

No stitches are required after a lens implant

What happens if my vision changes?

Committing to implantable contact lenses doesn't mean you are stuck with them for life. Should they no longer suit your vision, or if you simply don't want them anymore, they can be replaced or removed. This is because this surgery doesn't change the shape of the cornea, or its function. While you can change your contacts as and when your prescription changes, it is worth analysing the stability of your eyesight and the potential of multiple surgeries.

A thorough eye evaluation takes place before surgery, including measuring dimensions to determine implant size

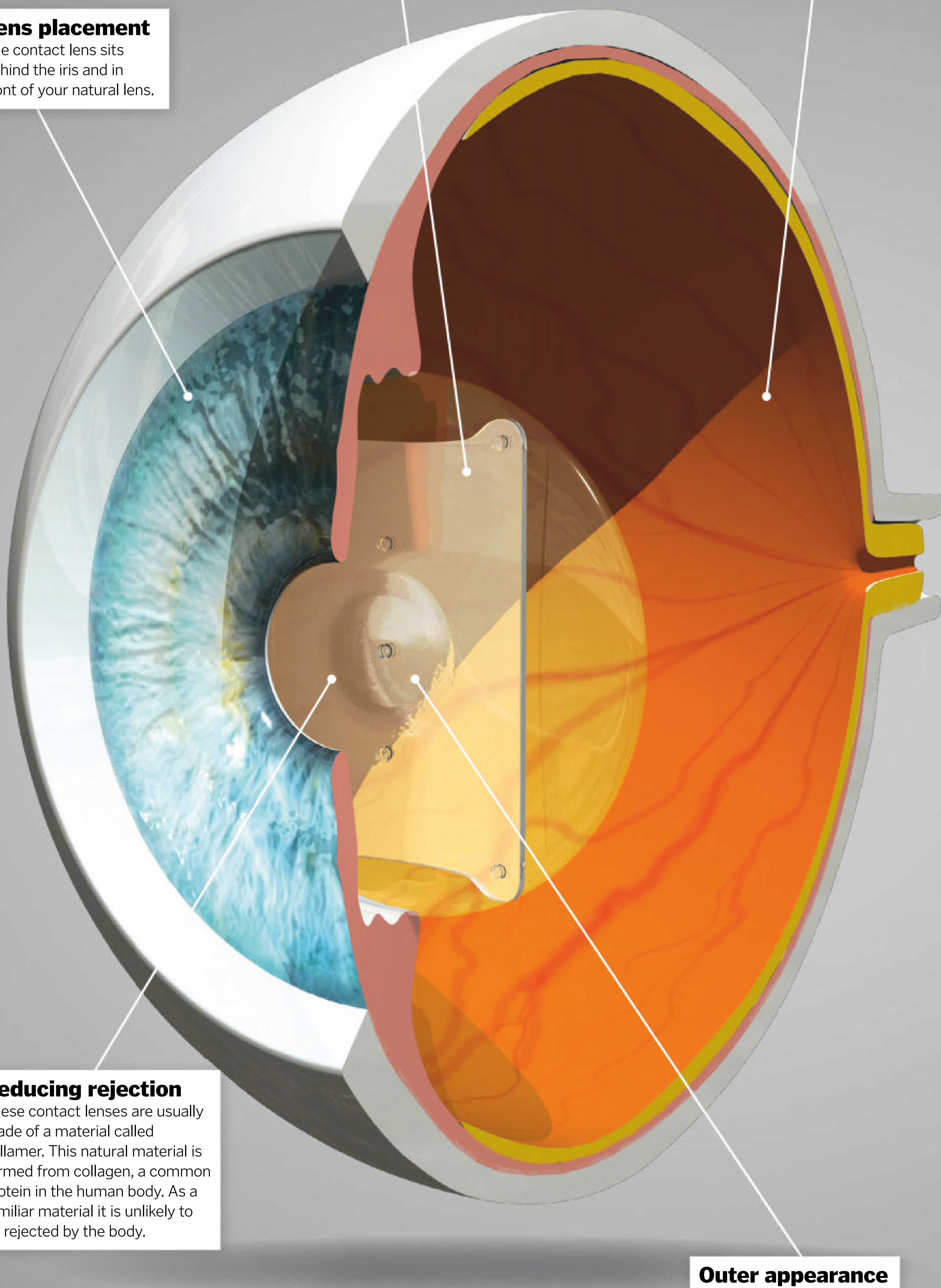
Inside the eye

When inserted, how does an implantable contact lens fit into the eye's anatomy?

Lens placement
The contact lens sits behind the iris and in front of your natural lens.

Limiting damage
Eyes are delicate organs that can be easily scratched. To ensure no damage is done in this invasive surgery, lenses are soft.

Light manipulation
To stop short-sightedness, contact lenses can work to focus light towards the back of the eye. This signals the eye to focus better on objects further away.



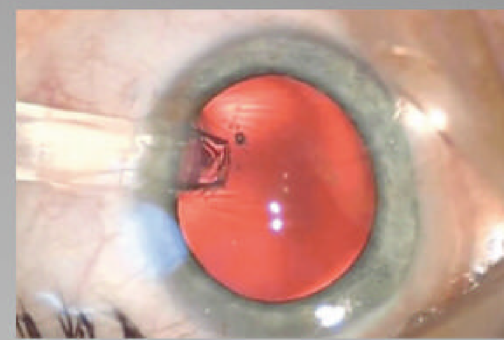
Reducing rejection
These contact lenses are usually made of a material called collamer. This natural material is formed from collagen, a common protein in the human body. As a familiar material it is unlikely to be rejected by the body.

Outer appearance
Lenses that are placed behind the iris are hidden and not visible. Those that sit in front of it can be seen when looking closely.

AR ZONE! SCAN HERE

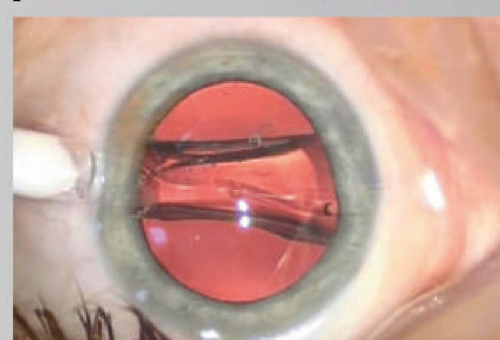
Under the knife

How the surgery implants the lens within the eye

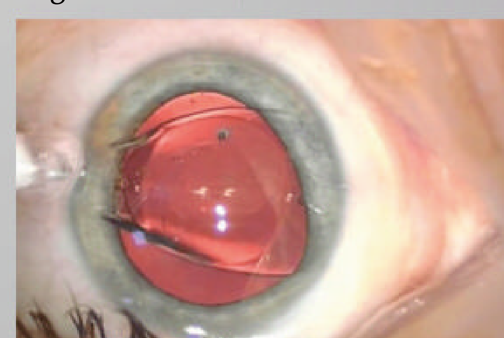


1 Rolled up in the apparatus, the contact lens is ready to be inserted.

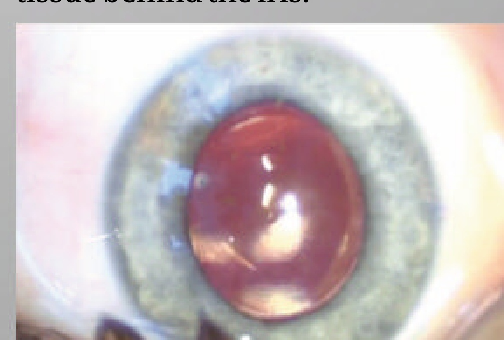
2 After the pupil has been dilated to increase the area, the lens is pushed into the centre.



3 After removing the tool from the contact lens, it automatically begins to unfold.



4 Once it has fully unfolded, the surgeon tucks the edges into tissue behind the iris.



5x © Augen33

5 Fixed behind the pupil, with the edges out of sight, the lens is undetectable.

"When learning, a cat closely observes what goes on. Originating from watching their mothers hunt, today domestic cats can learn how to get into cupboards by watching you."

How to tell what a cat is thinking

These sociable animals communicate with each other both verbally and visually, but how can we learn to think cat?

Words by **Ailsa Harvey**

As one of the world's most popular pets, there are more than 500 million domestic cats living in homes all over the world. People are keen to give their own thoughts on cats, sharing their favourite kitten pictures across the web and welcoming them lovingly into their homes. But have you ever stopped to question what cats think about us? What thoughts take place inside a cat's head?

According to some animal-behaviour experts, cats might not see as many differences in us as we see in them. Although they see our larger size, this doesn't make them intimidated. They often approach humans similarly to how they would treat another of their own species. If they continue to view us as fellow cats, they may also expect us to recognise their feelings using the clues other cats would naturally understand.

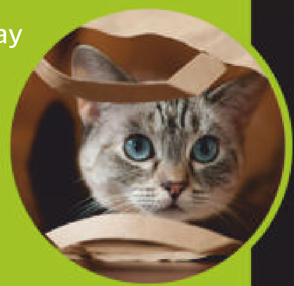
How can humans begin to think like their pets without the ability to speak with them? Much research has been carried out into the lives and behaviour of felines, both in homes and out in the wild.

A cat's thoughts continue into sleep, and their dreams involve complex thoughts and long sequences of events. While it took detailed scientific studies to better understand these furry pets, there are simpler ways you can get inside the mind of your feline friend through observation at home – you just have to know what to look for. And it is important for us to be able to process what is going on in our pets heads' if we are going to look after them. Ignoring vital signs of stress and discomfort can have significant impacts on the mental health of these animals.

Most mammals feel emotions, but the ways in which different species experience and display these varies. Cats are thought to experience happiness, sadness, fear, anger, grief, anxiety and curiosity. While less attached to their owners than dogs, cats are still believed to possess an affection for humans. This is shown in those cats choosing to stay with specific people in their houses, even when they are not

Cat personalities: the 'Feline Five'

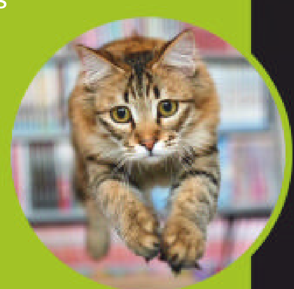
Like humans, research has shown cats to have five main personality traits



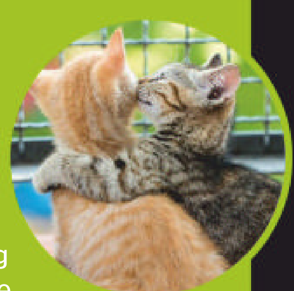
1 Skittish
An anxious cat will run away from visitors and hide from new situations until they have established safety. If your cat is shy, it is best to ensure there are multiple places to hide around your home.

2 Outgoing
Curious and extroverted cats need constant brain stimulation. Domestic cats with this trait may get bored easily, so continuous new items are needed to keep them occupied. This might mean buying new toys to get their heads around.

3 Dominant
This uniquely feline personality comes from wildcats showing who is in charge in wild groups. Dominant cats can prove a problem in households with more than one cat as they often take food and toys from the less dominant.



4 Spontaneous
Cats are impulsive in a different way to humans. Their spontaneity isn't always a choice, and comes from anxiety. Unable to cope, erratic cats act in unpredictable ways. If your cat shows random aggression, you shouldn't shout at them, as this can make them more stressed and exacerbate their spontaneous acts.



5 Friendly
Sociable cats are often those that were exposed to constant interaction as kittens. Appearing happy most of the time, these cats get along with others in the area with little fighting. Friendlier cats also show more affection and contact with their owners.

© Getty

Their wild side

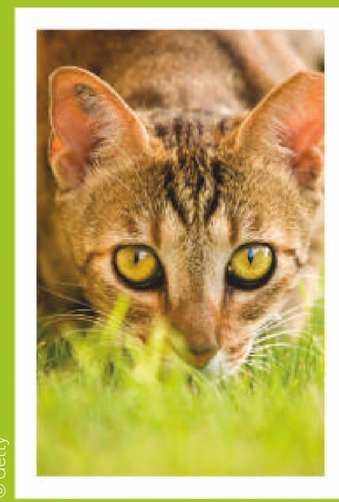
Wild cats lead entirely different lives to those within our households, but they still share some of the same traits. Tigers and house cats share around 95 per cent of their DNA, and in some mannerisms this can show.

Initially, domestic kittens have to learn to like people, with regular interactions and training necessary to develop their dependence and co-existence within a human household. After adapting to tamer lives, how do cats continue to display habits of their distant relatives?

The most obvious link to their wild side is their approach to food as prey. Playing with their food, cats quickly learn how to torment and disorientate animals before killing them. You can feed your cat all the tinned food in the world, but chances are they will still drag a dismantled mouse into the house from time to time.

On a separate issue, have you ever wondered why your cat insists on gently headbutting you as it passes by? This behaviour stems from particularly social big cats – lions. Their faces are full of scent glands on their chins, cheeks and lips, and both lions and domestic cats brush these against others to declare them friends or allies, so maybe you can take it as a compliment.

A less forgivable quality of wildcat nature for many feline owners is evident on furniture, curtains and carpet in the form of scratch marks. As a technique used in the wild to mark territory, scratching trees shows other cats passing by the height of the territory's owner – inferring their strength. This may intimidate other cats, but in the confines of our houses the emotion mostly generated is frustration.



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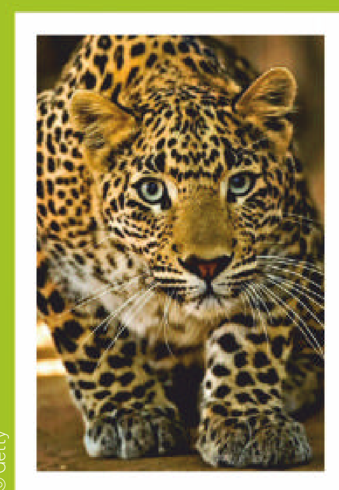
Both wild and domestic cats stalk their prey, staying low, hiding with a fixed gaze before pouncing



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Inside a cat's brain

16 days

This is the average time taken before a newborn kitten responds to noise and sound. Their whiskers detect stimuli and send signals to the brain

91,000 gigabytes

A cat's brain can store over 1,500 times more information than an iPad

16 hours

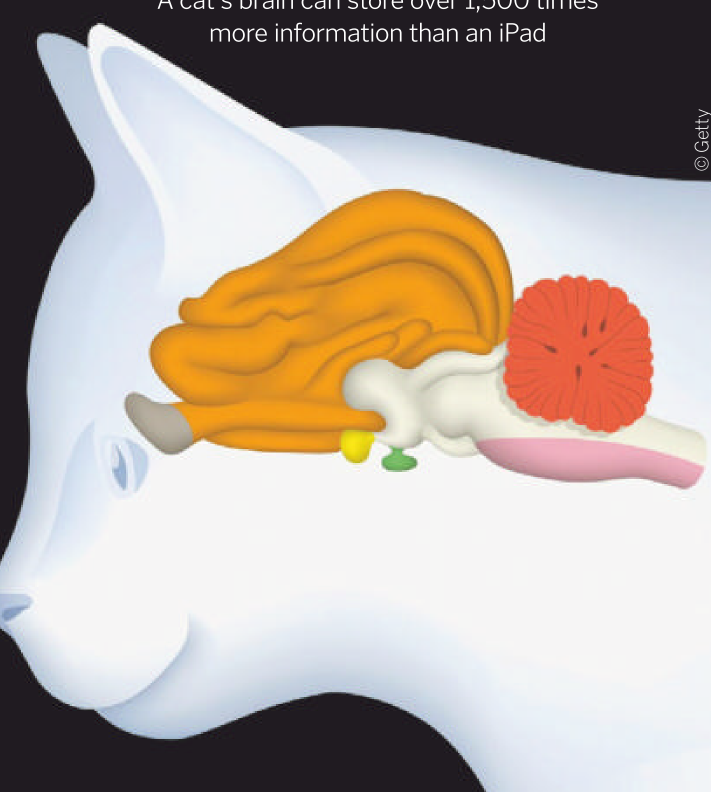
A cat can hold a short-term memory 200-times longer than a dog

300 million

Cats' brains have almost twice as many neurons as dogs'

6.1 trillion

The number of operations made by a cat's brain every second



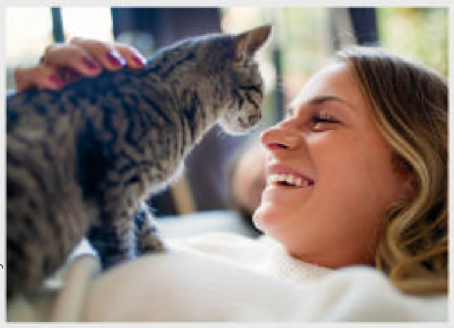
© Getty

being provided with food.

Cats are smarter than we may give them credit for. As we analyse them, they are also taking in our movements and actions. In some households, cats may seem to favour one family member over another. Often this is because they have observed who is more likely to give them a treat. By learning to understand and respect your cat better, you may even win them over as their favourite human.

5 FACTS ABOUT
HOW TO COMMUNICATE WITH YOUR CAT

1 Blink slowly When your cat performs a series of long, slow blinks, this is actually a sign that your cat is happy and trusts you. Cats use this to show others that they don't see them as a threat, establishing a trusting relationship.



© Getty

2 Don't stare Creating the opposite effect to blinking, staring can be threatening to cats. This can be difficult for some pet owners as they love to watch their cats, but be sure not to stare directly for prolonged periods – unless you intend to start trouble.

3 Understand chattering You may have noticed your cat making a range of different noises. This chattering is generally a good thing and is a cat's way of greeting you and communicating.

© Getty

4 No tummy rubs Often when cats relax they lie on their backs with their bellies exposed. This gives many owners the urge to pet them. Generally cats don't like being rubbed here. Instead, you should build their trust by understanding that they want to be left alone to relax.

5 Listen to purrs When your cat is content, it will make the soft purring noise that most owners love to hear. While this noise is a sign of love, you should be aware that when a cat is sick it also purrs. Always ensure your cat is healthy.

Understanding body language

From the tips of their ears to the ends of their tails, discover what a cat is trying to tell you

Alerted eyes

Eyes are often a gateway to emotion, and for cats this is no different. The size of a cat's pupils and the wideness of their eyes at any given time can be used as an indication of inner feelings.

Large pupils on a cat show that they are highly stimulated by their surroundings. Whether they are absorbing signs of threat or excited or surprised by a change in the environment around them, their eyes are usually one of the best giveaways.

Pupils constrict when a cat is angry or fearful. Just before making a swipe at a teasing owner, you will see a cat widen its eyes so that they are large and round, but the pupil will be a small black slit in the centre. Sometimes the eyes aren't entirely visible, revealing only a sliver of the eye through narrowed eyelids. This is an affectionate sign, and can mean they trust you and are relaxed enough to fall asleep.

Partially dilated pupils can be a sign of relaxation and peace of mind when the eyes are slightly closed. These pupils in wide eyes can mean the cat is alert.

Cats' pupils are usually vertical slits, which are capable of adapting quickly to light. Smaller slit shapes will be seen in the light, with wide, round pupils in the dark.

Wide, round pupils have a variety of possible meanings. Usually seen when a cat is absorbing surroundings intently, these eyes can show affection, alertness, play and fear.

Small slits are a warning of conflict between cats. Narrowing pupil size is a mechanism used to avoid injury.

© Shutterstock

Proportionally much smaller than a human's, domestic cats' brains take up 0.91 per cent of their body mass. Human brains are roughly 2.33 per cent of their mass in comparison.

Ear indication

The position of a cat's ears varies based on two crucial factors: aggression and fear levels. Unlike us, cats can easily point their ears forward, sideways and backwards with up to 30 muscles controlling them. Turning 180 degrees and rising and folding, these extremities act as a display of their feelings.

In a natural state of being relaxed and happy, a cat's ears face forwards and tilt slightly back. If it hears a noise they become more upright, but give a constant appearance to others that they are alerted to the surroundings.

The more fearful the feline, the lower the ears become. When overcome with fear the animal isn't likely to be aggressive, and the ears face right back behind the head. If the cat is scared but also aggressive, its ears can be seen turning backwards but staying pointed upwards to assert as much dominance as possible.

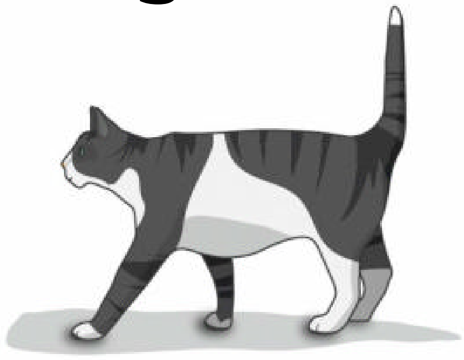
The aggressive state of a cat is monitored in the ears by pointing upwards. Regardless of which way the ears are facing, sitting upright gives a more threatening overall appearance.

Sometimes these feelings aren't instant and the cat is apprehensive. When unsure of how to respond to its surroundings, a cat can sometimes keep one ear up and one down.

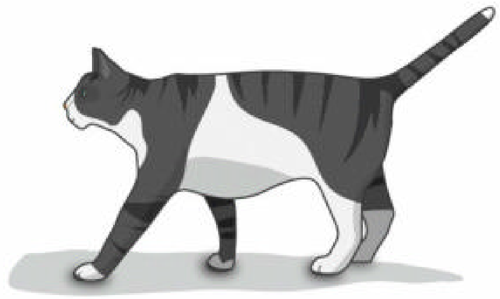
© Getty

Telling tails

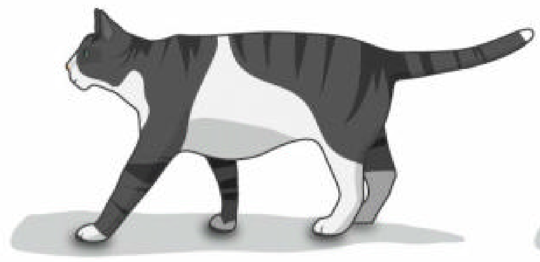
Your cat expresses a range of emotions with its rear end



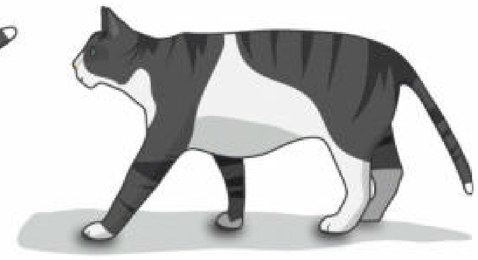
Content
When calm, a straight vertical tail is a cat's way of showing it is pleased to see you.



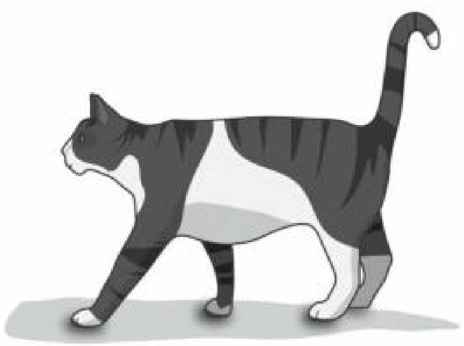
Uncertain
If pointing up at a 45-degree angle, the cat isn't being threatening but is unsure how it feels about the situation at hand.



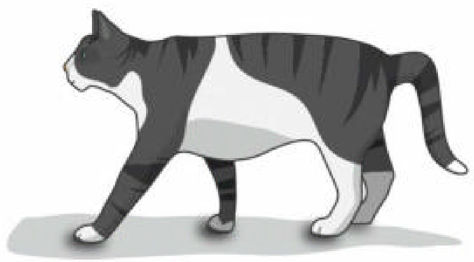
Mocking
If you ever see your cat swaying its upright tail, it is likely showing a derisive attitude towards you or your actions.



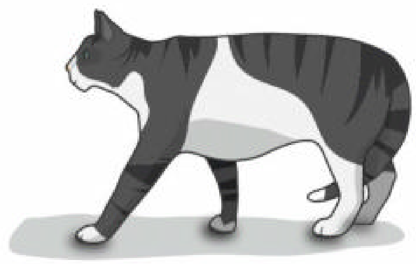
Ecstatic
Being greeted by a completely upright and quivering tail signifies that your cat is very happy to see you.



Friendly uncertainty
An upright tail with a hooked tip shows uncertainty on the cat's behalf, but with no signs of aggression.

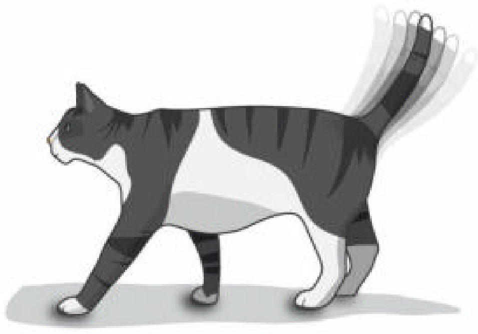


Amicable
A tail held out horizontally behind a cat means it isn't scared or angry. You have caught your cat in a mild, pleasant mood.



Defensive
Pointed down with a hooked end, the cat isn't angry but is ready to strike out if a threat emerges.

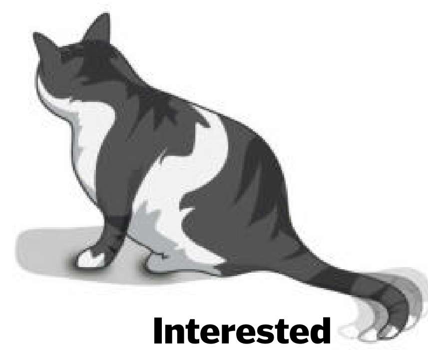
Passive aggressive
When your cat sits, thrashing its tail around on the floor, you might not want to aggravate it further as it is probably in an irritable mood.



Highly angry
The most obvious sign of cat anger, a straight, bristling tail is used by cats as an attempt to appear bigger than they are. If a threat approaches a cat in this state it will retaliate.

Agitated
If you see your cat's tail pointing straight down, this is a sign to give it some space. It is likely to be agitated and potentially aggressive if agitated further.

Submissive
Walking with their tails tucked under their legs, cats are showing compliance. When in confrontation, cats express their capitulation by doing this.



Interested
Sitting or lying down indicates that a cat is relaxed, but with its tail tapping the ground, they are also fixated on something happening around them. In this state, cats are deceptively alert.

Interpreting posture

The shape of a cat's main body and the way they move are a constant tool for silently expressing their mood. By differentiating between the animal's noises we can further determine their emotions.

An arched back is a common depiction of a scared cat, but this isn't all this means. If the fur is standing upright then the arched cat is frightened or angry, but flat fur means it will let you stroke it. These similar shapes have two very contrasting outcomes and show the importance of looking for all the signals.

Finding your cat lying on its back also has a range of meanings. A purring noise indicates that the cat is calm and relaxed. This shouldn't be mistaken for growling, which can be heard when the cat is upset and likely to act out.

Identifying spring buds

As the flowering buds on trees begin to appear, here's how you can tell them apart

A plant's buds act as a shield for the delicate flowers inside. Flowers of different shapes, sizes and forms come with individual and distinct protection. Throughout winter these buds remain closed and dormant, surviving the cold until their time comes to thrive in the spring, making a vibrant emergence from their compact casing. While it's usually easy to distinguish a species from its distinct flowers, buds can have more subtle differences. This visual guide to the more common tree buds should help you identify them.

Alder
[Alnus glutinosa]
Lilac buds appear on light brown, sticky stems. They live in damp areas near marshes and rivers.

Ash
[Fraxinus excelsior]
Ash trees are identifiable by their two tiny, sooty black buds either side of a larger bud.

Beech
[Fagus sylvatica]
Beech buds are long and thin, with sharp points and spiky cases, and are a coppery-brown colour.

Blackthorn
[Prunus spinosa]
A blackthorn's buds are dark in colour. They're dispersed along the spiny, black-purple bark.

Cherry
[Prunus avium]
Found mainly in oak woods, their egg-shaped buds can be seen displaying dark-orange, blunt points.

Common lime
[Tilia x europaea]
Found on smooth, brown branches, common lime tree buds are red-pink and pointed.

Downy birch
[Betula pubescens]
These buds are small but prominent. Usually brown in colour, they sometimes hold a greenish tinge.

Elder
[Sambucus nigra]
Organised in pairs on opposite sides of the branches, purple buds grow to have spiky tops.

English elm
[Ulmus procera]
These plants display red hairs scattered over both the buds and twigs, usually found near leaf scars.

English oak
[Quercus robur]
Plentiful in orange-brown clusters, these oak buds consist of around 20 waxy scales for protection.

Goat willow
[Salix caprea]
Beginning small and hairless, in early spring these yellow buds transform into fluffy, white spectacles.

Hawthorn
[Crataegus monogyna]
Before revealing their dainty, fragrant white flower, Hawthorn buds are small and red.

Hazel
[Corylus avellana]
Quite chunky in shape, hazel buds are relatively large, green ovals at the end of hairy shoots.

Hornbeam
[Carpinus betulus]
These long, rough buds cling close to the twig, following their line of growth. They are curved at the tips.

Horse chestnut
[Aesculus hippocastanum]
Dark-red and sticky to touch. Oval in shape, they are protected by scales.

Osier willow
[Salix viminalis]
These green-brown buds are narrow and press close to the twigs, disguising them.

Rowan
[Sorbus aucuparia]
Before bearing their scarlet berries, Rowan buds provide a contrasting dark-purple appearance.

Silver birch
[Betula pendula]
Small and slightly pointed, silver birch buds are mainly light green. Look for the trees' distinctive white bark.

Sweet chestnut
[Castanea sativa]
The oval shapes of these plum-coloured buds are smoother than the horse chestnut's and lack scales.

Sycamore
[Acer pseudoplatanus]
Contained within defined scales, sycamore buds are large and light green at the end of the twig.

Whitebeam
[Sorbus aria]
Irregular in shape with hair growing only around the edges, these are quite thick with a red-brown shine.

White poplar
[Populus alba]
White poplars have a spiral design. They grow following the direction of the twig and their scales overlap.

Wych elm
[Ulmus glabra]
A rarer find due to Dutch elm disease, wych elm have buds and twigs covered with orange hair.

White willow
[Salix alba]
Only protruding slightly, both narrow, brown buds and twigs are covered in white hairs.

HOW T
SPA

Words by **Jonathan O'Callaghan**

O FLY A
CRAFT

GET YOUR HANDS ON THE CONTROLS AS WE FIND OUT WHAT SPACE FLIGHT IS LIKE

Humans have been flying into space since 1961. Back then, Soviet cosmonaut Yuri Gagarin was launched on a short trip into space lasting just 108 minutes in an automated spacecraft called Vostok 1. Unsure how humans would cope with the rigours of spaceflight, engineers designed the spacecraft to need no human input – Gagarin was simply a passenger from launch to landing.

But in the subsequent years, things started to change. Complicated manoeuvres in orbit, such as attempting to dock two spacecraft, required direct human input. Similarly, missions to the Moon required real-time input from human pilots to actually land on the surface. It wasn't

© NASA

The crew of Columbia's first mission in its flight deck

© Getty

until 1981 with the arrival of NASA's Space Shuttle, however, that astronauts would get a real taste of what it's like to pilot a spacecraft fully from post-launch to landing.

Spaceflight is tricky because in the absence of gravity, there are multiple factors to consider. Planes rely on three axes: roll (front to back), pitch (side to side) and yaw (the vertical axis). But in space, with no atmosphere or gravity to also control the vehicle, pilots must also contend with the rotation and orientation of the spacecraft.

Spacecraft are equipped with thrusters to manoeuvre themselves in space. But once they reach orbit, it's not simply a case of pointing where you want to go and flying in that direction. Instead, it's all about orbital mechanics; if you want to catch something ahead of you, you actually need to lower the altitude of your orbit. This makes your orbit around Earth smaller, so you catch up. If you tried to go forwards, your orbit would increase and you would shoot past the target.

Vehicles like the Space Shuttle, which was retired in 2011, relied heavily on human input. With a cockpit that didn't look too dissimilar to that of an aircraft, the pilot used a joystick to manoeuvre the spacecraft in space. Firing different thrusters enabled the orientation of the Shuttle to be changed, letting it perform a number of tasks in orbit such as fixing the Hubble Space Telescope or deploying satellites.

At the end of its mission, the Shuttle would re-enter Earth's atmosphere. Most other spacecraft have handled end-of-mission by returning to Earth via parachute, touching down either on land or at sea, but not the Space Shuttle. Designed to fly through Earth's skies like an extremely heavy glider, the Space Shuttle could be piloted – with some difficulty – to a runway landing on the ground, ready for another flight.

NASA's newest astronauts after graduation, having completed a two-year training programme

There have been a lot of famous astronauts who have piloted different spacecraft. Neil Armstrong, of course, famously piloted the Apollo 11 lunar lander for its historic touchdown on the Moon in July 1969. Running low on fuel and frantically looking for a suitable landing site, Armstrong relied on his expertise to bring himself and Buzz Aldrin to a safe landing, with just seconds of fuel to spare.

Astronaut Robert Crippen, meanwhile, was entrusted with piloting the first crewed Space Shuttle mission in April 1981, carrying just himself and his commander John Young aboard Space Shuttle Columbia.

Today, many spacecraft rely on automation rather than human intervention. Russia's Soyuz spacecraft relies on an automated system to dock with the International Space Station (ISS). SpaceX's upcoming Crew Dragon capsule is designed to be fully autonomous, with astronauts on board having little input. Similarly, Boeing's Starliner spacecraft also uses automation, but with the potential for astronauts to take over when needed.

Virgin Galactic's space plane is designed to take paying customers to space

Flying a space passenger jet

Over the years, several attempts have been made to build vehicles that combine the flight of a plane with the spacefaring capabilities of a spacecraft, known as space planes. Today the only operational space plane capable of reaching space is Virgin Galactic's SpaceShipTwo. Carried into the air on a modified Boeing jet, the vehicle is then dropped and activates its rocket engine, soaring upwards.

The vehicle is designed to surpass the official boundary of space at 100 kilometres (62 miles) above Earth, where it gives its occupants several minutes of weightlessness. It then falls back into the atmosphere, turning its tail upwards using a 'feathering' system to survive the journey back to Earth and then landing on a runway. It is designed to carry up to eight people on board: two crew and six customers who have paid for the experience of going to space, with ticket prices currently about $250,000 (approximately £190,000).

What do you need to be a space pilot?

A degree

You'll need a bachelor's degree in engineering, biological science, physical science, computer science or mathematics to consider becoming an astronaut.

Flight time

If you want to be a pilot you'll also need at least 1,000 hours of piloting time on jet aircraft.

Good eyesight

You'll need to have 20/20 vision in both eyes if you want to become an astronaut – but you can use glasses!

Leadership skills

Make sure you can demonstrate key leadership skills, which is an important trait for anyone who wants to be an astronaut.

Team player

And you'll need to be able to work as a team – spaceflight is all about working with your crew, and if you can't work together, you won't fly.

Astronauts train in diving gear, as being underwater mimics weightlessness

© Bill Brassard/NASA

"In the absence of gravity, there are multiple factors to consider"

Neil Armstrong and Buzz Aldrin spent over 21 hours on the lunar surface

© NASA

STS-1, the first crewed Space Shuttle mission, lifted off on 12 April 1981

© NASA

Q&A Interplanetary missions

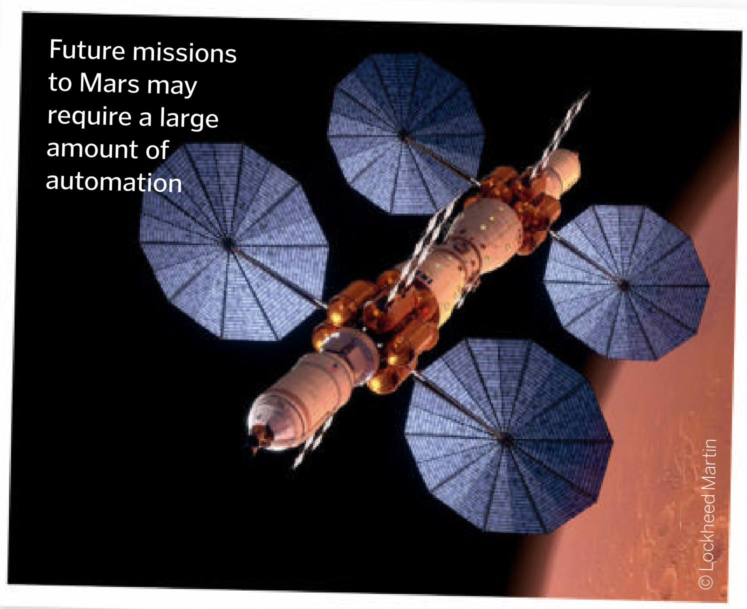
Andrea Accomazzo, head of the Solar System and Exploration Missions Division at the European Space Agency, tells us what it's like to guide uncrewed spacecraft to other worlds

© ESA

What spacecraft have you been involved with?
I've done Venus Express, a probe that flew to Venus. More recently I've been involved in an Earth observation satellite, Sentinel-3A. And now I've been acting as the flight director for the BepiColombo mission to Mercury, and we're launching a probe called Solar Orbiter, which will be orbiting the Sun.

What are the main things that need to be considered when flying to other worlds?
One huge difference is that the orbital mechanics are much more demanding than an Earth-bound mission. The second one is the reaction time; everything on a plane happens much more quickly than on a spacecraft. We collect all the input of what we want to do, we [create] a simulation of what is going to happen, we double check it, then we generate the telecommands for the spacecraft and we uplink them. They're typically valid for the next two or three days or the next week, depending on the mission. This is the way you control the spacecraft.

How do modern spacecraft compare to older spacecraft?
Almost every spacecraft now has an autonomous capability to determine which direction it's oriented in space. For Earth-observation spacecraft we not only have that, but the spacecraft are autonomous in determining where they are positioned around Earth [using GPS]. This is true for spacecraft which are orbiting Earth, but is not the case for interplanetary missions. If I'm approaching Mars, I cannot have a GPS telling me where the spacecraft is with respect to Mars. But I can have a camera that can take pictures of Mars and determines the movement of the spacecraft, and autonomously could determine the relative trajectory of the spacecraft with respect to the body. This is something that might [be used] more and more for spacecraft.



Future missions to Mars may require a large amount of automation

© Lockheed Martin

5 FACTS ABOUT SPACEFLIGHT

1 One orbit
Yuri Gagarin's first flight to space in 1961 involved just one orbit of our planet before he returned to Earth's surface in his Vostok 1 spacecraft.

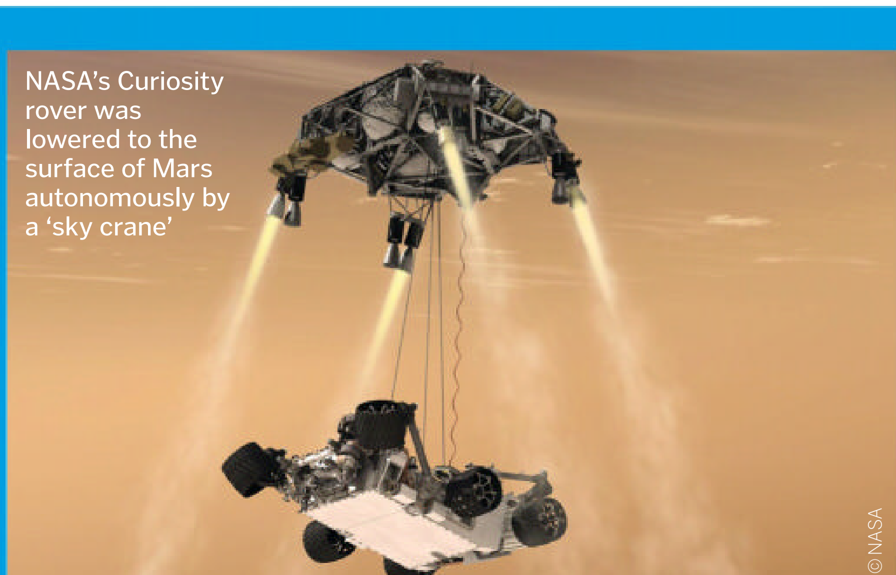
2 Weak at the knees
Prolonged spaceflight can have detrimental effects on the human body, lowering bone and muscle mass, so astronauts can struggle to stand when they return home.

3 Longest flight
The longest time spent by someone on one mission was Russian Valeri Polyakov, who stayed in space for 437 days on the Mir space station from 1994 to 1995.

4 Highest speed
The highest speed ever reached by humans was by the crew of Apollo 10. Their capsule reached 39,897 kilometres per hour on their return from the Moon.

5 Farthest from Earth
The Voyager 1 spacecraft is the farthest from Earth. At about 150 times the Earth-Sun distance, it takes more than 40 hours to send a command and get a response.

"Almost every spacecraft now has an autonomous capability"



NASA's Curiosity rover was lowered to the surface of Mars autonomously by a 'sky crane'

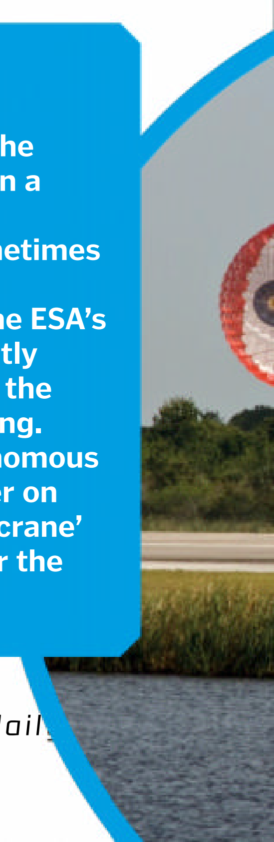
© NASA

Timing is everything

When it comes to autonomously landing on or flying to other worlds, the timing of everything in the mission is critical. Spacecraft must be given a series of commands to perform at given times so that they enter orbit around a planet or land on its surface. Sometimes this works, and sometimes it doesn't.

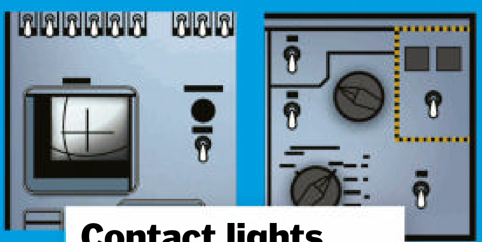
An infamous example of this not quite working was in 2016, when the ESA's Schiaparelli lander experienced a problem landing on Mars. It incorrectly calculated that it was below the surface – when it was still high above the ground – and deployed its parachute too early, leading to a crash landing.

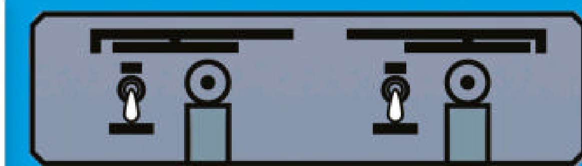
But things can go right, too. Perhaps one of the most complex autonomous manoeuvres on another world was NASA's landing of its Curiosity rover on Mars in 2012. The rover was dropped onto Mars by an innovative 'sky crane' system, with a thruster-powered platform using cables to gently lower the rover onto the surface.

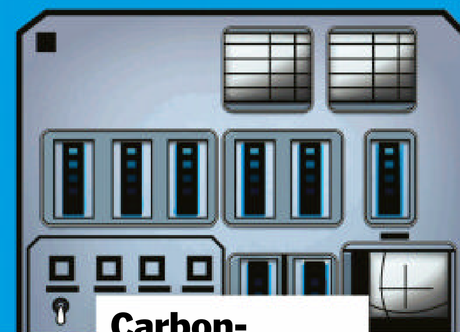


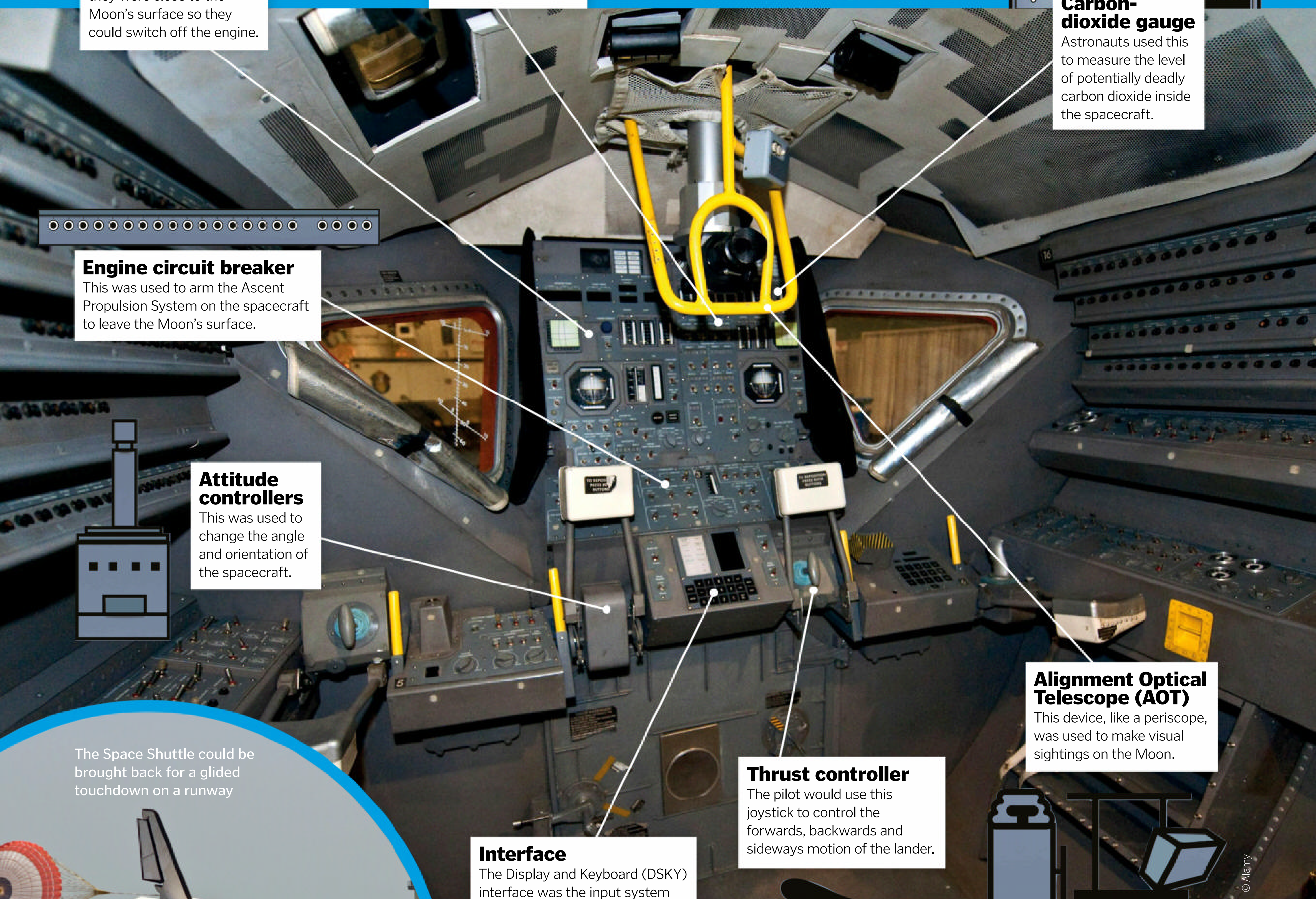
HANDS-ON THE CONTROLS

This was the control panel used to manoeuvre the old Apollo Lunar Modules









Contact lights
This told the crew when they were close to the Moon's surface so they could switch off the engine.

Utility light
These switches let the astronauts control the intensity of the light in the spacecraft.

Carbon-dioxide gauge
Astronauts used this to measure the level of potentially deadly carbon dioxide inside the spacecraft.

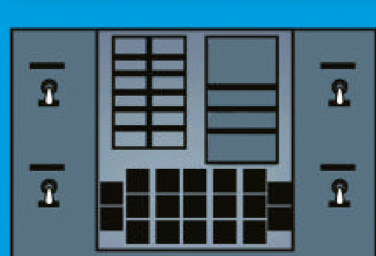
Engine circuit breaker
This was used to arm the Ascent Propulsion System on the spacecraft to leave the Moon's surface.

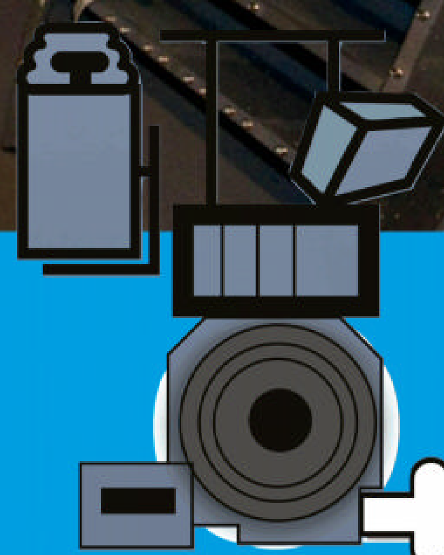
Attitude controllers
This was used to change the angle and orientation of the spacecraft.

Alignment Optical Telescope (AOT)
This device, like a periscope, was used to make visual sightings on the Moon.

Thrust controller
The pilot would use this joystick to control the forwards, backwards and sideways motion of the lander.

Interface
The Display and Keyboard (DSKY) interface was the input system for the spacecraft's computer.





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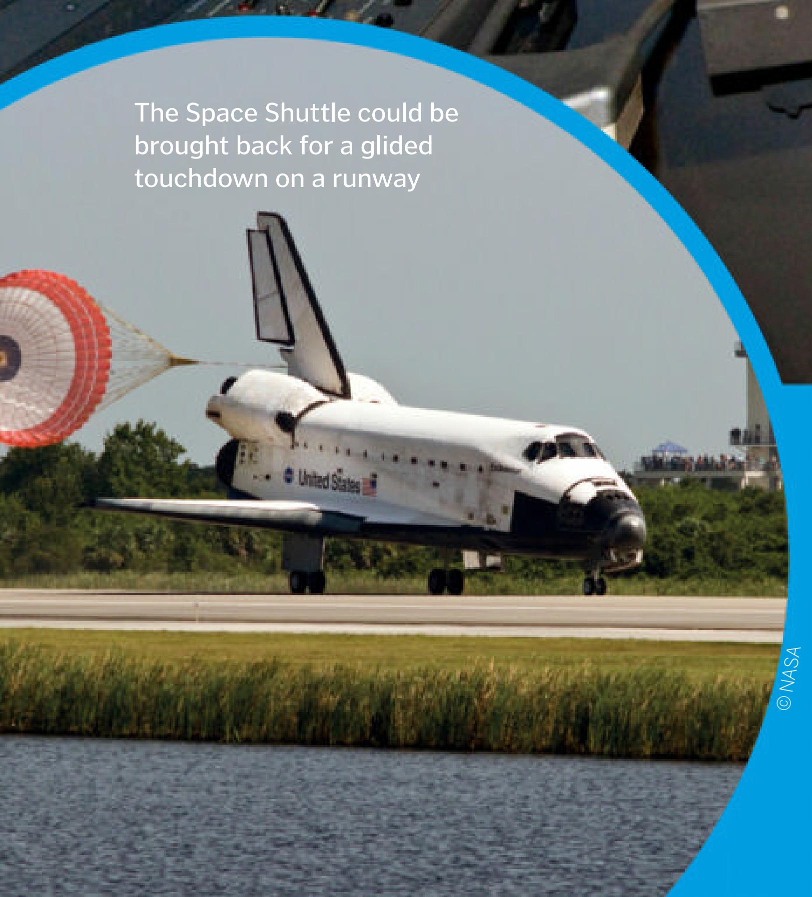


The Space Shuttle could be brought back for a glided touchdown on a runway

© NASA

Plants on other planets

How would forests on an alien planet survive and what might they look like?

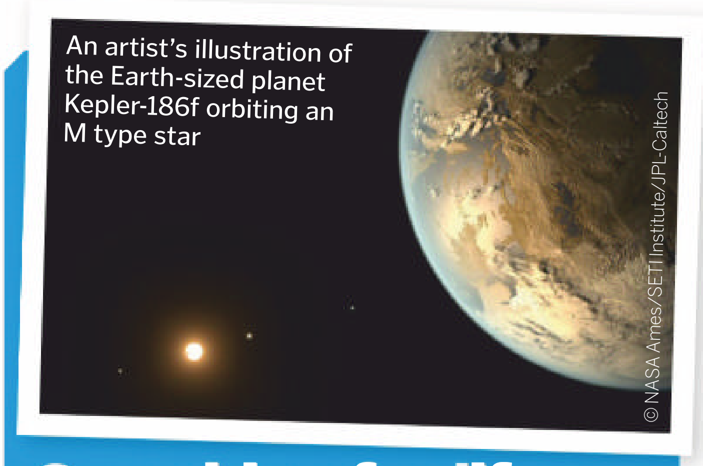
It might seem like a concept straight out of a sci-fi movie, but over the years astrobiologists have tried to determine what plant life might look like on other, potentially habitable, planets. On Earth, the majority of plant species sport a lush green colour due to a pigment called chlorophyll. This pigment is vital to the self-feeding process of photosynthesis. The plants on our home planet display their green colour as a result of their ability to absorb all the wavelengths of visible light, except for the wavelength that matches the colour green.

As a result these wavelengths are reflected from the plants' surface, making it appear green to the human eye. However, plants that might live outside of our planet or indeed our Solar System might not share the same aversion to the colour green.

To form a picture of what plants might look like on another world, the answer lies in the type of star a resident exoplanet orbits. Typically planets with the potential to sustain life orbit either an F, G, K or M type star. Our Sun is a G type star. These star types emit different wavelengths of light that plants and other photosynthetic organisms such as algae can utilise for photosynthesis. However, differences in the wavelengths of light emitted by these exoplanet-supporting stars can drastically change the appearance of alien planets. For example, cooler K and M type stars emit low levels of light, as much as half the amount that reaches Earth's surface. This may lead to light-hungry plants absorbing as much light as possible with little reflection, and may appear dark shades of red or even black.

© Caltech Illustration by Doug Cummings

Artist's impression of how an alien landscape might look, abundant in vibrant plant life



An artist's illustration of the Earth-sized planet Kepler-186f orbiting an M type star

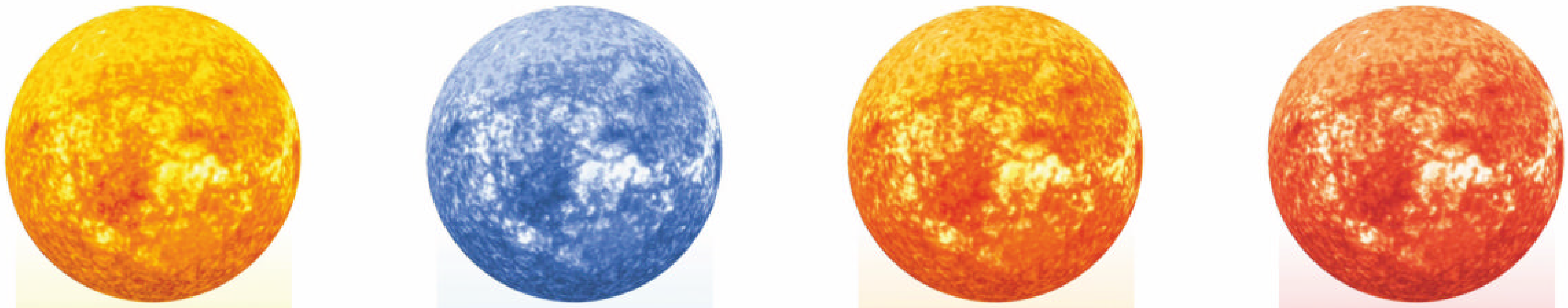
© NASA Ames/SETI Institute/JPL-Caltech

Searching for life

Understanding the colour of photosynthetic organisms, such as plants and algae, on other planets might seem a trivial pursuit. However, it can be a great tool for planet hunters. Along with reflecting unabsorbed colours, plants also reflect near-infrared radiation (NIR). Known as 'red edge', planet hunters can search for a rise in NIR, alongside visible light, in the hope of finding the next habitable exoplanet. The more vegetation or photosynthetic organisms on a planet's surface, the greater its red edge. This biosignature is particularly useful when exploring potential planets around M type stars, as these stars produce high levels of NIR, which would be more readily reflected by an exoplanet's plants.

Changing colours

How different stars can dictate the appearance of plants on other planets



G type star

Around 40 per cent of the electromagnetic radiation emitted from our Sun is the full-colour spectrum of visible light. With the exception of green-coloured wavelengths, plants on Earth absorb all other colours, particularly red and blue wavelengths. It is the energy from these two colour wavelengths that provide plants with enough energy to carry out photosynthesis.

F type star

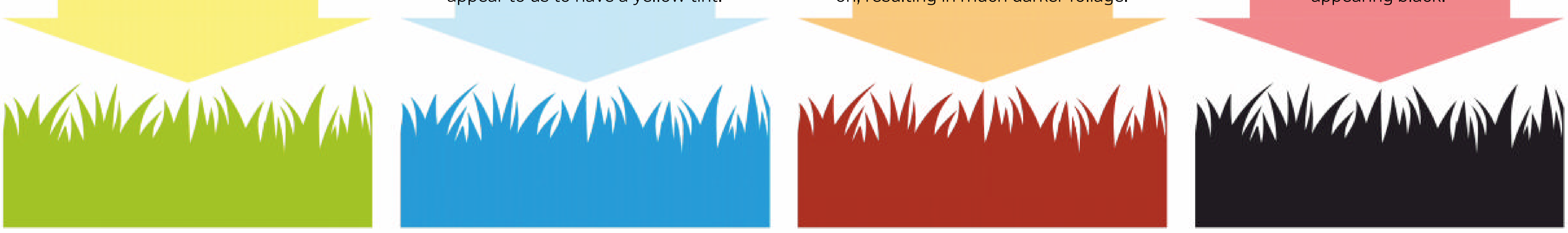
Compared to our own Sun, F type stars are typically hotter, bluer and radiate more harmful ultraviolet light. When bombarded with abundant blue light it has been theorised that an exoplanet's plant life might reflect excess blue light and UV radiation for protection, appearing with a bluish hue. However, it is also possible that they may have evolved a way to harness the blue light and reflect green and red, which would appear to us to have a yellow tint.

K type star

Sitting between G and M type stars, it's difficult to predict what colour photosynthetic life on planets orbiting K type stars would be. Similar in size to our Sun, alien plant life may have evolved in a similar way to those on Earth. However, K type stars release less visible light and a greater amount of near-infrared light, which would result in plants photosynthesising with all the light they can get their leaves on, resulting in much darker foliage.

M type star

With an average mass of around 0.3 times that of the Sun, M type stars are some of the smallest known stars. This also means that the light energy they produce is also minimal, but still enough to possibly support photosynthesis. With a limited amount of light, plants around these stars might not be as picky with what wavelengths they can absorb and might not reflect any colour, potentially appearing black.



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AIRFIX QUICK BUILD

- Stickers Included
- Rolling Wheels
- Pre-Coloured
- Push Fit

J6033
Jaguar I-PACE eTROPHY

Jaguar I-PACE eTROPHY

Build an Iconic Model

The all-electric Jaguar I-PACE has completed an historic treble at the 2019 World Car Awards. Not only has it won the coveted 2019 World Car of the Year and World Car Design of the Year titles , it has also been named World Green Car.

The I-PACE is the first model ever to win three World Car titles in the 15-year history of the awards.

The dramatic, cab-forward profile, short overhangs and taut, muscular haunches give it a sense of drama which set it apart from other SUVs, which when building with the 40 pieces included you will see as the car grows before you.

Jaguar and the leaper device are trademarks owned and licensed by Jaguar Land Rover Limited.

This vehicle has already become a true icon. You can create your own version at home with this Airfix QuickBuild kit. You can recreate brilliant scale models of a wide variety of iconic aircraft, tanks and cars with QuickBuild kits. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.

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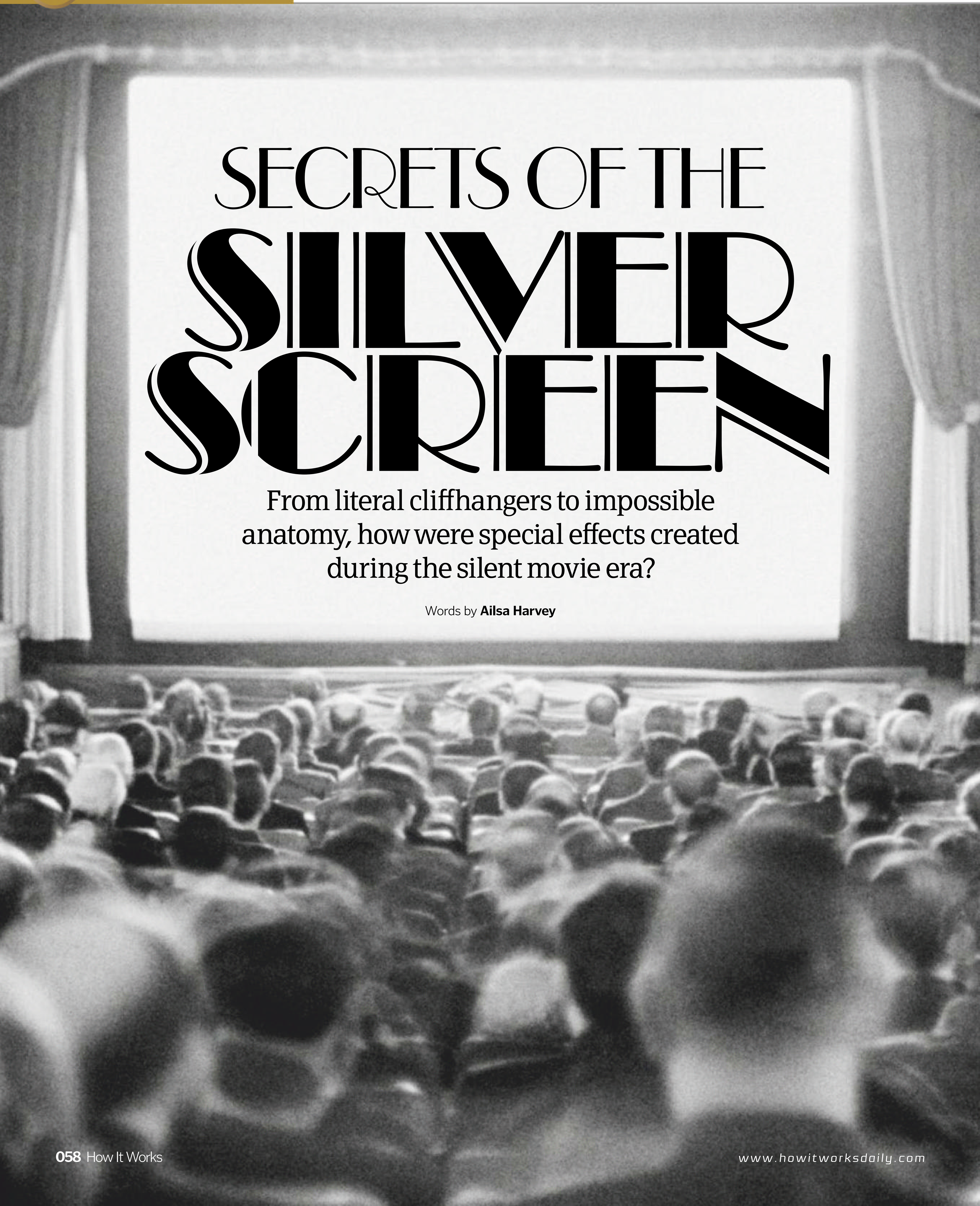


SECRETS OF THE SILVER SCREEN

From literal cliffhangers to impossible anatomy, how were special effects created during the silent movie era?

Words by **Ailsa Harvey**

Current film production and viewing experiences are in a different league to those of a century ago. Stepping into your local cinema, you know that your experience is going to be almost identical to that of someone in the next town. Films are produced as a full package of visuals and sound, ready to be widely distributed upon release. They are presented on enormous screens, encapsulating the room and placing viewers in the centre of the action.

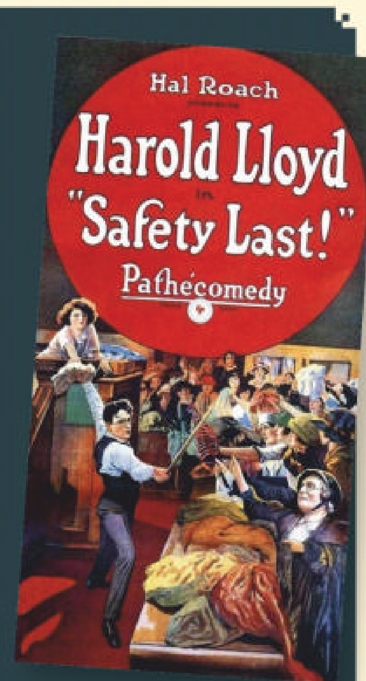
In the early 1900s the black-and-white masterpieces on cinema screens were totally silent and required an accompaniment of live musicians to add an extra element of drama. This was the silent era of film, and a notably successful one for Hollywood.

In a world long before technology allowed for computer-generated imagery (CGI), film directors of this time had to find ways to create gripping storylines while keeping the visuals believable. While today's manipulated graphics demonstrate next-level skill and can have us leaving the cinema in awe, in some ways the effects that were accomplished a century ago are even more impressive. How were actors able to swing from buildings, defy gravity or appear to perform science-defying acts with their bodies, despite such limited technology? Old-fashioned classics may not have been able to utilise computerised imagery to the point of perfection, like in modern-day movies, they had simpler yet effective ways of deceiving the eye. Most of the methods used in today's special effects are simply upgraded variations of those seen in classic Hollywood films.

Some of the best scenes on screen are the most extreme, whether that's through intensified danger, plot twists, unique comedy or raw emotion. Taking the characters out of the everyday and into situations nobody would choose to put themselves in was essential. But actors weren't stupid. To hang them from cliffs, manipulate their bodies or place them into dangerous environments would require artful camera placement and innovative trickery. Without computer-generated content, actors had to be incredibly nimble, believable and versatile. Meanwhile, camera skills and set construction were tested and explored to find the best shooting angles and put together realistic film sets. The silent-film era lasted from the mid-1890s to the late 1920s, but this wasn't the end for this type of film. Even once the 'talkies' became popular, silent films continued to be produced successfully for another decade.

Perspective sets

Safety Last! – 1923



The main character in *Safety Last!* encounters trouble when working as a sales assistant in the big city. Forced to exit the building while on the run, he finds himself in a rather compromising position. The rather amusing, yet terrifying scene required actor Harold Lloyd to dangle from a clock face over what appears to be an extreme drop. While no CGI was used to create this vision, Lloyd didn't have to risk his life when playing this part. Using a specially built set, the stage was constructed on a block on the roof of a tall building. By angling the camera during filming so as not to show the roof, the backdrop makes it appear as if nothing sits between his feet and the road, many metres below.


While what you see is unedited, it's what's happening just out of shot that counts


When first testing the safety of the mattress, a dummy bounced off and fell onto the street below

© Criterion Collection 'Location and Effects' documentary

Jelly props

The Ten Commandments – 1923

In one of the most memorable scenes in cinematic history, the ocean parts through the middle, creating a walkway. Today this imagery could be easily accomplished using computers, but in the 1920s a much simpler technique was exploited. Viewers could be fooled into thinking a miracle really had descended on the sea, but this is the work of a much-loved sweet treat: jelly. Proving its versatility, the gelatin in the dessert created the perfect image and consistency for the scene. A tank of jelly was recorded being flooded with water, and when the film was reversed, it gave the appearance of the sea parting.

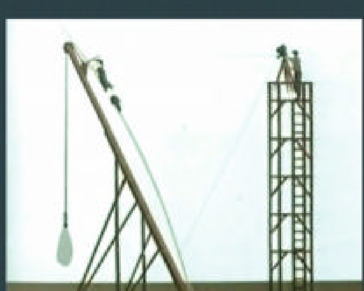

The close-up jelly footage was combined with film shot in California for the illusion of the sea parting

In the footage, Douglas Fairbanks appears to use a knife to slide down a sail

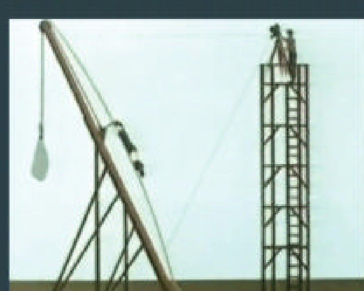
Harnessing

The Black Pirate – 1926

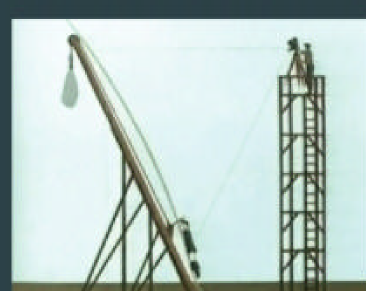
When Fairbanks' character reaches a merchant ship he plans on capturing single-handedly, the way he lands on deck brims with confidence. Filled with anger and eager for revenge at being attacked by pirates earlier in the film, he arrives in style as he destroys the ship's sail. But how was the scene manipulated to perfectly plan his descent? Using a weight to steady the motion, he is lowered in a controlled manner as he tears the sail in the process. To create the effect of being out at sea, aeroplane propellers placed behind the sail keep them billowing throughout the scene.



The actor is attached to the set using a harness



With a weight at the end of the string, descent is slowed

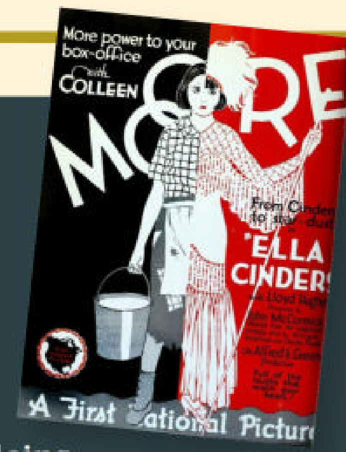


The weight rises to the top of the sail as the sail slices open

Charlie Chaplin rose to fame during the silent film era. Following the arrival of 'talkies', he continued to direct silent films

Split screen

Ella Cinders – 1926



In *Ella Cinders*, wannabe Hollywood star Ella is shown doing some science-defying eye tricks as she studies to become an actress. Her eye exercises involve the unusual spectacle of her eyes frantically darting off in separate directions.

To achieve this effect, half of the camera lens was covered and the other was shot in two takes. For the most realistic and seamless result, the actress needed to remain as still as possible so that the background fit together perfectly.

In these stills, her eyes move in different directions to the surprise of the audience

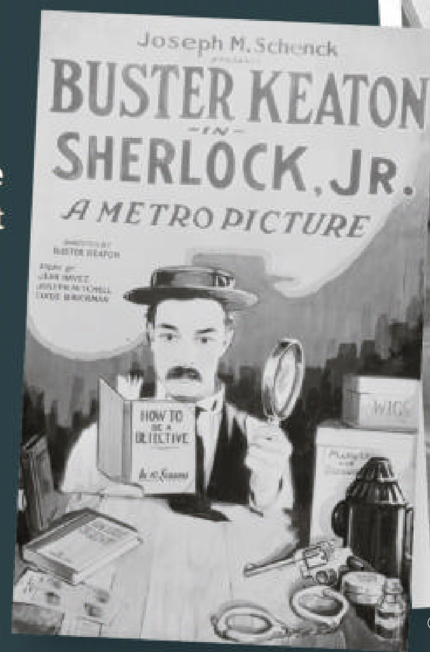
The first scene is shot with only the right half of the actress' face visible as she moves her eyes in a random sequence

The opposite side is covered. When the two halves are spliced together, her eyes look as though they move independently

Double exposure

Sherlock Jr. – 1924

Played by Buster Keaton, *Sherlock Jr.*'s main character longs to be a detective. And there is nothing smoother than the timing he casually displays in one motorbike scene. This scene looks like a case of being in the right place at the right time. As two trucks pass through a gap in his path, the biker is able to cross the gap unfazed. This stunt didn't need perfecting in real time due to an effect called double exposure. Filming the motorbike and the truck drivers separately and slotting the two separate pieces of film together at the right time created this interesting illusion.



© Getty

Buster Keaton rides on the front of a motorcycle for a scene in Sherlock Junior

How to jump a gap

A step-by-step on how they pulled off the stunt

Actor Buster Keaton is seen in the distance approaching a gap in his path

Two trucks are filmed travelling through the gap from the ground

The biker is filmed reaching the trucks at an opportune moment

The three vehicles meet in a smooth and fluid shot

To achieve this, the bike was filmed separately and the footage was then combined

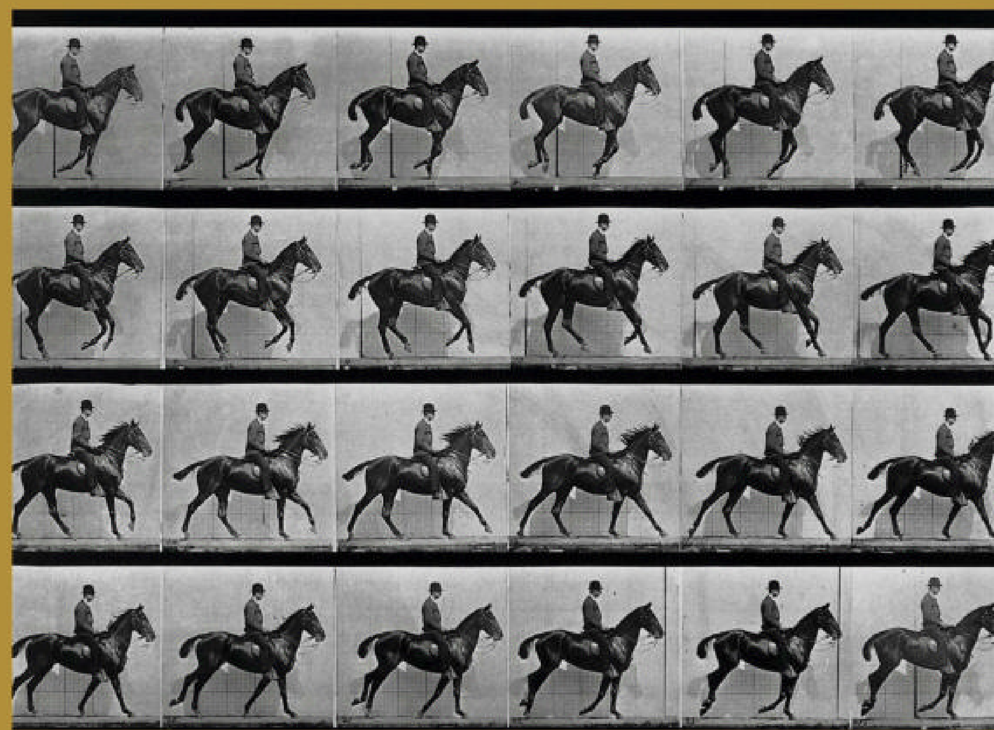
How does stop motion work?

Stop-motion animation was first used shortly before the 1900s, and the effect was brought into the silent-film era. In the early days of stop motion, film didn't exist, and the new technique was only viewed on a Stereoscope-fantascope. This device had a viewing section, and as pictures span around inside, entering and leaving the viewpoint, it appeared as if it was one moving image.

Animation in this form used a series of photographs which when played together in sequence caused the objects to move and interact with each other. Shown rapidly, each frame is played for a small fraction of a second, creating a smooth and fluid movement.

As one of the most advanced early uses of stop motion, the 1933 *King Kong* captured the imagination of its viewers. The live-action filming of human actors combined with the stop-motion creature models made it appear that the two were interacting in the same location. One fighting scene between King Kong and the Tyrannosaurus took seven weeks to achieve with stop motion.

This film effect became so widespread and successful that the method is still in use today. *Wallace and Gromit* is one of the best-known British stop-motion productions, with clay models being produced for each frame rather than drawings. In the first full-length *Wallace and Gromit* film, 43 different Gromit models were used.


© Alamy

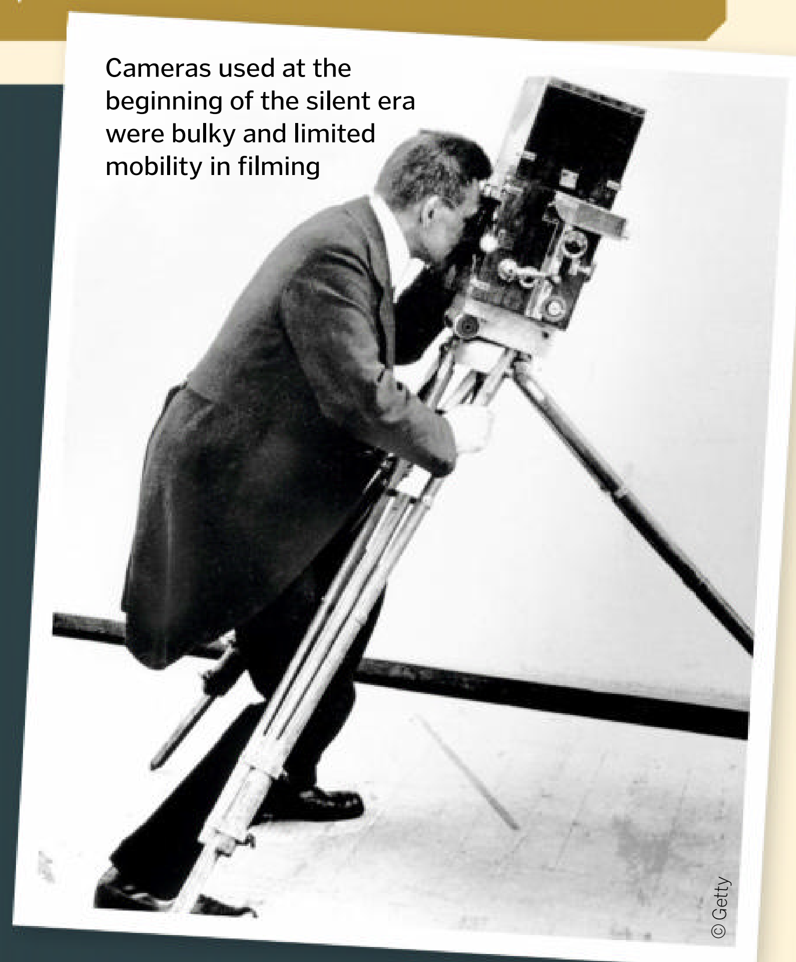
For images to play realistically in sequence, between 12 and 24 photographs are displayed per second

Cloning

Little Lord Fauntleroy – 1936

How do you have one actress play the part of two people in one scene? With double the roles comes double the exposure, in another case of filming through a matte cover.

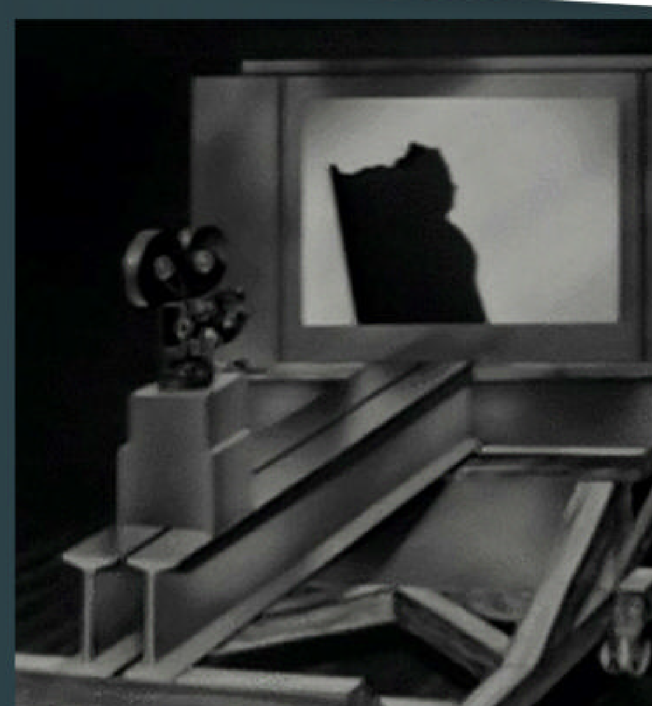
For one scene, where the actress plants a kiss on her clone's face, the still figure is filmed first. This enables an exact outline of one character to be used as a reference point. Knowing where the previously filmed footage will fall in the camera frame allows contact to be made accurately. For this the actress is being directed by those behind the camera and looking through the matte cover.

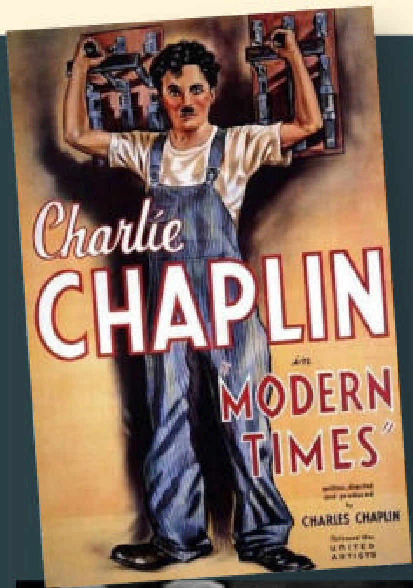

Cameras used at the beginning of the silent era were bulky and limited mobility in filming

© Getty


The character on the right moves, while the character on the left remains still


The outline of the still character is placed in front of the camera for the second shot


This outline is used when filming the other character to direct them to the correct position



Glass matte painting

Modern Times – 1936

As part of a clever effect, Charlie Chaplin's roller-skating scene was not quite as daring as it appears. While working as a performer, the scene shows him travelling backwards as he practises his skating, stopping tantalisingly close to a substantial drop. In filming, however, this was never a real danger. To produce this shot, an image of the drop was painted onto a glass pane placed in front of the camera. Perfecting the smooth backwards skate is still considered an artful stunt in itself.

Travelling backwards, the footage reveals an impressively big drop and a prominent 'danger' sign, which the character cannot see


As he reaches the edge of the platform, the shot gives the illusion that he has stopped millimetres from certain death

5 FACTS ABOUT THE SILENT-FILM ERA

1 Early salaries
A good weekly salary for early Hollywood film executives was $50, while film extras were paid around $1.50 per day.

2 No doubles
Stunt doubles didn't exist in most silent film productions. Producers would rather hire daredevil actors than spend the money on extra people.

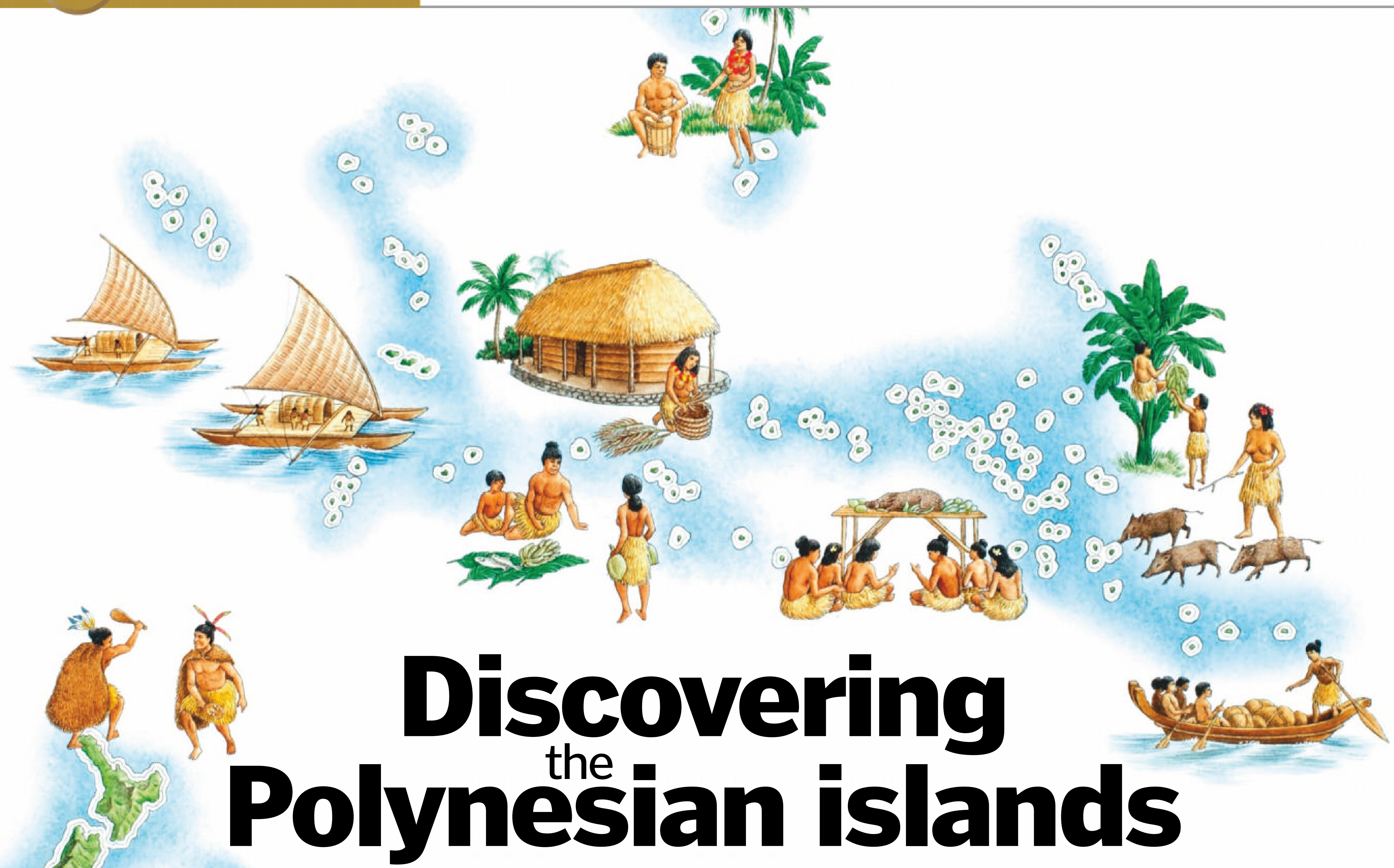
3 Annual production
During the 1920s, Hollywood produced around 800 feature films each year.

4 Lost creations
With many early film reels being made using nitrate films, some of the classics have been lost forever through decomposition. An estimated 80 per cent of original silent films have been destroyed.

5 Stopping the silence
The first commercially successful sound film, or 'talkie', was *The Jazz Singer* in 1927. This marks the end of the 'silent era'.


Between the camera and the action, a transparent screen is placed


With the depths of the drop shown to be just a well-positioned painting on the glass screen, Chaplin was never at risk. He did, however, have to perfect the timing of his stop – even if his life didn't depend on it



Discovering the Polynesian islands

Words by **Ailsa Harvey**

© Getty

Setting sail into the unknown on handmade canoes, this is how skilful navigators earned their homeland thousands of years ago

When early Europeans eventually explored the islands of the Pacific Ocean, they discovered they weren't the first to find them. In fact, they were many hundreds of years late. The people they encountered on these islands were dispersed over thousands of kilometres, but had similar beliefs and customs. These were the Polynesian islanders, and their perfected navigational skills enabled them to travel distances of over 3,000 kilometres between landmasses. As they made these vast voyages, they discovered a plethora of remote islands, one by one, and became the first humans to set foot on them.

As groups of island hoppers ended their time at sea, families settled and established their home on one of 10,000 Polynesian islands. As time passed and with permanent settlers on these islands, new cultures, beliefs and language variations emerged to produce today's communities. DNA analysis shows that all early Polynesian settlers descended from a single race of people. Studies of their past have led most to believe they originated in southeast Asia, leaving in boats to form the new populations. The ambition of these islanders is shown in the evidence of the equipment they brought with them and the intent in their navigation.

Researchers rule out the possibility of drifters accidentally discovering the islands due to the resources they carried with them to start new lives. Food and animals were taken on boats, including three known domesticated animals: pigs, dogs and chickens.

Dealing with crowded boats of people, animals and supplies, groups tackled the ocean's menacing moods with patience and respect. Part of the Polynesian culture, living in a water-orientated part of the world, these particularly brave and persistent individuals embraced open-sea voyages despite their vulnerability, travelling for many weeks at a time. By adopting and spreading successful seafaring methods, the islanders tuned into the tides in a way most modern sailors can only begin to imagine. With none of the technology of today, could this mean these ancient people are the best navigators of all time?

Ancient vessels

Built using tools of stone, bone and coral, how did Polynesian canoes withstand the mighty mileage?

Wind harnessing
To cover great distances, Polynesian sailors used sails that harnessed the power of wind. Triangular in shape like a crab claw, they consisted of fine-woven mats of palm-like pandanus leaves.

Deep hulls
The bottom of the canoes entered the water deep enough to cut through waves efficiently. Displaying early seafaring knowledge, the surfaces that passed through the water were curved, as this reduces drag.

Paddle power
These voyagers would have also carried paddles, sometimes using pure body strength to power the boats, but only for minimal periods of time to conserve energy. This method is thought to have been used when launching and landing canoes, as well as in emergencies to steer away from danger.

Double-hulled
Fixing together two canoes side-by-side created a wider vessel for the voyagers on board. This also made the boat more balanced for use on choppy seas. The boats' design, with space between the two canoes, helped to reduce drag from wind and sea.

Storage space
Connecting two canoes meant that there was more space available to carry loads for long journeys. Sea navigators would need supplies to survive the long voyage.

Curved end
Their boats were distinctly pointed and tall. Many New Zealand and Hawaiian boats were elaborately carved. These impressive additions were purely ornamental, showing the pride they took in their craft.

© Alamy

Island hunting

On small islands, space was limited. When an island began to struggle with overpopulation, it was down to designated navigators to take to their canoes in search of more undiscovered islands. Experience and skill meant that Polynesian populations could migrate to unpopulated islands great distances over the sea.

Heading to sea for incalculable periods, ancient Polynesians had their own methods of traversing the vast and unpredictable ocean. Unequipped with technology, but well-equipped with knowledge and instinct, they followed signs from the stars, swells in the ocean and cloud formations in the sky. Some accounts speak of master navigators being able to feel five different swells that rocked their boat, just by closing their eyes. They could use these movements to tell if they were travelling in the right direction.

Some voyagers followed land-dwelling birds in the sky. They learned that the birds that fished out at sea flew from their islands in the morning and returned towards them in the evening. This helped to keep boats moving in the right direction.

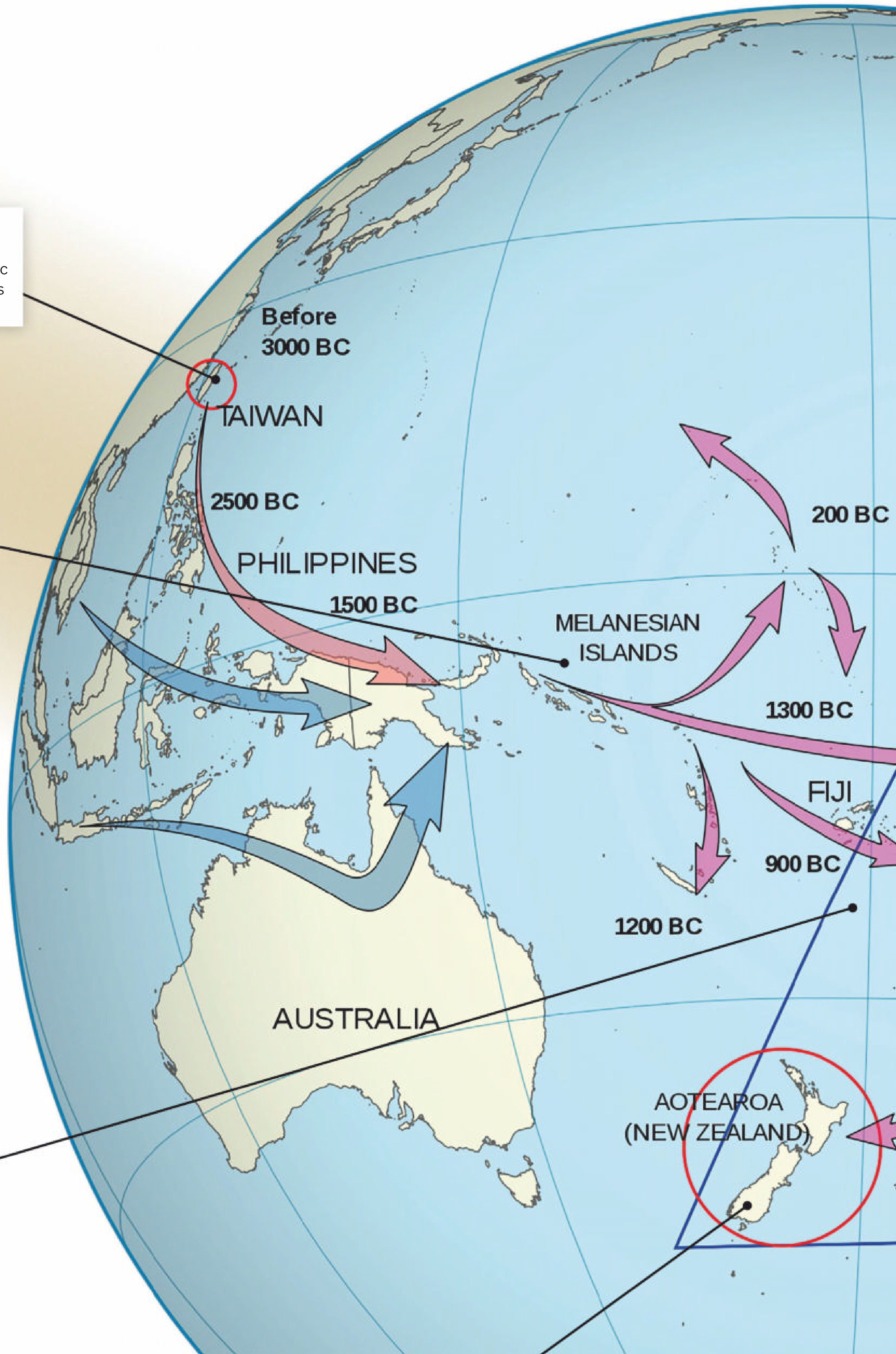
Once navigation was mastered, these ancient people didn't yet possess the ability to write down their findings. Their wisdom was taught entirely by word of mouth – which was passed on down the generations to their descendants, modern Polynesians.

© Newportm

This star compass, recreated on the sand, shows how Polynesian islanders could be taught to follow stars before setting sail. This information was only stored in memory

Distant voyages

Track the routes taken by ancient Polynesians and learn how settlers created their isolated communities



Setting sail

Polynesians are believed to have originated from modern-day Taiwan over 4,000 years ago. Linguistic studies, archaeological findings and genetic analysis have drawn strong links between the two areas.

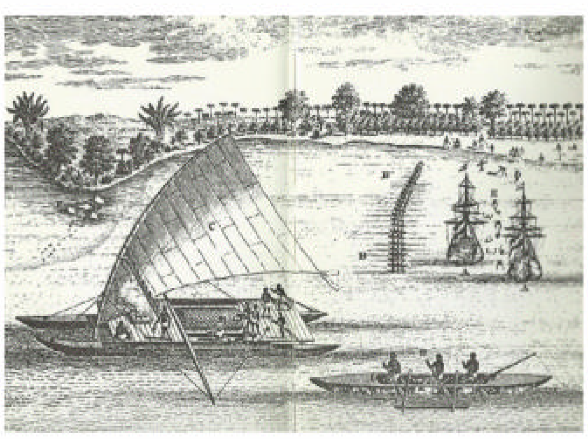
Through Melanesia

There has been much debate regarding the interactions between the Polynesian and Melanesian islanders. Some scientists believe their path took the majority of Polynesians past the Melanesians without too much interaction, while others speculate that they stopped and the two groups mixed together. The newest findings suggest that Polynesians island-hopped through Melanesia without picking up their genes. Later, some Melanesians ventured into the Triangle to live with the settled Polynesians.

There are 7,000 different cultural groups in Papua New Guinea. Living in isolation, many of these groups have carried out a similar lifestyle for 40,000 years

Entering the Triangle

From Papua New Guinea and through Melanesia, people travelled towards Tonga and Samoa. In these areas, Polynesian culture grew, later spreading to islands further east. Closely related in language, culture and heritage, there is thought to be early interaction and travel between these islands.

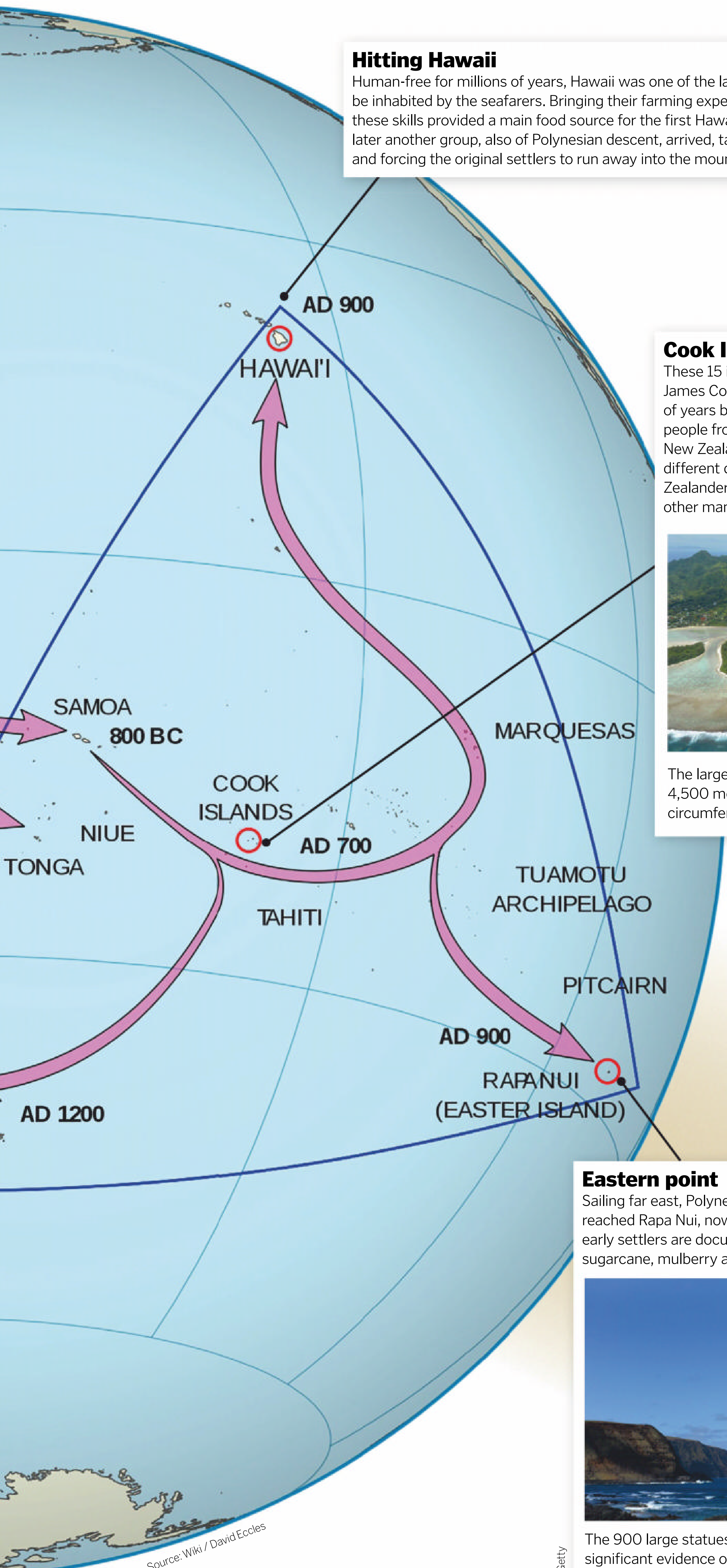


The traditional Tongan travelling and fishing boats observed by later European explorers

Arrival of Maori

This was the last major land mass, other than the Arctic and Antarctic, to gain settlers. New Zealand marks one of the three corners in the Polynesian Triangle and the first inhabitants, the Maori, were mainly living on its east coast. This area had a milder, more habitable climate.

This is a Maori king of the 1800s. Maori gave themselves this name after Europeans arrived. Meaning 'ordinary', it was used to identify the original settlers



Hitting Hawaii

Human-free for millions of years, Hawaii was one of the last places to be inhabited by the seafarers. Bringing their farming experience, these skills provided a main food source for the first Hawaiians. Years later another group, also of Polynesian descent, arrived, taking control and forcing the original settlers to run away into the mountains.

Cook Islands: pre-Cook

These 15 islands are named after British explorer James Cook, but were truly discovered hundreds of years before by Polynesian islanders. Some people from these islands ventured south towards New Zealand. Despite developing a slightly different dialect, Cook islanders and New Zealanders were still able to understand each other many hundreds of years later.

The largest of the Cook Islands, Rarotonga, rises 4,500 metres above the ocean with a circumference of 32 kilometres

© Alamy

Eastern point

Sailing far east, Polynesian navigators who left Samoa reached Rapa Nui, now also known as Easter Island. These early settlers are documented to have brought bananas, sugarcane, mulberry and rats, which they may have eaten.

The 900 large statues on Rapa Nui serve as the most significant evidence of the original settlers' rich culture

© Getty

5 FACTS ABOUT PACIFIC ISLANDS

1 Volcanic land
Most of the islands in Polynesia were formed by lava erupting from the sea floor. Over thousands of years, as new lava spilled and cooled in the ocean's water, the volcanic rock increased to a habitable size.

2 Thriving coral
Abundant in coral, the reefs in French Polynesia have fared better than other coral around the world. 58 per cent of reefs in French Polynesia are home to coral, with a contrasting ten per cent in some areas of the Caribbean Sea.

3 Island dance
As an important part of Polynesian culture, dancing varies on each island. Dances include the hula in Hawaii and the haka in New Zealand. Island dancing began as a way to act out traditional stories with very literal dances.

4 Insect importance
When tracing back the history of the islands' habitation, analysing insect species has proved useful. As these islands are incredibly isolated, most species of insect could only have arrived with people – or on plants from their previous land. An island's insects can be dated to determine the chronology of movement.

5 Spread population
Across the islands live a total of over 6 million people. Of these people, half are estimated to be of Polynesian heritage. New Zealand is home to 260,000 Polynesians out of its 4 million people. Its city of Auckland has the largest concentration of Polynesians in the entire South Pacific.

A voyaging canoe 18 metres long could carry two dozen people and their supplies across the ocean

© Getty

What was prohibition?

How a 13-year alcohol ban 100 years ago led to the booziest years in American history

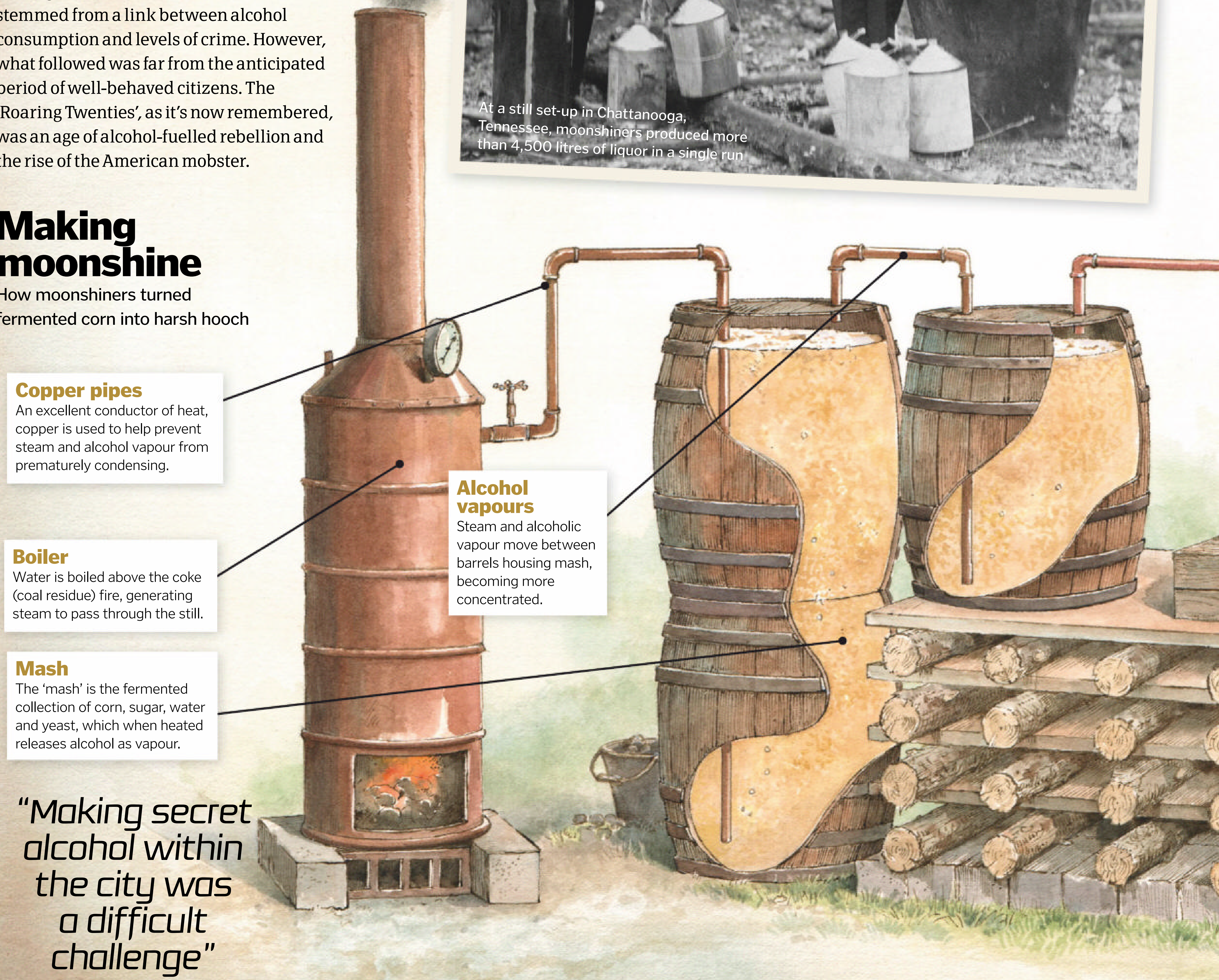
Following the end of World War I, calls for the removal of alcohol from sale in America grew louder across the country. At the stroke of midnight on 17 January 1920, the National Prohibition Act, commonly known as the Volstead Act, came into effect, prohibiting the manufacture and sale of 'intoxicating liquor' across America. Seen as a social triumph by many evangelicals, prohibition saw countless litres of wine, beers and spirits dumped in the streets by the newly formed Bureau of Prohibition.

The government's rationale for the ban stemmed from a link between alcohol consumption and levels of crime. However, what followed was far from the anticipated period of well-behaved citizens. The 'Roaring Twenties', as it's now remembered, was an age of alcohol-fuelled rebellion and the rise of the American mobster.

At a still set-up in Chattanooga, Tennessee, moonshiners produced more than 4,500 litres of liquor in a single run

Making moonshine

How moonshiners turned fermented corn into harsh hooch



"Making secret alcohol within the city was a difficult challenge"

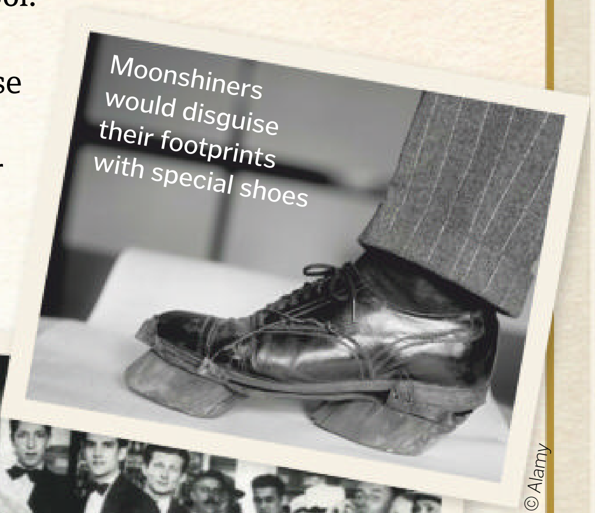
A country that was once a bountiful source of booze had found itself sober – or so it appeared on the surface. As soon as the ban came into effect, a new underground order of brewers and illegal bars called 'speakeasies' began to take shape. It's thought that in New York City alone there were between 30,000 and 100,000 illegal bars by 1925. 'Moonshiners', as they were known, were unlawful brewers in the countryside, and 'bootleggers' took on the role of distribution throughout the cities while 'rum-runners' moved goods across seas.

Making secret alcohol within the city was a difficult challenge for moonshiners, with some stewing 'bathtub gin' in their homes. However, to meet the overwhelming demand of the parched public, most turned their attention to distilling a strong form of alcohol known as moonshine deep in the woods.

Essentially this was a recipe for whiskey: cornmeal, sugar, water and yeast were fermented in batches and distilled to produce the clear form of whiskey. This potent alcoholic beverage would normally be left to mellow over time in barrels and develop whiskey's brown hue. However, in this era of thirsty clientele, no such time was allowed. Making quick booze came with its risks, and without regulated manufacturing conditions, moonshine was often unsafe to drink – in some cases containing harmful poisons created in the distillation stills.

Prohibition enforcement officers who suspected illegal activity between the trees kept an eye out for muddy footprints leading into the woods. However, in an ingenious method to throw the cops off their scent, moonshiners attached a block of wood to the ball and heel of their shoes, giving a muddy impression resembling a cow's hoof.

Despite being intended as an exercise in criminal reform, prohibition proved far from successful, so in 1933 it was repealed.

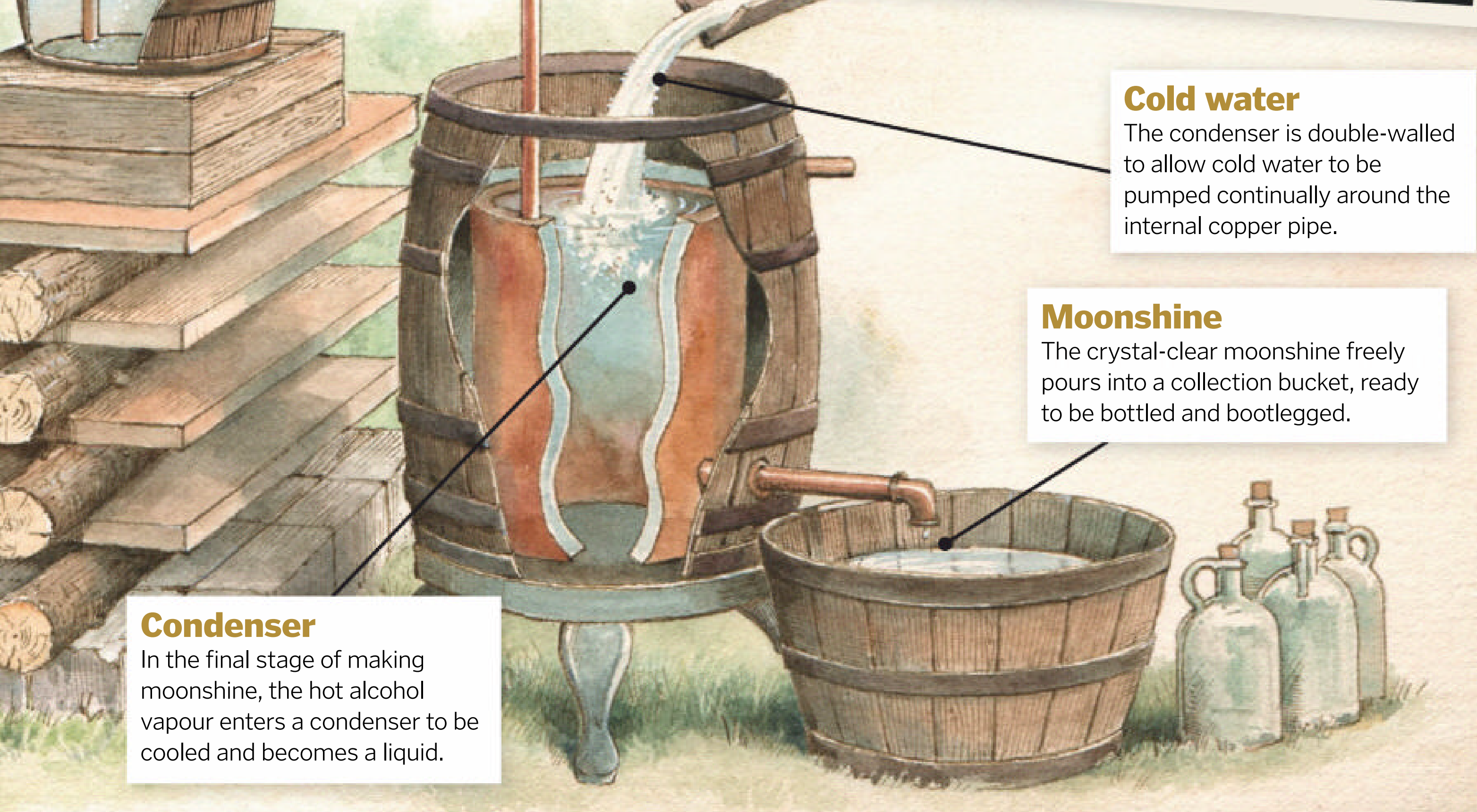


Moonshiners would disguise their footprints with special shoes

© Alamy

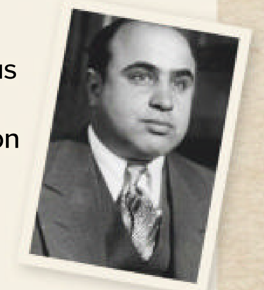
Illegal drinking establishments called speakeasies gave people the chance to get their hands on some hooch

© Alamy



MOONSHINE KINGPINS

1 Al Capone
1899-1947



Becoming a notorious Chicago mobster, Capone capitalised on the profitable potential of prohibition, arranging a network of moonshiners and bootleggers to illegally sell alcohol to the public. But in 1931, Capone was sentenced to 11 years in prison for tax evasion and fined $80,000.

2 Roy Olmstead
1886-1966

Once a promising lieutenant in the Seattle police force, Olmstead was discovered bootlegging whiskey and was removed from the force. He continued his criminal activities out of uniform until a wiretap caught him red-handed in 1924 and a court sentenced him to four years of hard labour.

3 George Remus
1874-1952

© Getty

Having built an alcohol empire with thousands of employees, criminal attorney George Remus was one of the biggest bootleggers to exploit prohibition. Reportedly responsible for 30 per cent of all the alcohol consumed in America during the period, Remus used his legal knowledge to evade capture for several years. That was until 1925, when he was indicted and charged with 3,000 violations of the Volstead Act.

4 Charles Dean O'Banion
1892-1924

© Alamy

Another infamous mobster in Chicago, O'Banion became a powerful bootlegger and found himself a rival to Capone, often shipping alcohol from Canada to his mob-controlled North Side and Gold Coast. Conflict over bootlegging territories between O'Banion and Capone came to a fatal end in 1924 when Capone arranged two of his gunman to take out O'Banion, shooting him twice in the chest.

How do SATEL

© Getty

LITES talk to Earth?

Discover how these eyes in the sky keep us all connected from space

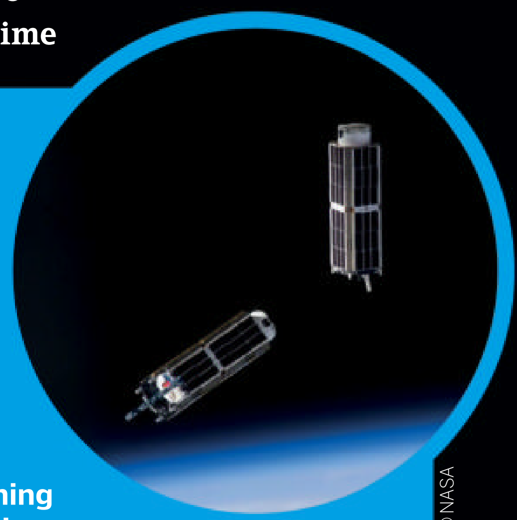
Words by **Scott Dutfield**

Gazing up at the sky past the clouds, it's hard to imagine an entire civilisation of satellites all chatting with one another right above our heads. Populated in their thousands, satellites are the orbiting neighbours we need to stay connected down on Earth. Although varying in their occupation, satellites are typically either used for communication, imaging or navigation.

To keep us all connected, communications satellites work as 'space mirrors', bouncing signals off one another before delivering the message back to Earth. These messages take the form of radio waves, which are received, amplified and sent on their way by transponders on the satellite. For example, when watching the television the picture you see is the result of a signal 'uplink' to a satellite by the programme producers, amplified and transmitted to another before 'downlink' of the signal is beamed to your home receiver, decrypted and played on screen. This up-and-down style of transmission allows signals to be sent all around the world at the speed of light, around 300,000 kilometres per second.

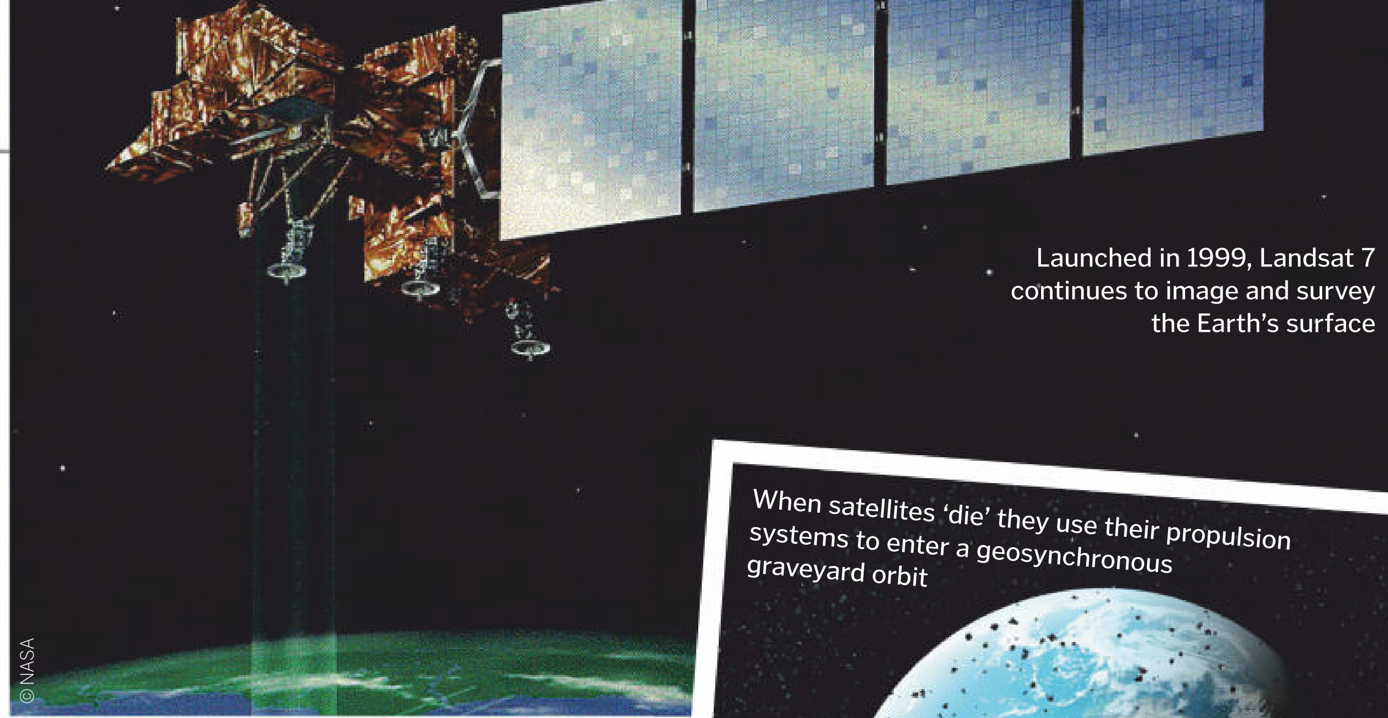
Other satellite types operate similarly in how they communicate with Earth and with each other. The technology on board dictates their outer-space occupation. For example, the network of satellites which form the Global Positioning System (GPS) send information to one another via radio signals to locate different points on our planet. To achieve this, they use the principle that time

Mini satellites



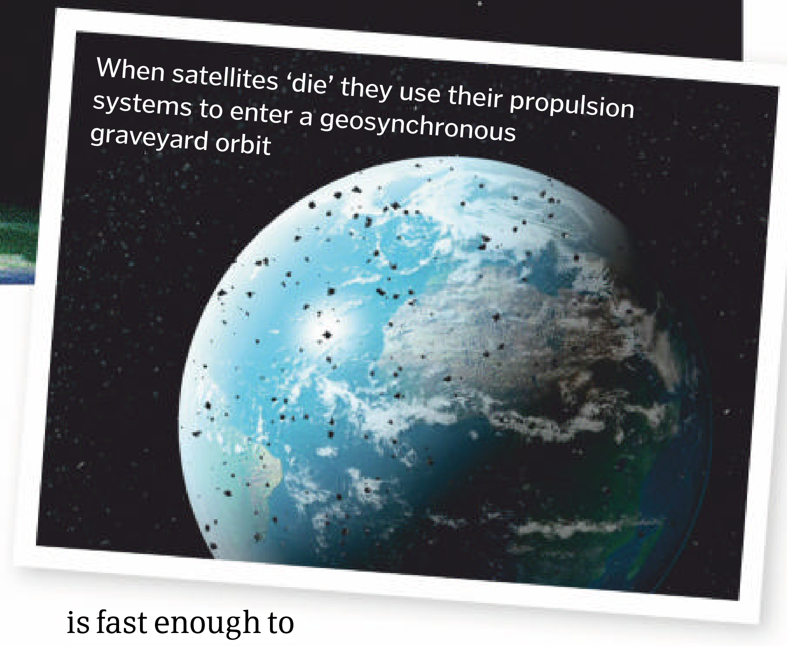
© NASA

Sending satellites into space can be an expensive game, so how do budding engineers test out their designs without breaking the bank? Costing a fraction of the price of their full-size counterparts, CubeSats, or nanosatellites, are tiny handheld satellites that hitch a ride on rocket launches to enter low-Earth orbit. Weighing up to 1.33 kilograms, CubeSats allow trainee engineers to test out new technologies and get them into space. With the help of programmes such as NASA's CubeSat Launch Initiative (CSLI), these mini satellites are able to launch with other craft, lowering costs. However, due to their small size CubeSats are susceptible to the effects of radiation, meaning they only have a shelf life of a few weeks or months before ceasing to operate and falling back to Earth.



Launched in 1999, Landsat 7 continues to image and survey the Earth's surface

© NASA



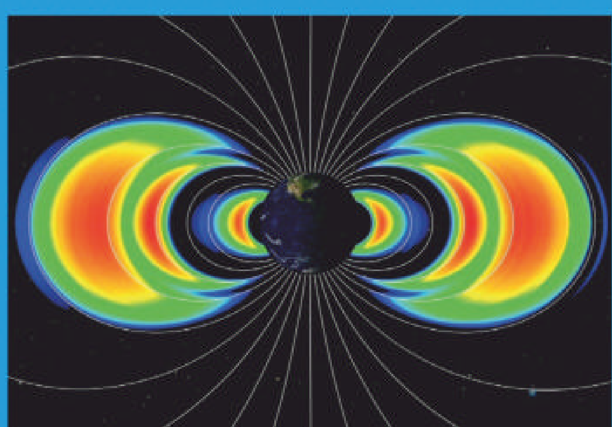
When satellites 'die' they use their propulsion systems to enter a geosynchronous graveyard orbit

© Getty

Earth's satellite killer

Earth's built-in force field may be great at protecting us from the full force of the Sun, but it can wreak havoc on orbiting satellites. Swirling around our planet is a giant doughnut-shaped swarm of highly energetic charged particles called the Van Allen radiation belt. Named after the American physicist James Van Allen, this natural phenomenon was discovered in 1958 by the first US satellite, Explorer 1.

Often the cause of spaceship and satellite failure, these high-energy particles can interfere with electronics by penetrating shielding and digging into satellite insulation where they collect and can potentially release an electrical discharge, knocking the satellite out of action. For this reason, satellites are often parked outside the Van Allen belt for safety.



Earth has two belts of highly energetic particles, shaped by the solar wind

© NASA

taken for a signal to be sent and received can equal the distance between two objects, in this case the satellite and the Earth. This means that their time-keeping has to be impeccable. Atomic clocks are stored aboard GPS satellites. Trapped within each clock are excited atoms, usually caesium or rubidium, that tick in time to the hands of a clock. Much more reliable than the quartz oscillators found in Earth-bound wristwatches, the atoms in the atomic clock remain relatively unaffected by the effects of gravity. Having an atomic grasp on time means that GPS satellites' distances can be calculated with razor-sharp precision.

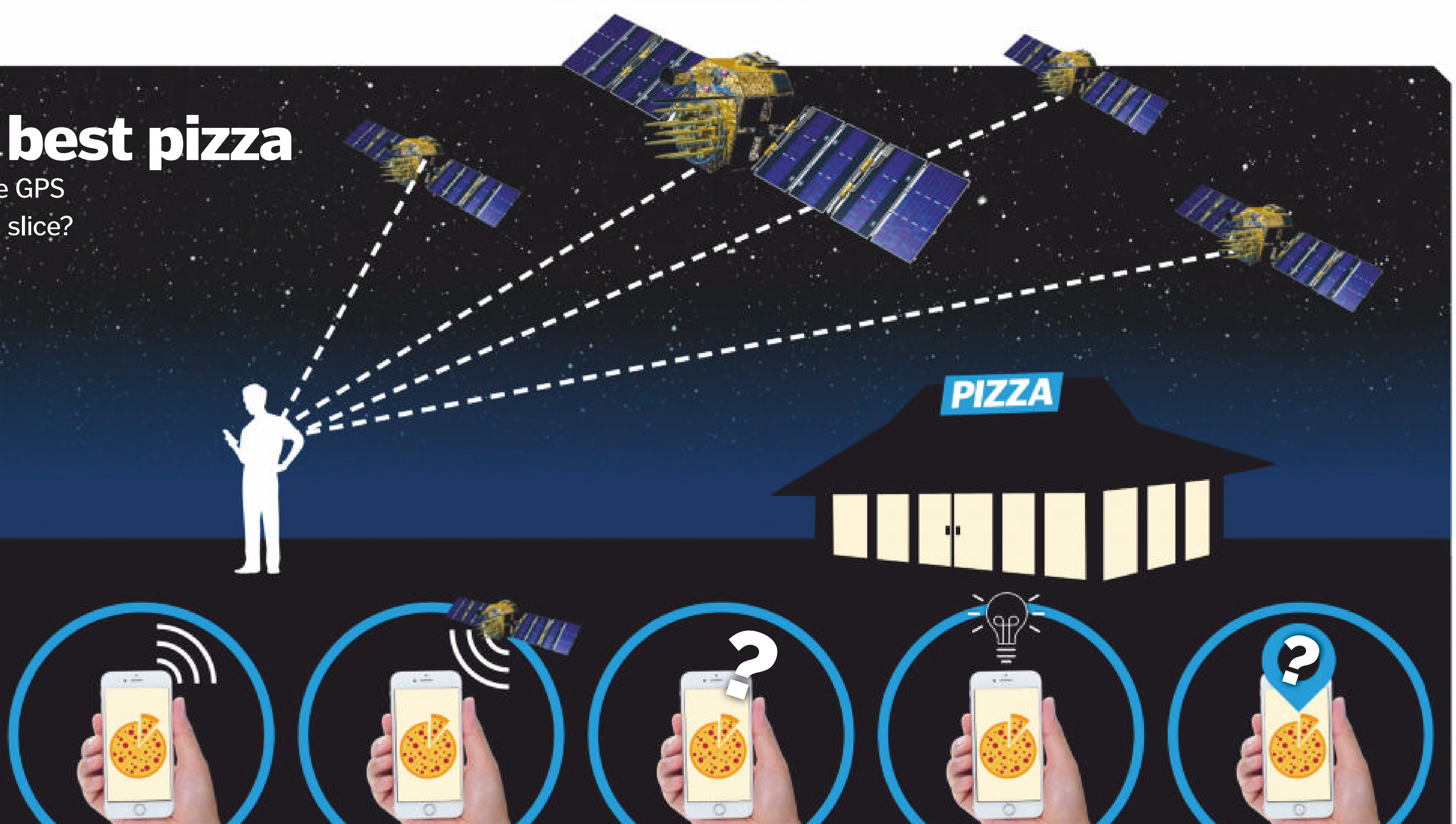
But what stops all these satellites from falling out of the sky? It's a dance between the satellites' speed and the gravitational pull of Earth. Satellites are launched and sent through the atmosphere in a rocket. Breaking out into open space, the delivering rocket releases them into orbit. The speed at which they're released is fast enough to defy the gravitational pull, but not so fast that they hurtle out of Earth's orbit. Where the pull of the planet is strongest, such as at low-Earth orbit, satellites need a higher velocity to prevent being pulled down. In the outermost geosynchronous Earth orbit, satellites need less speed to stay on course with Earth. This balance between speed and gravity is what keeps all the satellites from crashing down to Earth. Unless, of course, one is knocked out of orbit. Although this event is a rarity due to the precision of where a satellite is placed in space, orbits can change and satellites can be thrown into collisions courses.

Finding the best pizza

What happens when we use GPS satellites to find the perfect slice?

Trilateration

To find your exact location, several satellites work together using radio signals. Emitted as a sphere, these signals are transmitted towards Earth to the receiver in your smartphone. In almost a Venn diagram-style search, overlapping spheres pinpoint your general location. Measuring the time taken for the signals to be sent from the satellite to the receiver and back again is how these eyes in the sky are able to accurately find out where in the world you are.



The smartphone's receiver is able to tune into the continuous radio signal from nearby satellites.

A smartphone will then use these signals to identify the satellites and their position in the sky.

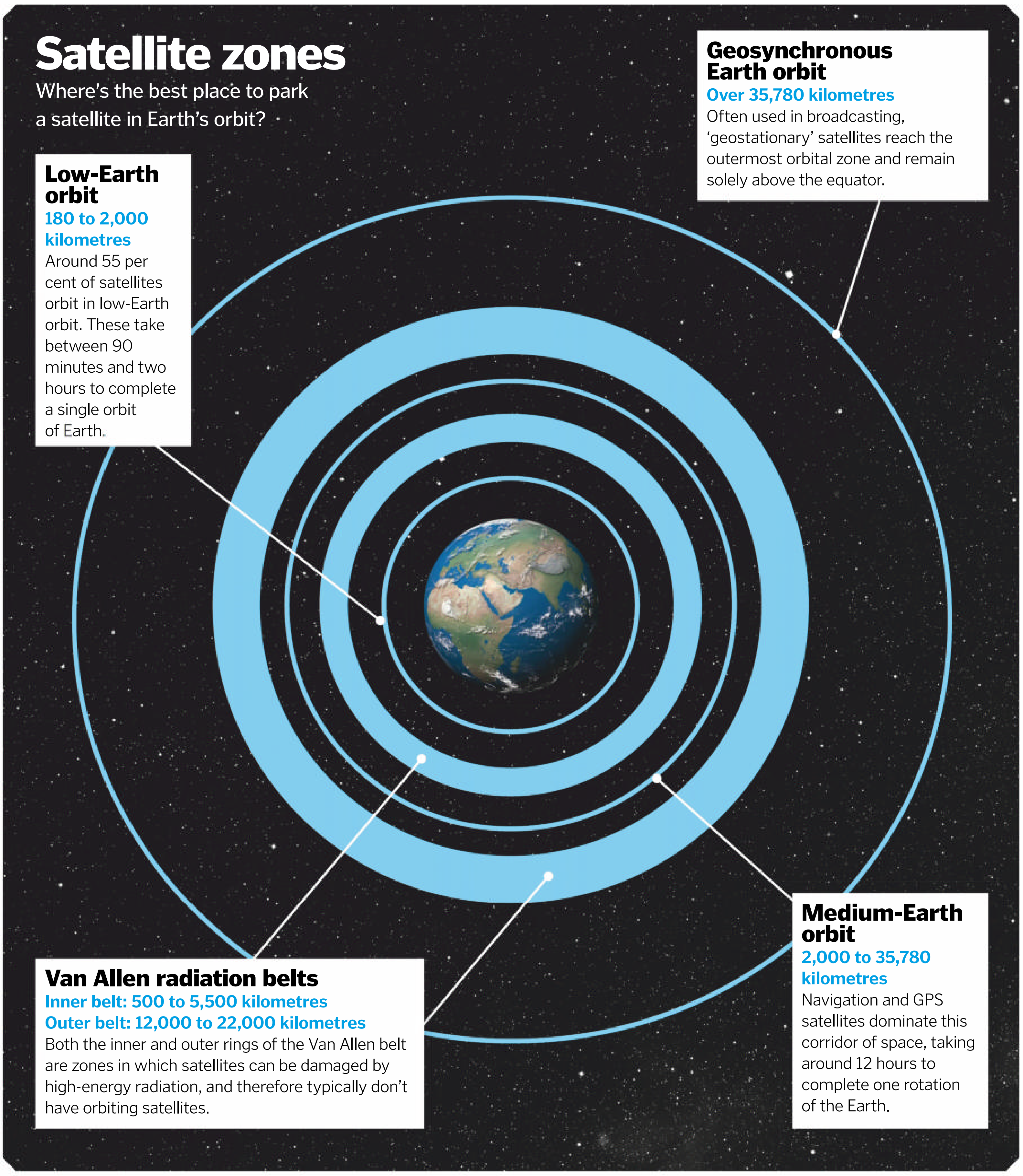
A smartphone will calculate its location based on the time it takes the signal to bounce back and forth.

With the help of the internet, the pair work together to point you in the right direction of the closest pizzeria.

Connecting the dots to your destination, GPS satellites will track your position and guide you to the store.

Satellite zones

Where's the best place to park a satellite in Earth's orbit?

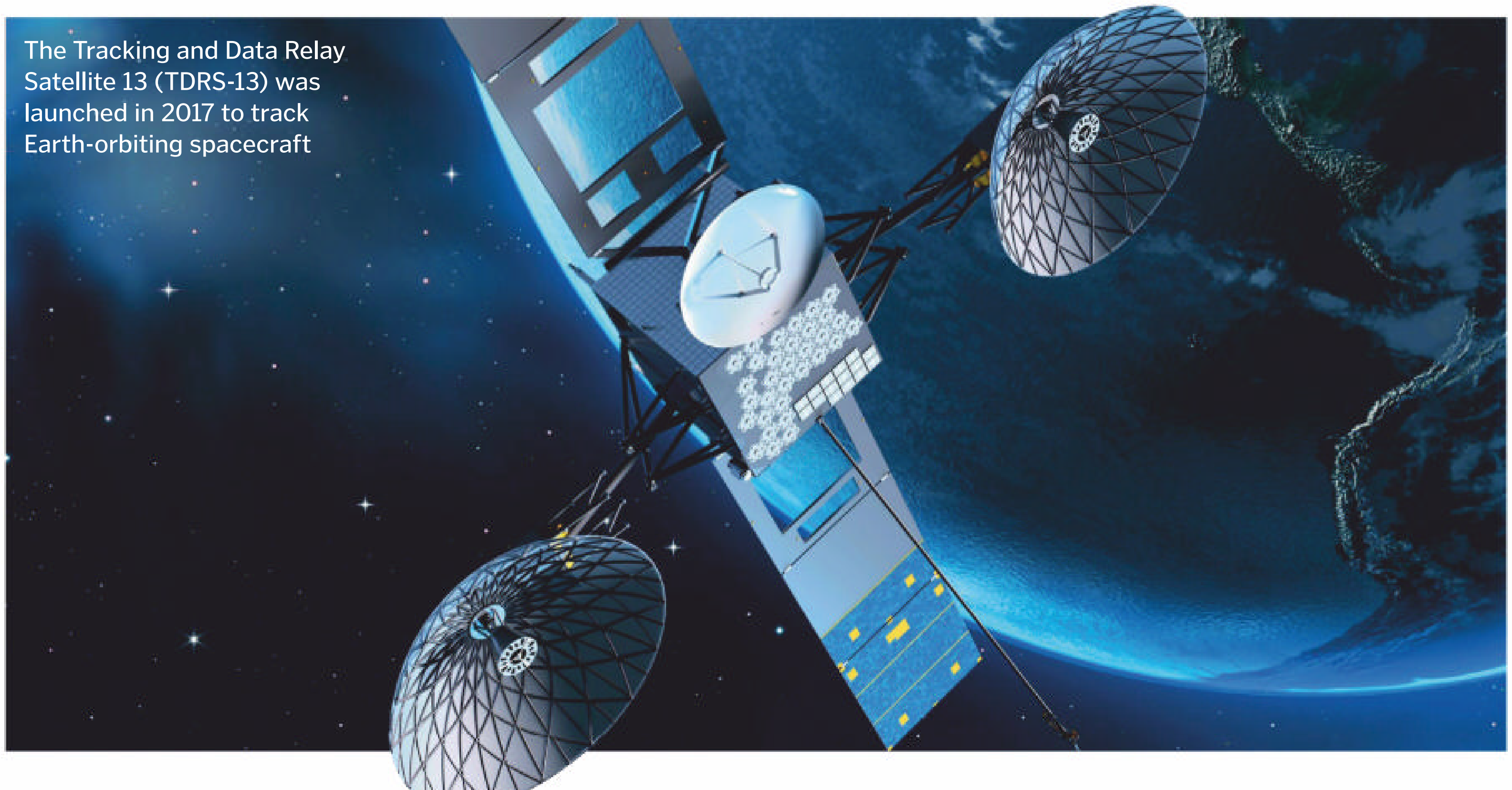


Low-Earth orbit
180 to 2,000 kilometres
Around 55 per cent of satellites orbit in low-Earth orbit. These take between 90 minutes and two hours to complete a single orbit of Earth.

Geosynchronous Earth orbit
Over 35,780 kilometres
Often used in broadcasting, 'geostationary' satellites reach the outermost orbital zone and remain solely above the equator.

Van Allen radiation belts
Inner belt: 500 to 5,500 kilometres
Outer belt: 12,000 to 22,000 kilometres
Both the inner and outer rings of the Van Allen belt are zones in which satellites can be damaged by high-energy radiation, and therefore typically don't have orbiting satellites.

Medium-Earth orbit
2,000 to 35,780 kilometres
Navigation and GPS satellites dominate this corridor of space, taking around 12 hours to complete one rotation of the Earth.



The Tracking and Data Relay Satellite 13 (TDRS-13) was launched in 2017 to track Earth-orbiting spacecraft

LG is betting on 8K OLED screens being the future of TV

© LG

TV tech explained

From CRT to 4K, OLED to HDR, understand the acronyms that have marked telly's transformation

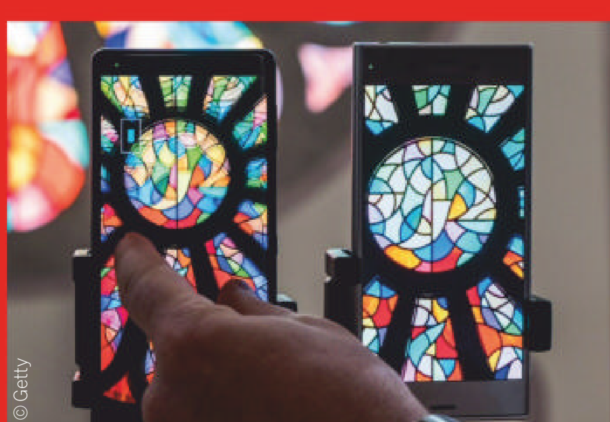
On 26 January 1926, Scottish inventor John Logie Baird demonstrated a working television at his London lab. However, few of us today would recognise what he called a 'televisor' as a TV. It used mechanically driven discs covered with lenses. These broke down light reflected by an object. The reflections were turned into an electrical signal and transmitted to a radio receiver that reconstructed an image of the object.

Baird's mechanical television was quickly replaced by an electronic version, which made it easier to capture and transmit images. In 1931, Allen B DuMont's cathode-ray tube (CRT) set the standard for television. Even the shift from black-and-white to colour TV in the late 1960s still used the same technology, cementing the place of the 'tube' in our homes for the rest of the 20th century.

Since the millennium, however, there's been a TV tech explosion. Not only have these innovations kicked CRTs to the curb, they've been hard to keep up with. In 20 years we've gone from plasma TVs you could hang on your wall to OLEDs that are as little as 4mm thick. At the same time the images have gotten much sharper, with the development of 1080p or Full HD giving way to 4K and increasingly 8K.

The power of pixels

Image resolution refers to how many pixels – tiny dots of colour – a screen has. A standard 1080p TV has 1920 pixels across the display, and 1080 pixels going upwards. That's around 2 million pixels. 4K has four times the number of pixels as a 1080p TV. The more pixels you have, the clearer and sharper the image. Better resolution doesn't require a bigger screen, as pixels can be densely packed. That's why you can now get smartphones with 4K screens.



© Getty

Sony's Xperia XZ2 smartphone screen has a 4K resolution, despite being much smaller than a TV

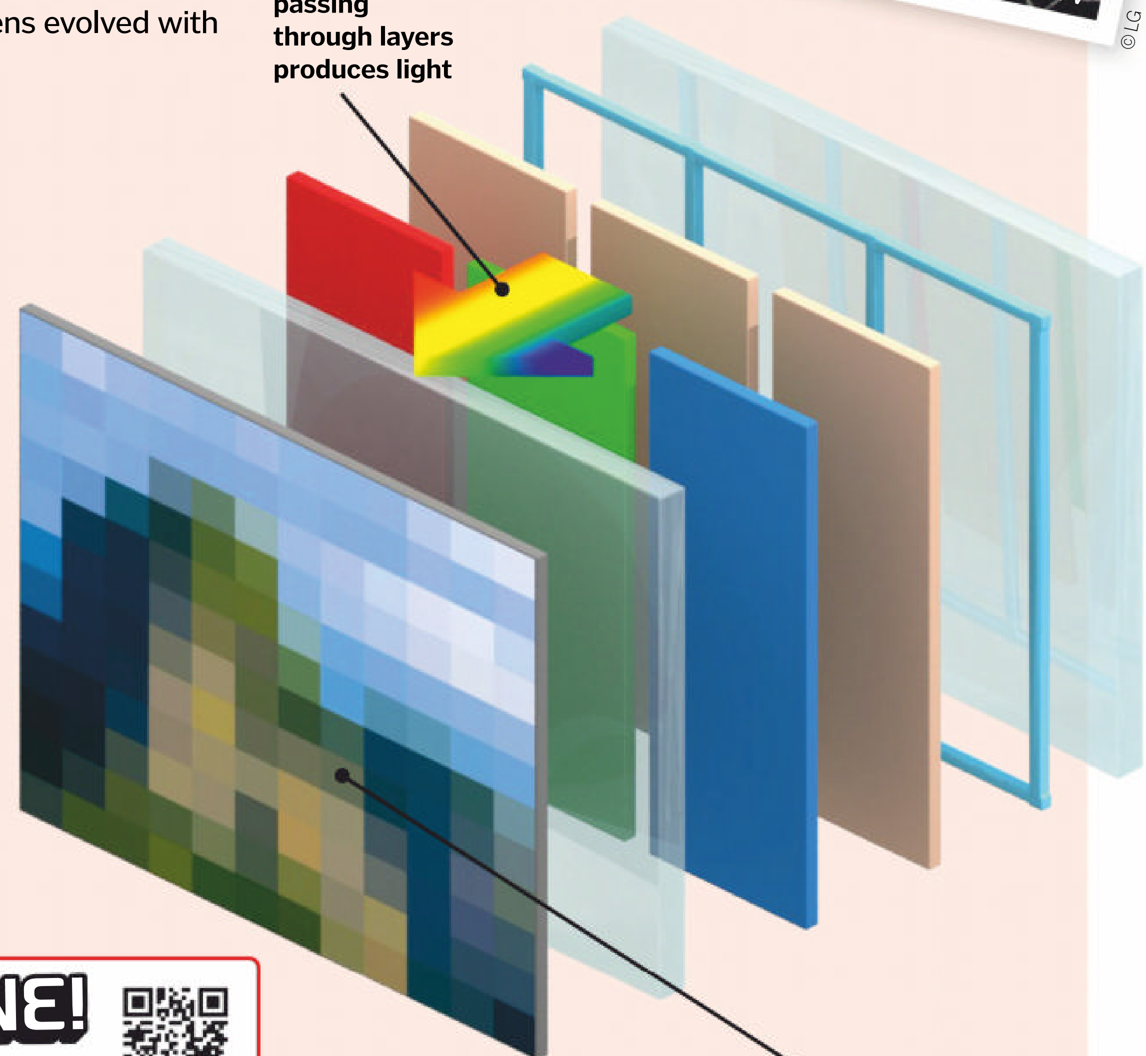
Inside TVs

How have our screens evolved with new technology?

Organic light-emitting diode (OLED)

These TVs use a carbon-based film that glows when heated, so no backlight is needed. This light can also be controlled on a pixel-by-pixel basis for a sharper image.

- ✔ Displays are just millimetres thick
- ✔ Brilliant colours with high contrast
- ✘ Still very expensive to produce
- ✘ Small risk of screen burn

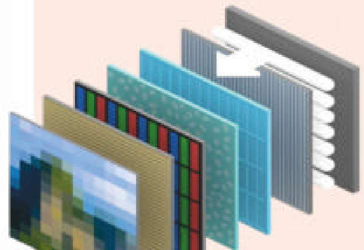


AR ZONE! SCAN HERE

Liquid-crystal display (LCD)

These TVs shine light through a screen made up of liquid-crystal cells. Signals control each cell, making the crystals move and twist, letting different amounts and colours of light through.

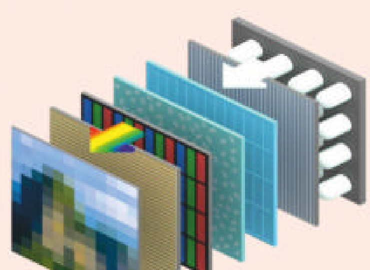
- ✔ Extremely high-resolution image
- ✔ Accurately reproduces a range of colours
- ✘ Poor reproduction of black images
- ✘ Lower contrast and limited brightness



Light-emitting diode (LED)

A lot like LCDs, these TVs replace the fluorescent backlight with tiny LEDs. These can be arranged around the edge of the display, making for an even slimmer flat screen.

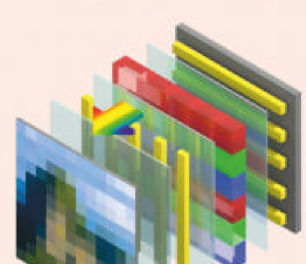
- ✔ LEDs give off natural-looking light
- ✔ They're also more energy efficient
- ✘ Early versions had patchy colours
- ✘ Screen lighting can be inconsistent



Plasma

A voltage is run through two thin sheets of glass containing plasma – ionised gas, often xenon or neon – that lights up when heated, making red, green and blue pixels glow.

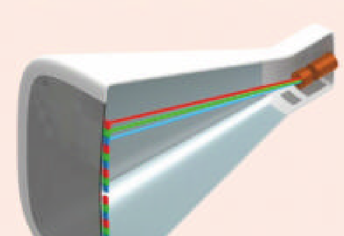
- ✔ Great dark-room and wide-angle viewing
- ✔ Smooth picture with no motion blur
- ✘ It uses a lot of power
- ✘ Danger of screen burn



Cathode-ray tube (CRT)

Guided by magnets, beams of electrons are continuously fired through a glass vacuum tube at a screen covered in millions of red, blue and green dots to create an image.

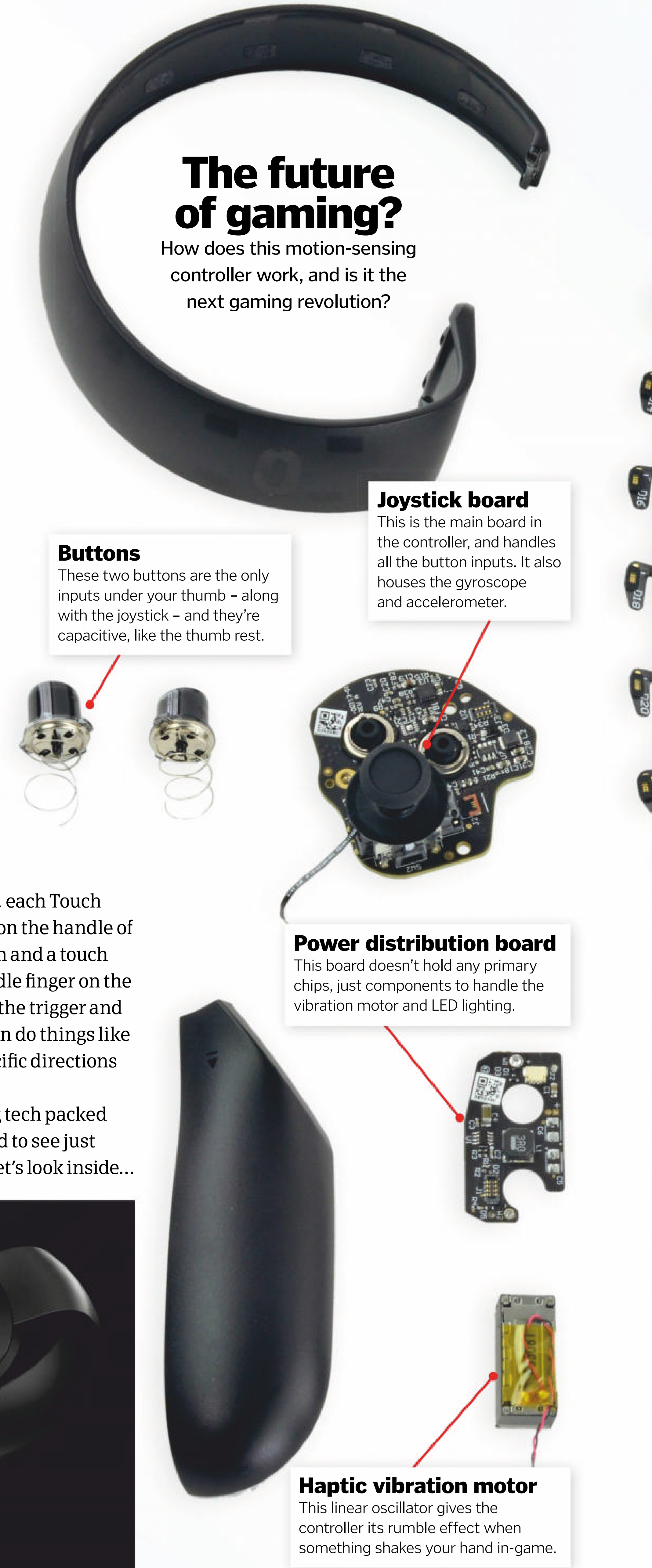
- ✔ TV picture offered high colour contrast
- ✔ Reduced input lag, better for gaming
- ✘ CRT's were big and very heavy
- ✘ Low resolution seems blurry today



© Adrian Mann

The future of gaming?

How does this motion-sensing controller work, and is it the next gaming revolution?



Inside the Oculus Touch

We deconstruct this virtual-reality device's Blutooth controller to find out how it works

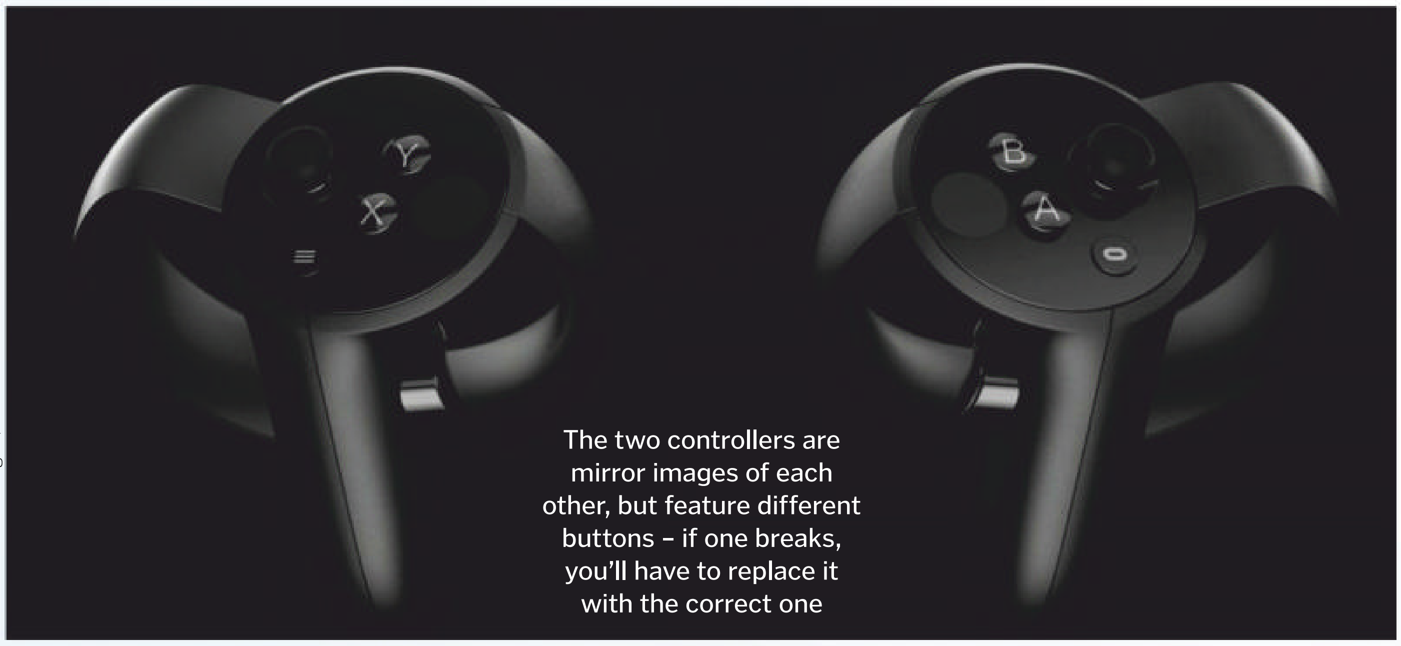
There's no doubt that virtual reality provides the most immersive gaming experience available right now. Put on a headset and you can explore whole new worlds just by turning your head – it really makes you feel like you're there. But these experiences can only truly draw you in if you can properly interact with the world around you. And for that, you need a powerful motion-sensitive controller.

Enter the Oculus Touch. These two handheld pads let you pick up, catch and hold all kinds of objects, navigate through the virtual world and do normal, boring gaming things like choose options in menus.

It's all possible thanks to a circle of infrared LEDs that pump out light that's invisible to the naked eye, but can be picked up by special sensors to track where the controllers are in 3D space. Your computer converts this information into the game, and when you look down at where your hands are, you can see and move them around in the virtual realm.

As well as detailed 3D tracking, each Touch controller includes a grip button on the handle of the controller and a trigger button and a touch sensor on the top. With your middle finger on the grip button, your index finger on the trigger and your thumb on the sensor, you can do things like give a thumbs-up or point in specific directions within the game.

With all this powerful tracking tech packed into a small controller, we wanted to see just how the Oculus Touch worked. Let's look inside…



The two controllers are mirror images of each other, but feature different buttons – if one breaks, you'll have to replace it with the correct one

LED strip
This contains 22 infrared LEDs, which wrap around the grip ring to provide the best tracking coverage possible.

Grip ring
When you're holding the controller, this ring encircles your knuckles – which you'll appreciate if you get too close to a wall during an exciting gaming session.

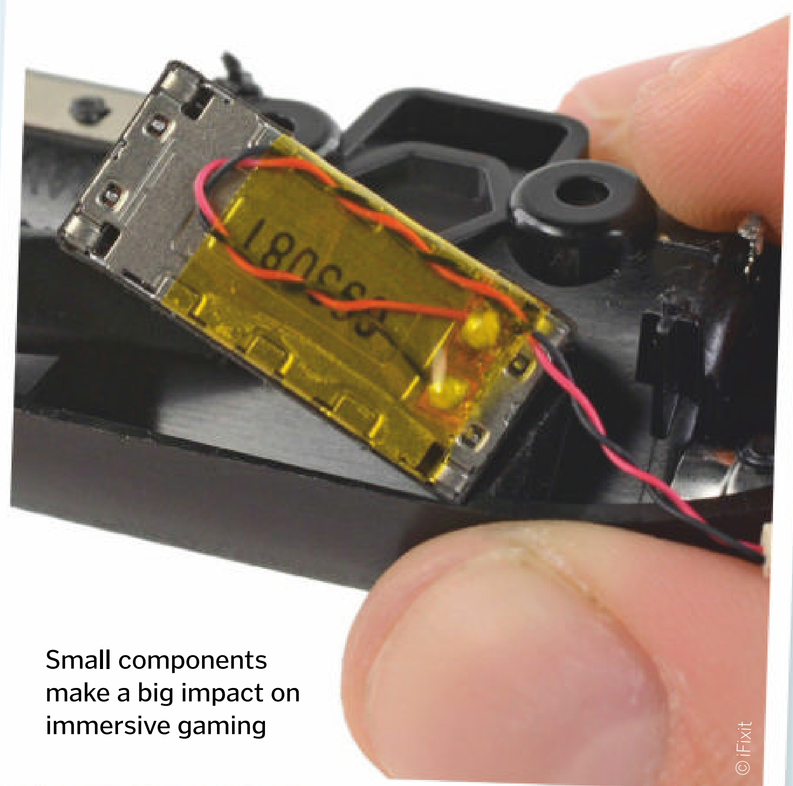
Ribbon cable
This cable contains two more infrared LEDs, bringing the total in each controller to 24, and connectors for the main button pad.

Capacitative thumb rest
This plate may just look like a piece of plastic, but a capacitive sensor knows when your thumb is touching it, so you can release it to give a thumbs-up.

Grips
These pieces come together to form the main controller grip. This one in particular holds the grip button and the trigger.

© iFixit

"You can pick up, catch and hold all kinds of objects"



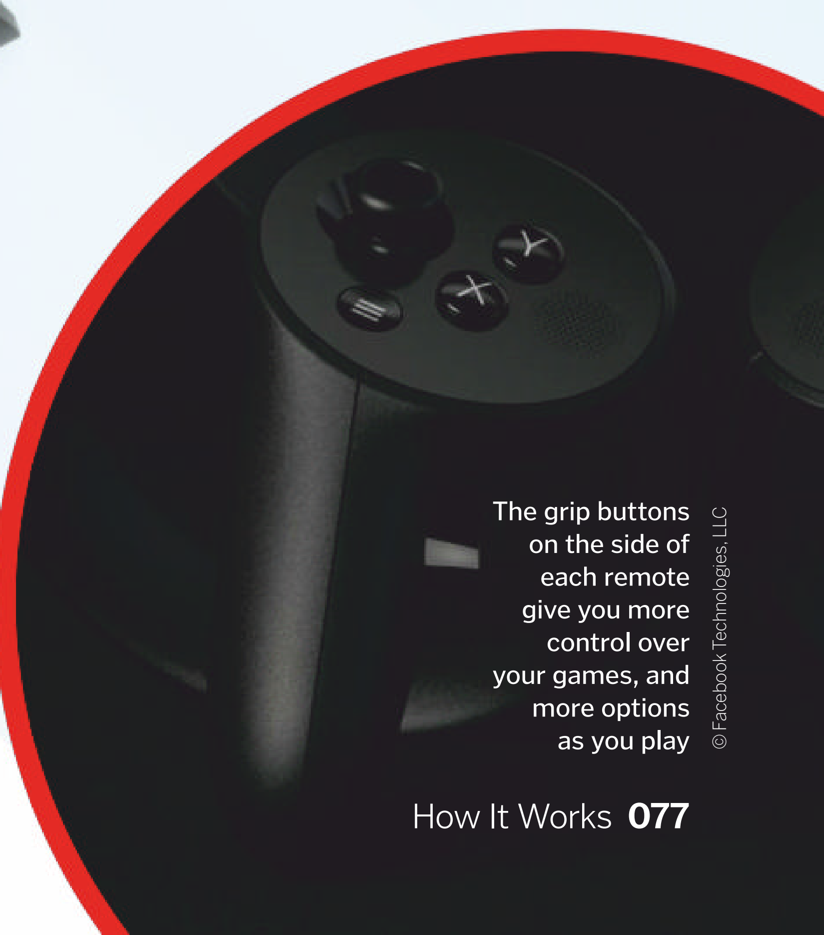
Small components make a big impact on immersive gaming

© iFixit

Haptic feedback

Haptic feedback is vibration feedback that mimics the feeling of touches and shakes in real life. These vibrations are created by a weighted magnetic core between two springs. The system uses electromagnetism to shake the weighted magnet back and forth at a high speed. Depending on how quickly and how far the magnetic core moves, the user will feel different kinds of vibrations.

All kinds of devices use these linear oscillators today, from mobile phones and laptops to gaming controllers like the Oculus Touch and the Nintendo Switch's JoyCons. In laptops they are used to create a 'click' feeling when you press on the touchpad, they make your phone ring when it's on silent and they shake the controllers in your hand when you're playing games.



The grip buttons on the side of each remote give you more control over your games, and more options as you play

© Facebook Technologies, LLC

Ride the London Eye

It's 20 years since this giant city-centre wheel opened: jump aboard and have a look inside

In 2009 the 11-tonne capsules were upgraded with better heating, WiFi and ceiling-mounted screens

© Getty

For 20 years, one large eye has watched over the antics of the UK's capital city, attracting 3.5 million customers every year. But how was the London Eye designed?

In 1993 a competition was launched for architects and designers to create a suitable landmark to commemorate the upcoming turn of the millennium. No entry was ever chosen, but that didn't stop husband and wife David Marks and Julia Barfield from presenting their entry to city planners anyway. Their idea was the 'Millennium Wheel', which would later be renamed the 'London Eye'.

As key parts in this modernised version of a traditional Ferris wheel, the passenger capsules are a standout feature. These pods allow passengers to be completely contained, instead of the usual open-air gondolas. As a large open space with minimal seating, the experience inside aims to create a feeling of freedom, allowing people to explore the views from unlimited angles.

The original design incorporated 60 pods – symbolic of the minutes on a clock face – but in practice this proved too many, as packing them closely together limited their viewing range. Today, 32 pods can be counted around the wheel, equalling the number of boroughs in London.

This unique piece of architecture was assembled by specialists all across Europe: the main structure was built in the Netherlands, the cables in Italy, the spindle in the Czech Republic, the rim bearings in Germany and the capsules in a ski resort in France. The ovoid capsules they created house up to 800 people at a time and are constantly rotating every day, reminding all of the turning of the millennium in a city that never stops.

"The experience inside aims to create a feeling of freedom"

© Alamy

The wheel's hydraulic motors consist of 150kW power packs and rubber wheels

How does the wheel turn?

The wheel only turns at 26 centimetres a second, meaning a complete rotation takes half an hour. Moving slightly faster than a sprinting tortoise, there is plenty of time to take in London's scenery. It also enables customers to step on and off the capsules while the wheel is still in motion. When entering your allocated capsule, the colossal structure is moving using some of the same equipment that lorries use – tyres. The lorry tyres rotate with the help of hydraulic motors, which connect to the wheel's rim. These power units operate eight pairs of tyres, acting as friction rollers. They push the wheel's frame through the system in one direction, causing the entire Eye to spin.

The Great Wheel

If you thought the Eye was a first for giant Ferris wheels in London, think again. Over 100 years before the arrival of the London Eye came the Great Wheel. Also known as the Gigantic Wheel, construction began in 1894. Serving the city of London for just over a decade, it welcomed over 2.5 million people on board.

While 'great' by name, how did its design compare to the modern wheel? Measuring 41 metres short of the London Eye, its structure was based on the original Ferris wheel. Adorned with 40 carriers, the wheel had a higher full capacity, with each able to hold five more people than today's pods. Their main difference in design is the fully enclosed, climate-controlled pods attached to the outside of the London Eye, while its predecessor had suspended open-top gondolas.

At 94 metres, the Great Wheel was just two metres shorter than Big Ben

Capsule components

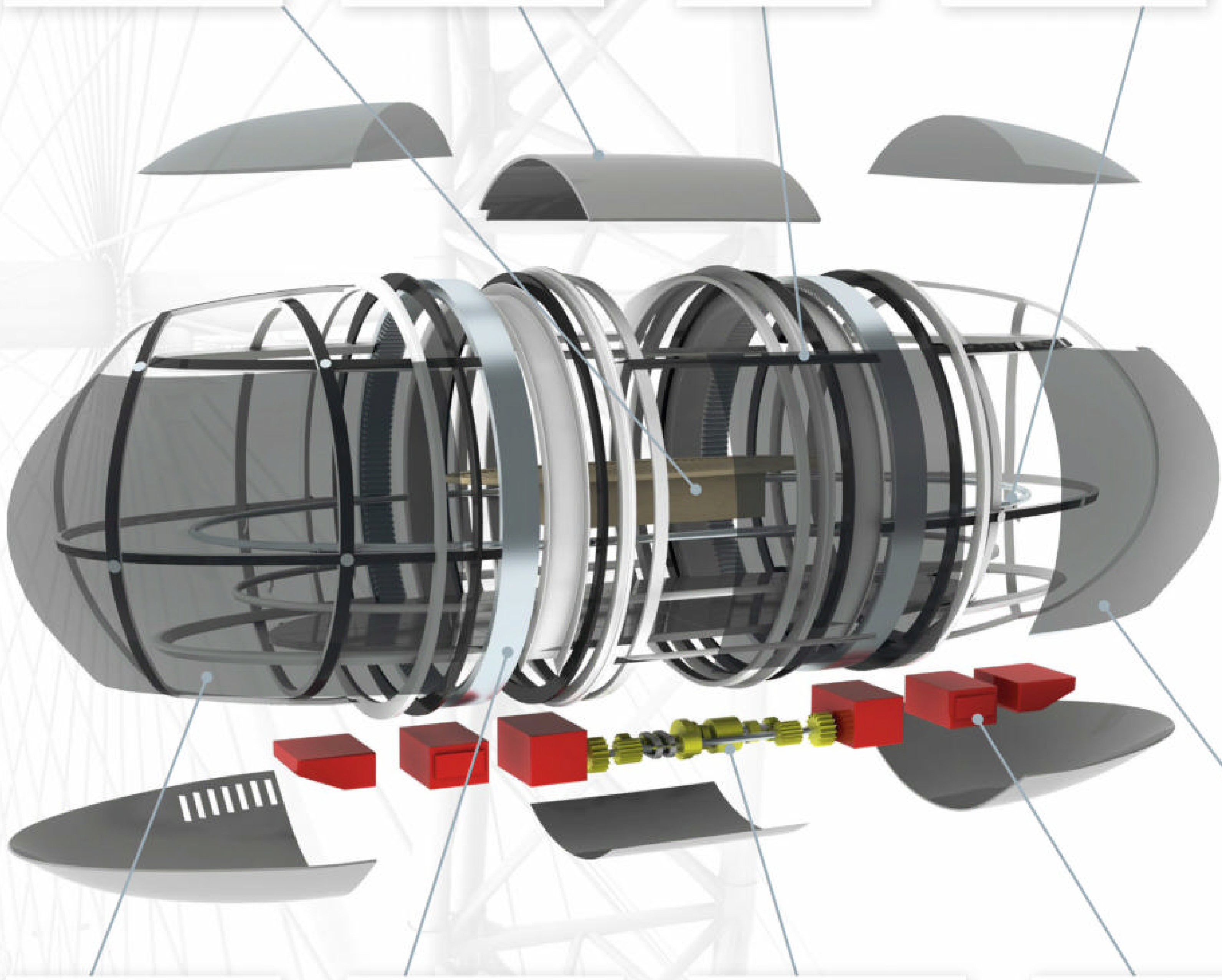
How were the pods assembled to provide the ultimate round-trip experience?

Mounting position
The capsules are attached to the outside of the wheel's frame. This maximises the accessible views of the city without obstructions.

Ceiling components
Inside the top of the capsules are lights, security cameras, two-way radios and speakers.

Caged frame
This lightweight steel frame acts as a basic framework for the exterior panels.

Safety locks
Using capsule position data, the door automatically locks and unlocks when entering and leaving the boarding platform.



Curved design
Each capsule consists of 36 glass panels, all double-curved. Glass sheets are laminated together with a resin layer in between. These windows are attached to the pod with a silicone sealant.

Twisting pods
The capsules attach to the wheel's main frame via circular mounting rings. The rings make the compartment turn with the wheel so that the pods stay the right way up.

Stability system
This section is responsible for keeping a controlled turning motion. Rotating in the opposite direction to the wheel's movement, passengers are kept standing on a horizontal surface.

Inside climate
Every capsule comes with a separate electronic system to heat and ventilate the pod for passenger comfort. This also prevents condensation from limiting pod views.

Resistant windows
The wide glass panels not only serve to provide the best panoramic views of London, but are made from weather-resistant material. The triple-layered laminated glass protects the compartment and is believed to be able to withstand the worst storms predicted for the next 50 years.

5 FACTS ABOUT THE SKY-HIGH LONDON EYE

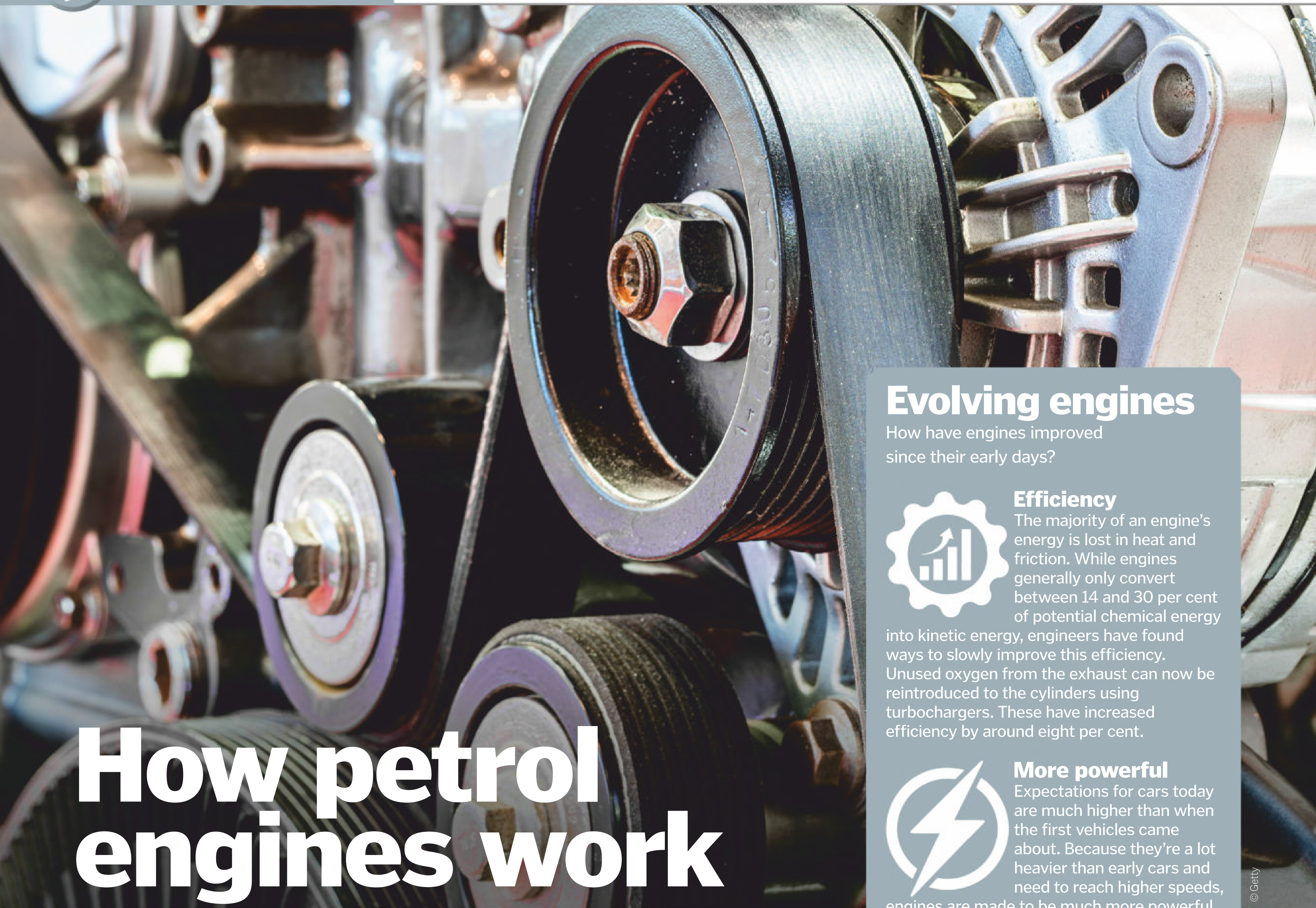
1 Rising wheel
At 135 metres in height, the wheel's structure is the equivalent of 64 of London's telephone boxes stacked on top of each other.

2 Becoming permanent
Originally the London Eye was only given permission to stay for five years. Two years after it was open to the public, city council granted its permanency.

3 Upstream assembly
The main components were built offsite and transported up the River Thames when ready for assembly.

4 Pod placement
It took a total of eight days to attach the 32 pods to the wheel.

5 Seeing the city
When in the pod and at the highest point, you can view to a distance of 40 kilometres.



How petrol engines work

Under the hood, a series of tiny explosions powers your vehicle

Words by **Ailsa Harvey**

Pushing down on the accelerator commands your car to propel you faster along the road, almost instantly. But what is going on inside your car to make this happen? While you sit comfortably in your seat, the car's internal combustion engine is working frantically to create a series of small explosions.

Consisting of a chain of cylindrical containers, air and fuel are passed through this energy production line. As the air and fuel combine inside the engine, a series of controlled blasts are formed, producing the energy needed to turn the car's wheels.

Because a car engine's pistons are pumping at around 10 to 20 times a second or more, the energy they produce needs to be harnessed and released in a controlled way. It is the driver who controls the use of the engine's output through the changing of gears.

Between the engine and the wheels, the gearbox acts as the middleman. Without it, cars would have a minimum speed of around 120 kilometres per hour. Imagine how chaotic it would be if as soon as you started the ignition you were hurtling down your street at motorway speed. Engines have the power to revolve your wheels at hundreds of miles an hour, so engines work with the rest of the car to keep these violent power sources powering the vehicle in a controlled manner.

The product of a car's combustion engine is around 13% carbon dioxide, 13% water and 73% nitrogen

Evolving engines

How have engines improved since their early days?

Efficiency

The majority of an engine's energy is lost in heat and friction. While engines generally only convert between 14 and 30 per cent of potential chemical energy into kinetic energy, engineers have found ways to slowly improve this efficiency. Unused oxygen from the exhaust can now be reintroduced to the cylinders using turbochargers. These have increased efficiency by around eight per cent.

More powerful

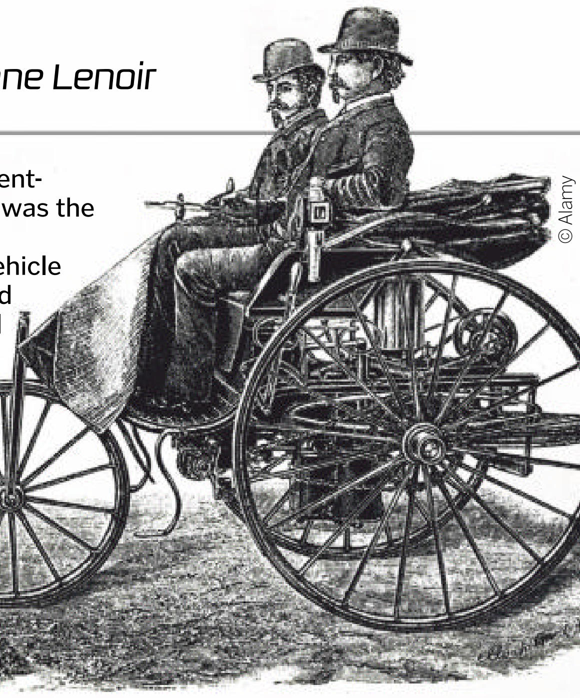
Expectations for cars today are much higher than when the first vehicles came about. Because they're a lot heavier than early cars and need to reach higher speeds, engines are made to be much more powerful.

Slight shrinkage

Generally, vehicles generating more power require larger engines for greater combustion. However, engines have experienced a reduction in size over the years. This is due to efficiency-improving technology. In 2011 Ford showcased this with two F-150 trucks that had new 'eco boost' 3.5-litre engines producing 365 horsepower, compared to the outgoing 5.0-litre, 360-horsepower trucks built the same year using old technology.

Smarter systems

Some of today's engines are much less likely to experience mechanical issues because mechanical parts have been replaced with electrical components, and newer technology means engines are largely monitored by sensors. One modern system that improves engine efficiency is cylinder deactivation. When less power is needed, less cylinders are required. Some can be deactivated so that they are not being used unnecessarily.



The Benz Patent-Motorwagen was the world's first production vehicle to be powered by an internal combustion engine

Power production

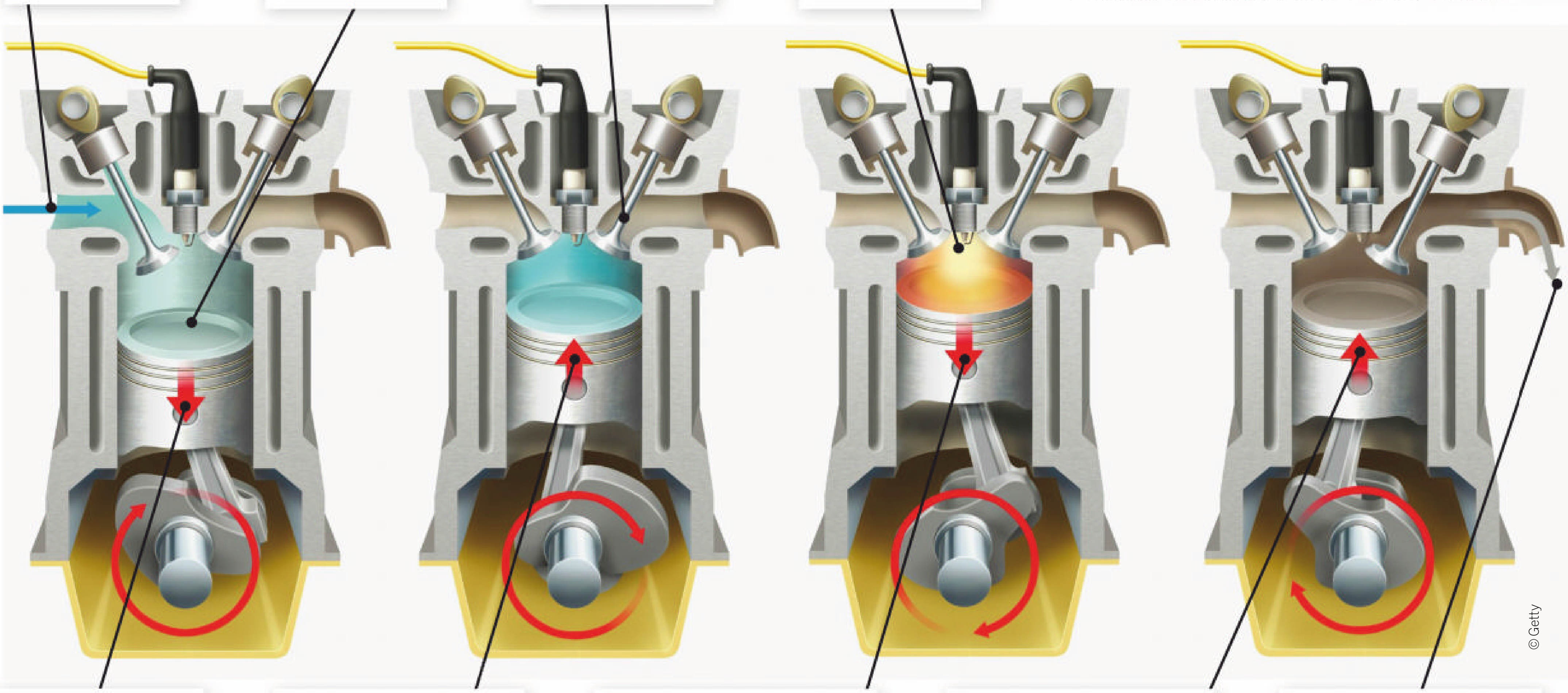
How are fuel and air manipulated to move vehicles?

Open intake valve
Air and fuel enter the engine cylinder through the intake valve.

Combustion chamber
Inside the cylinder, the fuel and air combine to create a powerful, explosive mixture.

Contained space
Both valves remain shut to make sure no mixture escapes from the high-pressure environment.

Creating a bang
A burst of electricity from the spark plug ignites the fuel-air mixture surrounding it, and a mini explosion takes place within the engine.



Increasing cylinder space
The piston moves downwards to create more space inside the cylinder for more air to enter.

High pressure
As the piston is lifted higher, this reduces the space in the cylinder. With the mixture compressed into an area a tenth of its original size, pressure increases.

Explosive force
The explosion pushes the piston back down. This movement also moves the rod downwards, which turns the crankshaft below. As the crankshaft rotates, it powers the engine.

Preparing to repeat
The piston reduces the space inside the cylinder by pushing upwards. This limited space forces the spent mixture out quicker so that the cycle can begin again.

Releasing waste
Used fuel produces waste gases at the end of combustion. The exhaust valve opens to allow by-products, such as carbon dioxide and steam, to escape.

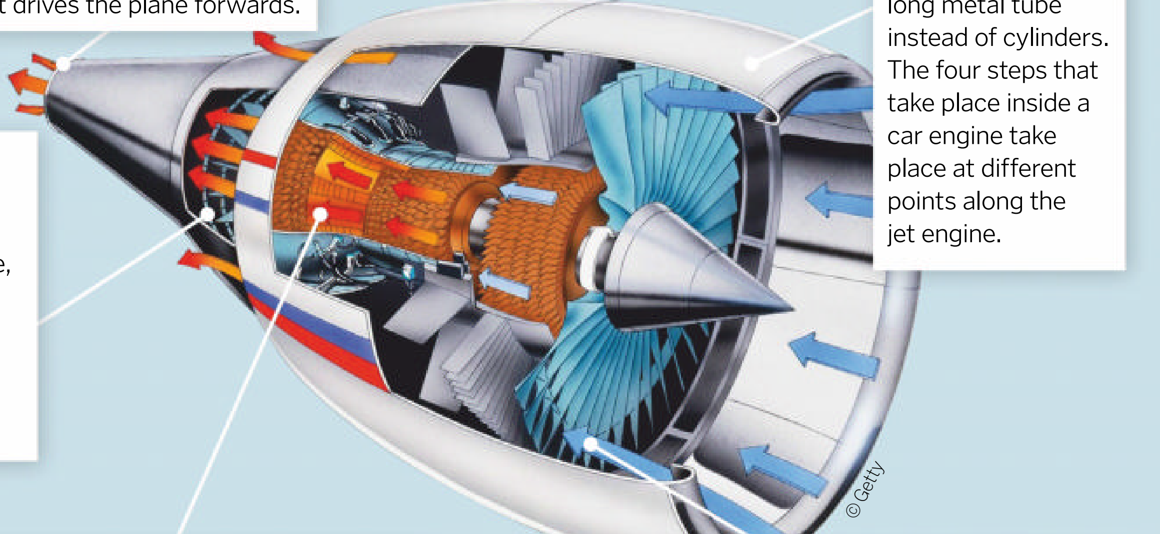
Engine differences

Vehicles for different purposes have different power outputs. Rocket engines, for example, can exert forces thousands of times more powerful than a car is capable of. The speed achieved by a particular vehicle hugely depends on engine size. While cars used on public roads are limited to safer speeds, racing cars usually require big engines for high-speed thrills. These racing engines have more cylinders to allow for higher combustion rates.

Jet engines work on a different principle to car engines. Instead of using the cycle of car engines – with four or more steps – jet engines have adopted the method of burning fuel in one continuous air stream. By achieving continuous combustion, rather than just a fraction of the time as in cars, energy production is more rapid for propelling planes through the sky.

Exhaust
The waste gases leave the jet engine, travelling at twice the speed of the sky's cool air. This backwards movement drives the plane forwards.

Cylinder replacement
Jet engines use a long metal tube instead of cylinders. The four steps that take place inside a car engine take place at different points along the jet engine.



Cooling
Exhaust gases from combustion pass through a final turbine, which is connected to the first fan to help it turn. As the gases spin the turbine, they cool down.

Combustion
Liquid fuel is squirted into the combustion chamber from the fuel tank. Mixing with the air, it burns at around 900 degrees Celsius.

Compression
The air drawn into the engine is taken into the first fan, which slows down the air, and a second, which compresses it.

WIN!

A CELESTRON TELESCOPE

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This month we are giving away an Astromaster 90 EQ telescope by Celestron. Stargazing is made easy with this 90-millimetre refractor telescope, capable of 100x magnification so you can peer deep into the cosmos.

For your chance to win, answer the following question:

Earth is located in which galaxy?

a) **Andromeda**

b) **Milky Way**

c) **Messier 82**

Enter online at **howitworksdaily.com** and one lucky winner will win!

Terms and Conditions: competition closes at 00:00 GMT on 12 March 2020. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: www.futuretcs.com. Entries must be received by 00:00 GMT on 12/03/2020. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

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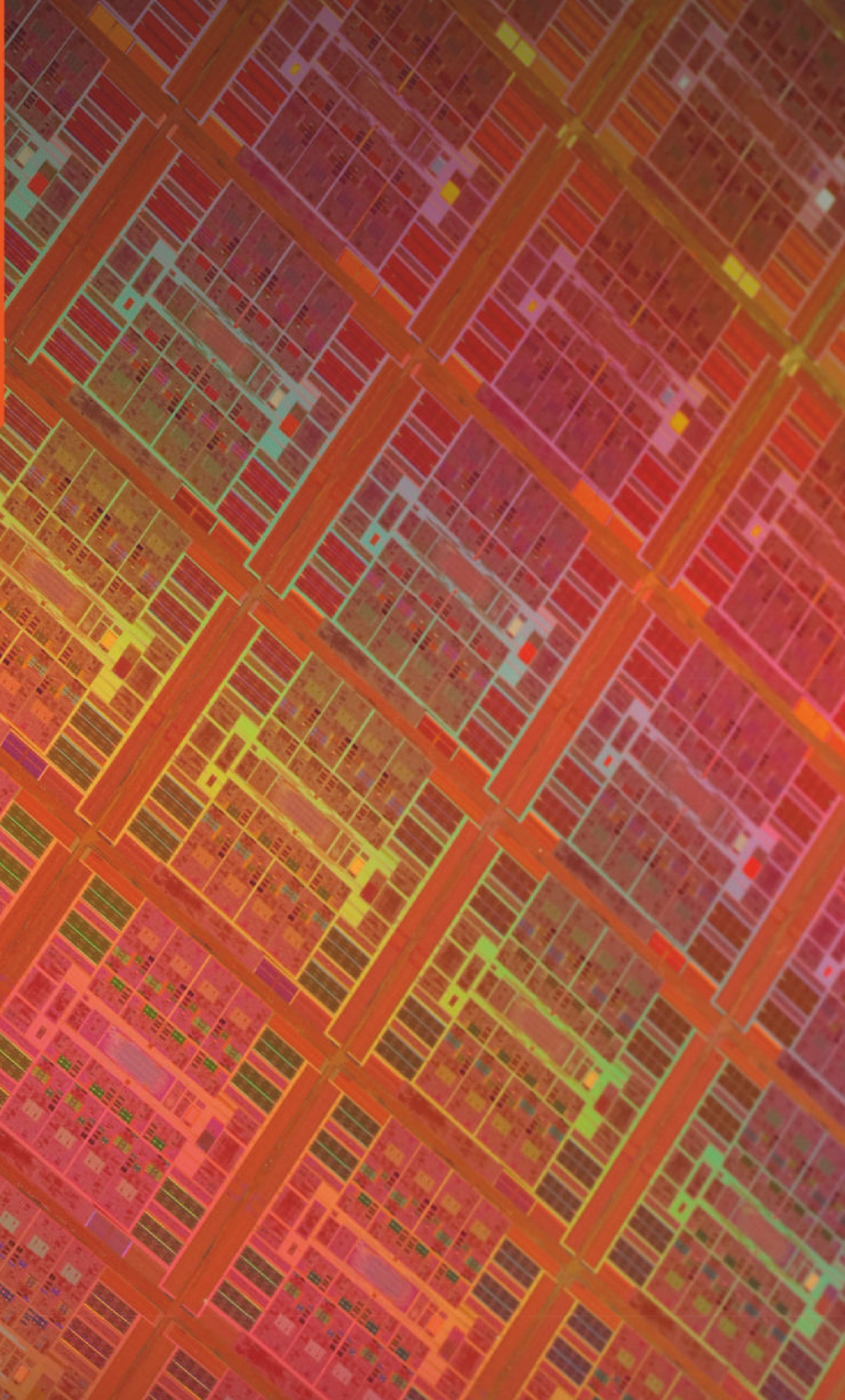
BRAIN DUMP

Because enquiring minds need to know...



Microchips are built on silicon wafers out of billions of individual transistor switches

© Getty

MEET THE EXPERTS

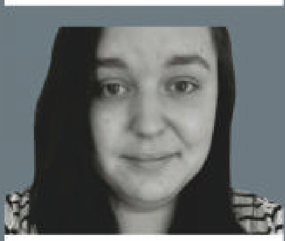
Who's answering your questions this month?

JO ELPHICK

MARK SMITH

ANDY EXTANCE

ANDREW MAY



AMY GRISDALE

Want answers?

Send your questions to...

How It Works magazine

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Why are microchips made of silicon?

David Hoffman

Silicon works well for microchips as it makes good switches, because it is a semiconductor. It's not electrically conductive like copper, which we use to make wires that carry electricity. It's not a non-conductive insulator, like rubber. Insulators don't carry electricity, so we use them to protect wires. Silicon is between these two, meaning we can use it to make switches called transistors. Silicon transistors turn from being an insulator to being conductive when we apply a little electricity. Microchips contain billions of silicon transistors. We use their switching to do mathematical and logical processes that power our electronic devices. **AE**

© European Southern Observatory

What was there before the Solar System formed?

Jamil Khalid

■ The Solar System formed out of an interstellar molecular cloud – a huge volume of tenuous gas and dust – which collapsed down under gravity to form the Sun and planets. **AM**

If dolphins can't breathe underwater, how do they sleep?

Ava Perez

■ Every breath a dolphin takes is a conscious decision. They can't go into autopilot like humans do because they might drown. To solve this problem they rest half of their brains at a time, allowing them to stay alert enough to come up for air and watch for predators while half-asleep. **AG**

Sleeping dolphins breathe up to 75 per cent less than when wide awake

© Getty

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How high can a hot air balloon go?

Rachel Boyd

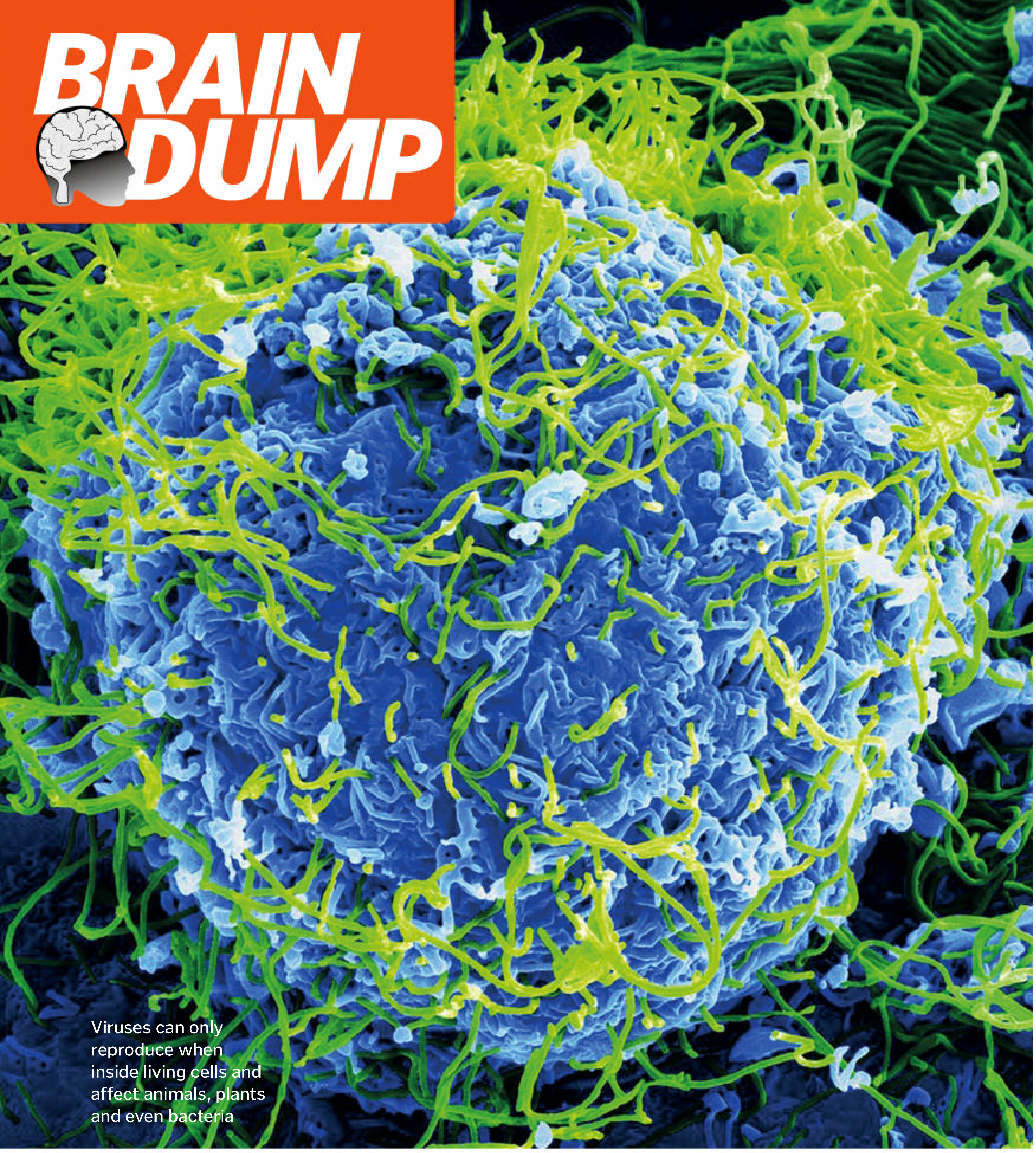
■ The highest a hot air balloon has ever flown is 21,027 metres, a record achieved by Dr Vijaypat Singhania, who flew over the Indian city of Mumbai in November 2005. **MS**

© Getty

What kind of plants are fungi?

Elizabeth Wilson

■ Fungi aren't plants at all. They were classified as a distinct group in 1969. While mushrooms may spring from the ground they don't have roots, aren't made of cellulose and can't photosynthesise. **AG**



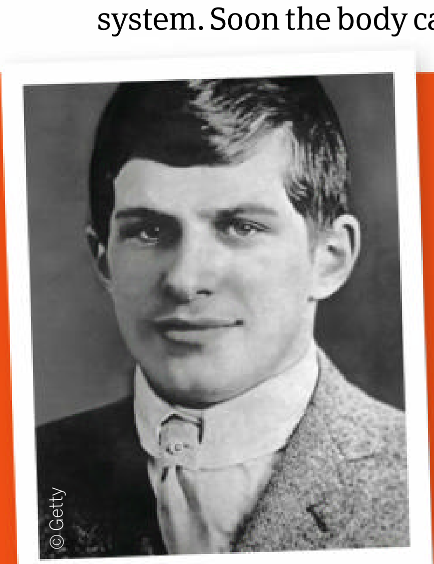
Viruses can only reproduce when inside living cells and affect animals, plants and even bacteria

Source: Wk / BernbaumJG

What is the deadliest virus?

Paige Scavo

■ Smallpox is widely considered to be the most dangerous viral disease in history. It claimed 300 million lives in the 20th century alone. The symptoms start just like flu, but within 24 hours the whole body is covered in painful sores. Meanwhile, the virus works on the immune system. Soon the body can't stop the virus from replicating and eventually succumbs to death. Survivors have widespread scarring and may even go blind. The good news is that smallpox was declared eradicated in 1980 thanks to a global vaccination programme. Unfortunately there are still deadly viruses around. Ebola, HIV and influenza are just three that kill thousands every year. **AG**



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What is an IQ and what's the highest ever recorded?

Mina Dhital

■ IQ is an acronym for intelligence quotient and is a way of measuring your ability to reason and solve problems. Having answered a series of questions, your score is added up and compared to a representative sample of a similar age group. An average IQ is between 90 and 110, while the highest IQ ever recorded belonged to William James Sidis with a score of 250 to 300. He was admitted into Harvard at the age of 11! **JE**

© Getty

How do flies walk on the ceiling?

Caroline Kelly

■ Insect feet are covered in bristles that cling to tiny imperfections in sheer surfaces. There are also claw-like structures on the end of the legs that provide grip. Flies also have wide, sticky pads on their feet covered in gluey liquid that help them defy gravity. **AG**

© Dorgan

What's the strongest human-made acid and what can it dissolve?

Michelle Tucker

■ Many say that fluoroantimonic acid is the strongest human-made acid, stronger even than the brilliantly named 'magic acid'. It dissolves glass, so must be kept in a Teflon bottle. The strongest acid many professional chemists ever work with is hydrogen fluoride. Mixing hydrogen fluoride with antimony pentafluoride makes fluoroantimonic acid. **AE**

In the future will we be using hyperloops to commute?

Ewan Bailey

A hyperloop – an enclosed steel tube through which a vehicle moves at more than 965 kilometres per hour – could one day be used for commuting, but we're still some way off.

Tesla founder Elon Musk and Virgin boss Richard Branson are among those trying to turn the tech into reality, with Virgin building a full-sized pod in 2017 in Nevada which reached speeds of 387 kilometres an hour. However, experts predict we won't see a usable hyperloop until at least 2030. **MS**

Source: Wiki/Neuhausengroup

Hyperloops could travel at over 965kph, but they're ten years away

Why don't aeroplanes flap their wings like birds?

The Festo SmartBird is a remote-controlled ornithopter that flies by flapping its metre-long wings

Source: Wiki/Festo

Reece Wood

A bird's wings serve two functions. Firstly to provide upward lift and secondly – this is where flapping comes in – forward propulsion. A plane's wings are only needed for the first, because its engines can provide propulsion far more efficiently. People haven't always realised this, and several early aircraft designs – called 'ornithopters' – attempted to mimic a bird's flight. In fact, despite its inefficiency, flapping does have some advantages, such as greater agility, and it's possible that ornithopters will make a comeback in the future in the form of small robotic drones. **AM**

What was the Commonwealth of England?

Ben Horrocks

After the execution of Charles I, the Rump Parliament governed England, Wales, Scotland and Ireland as a republic, naming it the Commonwealth and making Oliver Cromwell its Lord Protector. **JE**

© Getty

BRAIN DUMP

Although galaxies contain billions of stars, mathematical analysis shows that they're collisionless systems

© NASA

Could our Solar System collide with another system in the Milky Way?

Tia Khan

■ With at least a hundred billion stars, the Milky Way galaxy sounds like a very crowded place – but due to its vast size it's still mostly empty space. Astronomers have estimated the average time between stellar collisions, and it turns out to be enormously longer than the age of the universe, so there's absolutely no chance that the Sun and its system of planets will collide with one of our neighbours. **AM**

When was London first settled?

Sharon Richards

■ In about 6000 BCE a tribe of hunter-gatherers settled in the area alongside the River Thames. Further groups lived here during the Bronze Age and Iron Age, but it was the Romans who founded a port and set up a trading settlement, naming it Londinium in 43 CE. **JE**

© Getty

A baby spends most of its time fast asleep while its body develops

© Getty

Can humans die from lack of sleep?

Theodor Filimon

■ There is no known evidence to prove that a human could die from lack of sleep. However, sleep deprivation will definitely make a person feel extremely unwell. First signs tend to be a change in mood – usually for the worse! This is most often followed with a loss of coordination resulting in clumsy and erratic behaviour. After a few days the brain attempts to save energy by shutting down non-vital functions, which may lead to hallucinations. All five of the senses are badly affected, with sleepless patients complaining of bizarre smells, noises and other inexplicable sensations. **JE**

© Getty

When was the first elevator built?

Dylan Porter

■ Platforms that move up and down actually date back to ancient Rome, but the type of hydraulic cable elevator we're used to today was devised by Elisha Otis in 1852. **MS**

© Drents Museum

The Pesse canoe is the oldest boat yet discovered, dating back to 7600 BCE

What was the first human-made vehicle?

Olivier Robertson

■ The first handmade method of transportation is actually thought to have been a type of canoe. Ancient peoples who colonised Australia between 60,000 and 40,000 years ago used log boats, essentially a hollowed-out tree trunk. The Pesse canoe, now in the Drents Museum in the Netherlands, is the oldest boat discovered, dating to around 7600 BCE. When it came to getting around on land, the wheel was what transformed transportation. Up until then, ancient peoples had simply ridden horses.

Invented in ancient Iraq in 3500 BCE, the wheel was initially used for pottery, but around 300 years later it was incorporated into an early form of chariot. **MS**

What is tinned SPAM made of?

Linda Duncan

■ Hormel Foods Corporation makes SPAM by mixing ground ham and pork, then adding salt, sugar, water and potato starch. It cooks these ingredients, then cans them. **AE**

© Getty

Where does Earth's atmosphere finish and space start?

Zak Wilkinson

■ The atmosphere doesn't have a sharp upper edge, but just gets thinner the higher you go. Even at the altitude of the ISS, there's some air. By convention, space starts at the 'Karman line', 100 kilometres above the Earth, where spaceflight become easier than aerodynamic flight. **AM**

© NASA

What's a stem cell?

Joshua Montgomery

■ A better name for stem cells might be 'transformer cells'. That's because stem cells can change to become another type of cell. That's unusual – most cells stay as the same type, for example a skin cell or a blood cell. But the cells that become babies in their mothers' wombs start out as stem cells. We also have some reserves of stem cells that make new replacements for our cells when they die. **AE**

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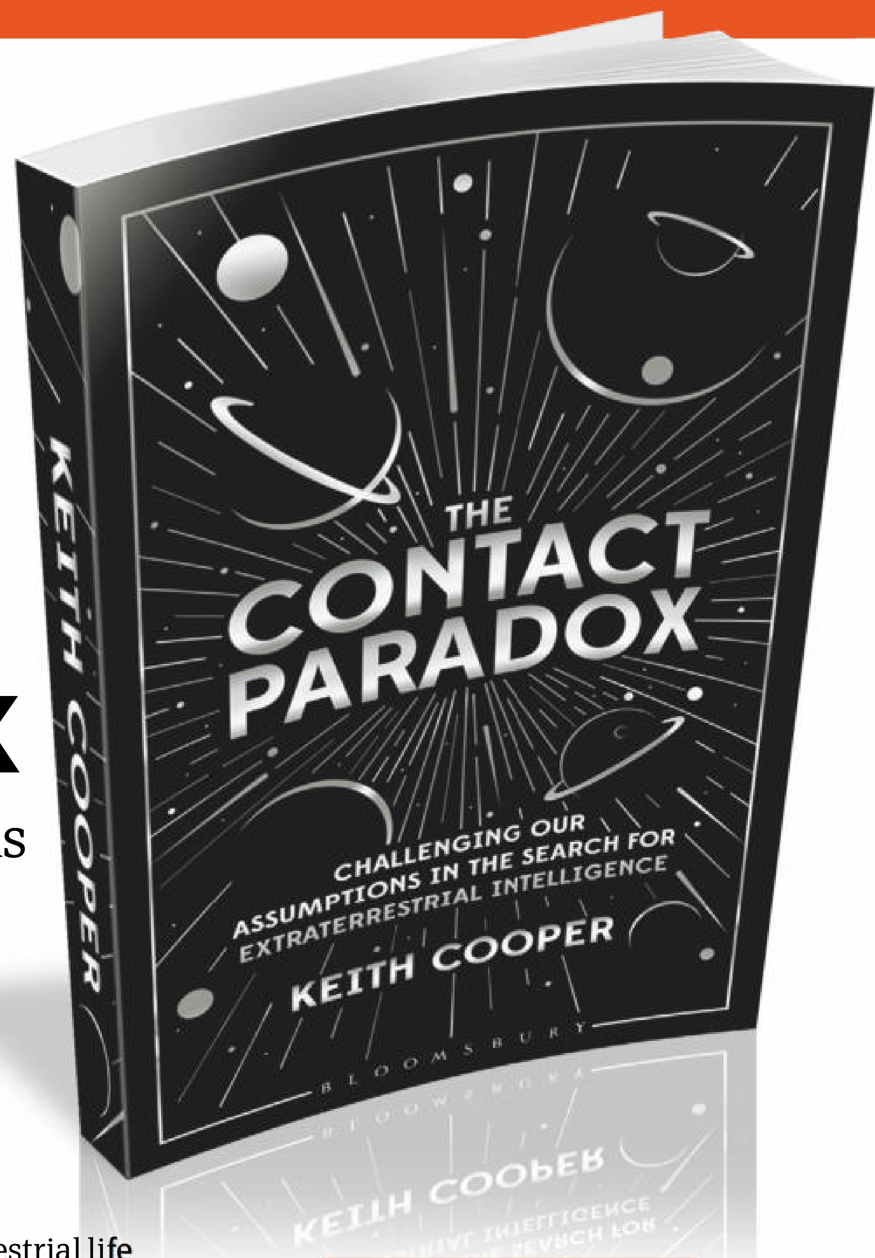
BOOK REVIEWS

The latest releases for curious minds



The Contact Paradox

Asking the big questions about intergalactic correspondence

- Author: **Keith Cooper**
- Publisher: **Bloomsbury Sigma**
- Price: **£18.99 / $28**
- Release: **Out now**

The question of whether extraterrestrial life exists in our universe is perhaps one of the biggest and most challenging topics of all. With no definitive answer available, our long-running search for life beyond our skies is packed with intricacies that this book does a fantastic job of untangling.

The Contact Paradox deals with the big scientific questions of contact with other worlds, such as what the best way to send a signal is, and how and where we should be looking for signals from others in the universe. As Cooper points out, agencies like NASA are still well funded – especially compared to the teams at SETI (the Search for Extraterrestrial Intelligence), who are arguably doing more to discover life in the stars than the space agency itself.

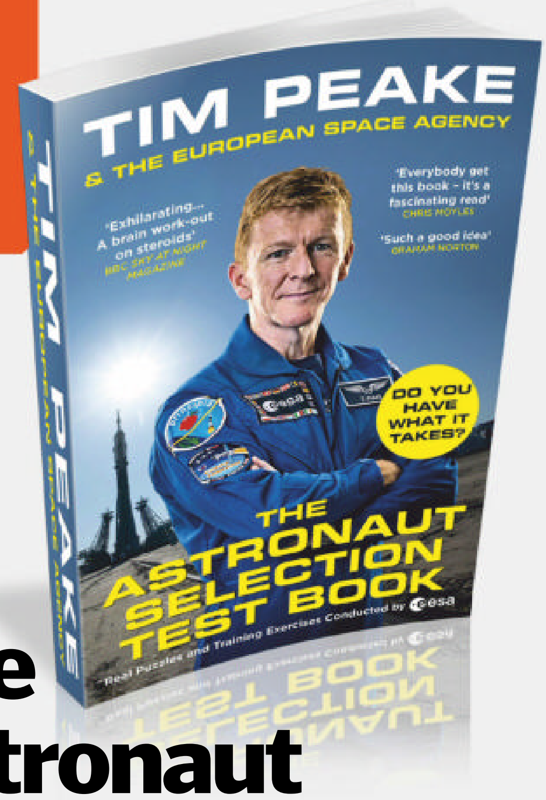
But there are also some serious philosophical questions explained here. The first chapter of the book, for example, isn't about whether radio waves or laser beams are the best way to send messages from Earth. Instead it explores the idea of altruism, questioning how an alien species might act if they did come into contact with us. It's an interesting start, and one that sets the tone for the rest of book brilliantly.

There are plenty of other big questions here too – including the Rare Earth question. While the Drake equation, formulated in the 1960s, suggests that there are likely to be between 1,000 and 100,000,000 civilisations in our galaxy capable of sending out similar signals to us, we have still yet to communicate with one. Is it perhaps the case that our planet, with its perfect distance from a star, its abundance of water and oxygen and its ideal geographic make-up is perhaps rarer than we might think? And does that mean alien life might be less common than our current estimations suggest?

> "There are some serious philosophical questions explained here"

While Cooper can't answer many of these questions definitively, he does a fantastic job of expanding the reader's knowledge. To illustrate his points, he packs in science-fiction references, from Jodie Foster in *Contact* to classic *Star Trek* episodes and plenty of books that avid readers will likely want to pick up for further reading. These help lift what can sometimes be quite a serious tone and make it much more relatable when it's digging into heavy scientific or philosophical principles.

★★★★☆



The Astronaut Selection Test Book

Do you belong out there?

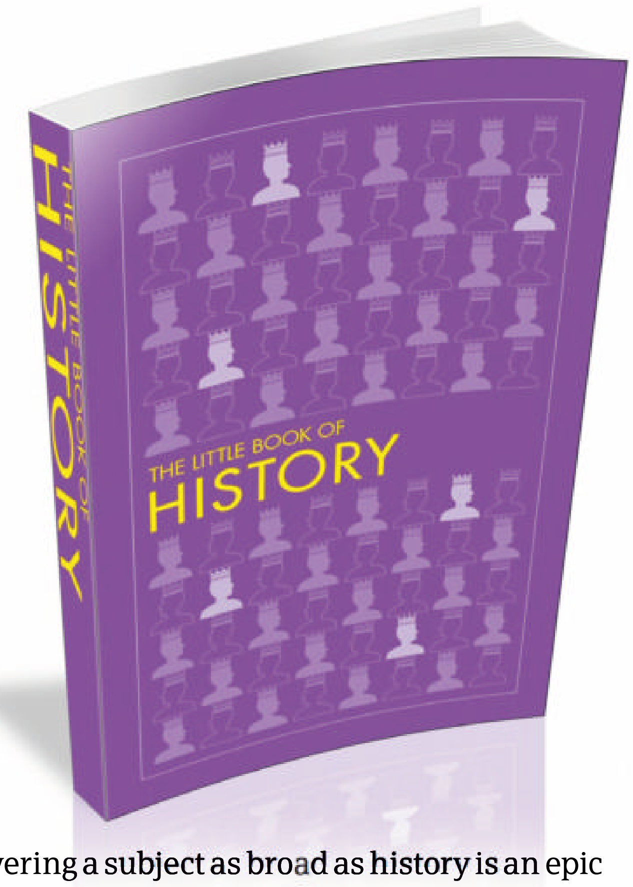
- Author: **Tim Peake and the European Space Agency**
- Publisher: **Century**
- Price: **£12.99 (approx. $15)**
- Release: **Out now**

Long ago, we made peace with the fact that we would probably never become an astronaut. But there might still be hope for some of you – and who better to draw it out of you than Tim Peake, Britain's very own guitar-strumming space oddity?

As you would expect, however, fulfilling the requirements isn't easy. Sure enough, the opening pages present you with the kind of scenarios that would leave even *The Martian*'s Mark Watney scratching his space helmet. After this crash course the book focuses on four more specific sections: 'hard skills', specific, often non-teachable abilities like visual perception, memory and concentration; 'soft skills', physical and psychological requirements; the job interview itself, followed by what the responsibilities of an astronaut are likely to encompass.

Astronauts generally have to be all-rounders, so there's nothing to be ashamed of if you can't immediately respond to every question in this book. Really, your enjoyment will depend on how you approach this: if taken seriously, then it's only likely to increase your own feelings of inadequacy. Conversely, if you look at this both as a bit of a lark, and an indicator of just what it takes to do the job, you're likely to glean more pleasure from this.

★★★★☆



The Little Book of History

A short history of everything

- Author: **Various**
- Publisher: **Dorling Kindersley**
- Price: **£8.99 (approx. $10)**
- Release: **Out now**

Covering a subject as broad as history is an epic undertaking, which makes it rather apt that Dorling Kindersley is the one to take on the mantle, seeing as how the publisher seamlessly goes hand in hand with the highest of production values.

While this represents a somewhat different approach to what DK is genuinely associated with – a brief guide to general subject matter as apposed to an in-depth presentation of a more specific area of history – the results are no less effective. Starting from ancient civilisations before progressing all the way through to the modern day, this serves as a comprehensive journey through the evolution of life and societies on Earth.

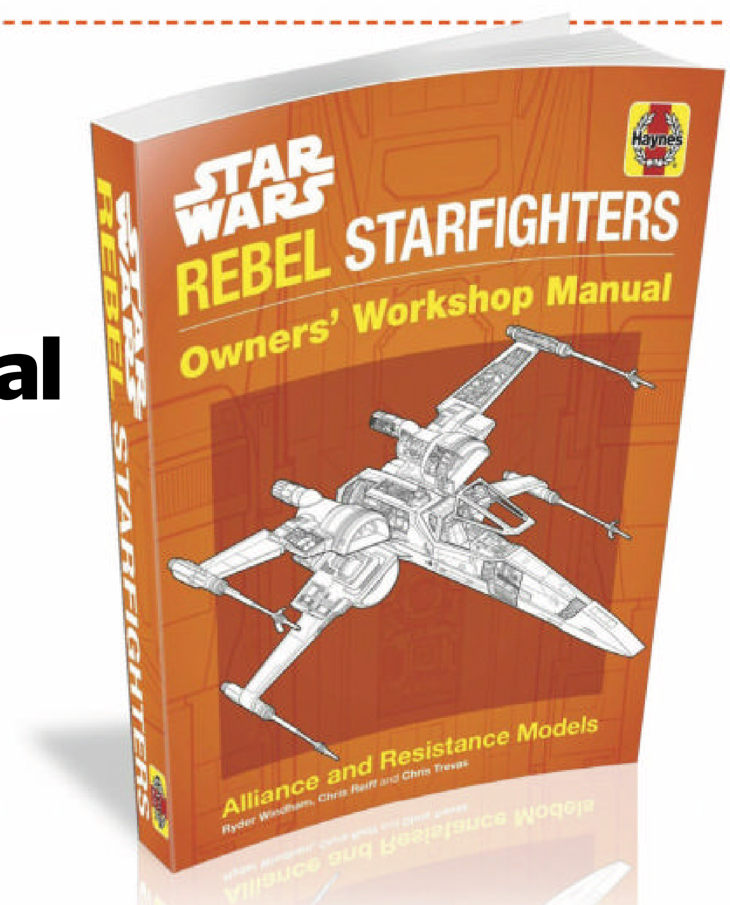
Text heavy in the style of something like *The Economist* rather than the diagram and annotation-heavy pages DK is known for, this is designed to be dipped in and out of a few pages at a time. It's not pretty – parts of it resemble the interior of a phone book – but we have to applaud the sheer amount of information it somehow manages to pack in.

Overall this proves to be effective both as a gateway to learning about different areas of history and as a means of gaining a more general understanding. ★★★★☆

Rebel Starfighters: Owners' Workshop Manual

Red Five standing by

- Author: **Ryder Windham, Chris Reiff, Chris Trevas**
- Publisher: **Haynes**
- Price: **£19.99 / $24.99**
- Release: **Out now**



If *The Rise of Skywalker* has left you put out that there isn't a real galactic civil war going on for you to take sides in, then this is the next best thing. From the brainy bods at Haynes, you can learn the inner workings of the Rebel Alliance's – and latterly the Resistance's – most hardy one-man fighters.

Whether you're an X-Wing ace, an A-Wing aficionado or a budding B-Wing pilot, you're covered here. Containing the most in-depth descriptions this side of Wookieepedia, you're taken through their history, how to fly them and some of their most famous heroes.

Inevitably, this might come across as a bit dry if you're not particularly familiar with the subject matter, which can only lead us to conclude that you've picked this up by accident. But if you're a *Star Wars* fan, then there are plenty of nerdy nuggets to keep you entertained. ★★★★★

Tales of Amazing Animal Heroes

The circle of life

- Author: **Mike Unwin**
- Publisher: **Puffin**
- Price: **£12.99 (approx. $15)**
- Release: **Out now**

Sometimes it's hard to shake the feeling that we're growing up in troubled times. With this in mind, it only makes books like this more essential, depicting various animals acting with the kind of bravery and selflessness that would likely prove anathema to most of our world leaders.

It functions almost like a compendium of feel-good stories: whether it's the story of Sergeant Bill the head-butting goat, Jet the search-and-rescue dog or GI Joe the top-speed pigeon, you're likely to be left wiping away more than a few tears thanks to the sheer heroism on show.

Accompanied by an introduction from author Michael Morpurgo, along with a series of hand-drawn illustrations that help bring the stories to life, we had a lot of fun with this, and we're sure that given the chance, you will too. ★★★★★

> "You're likely to be left wiping away more than a few tears"

BRAIN GYM
GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 How many different species of bacteria live in your gut?
- 100
- 1,000
- 10,000
- 1 million

Q2 Why was Neil Armstrong first out of the Lunar Module?
- He was nearest the door
- Buzz Aldrin was busy
- Neil won a coin toss
- He was ordered to

Q3 Typically, what kind of spirit is moonshine?
- Gin
- Whisky
- Vodka
- Brandy

Q4 How do you put out an electrical fire?
- Pour water on it
- Stamp on it
- Spray it with dry powder
- Pour petrol on it

Q5 What is the 'North Star' called?
- Polaris
- Altair
- Betelgeuse
- Sirius

Q6 Why is uranium so dangerous?
- It turns skin green
- It's radioactive
- It's very heavy
- It glows very brightly

Spot the difference

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

Sudoku

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

EASY

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

DIFFICULT

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

What is it?

Hint: Despite its name, this big berry is native to China, not New Zealand

A ....

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

Wordsearch

FIND THE FOLLOWING WORDS...

MICROBIOME
VIRUS
FIRE
POLONIUM
MEOW
VOSTOK
PERSPECTIVE
POLYNESIA
BOOTLEG
OCULUS
EYE
ENGINE

Check your answers

Find the solutions to last issue's puzzle pages

SPOT THE DIFFERENCE

QUICKFIRE QUESTIONS

Q1 £500,000
Q2 100 terabytes
Q3 Bathymetry
Q4 They were flammable

WHAT IS IT?...TASTE BUDS

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

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

How to navigate using the stars

Never get lost again with these simple tips on finding your way in the Northern Hemisphere

1 Find the dippers

First, look for Ursa Major (the Big Dipper, also known as the Plough) and Ursa Minor (the Little Dipper) – they're similar shapes, but the Big Dipper is usually easier to spot. You can use one to find the other because they're close.

2 Find the North Star

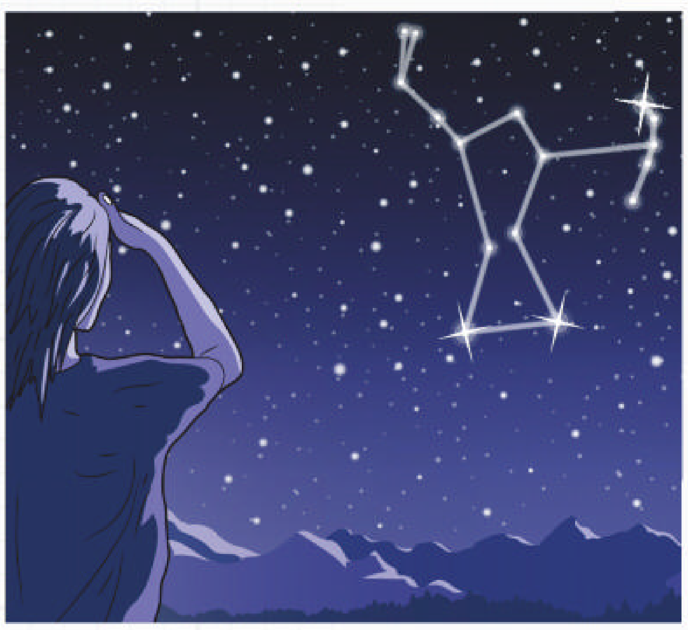
The last star on the tail of the Little Dipper is the North Star, called Polaris – it's often quite bright in the sky, so it shouldn't be too hard to find. If you're in the Northern Hemisphere, this star is northwards.

3 Calculate your latitude

Once you know where the North Star is, you can use it to calculate your latitude on the Earth. Sailors might use a sextant for this, but you can make a quadrant from a protractor and a weighted string.

4 Or, use an ancient technique

Hold your arm out in front of you and make a fist, lined up with the horizon. Put your other fist on top, and keep going until you reach the North Star. Each fist is around 10 degrees.



5 Find Orion, find south

Now, turn around to try and find south. You need to find Orion. His belt is made of three evenly spaced stars close together, and that should be all you need to find.

6 Follow his sword

Below Orion's belt are three stars close together in a line. These three stars point south, so draw an imaginary line starting with them and follow it to the horizon.

SUMMARY...

Because the axis of the Earth is stable, the North Star doesn't move around the sky – it always stays above the North Pole as the Earth spins, making it very useful for navigation. Orion's sword is the same. Interestingly, the fuzzy 'star' in the sword is actually the Orion Nebula, or Messier 42, an area in space where new stars are being formed.

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.

NEXT ISSUE
BUILD A BUG HOTEL

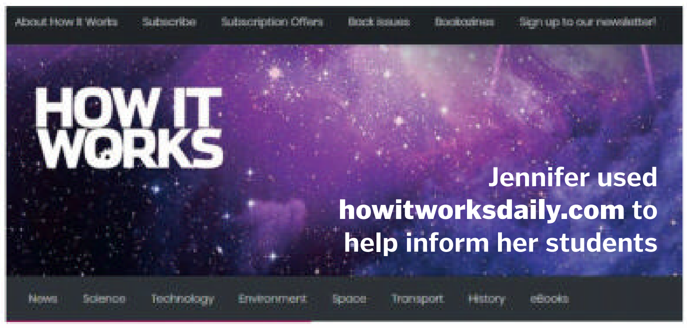
INBOX

Speak your mind...

Get in touch

If you have any questions or comments for us, send them to:

How It Works magazine @HowItWorksmag howitworks@futurenet.com



Jennifer used **howitworksdaily.com** to help inform her students

Online learning

Hello **HIW,**

I am Jennifer, a teacher. As my profession requires, I need to know a lot of information and always have answers to all my pupil's questions. I keep reading regularly for at least an hour to keep track of trends and what is going on every single day.

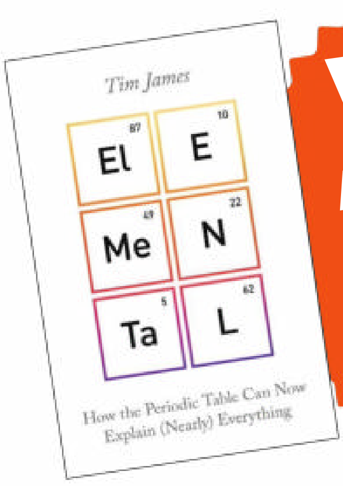
I notice that times have changed a lot thanks to technology and if we focus on its good side we can benefit a lot from it. I had a subject to share about gravity and forces and I wanted to do something special for my students, so I checked online and I really enjoyed your masterpiece '25 mind-blowing facts about gravity'. I not only got all the information I was seeking, I also learned new things too.

I read a few articles, and one got stuck in my head on balanced and unbalanced forces. I think this article gives helpful advice to a lot of curious children who are so into physics, and that's why I am asking if you could include something similar in your magazine because I think it would take it to the next level. Let me know what you think,

Jennifer

Hi Jennifer, thank you for your letter. We think it's great that you are teaching your pupils some of the most current topics from a variety of publications. Additionally, we love to hear what our readers enjoyed and want to learn more about.

As we cover a range of connected topics, we often add links to the bottom of online posts to take interested readers on to similar articles. Look out for these to allow their curiosity to develop further past each page.



WIN!

ELEMENTAL

An informative and entertaining, illustrated guide to how the periodic table is relevant to our day-to-day lives

Letter of the month

Keeping clean

Hi **HIW,**

You wash your hands after you've been to the toilet – supposedly to remove germs. However, you must transfer some of the germs on your hands to the tap as you turn it on. Then after we have washed our hands, transfer some germs back to your hands from the tap in the act of turning off the tap. So how useful is washing? Also, soap harbours germs, so how beneficial is using it?

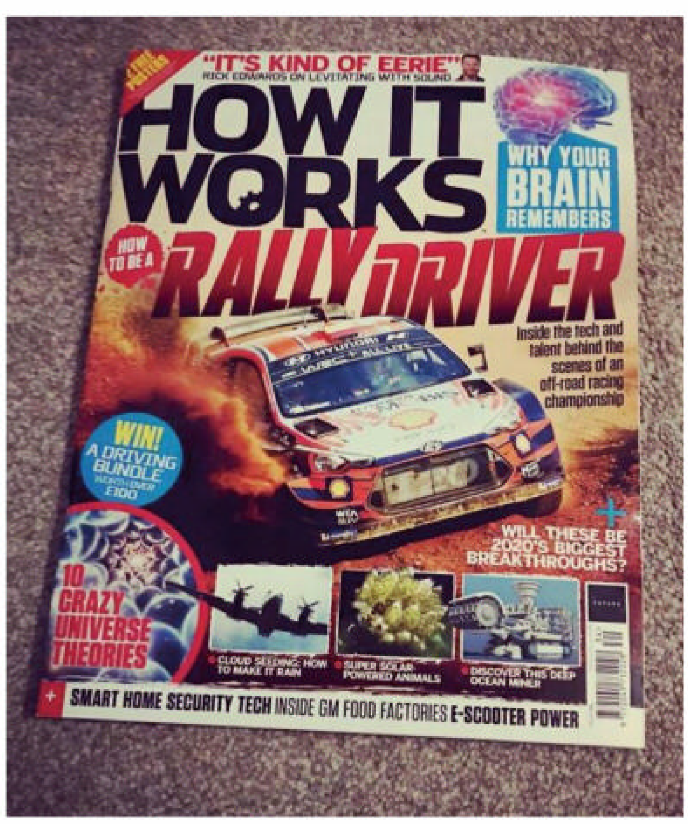
Stephen Conn

Soap is designed to clean your hands by dissolving the layer of fats, oils and dead cells. However, as you mention, this process involves touching the taps and soap with dirty hands, sometimes leaving the entire vicinity crawling with germs. Bathrooms can often be warm and damp, and this is an ideal environment for any germs. For this reason it is important to regularly clean your bathroom, including taps and the surrounding areas of the sink. Liquid soap generally transfers less dirt and germs back onto your hands than a bar, but their cleanliness can vary based on how you store your soap. Keeping your soap in a wet puddle by your sink increases the chances of bacteria growing.

While germs can spread easily through touch, washing hands well reduces the number of germs on your hands much more than simply avoiding the contaminated surfaces on taps and soap. It is recommended that you wash your hands with soap for around 20 seconds to ensure you leave the bathroom with cleaner hands than when you entered.

© Pixabay

Damp hands are 1,000 times more likely to spread bacteria than dry hands



@homeedder enjoyed our rally feature in issue 134

Inquiring minds

Dear **HIW,**

When I was searching for a magazine that would cover an array of topics, HIW ticked all the boxes, and it really does! It's packed with facts and figures, 98 pages of knowledge! If you have a curious child – let's be honest, they're all curious – this would be the perfect buy. It isn't aimed at children as such, but is easy enough to understand. Little person loved reading all about rally driving, how the brain remembers, solar-powered animals and so much more. I highly recommend it!

@homeedder

We're glad you enjoyed this issue's content and hope future topics continue to inspire. Childrens' minds can often be filled with questions, so we aim to provide something for everyone with our content.

Available in print from all good newsagents and **myfavouritemagazines.co.uk**, or as a digital edition for iOS and Android. To enjoy savings on the RRP and to make sure you never miss an issue, check out our subscription offers on pages 30 (UK) and 83 (US).

NEXT ISSUE...
Issue 136 on sale **19 MARCH 2020**

Primary school readers

Dear **HIW,**
Pod Pysgodyn challenge reading time. We are reading **How it Works** magazine and Oxford Owl in order to magpie ideas on how to write explanation texts. @HowItWorksmag #LlanLit #LlanDCF #LlanPysgodyn
@llanrhidianp

Thank you Llanrhidian Primary School for sharing this tweet with us. These pupils in Swansea, Wales, appear to be quite absorbed in past copies of How it Works. And it looks like an impressive method to teach a combination of science, language and IT skills, all at the same time!

Students at Llanrhidian Primary School have been reading past issues of **How It Works** for inspiration

Parrot personality

We have a 21-year-old African grey and believe me he really doesn't mimic. He has formed full sentences himself that make perfect sense.

He has everything we have food-wise. The other night we had steak. Hubby did caramelised red onions. Finn looked in his bowl then back at us and said, "Where's my gravy? I want gravy!"

This is barely the tip of the iceberg with him. He shouts "I'm starving 'ere! I'm wasting away!" while he has to wait for his food to cool down. I hope someone doesn't take it the wrong way!
Laura

On Facebook this month, we explored the science behind parrot chat. Scientists believe nuclei clusters in their brains help them to form social bonds with each other and their owners. While their tongues make them great at mimicking human speech, it was great to hear Laura's response, who told us all about her own parrot's cheeky personality.


© Pixabay
African grey parrots are among the most intelligent animals. They can identify, request and categorise over 80 different objects

What's happening on... social media?

This month we asked you what you think your cat thinks about the most


© littlelottee20
@littlelottee20
"She thinks about who's the boss of the house. And comes up with the same answer every time… herself!"

@Paulacomp0101
"Where does the water go?"

© Paulacomp0101

@SuzanneSmith88
"I reckon mine thinks about how she can get more food, how to get rid of the dog and a way to order takeaway mice"

HOW IT WORKS
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FAST FACTS

Amazing trivia to blow your mind

1887

CONTACT LENSES WERE INVENTED NEARLY 150 YEARS AGO

225° CELSIUS

N-BUTYL ACETATE BURNS WITH FLAMES THAT ARE FIVE-TIMES COOLER THAN A CANDLE'S

1,843,200 PIXELS

THE OCULUS RIFT S VIRTUAL REALITY HEADSET HAS AN LCD DISPLAY WITH MILLIONS OF PIXELS PER EYE

13TH CENTURY

THE HAWAIIN ISLANDS WERE FIRST SETTLED BY POLYNESIAN SAILORS FROM 1219 TO 1266

60

THE NUMBER OF SPECIES OF FUNGI FOUND IN HUMAN TOENAIL CLIPPINGS

THE ELEMENT CAESIUM WILL BURST INTO FLAME ON CONTACT WITH THE AIR AT ROOM TEMPERATURE

THE HUMAN CORONAVIRUS IS RESPONSIBLE FOR AROUND A THIRD OF COMMON COLDS

27.2 MILLION ACRES

A TOTAL AREA OVER FIVE TIMES THE SIZE OF WALES HAS BEEN BURNED IN AUSTRALIA'S RECENT WILDFIRES

75 YEARS

SILENT MOVIE STAR CHARLIE CHAPLIN'S CAREER IN FILMMAKING SPANNED MOST OF THE 20TH CENTURY

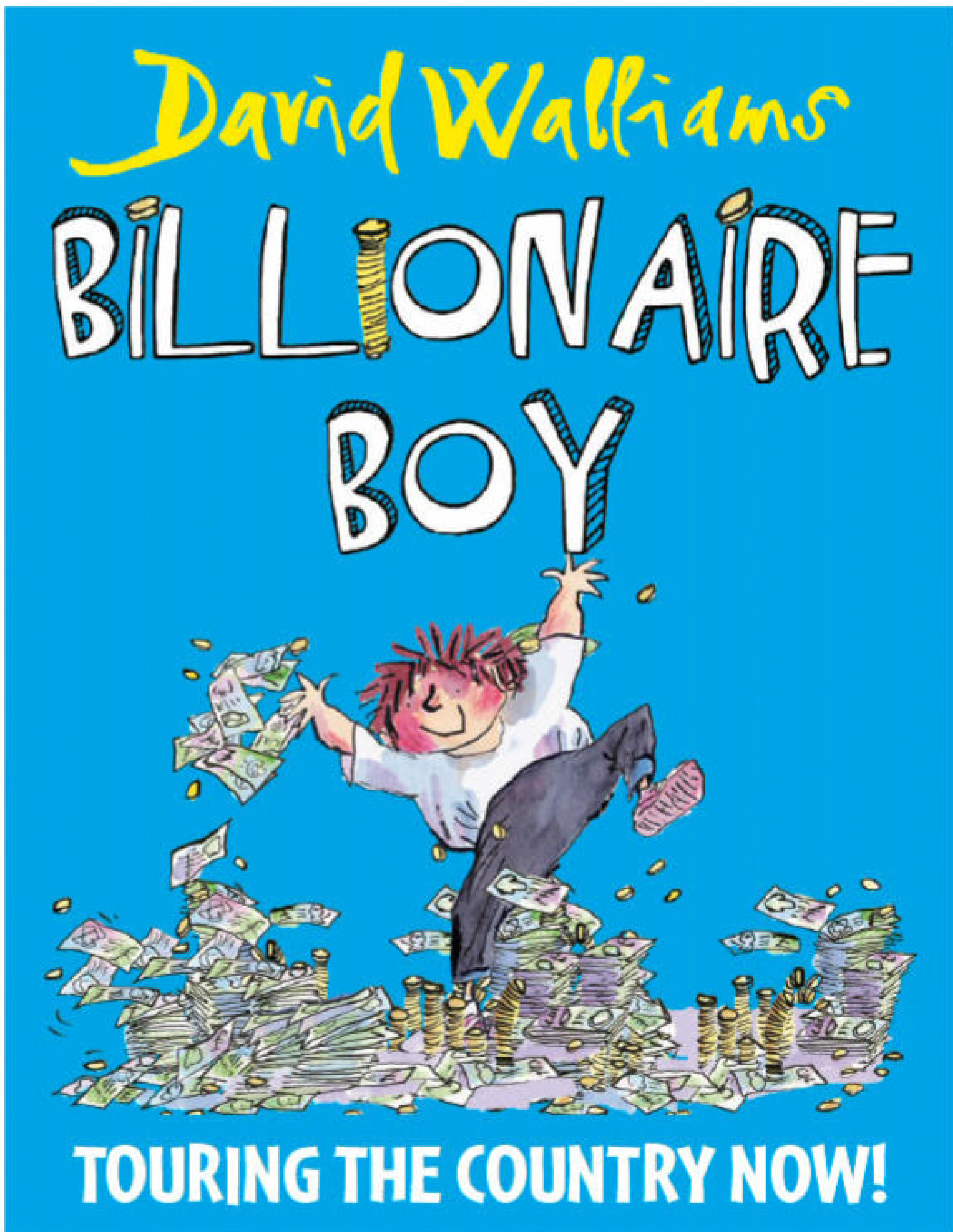
A BORED CAT WILL SCRATCH AND RUIN THE FURNITURE IN THEIR HOUSE

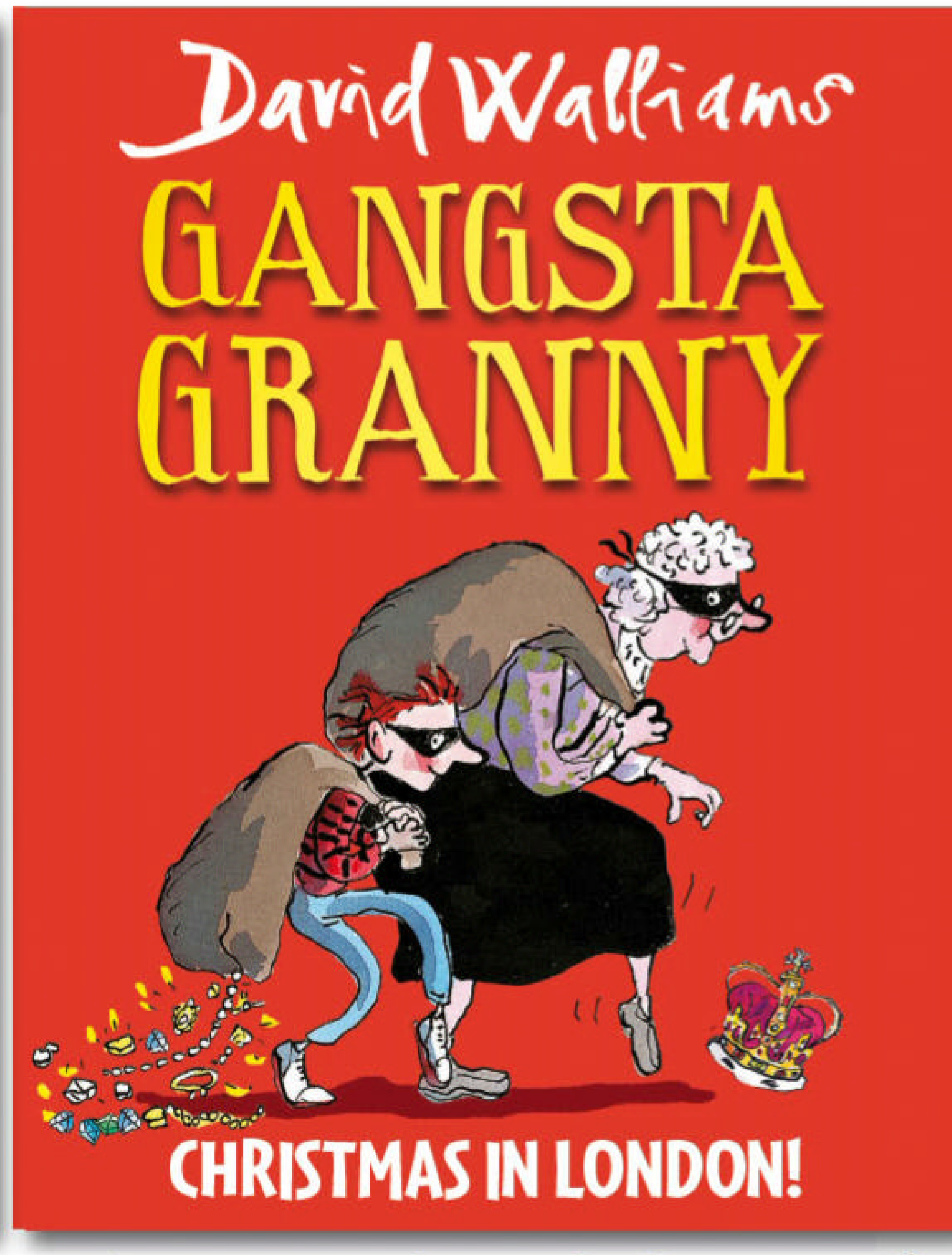
10-14 DAYS

IT WOULD TAKE PROHIBITION-ERA MOONSHINERS AROUND TWO WEEKS TO PRODUCE THEIR ILLEGAL ALCOHOL

THE PUPILS OF CATS' EYES CAN DILATE TO 135-TIMES BIGGER THAN WHEN THEY'RE FULLY CONTRACTED

FOUR GREAT SHOWS FOR YOU AND YOUR FAMILY!





See birminghamstage.com for your local theatre!