WHY IS JELLY WOBBLY?

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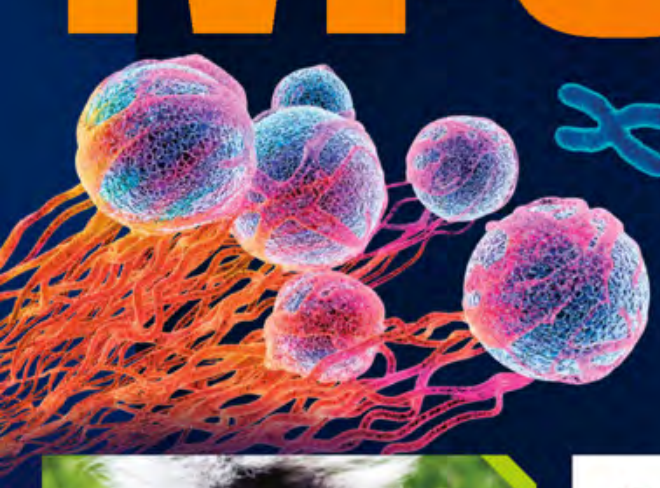
> WHY IS THE SKY BLUE?

> INSIDE A BLACK BOX FLIGHT RECORDER

> HOW VODKA IS MADE

Meet the MUTANTS

WHY THESE FREAKS OF NATURE ARE THE ENGINE OF EVOLUTION



WHAT MAKES SKUNKS STINK?

DISCOVER THE ROYAL ORIGINS OF CHESS

THE SECRET LIFE OF DEEP-SEA VENTS

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FUTURE
ISSUE 167

SCIENCE TECH ENVIRONMENT SPACE HISTORY TRANSPORT

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J6036
FORD MUSTANG GT

Ford Mustang GT
Build an Iconic Model

The sixth generation Ford Mustang (S550) is the current iteration of the Mustang pony car manufactured by Ford. In departure from prior Mustang models, the sixth generation Mustang includes fully independent rear suspension on all models, as well as an optional 2.3L EcoBoost turbocharged and direct injected four-cylinder engine. The new Mustang was introduced as a 2015 model year vehicle, marking the fiftieth anniversary of the Ford Mustang, which was revealed as a 1965 model year vehicle on April 17, 1964. The sixth generation is also the first Ford Mustang to be marketed and sold globally, and represented the first time that factory right hand drive Mustangs were produced in addition to the left hand drive models.

This vehicle has already become a true icon. You can create your own version at home with this Airfix QuickBuild kit. 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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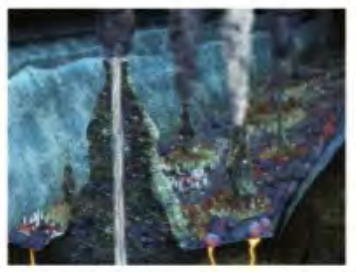
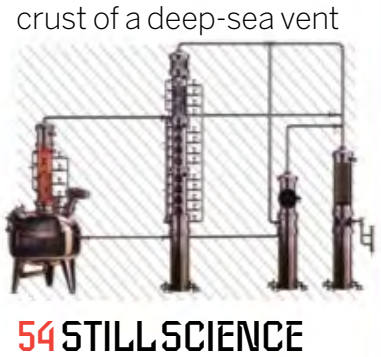
WELCOME

Issue 167

"Their long necks gave them an advantage and increased their chance of survival"

HIGHLIGHTS



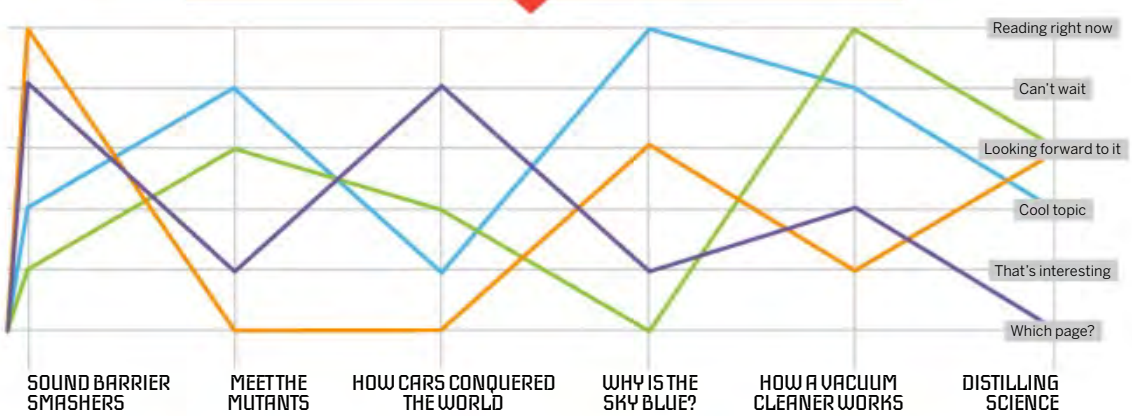


Meet the mutants
PAGE 26

The three skeletons in the image above are long-extinct species or subspecies of ancient humans: *Australopithecus afarensis* on the left, which lived in East Africa until around 2.9 million years ago; *Homo ergaster* in the middle, which lived up until around 1.4 million years ago, and the skeleton of a Neanderthal, which lived in Europe until around 40,000 years ago. All three enjoyed a long success as a species because of their mutations, just like any organism that thrives today. In this issue of **How It Works**, discover the trial and error that nature performs at the very core of every living thing – its DNA – and the freaky and sometimes fantastic mutations that can appear. Enjoy!

Ben Biggs
EDITOR

WHAT WE'RE ANTICIPATING



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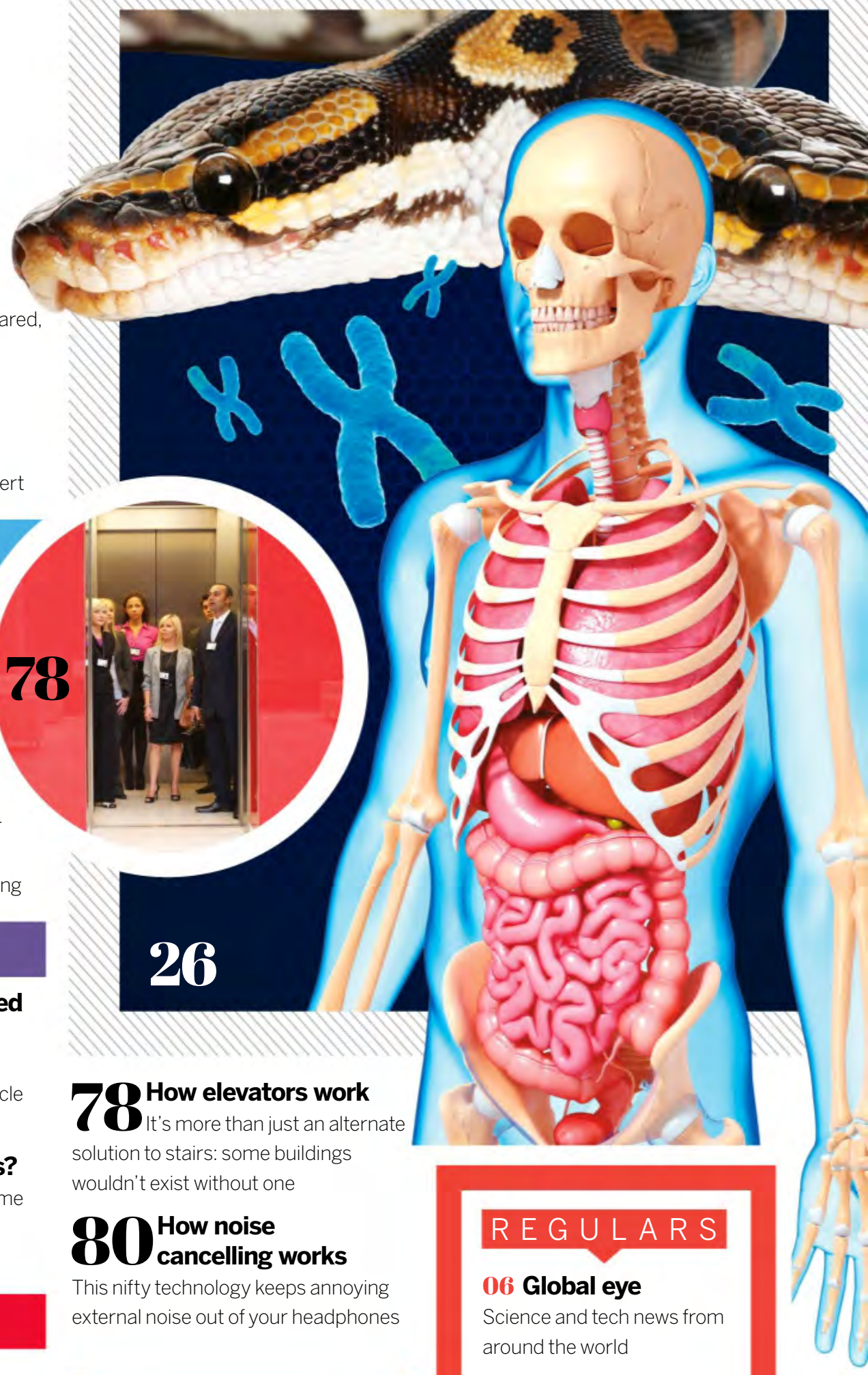
INSIDE

Issue 167



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26

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REGULARS

MEET THIS ISSUE'S EXPERTS

ROBERT LEA
Robert is a science journalist who specialises in science, space, physics and astronomy. He has a bachelor of science in physics and astronomy.

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

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

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.

Weevil close-up

There are around 62,000 species of beetles that belong to the Curculionidae family spread out across the world. Their defining snout serves several purposes, including puncturing and burrowing into plants to feed and lay their eggs. Due to their hunger for agricultural plants, some species of weevil, such as grain or wheat weevils, have become pests to farmers in some areas of the world.

Coral borders

Taken by an astronaut aboard the International Space Station (ISS), this image shows a portion of the 1,000-mile-long fringing coral reefs off the coast of New Caledonia. The reefs can be seen as the brownish dividing line between the light blue shallow waters and the dark blue Pacific Ocean. It's estimated that within the reefs are around 9,300 marine species and 500 species of coral.

Great reindeer migration

This aerial shot shows reindeer herds journeying hundreds of miles to their summer feeding grounds in the Arctic tundra. Reindeer, also known in the US as caribou, can achieve migration distances of 745 miles on a year-long round trip. The reindeer migration is the longest animal migration on land, but some marine and avian species migrate over distances that span thousands of miles.

Martian crash site

On the surface of Mars lies the crash site of the backshell and parachute that lowered the Perseverance rover through Mars' thin atmosphere. Together these components enabled Perseverance to safely land on Mars despite a fiery descent into Jezero crater. The backshell and the parachute are connected by suspension lines, now covered in Martian dust.

Webb has produced the deepest and sharpest infrared image of the distant universe to date

SPACE

James Webb Space Telescope snaps deepest space image ever

WORDS **BEN TURNER**

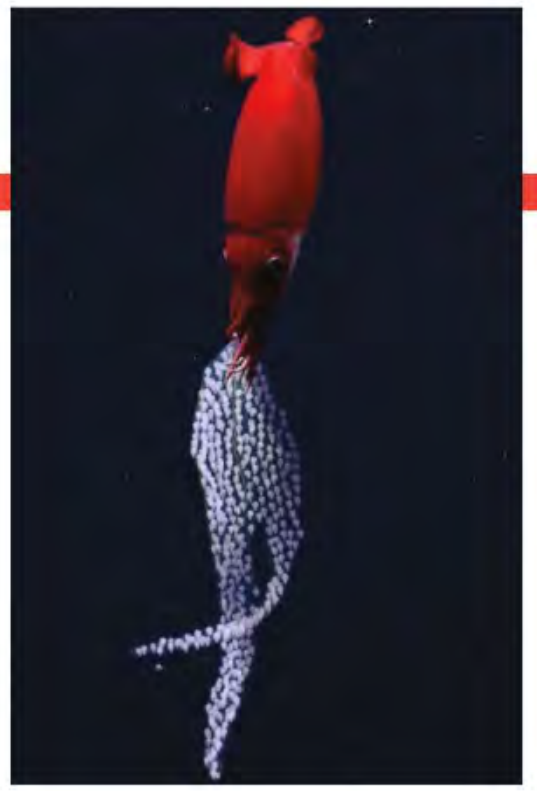
The first full-colour image from the James Webb Space Telescope (JWST) has been unveiled by NASA and President Joe Biden and is the deepest and most detailed image of the universe ever captured. Named Webb's First Deep Field, the spectacular and mind-bending photo shows our universe only a few hundred million years after the Big Bang, just as galaxies began to form and light started flickering from the very first stars. This starlight has taken roughly 13.5 billion years – or most of the age of the universe – to travel to us, arriving at the James Webb Space Telescope after the space-time warping gravitational pull of the galaxy cluster SMACS 0723 steered even the fainter and more distant light into focus.

"We're going back 13.5 billion years," said NASA administrator Bill Nelson. "And since we know the universe is 13.8 billion years old, we're going back almost to the beginning." Nelson added that the telescope "is going to be so precise we are going to see whether or not planets are habitable," and that its unprecedented views of the universe would enable scientists to find answers to questions that haven't even been asked yet. Remarkably, despite the overwhelming density of galaxies, stars and potential planets contained within the image, it's just the tiniest slice of the night sky.

The previous record holder for capturing the deepest and oldest glimpse into space is the Hubble Space Telescope. Its series of deep fields showed how several hundred million years after the Big Bang, galaxies of glistening stars had already coalesced in our young universe. But to peer even further back in time, scientists needed to design a telescope both large enough to capture light from the faintest objects and capable of detecting the mid-infrared frequencies that the most distant light has been shifted to by the universe's expansion.

Enter the James Webb Space Telescope. Its primary mirror diameter measures 6.6 metres wide, compared with Hubble's mirror which is just 2.4 metres in diameter. This means Webb is capable of detecting objects 100 times fainter than Hubble could see. The telescope can also scan the universe in infrared, enabling it to glimpse galaxies that were born a mere 200 million years after the Big Bang.

Webb's extreme sensitivity to infrared frequencies meant that it needed to be isolated from disruptive heat signals on Earth. It now rests at a gravitationally stable location beyond the Moon's orbit – known as a Lagrange point – after being launched there from French Guiana atop an Ariane 5 rocket on Christmas Day 2021. Across the six months following its launch, NASA engineers calibrated the telescope's instruments and mirror segments in preparation for snapping the first images. Their progress was briefly interrupted after the telescope was unexpectedly struck by a micrometeoroid sometime between 23 and 25 May, but the impact did not damage the spacecraft. The image is the first of many to be collected by Webb. NASA has released four more images offering views of a stellar nursery, the atmosphere of a distant exoplanet, a figure-eight-shaped gas explosion from a dying star and a quintet of galaxies locked in a cosmic dance of endless near-collisions.



A close-up of the squid holding onto her eggs

ANIMALS

DEEP-SEA SQUID CARRIES A DAZZLING STRING OF EGGS

WORDS **HARRY BAKER**

Extremely rare footage of a squid mother carrying a gelatinous string of glimmering pearl-like eggs in her arms has been captured in the dark ocean depths off the coast of California. Researchers from the Monterey Bay Aquarium Research Institute (MBARI) recently spotted the deep-sea squid – an unknown species in the genus *Bathyteuthis* – around 56 miles off the coast at a depth of 1,390 meters. The team used a remotely operated vehicle (ROV) to capture high-definition footage of the squid and her still-developing offspring, allowing researchers to examine the pelagic parent in detail.

It's extremely unusual for female squids to be seen carrying their eggs along with them – this rare behaviour is known as brooding. "Most squids reproduce by depositing egg cases on the seafloor or releasing them en masse to drift through open water and then abandon their unhatched larva to fend for themselves," the MBARI researchers said. "Sometimes these nurturing mothers will carry the eggs until they hatch to improve their babies' chances for survival. But carrying eggs is also likely to be energetically expensive for the mother and increases her risk of being predated, which is why it's uncommon to see this behaviour in action."

PLANET EARTH

La Niña could bring a year of intense hurricanes

WORDS **JOANNA THOMPSON**

The South Pacific may be facing a potential third appearance of La Niña in a row, which could bring more rainfall to an already-saturated eastern Australia and continue the trend of intense hurricane seasons along the east coast of the US and drought conditions in the country's southwestern states. Since 1950, this has only happened twice. But predicting La Niña is tricky and climatologists likely won't know which way the winds will blow until September.

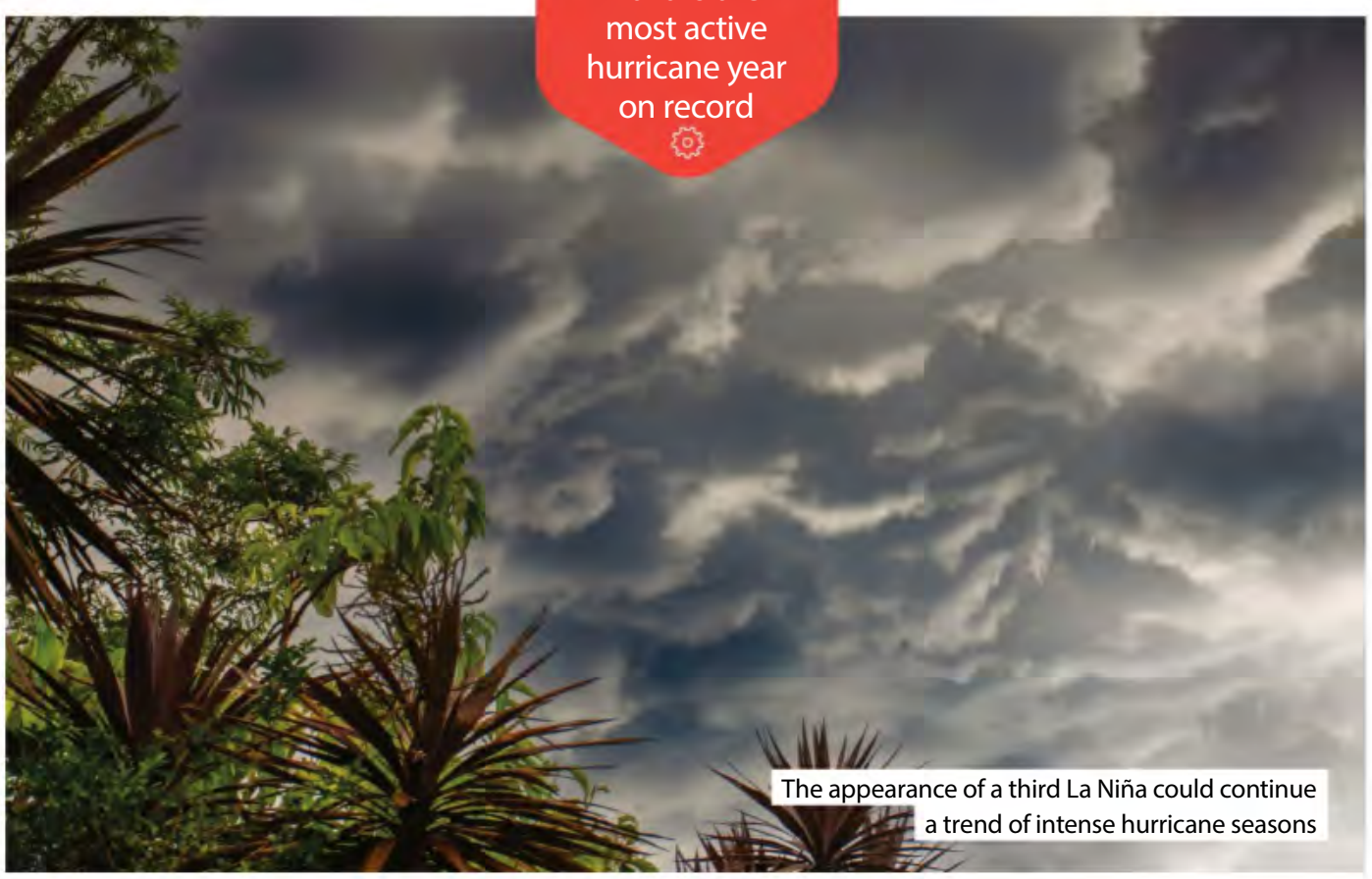
If you live in North America, you're probably familiar with El Niño, the periodic Pacific Ocean warming event that takes place every few years and shapes global weather patterns. But you might be less familiar with its twin sister La Niña. Both are part of a climate pattern known as the El Niño-Southern Oscillation (ENSO), which generates variations in weather conditions that last for months. El Niño means 'the Little Boy' in Spanish – it was so named in the 17th century by fishermen working off the coast of South America, likely a reference to Jesus Christ, as the ocean temperature shift that accompanies El Niño is most noticeable in December. Indigenous groups in South America almost certainly noticed the phenomenon as well, but their names for it didn't survive colonisation.

When El Niño conditions are active, sea surface temperatures are above average in the central and eastern tropical Pacific Ocean. As a result, trade winds across the Pacific weaken and worldwide rainfall patterns shift, bringing, for example, droughts to Indonesia and floods to Peru. This change lasts for around 9 to 12 months, after which the Pacific Ocean either settles back into an 'ENSO-neutral' year – in which sea surface temperatures are neither higher nor lower than average – or flips into La Niña. La Niña years are characterised by a sustained cooling effect around the equator and eastern tropical region of the Pacific caused by a shift in air-pressure systems. La Niña events bring a more active hurricane season to North America and can lead to heavy flooding in many Pacific Island nations, as well as droughts along South America's west coast.

The ENSO climate pattern cycles through El Niño and La Niña events about every three to seven years. However, climatologists did not officially recognise La Niña, 'the Little Girl', until the 1980s. While this ENSO pattern is persistent, it's notoriously difficult to predict, especially as it nears a fluctuation point. Unlike El Niño, La Niña can linger for multiple years. Both 2020 and 2021 were La Niña years, and as of right now the phenomenon has a 52 per cent chance of a three-peat. The last triple-dip for La Niña was more than two decades ago, from 1998 to 2001.

Experts say that escalating climate change will likely impact the intensity – though not necessarily the frequency – of future El Niño and La Niña events.

Did you know?
2020 is the most active hurricane year on record



The appearance of a third La Niña could continue a trend of intense hurricane seasons

A fragment of the Chelyabinsk meteorite, which entered Earth's atmosphere in 2013

PLANET EARTH

Never-before-seen crystals found in meteorite dust

WORDS **HARRY BAKER**

Researchers have discovered a new type of crystal hidden in tiny grains of perfectly preserved meteorite dust left behind by a massive space rock that exploded over Chelyabinsk, Russia, nine years ago. The 18-metre meteor exploded 14.5 miles above the city of Chelyabinsk in southern Russia, showering the surrounding area in tiny meteorites and avoiding a colossal single collision with the surface.

In a new study, researchers analysed some of the tiny fragments of space rock that were left behind after the meteor exploded, known as meteorite dust. Normally, meteors produce a small amount of dust as they burn up, but the tiny grains are lost to scientists because they are either too small to find, scattered by the wind, fall into water or are contaminated by the environment. However, after the Chelyabinsk meteor exploded, a massive plume of dust hung in the atmosphere for more than four days before eventually raining down on Earth's surface. And luckily, layers of snow that fell shortly before and after the event trapped and preserved some dust samples until scientists could recover them shortly after.

The researchers stumbled upon the new types of crystals while they were examining specks of the dust under a standard microscope. One of these tiny structures, which was only just big enough to see under the microscope, was fortuitously in focus right at the centre of one of the slides when one team member peered through the eyepiece. If it had been anywhere else, the team would likely have missed it. After analysing the dust with more powerful electron microscopes, the researchers found many more of these crystals and examined them in much greater detail.

The new crystals came in two distinct shapes – quasi-spherical shells and hexagonal rods – both of which were "unique morphological peculiarities". Further analysis using X-rays revealed that the crystals were made of layers of graphite – a form of carbon made from overlapping sheets of atoms and commonly used in pencils – surrounding a central nanocluster at the heart of the crystal. The researchers propose that the most likely candidates for these nanoclusters are buckminsterfullerene (C_{60}), a cage-like ball of carbon atoms, or polyhexacyclooctadecane ($C_{18}H_{12}$), a molecule made from carbon and hydrogen. The team suspects that the crystals formed in the high-temperature and high-pressure conditions created by the meteor breaking apart, although the exact mechanism is still unclear. In the future the scientists hope to track down other samples of meteorite dust from other space rocks to see if these crystals are a common byproduct of meteor breakups or are unique to the Chelyabinsk explosion.

ANIMALS

300-KILOGRAM STINGRAY BREAKS THE FRESHWATER CATCH RECORD

WORDS **STEPHANIE PAPPAS**

A fisherman in Cambodia landed what turned out to be the largest freshwater fish ever caught. The giant freshwater stingray (*Urogymnus polylepis*) is more than four meters long and weighed in at a whopping 299.8 kilograms. Despite its massive bulk, little is known about this species of stingray's habits and behaviour in the wild. Scientists tagged and released the record breaker in order to learn more about its migration patterns and preferred habitats.

The pancake-shaped find has now secured the status of the giant freshwater stingray as the largest known fish in the world, nudging out the Mekong giant catfish (*Pangasianodon gigas*), the largest of which was a 293-kilogram specimen caught in Thailand in 2005. The giant freshwater stingray also hails from the Mekong River. It was caught on 13 June by a fisherman named Moul Thun in the Stung Treng province of northeastern Cambodia. The next morning, Thun called in researchers from the conservation organisation Wonders of Mekong, which has been working to record and protect giant stingrays in the waterway. The Mekong is the only place in the world where these giant fish are found.

Scientists and officials in Cambodia pose with the largest freshwater fish ever caught, a giant freshwater stingray

The Supreme Court ruled in a 6-3 decision that the EPA should not regulate greenhouse gas emissions at a national scale

PLANET EARTH

Supreme Court cripples the US government's climate change fight

WORDS **BRANDON SPECKTOR**

The US Supreme Court severely limited the federal government's ability to regulate greenhouse gas emissions on 30 June in a 6-3 ruling split between the court's conservative majority and liberal minority. Ruling on the case, called West Virginia v. the Environmental Protection Agency (EPA), the court's six conservative justices held that the EPA, which was established in 1970 to curb widespread pollution and implement national environmental protection policies, does not have the authority to regulate greenhouse gas emissions on a national scale without express approval from US Congress.

Chief Justice John Roberts wrote the court's majority opinion: "Capping carbon dioxide emissions at a level that will force a nationwide transition away from the use of coal to generate electricity may be a sensible 'solution to the crisis of the day'," Roberts stated, quoting an earlier case. But "a decision of such magnitude and consequence rests with Congress itself, or an agency acting pursuant to a clear delegation from that representative body."

Dissenting on behalf of the court's three liberal justices, Elena Kagan wrote that the court had effectively substituted its own ill-informed judgment for the EPA's. "Whatever else this court may know about, it does not have a clue about how to address climate change," Kagan wrote. "The Court appoints itself – instead of Congress or the expert agency – the decision-maker on climate policy. I cannot think of many things more frightening." The case in question is based on an EPA policy called the Clean Power Plan, which President Barack Obama unveiled in 2015. The plan proposed three carbon-reducing strategies for states, including a shift to more renewable energy and a call to use more natural gas in order to retire heavily polluting coal plants.

The Supreme Court blocked the Clean Power Plan from coming into effect in 2016. The plan was never enacted, nor was an alternative successfully put into place by the Trump or Biden administrations. However, coal companies and several Republican-dominated states, including West Virginia, continued to fight against the hypothetical provisions in the now-defunct plan, finally bringing their complaints to the Supreme Court in West Virginia v. EPA.

While some legal scholars argued that the court should not hear the case at all, as the plaintiffs were fighting a regulatory plan that never took effect, the court agreed to hear the case and rule on whether the EPA should have the authority to enact any similar greenhouse gas emission-reducing policies on a national scale in the future. The court's ruling – that the EPA cannot mandate nationwide energy policies to limit greenhouse gas emissions without specific approval from Congress – threatens to cripple the US government's ability to fight climate change, according to the dissent. The US is the world's second-biggest annual emitter of greenhouse gasses after China. President Joe Biden's goals of converting the US power grid to clean energy by 2035 and cutting greenhouse emissions in half by the end of this decade now look remote.

Did you know?
12.2 per cent of US energy consumption is renewable

SPACE

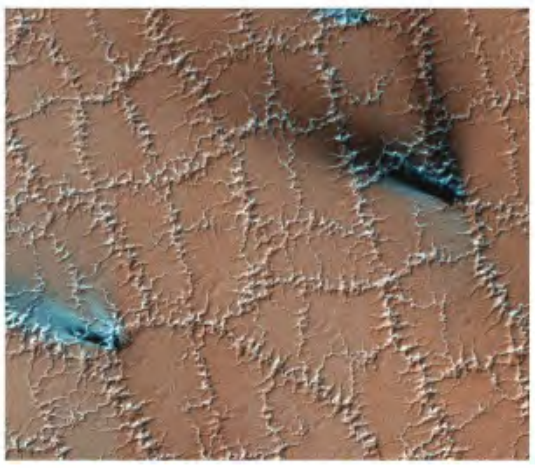
BIZARRE 'POLYGONS' ON MARS' SURFACE

WORDS **BRANDON SPECKTOR**

Recorded on 20 March 2022, a High Resolution Imaging Experiment (HiRISE) image reveals a patchwork of white zig-zags cracking across the Martian soil at high latitudes, with occasional sprays of black and blue mist fanning out between them. The zig-zags and colourful sprays are signature features of Martian spring, when hidden reservoirs of subterranean ice butt up against the dry Martian surface.

The edges of these polygons become cracked and frayed in springtime as surface ice transforms from a solid into a gas in a process known as sublimation. When this transformation occurs, vents of dry ice spray out of the Martian surface, leaving dark, fan-shaped deposits of particles spread across the ground. Where dark particles sink back into the dry ice on the surface, bright marks stain the ground.

A single ice vent can open and close multiple times, spraying particles in different directions across the Martian surface depending on the wind. That's why some areas show several different light and dark streaks jutting out of a single vent. Both the fans and polygons can stick around for many years, slowly warping the Martian landscape as ice expands and contracts seasonally. The HiRISE camera rides aboard NASA's Mars Reconnaissance Orbiter, which began its mission in 2006.



Polygons crack across the Martian surface as hidden ice expands and contracts with the seasons

HISTORY

Mysterious artefacts hint at ancient China's 'fairy world'

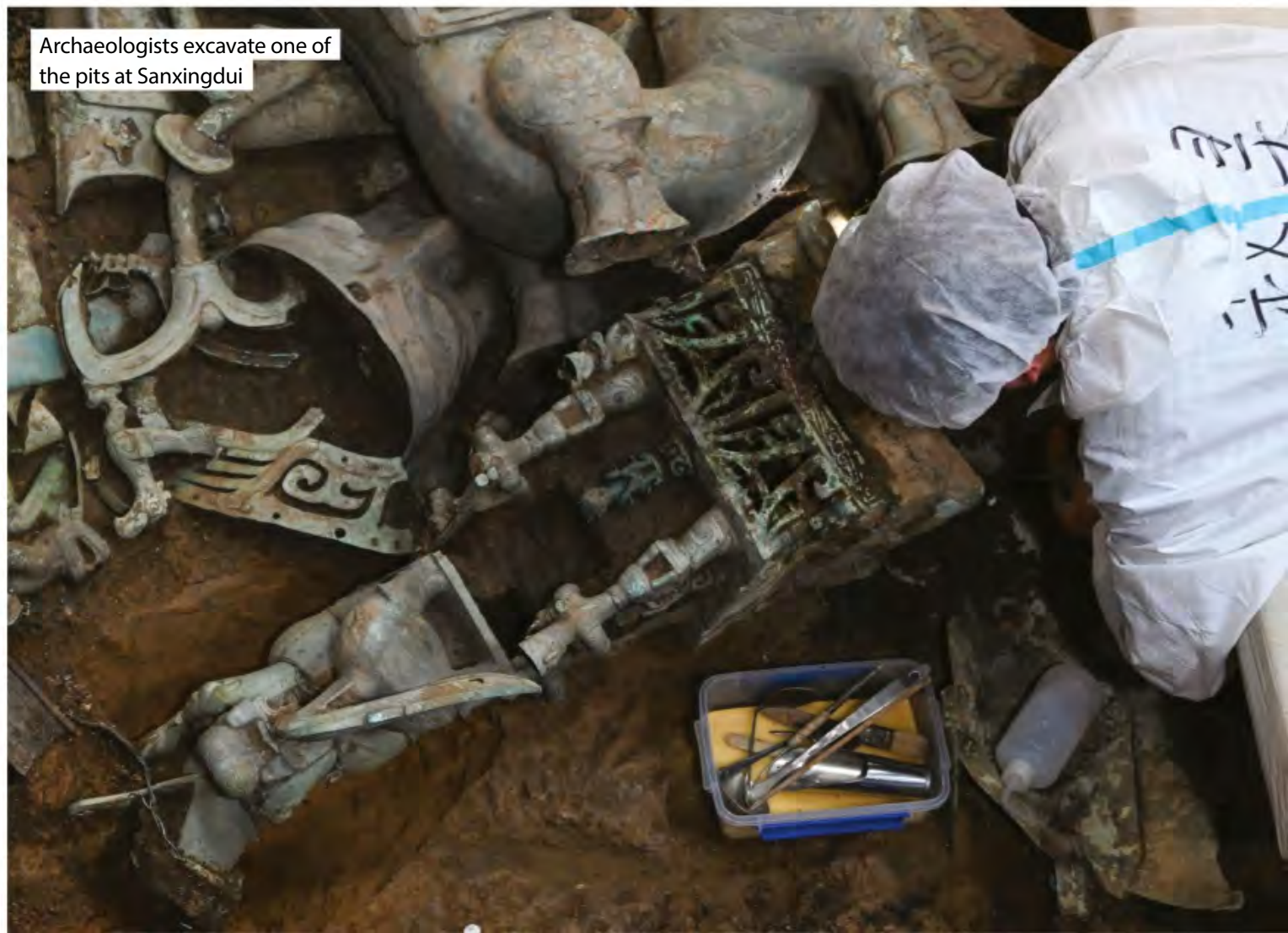
WORDS **OWEN JARUS**

A bronze sculpture of a snake with a human head, along with a large number of other artefacts including finds made of bronze, jade and gold, have been discovered in a series of pits at the archaeological site Sanxingdui in Sichuan, China. The discoveries also include a bronze box with jade inside, gold masks and a bronze altar. "The sculptures are very complex and imaginative, reflecting the fairy world imagined by people at that time, and they demonstrate the diversity and richness of Chinese civilisation," Zhao Hao, an associate professor at Peking University, said.

Two pits were excavated in the 1980s, and six more have been excavated since 2020. Archaeologists have discovered a total of 13,000 artefacts that are believed to date to the Bronze Age, between 4,500 and 3,000 years ago. As for the recently unearthed sculptures and artefacts, "it's great to find more," said Chen Shen, a senior curator at Toronto's Royal Ontario Museum. Shen noted that the first two pits to be excavated in 1986 contained artefacts that were similar to the new discoveries. Shen curated an exhibition on Sanxingdui at the Royal Ontario Museum in 2002 and has conducted research on the excavations and written about the site. To date, no evidence of human burials or cremation have been found there, suggesting that the pits were likely not funerary. However, the creation of the pits and the addition of artefacts may have served a ritual purpose, Shen added. Some of the artefacts show signs of being deliberately broken or burned. "The purposeful breakage and burning of highly valuable materials such as jades and bronzes shows us that this was not random or wanton destruction," said Jay Xu, the director and CEO of the Asian Art Museum of San Francisco.

Did you know?
Buddhism was introduced to China during the Han dynasty

"Bronze was so valuable – especially since it could be melted down and reused – that it tells us that the destruction of these images served an important ritual purpose," Xu said. "As with other human societies, ritual breaking and burning is often about a sanctified passage or communion with a world beyond our own. These burials were perhaps an attempt to move this society through crises with guidance or help from another realm," Xu said. Researchers will know more when "we are able to have a complete sense of the objects within the new pits, their processes of disposal and the relationships among things," said Rowan Flad, an archaeology professor in the department of anthropology at Harvard University.



Archaeologists excavate one of the pits at Sanxingdui

SPACE

Rare star survives death by supernova

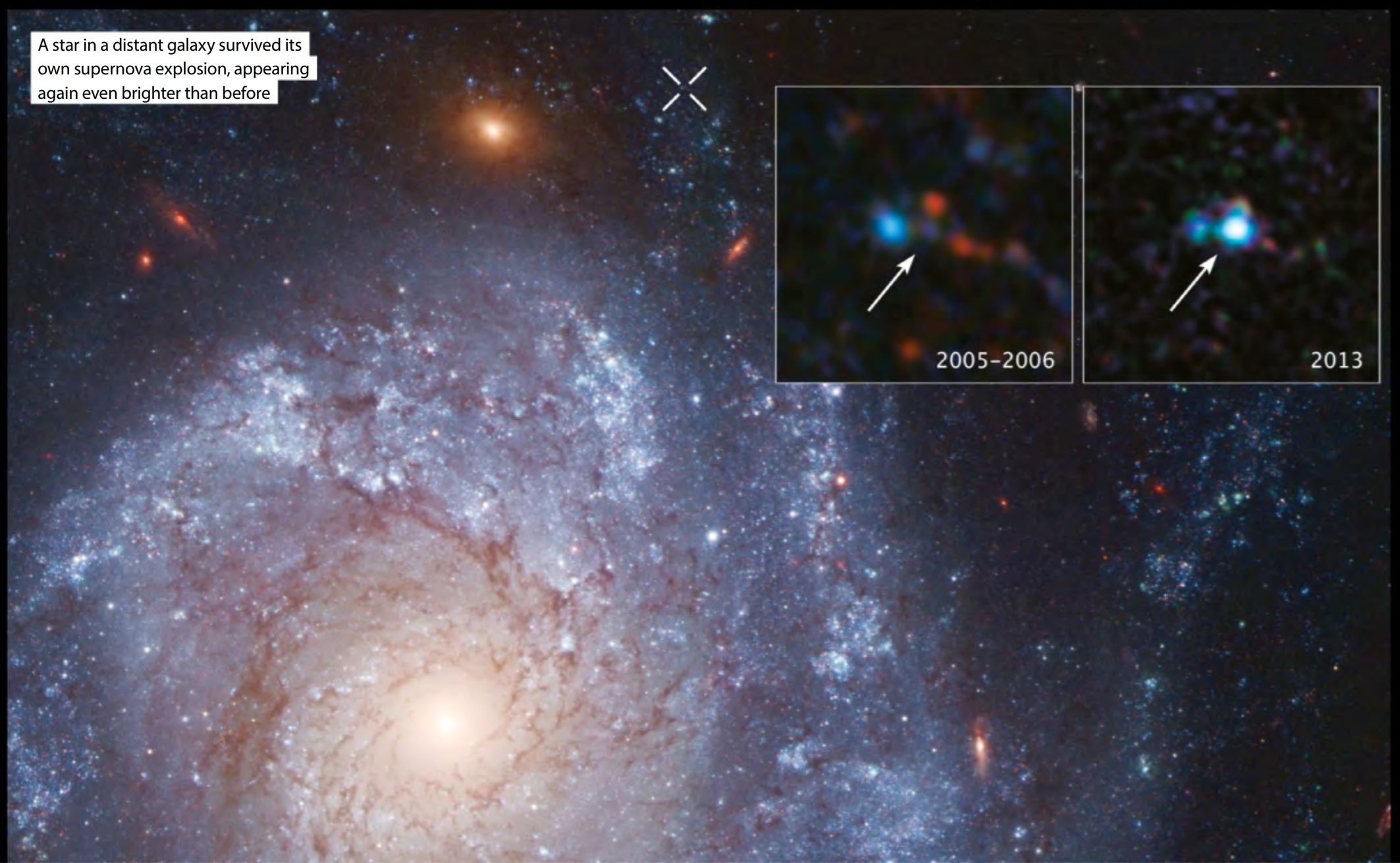
WORDS BRANDON SPECKTOR

In 2012, a shrivelled white star in a nearby galaxy reached the end of its life and exploded in a violent supernova. Such explosions – known as Type Ia supernovae – are a common end for billions of stars in our universe, typically resulting in the utter obliteration of the old star at the heart of the blast. But this time, something went wrong. As the old star blew up from the inside out, the explosion failed to reach the power and brightness of a typical Type Ia supernova. When the dust settled years later, scientists observing the stellar wreckage saw that the old star hadn't vanished at all – it was still there, even bigger and brighter than before. Somehow, the star had survived its own supernova explosion.

Astronomers first detected supernova SN 2012Z mid-explosion. Using the Hubble Space Telescope, researchers saw the bright flare of light on the edge of a spiral galaxy some 120 million light years from Earth. Based on its brightness and the type of light emitted, the blast appeared to be a Type Ia supernova – a thermonuclear explosion that's thought to occur in star systems where the shrivelled husk of a white dwarf star shares a close orbit with another larger star. Scientists aren't sure exactly how these explosions occur, but a popular theory suggests that the white dwarf gradually draws in gas from its companion star until the white dwarf reaches a critical mass that triggers a runaway thermonuclear reaction in its core, resulting in a massive supernova explosion.

Subsequent observations in 2014 revealed that the supernova was stranger than astronomers initially guessed. The explosion was much dimmer and weaker than a typical Type Ia supernova – putting it in a rare category of Type Iax supernova, or a 'failed' Type Ia supernova. But more baffling still, the researchers identified a white dwarf star at the exact epicentre of the explosion, shining even brighter than the progenitor star that had been there before. This was the first time that scientists had ever identified the progenitor star of a white dwarf supernova and the first time a white dwarf star had apparently survived its own thermonuclear explosion. It's possible that when the explosion ignited, it was too weak to fully blow away all the gas that comprised the white dwarf. Following the initial explosion, some of this material may have fallen back onto the partially exploded star, creating a zombie object called a bound remnant.

Counterintuitively, white dwarf stars have greater diameters when they have less mass and grow smaller as they become more massive. When the bound remnant formed after the weakened supernova, it became initially bigger and brighter than its progenitor white dwarf. Over time, the star will likely return to its initial state, becoming smaller and denser.



A star in a distant galaxy survived its own supernova explosion, appearing again even brighter than before

SPACE

Huge black hole devours an Earth-size chunk every second

WORDS HARRY BAKER

Astronomers have detected the brightest and fastest-growing black hole to have existed in the last 9 billion years. The enormous cosmic entity is 3 billion times more massive than the Sun and swallows up an Earth-size chunk of matter every second. The newly discovered supermassive black hole, known as J1144, is around 500 times as massive as Sagittarius A*, the supermassive black hole at the heart of the Milky Way. A ring of superhot plasma around the enormous void also emits around 7,000 times more light than our entire galaxy. Australian astronomers discovered the cosmic juggernaut using data from Australian National University's SkyMapper Southern Sky Survey, which aims to map out the entirety of the sky in the Southern Hemisphere. "Astronomers have been hunting for objects like this for more than 50 years," said Christopher Onken, an astronomer at the Australian National University in Canberra.

The black hole's voracious appetite dwarfs that of other similarly huge supermassive black holes. Normally, the growth rates of these enormous cosmic entities slow down as they become more massive. This is likely due to increased Hawking radiation – thermal radiation that is theorised to be released from black holes due to the effects of quantum mechanics. The newfound black hole eats up so much matter that its event horizon – the boundary past which nothing, including light, can escape – is unusually wide.

Black holes cannot be seen because they do not give off any light. But astronomers can spot black holes because their intense gravity pulls matter towards the event horizon so quickly that this matter gets turned into superhot plasma; this gives off light in a ring around the black hole, called an accretion disc. The newly discovered behemoth's accretion disc is the brightest that astronomers have ever detected due to its massive event horizon and the extreme speed at which it pulls in matter. Researchers are fairly confident that this is a record that will never be broken. The black hole boundary is so bright that even amateur astronomers would be able to see it with a powerful enough telescope trained at exactly the right part of the sky.

Did you know?
Sagittarius A* weighs 4.3 million solar masses

The team is now trying to determine why the massive black hole remains so unusually hungry for matter. The scientists suspect that a catastrophic cosmic event must be responsible for the birth of this gargantuan void. "Perhaps two big galaxies crashed into each other, funnelling a whole lot of material onto the black hole to feed it," Onken said. However, it may be hard to find out exactly how it formed. The researchers are sceptical that we will ever find another similarly massive and rapidly expanding black hole ever again, making it hard to test a general theory about the formation of such voracious cosmic objects. "This black hole is such an outlier that while you should never say never, I don't believe we will find another one like this," said Christian Wolf, an Australian National University astronomer and group leader of SkyMapper. However, some researchers predict that there are as many as 40 quintillion black holes in the universe – which could account for around one per cent of all matter – so the odds that there may still be an even more ravenous black hole out there somewhere are not zero.

Artist's impression of an expanding supermassive black hole

The US Navy destroyer escort USS Samuel B. Roberts, circa 1944

HISTORY

World's deepest shipwreck found

WORDS **BEN TURNER**

Explorers have discovered the world's deepest shipwreck after 78 years: a US Navy destroyer escort that sank during World War II's biggest naval battle. The explorers found the USS. Samuel B. Roberts – nicknamed 'Sammy B' – 6,985 metres below the surface of the Philippine Sea near Samar, the third-largest island of the Philippines. The wreck is snapped in half, and the two pieces lie just ten meters apart.

The ship sank during the final phase of the Battle of Leyte Gulf in October 1944, in which the US Navy defeated a far larger Japanese force. The Japanese Navy suffered its biggest loss of ships and was frustrated in its attempts to dislodge US forces from Leyte – an island invaded by the US as part of the Pacific War. Historical descriptions of the wreck's location were vague, so finding the ship wasn't easy. To locate the wreck, explorers searched through historical documents to narrow down the search area and deployed the deepest side-scan sonar device ever used, which was mounted on a submarine capable of taking it up to 11,000 metres below the ocean's surface.

During the Battle of Leyte Gulf the US lost two destroyers, two escort carriers, a light carrier, a destroyer escort, 255 aircraft and more than 1,000 men. Japanese losses were substantially higher, including one fleet carrier, three light carriers, three battleships, six heavy cruisers, four light cruisers, 11 destroyers and roughly 300 aircraft in the four-day battle, along with roughly 12,500 men. These losses forced Japan's Vice Admiral Kurita Takeo to lead a retreat from the battle aboard the battleship Yamato. As the US occupation of the Philippines cut Japan off from its oil supplies in Southeast Asia, the fight proved instrumental in the total destruction of the Japanese Navy as a fighting force.

Sammy B performed a notable role in the conflict. The destroyer escort launched three torpedoes at the Japanese heavy cruiser Chōkai, landing a hit with one that blew off the enemy ship's stern. Sammy B exchanged fire with other Japanese ships for more than an hour, completely depleting its ammunition and setting the bridge of another heavy cruiser, the Chikuma, ablaze. However, three 35.6-centimetre shells from the battleship Kongō ripped a 12-metre-long hole in Sammy B's stern, sending seawater flooding into its aft engine room. Of the crew, who were given the order to abandon ship, 89 died and 120 survived.

PLANET EARTH

RECORD-BREAKING ERUPTION CREATED THE FASTEST ATMOSPHERIC WAVES EVER

WORDS **NICOLETTA LANESE**

The massive eruption from the underwater Tonga volcano in the Pacific earlier this year generated a blast so powerful it sent massive pressure waves rippling through the atmosphere and around the globe. These waves were the fastest ever observed within our atmosphere, reaching speeds of 720 miles per hour. The atmospheric waves triggered by the volcano travelled at speeds very close to the theoretical limit.

The volcano, Hunga Tonga-Hunga Ha'apai, or just Hunga, lies about 40 miles northwest of the Tongan capital of Nuku'alofa and sits within a line of volcanoes called the Tonga-Kermadec Ridge. On 15 January, Hunga erupted and sent a towering plume of gas and particles billowing into the mesosphere, the third layer of the atmosphere above Earth's surface. The plume reached 36 miles at its highest point, making it the largest volcanic plume in the satellite record.

Researchers confirmed the Hunga eruption was among the most explosive volcanic events in modern history. Results suggest the waves produced by the volcano lapped Earth at least six times and reached speeds up to 320 metres per second.

In January, one of the most powerful volcanic eruptions in modern history took place in the Pacific

WISH LIST

The latest HOME ROBOT tech

ROOMBA I7+

WWW.IROBOT.COM £799 / $999

The Roomba i7+ is a Wi-Fi-connected self-emptying robot vacuum that makes light work of cleaning your home. Using sophisticated mapping technology, these autonomous devices can map out your home's layout and users can even designate 'clean zones' for the Roomba to maintain and 'keep out zones' for places that the Roomba should avoid. Users can also label areas around the home to make instructing the Roomba straightforward. For example, if there's been a mess made under the kitchen table, simply call on the Roomba to clean under the kitchen table and it'll know where to go. The i7+ also comes with a disposal system, where the Roomba will empty itself into an enclosed bag when it's full.

EBO SE

WWW.NA.ENABOT.COM £99 / $119

If you're looking for a spherical autonomous security robot, then look no further than the EBO SE. This camera on wheels will automatically patrol your home and record everything it sees using its high-definition camera. Using the companion app, users can monitor their homes in real time, checking for intruders and keeping an eye on household pets. There's also an integrated microphone for two-way communication. EBO can also record video footage at night by using an infrared camera. This compact security robot can either autonomously wander through the home or users can take control and manually drive EBO remotely.

MIKO 3

WWW.MIKO.AI £229.99 / $249

The Miko 3 is a child-friendly companion robot that helps kids learn new things and have fun. The smart robot boasts features children are sure to enjoy, including interactive games and story books. There is also an educational element to Miko. Using its learning platform, children can work with Miko on their maths and science, with live classes from educators from around the world. The Miko 3 can be controlled either using the companion app – which also offers a handy partner tracking system for usage – or by using its touchscreen to explore all the robot's entertaining features.

AIBO

US.AIBO.COM $2,899.99 (APPROX. £2,420)

As the ultimate robot dog, Aibo has quickly become one of the most beloved artificial intelligence pets on the market. Over time, Aibo's built-in AI will learn to respond to its given name, learn commands, demonstrate tricks and identify different members of the family. Aibo is much more than a traditional toy pet and seems to be more of a robotic addition to the family, with similar demands for interaction. As Aibo evolves over time, so will its personality. According to the manufacturers, no two Aibo are the same. Like any real dog, Aibo will learn to navigate your home, familiarise itself with its surroundings and will even take itself off to bed when it's tired and needs powering up.

CLICBOT

WWW.KEYIROBOT.COM

FROM £499.99 / $499.99

ClicBot is a programmable home robot with lots of personality. This modular robot straddles the line between robotic pets and coding toys for young adults. Its modular design allows users to build one of 20 configurations using its 11 different body parts, such as wheels, suction cups, graspers and much more. Using the companion app, users can transform the robot into whatever they can dream up, such as a remote-controlled race car, pet snake, high-tech selfie stick or robotic butler – the possibilities are only limited by the user's imagination. As well as being a fun interactive device for the family to enjoy, it offers real-world computer programming and coding lessons to its users.

ELLIQ

WWW.ELLIQ.COM $249.99 (APPROX. £209) PLUS SUBSCRIPTION

The ElliQ is a remarkable piece of technology that offers robotic companionship for those living alone. It's ideal for anyone living on their own to combat loneliness and improve mental health. Packed with a whole host of practical features, the autonomous robot can do any of the same things as other home assistants, such as report the weather, set reminders and relay the daily news. However, what's most impressive about the ElliQ is its level of engagement with its user. It can conduct morning check-ins, lengthy conversations, perform cognitive activities and mental health exercises and make assessments. ElliQ is truly an innovation in robotic companionship and wellness.

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Meet the MUTANTS

HOW CHANGES IN DNA CAN CAUSE UNUSUAL ABNORMALITIES, BUT ALSO SHAPE THE EVOLUTION OF A SPECIES

WORDS **SCOTT DUTFIELD**

What makes you who you are? It's a molecule called deoxyribonucleic acid, better known as DNA. This omnipotent molecule is made up of twisted strands of sugars and phosphates, creating its double-helix shape. Connecting the twisting strands are four bases known as nucleotides: adenine, cytosine, guanine and thymine. The sequence in which these bases find themselves along each strand is what ultimately determines the development and function of an organism.

The way DNA works is similar to the way a computer reads binary code. A molecule of DNA is divided by varying lengths of base sequences called genes. Some genes contain hundreds of bases, others millions. Each gene acts as a set of instructions to program an organism, controlling what it looks like, how its body functions and even how it behaves. The complete set of genetic information in an organism is known as its genome. The human genome is held in 23 pairs of chromosomes, long bundles of DNA which sit inside the nucleus of a cell. The size of an organism's genome varies across the spectrum of life – for example, a fruit fly has only 4 chromosome pairs, while a dog has 39.

There are two important distinctions within a DNA molecule: genes that are referred to as coding genes and non-coding genes. Around one per cent of DNA is made up of coding genes, which actively supply the information for the production of proteins. Proteins are vital molecules that act as the raw ingredients to grow and develop an organism. The remaining 99 per cent of DNA is made of non-coding genes; these don't provide the blueprints for protein production but can influence the way in which proteins are made and even prevent production.

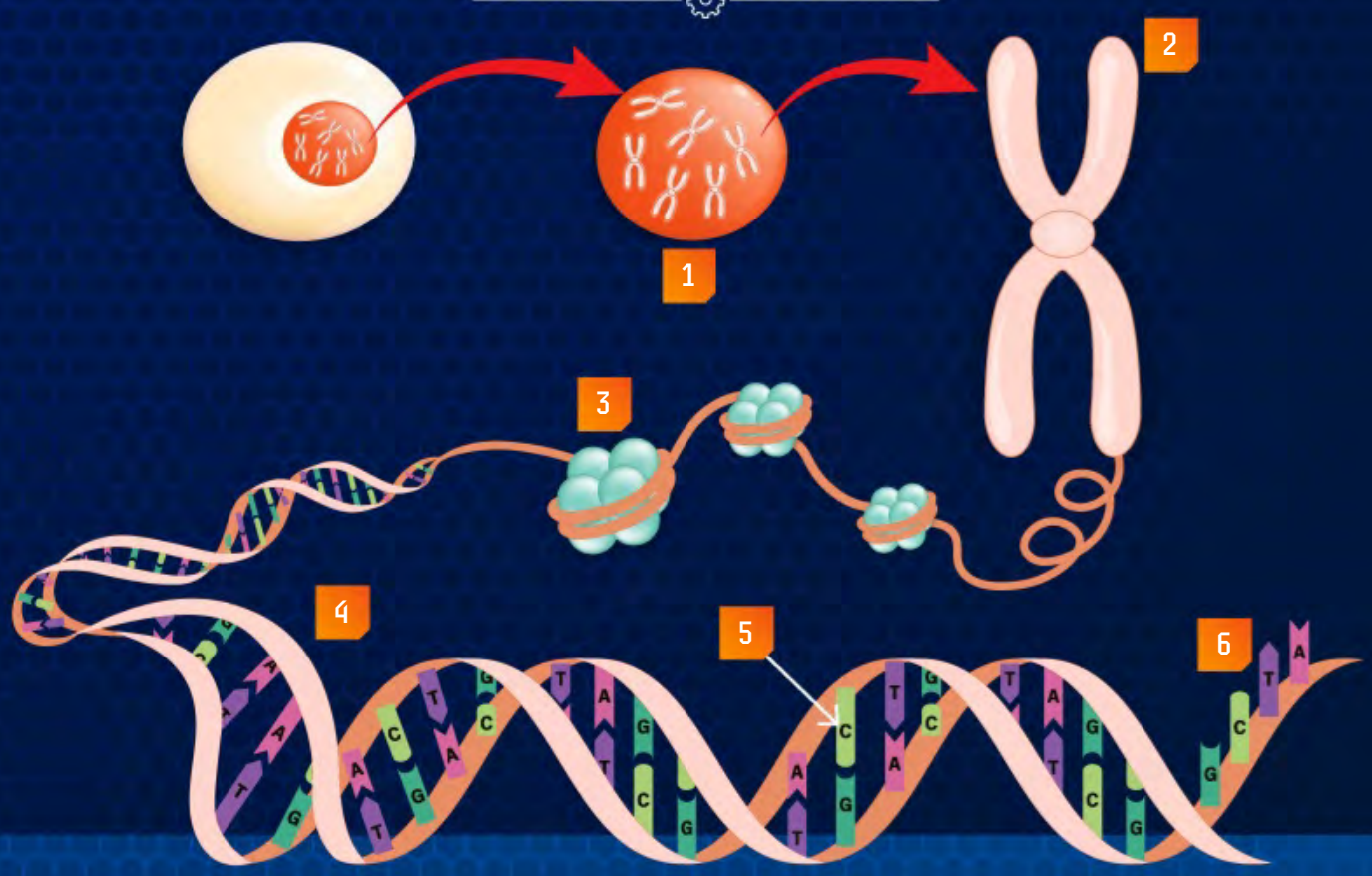
Like lines of computer code, when nucleotide sequences within a gene are changed, deleted or swapped, an organism's biological program is altered. This is known as a mutation. Mutations can be split into one of three categories: silent, missense and

DID YOU KNOW? The double-helix structure of DNA was discovered in 1953

WHAT IS DNA?

UNRAVELLING DNA

The genetic world that's held within our cells



1 NUCLEUS
This is the location in the cell where all an organism's genetic information is held.

2 CHROMOSOMES
Within each nucleus are 23 bundles of genetic information called chromosomes.

3 HISTONES
These basic proteins support the structure of a chromosome.

4 DNA
The structure of DNA is made up of a twisting double helix with a sugar phosphate backbone.

5 NUCLEOTIDES
Within DNA there is one of four nucleotides, also known as bases. These structural building blocks of DNA are the blueprints of an organism.

6 CODING
Nucleotides form specific pairs – adenine with thymine and cytosine with guanine. The arrangements in nucleotide sequence code for the production of certain proteins.

Did you know?

Down's syndrome is caused by a chromosome mutation

nonsense. Silent mutations are, as the name suggests, an alteration of nucleotides that have no protein production. Missense mutations, on the other hand, will alter the function of a protein. Finally, nonsense mutations cause proteins to be nonfunctional. Mutations occur during the time the cells of an organism divide and grow. During cell division, all the DNA information within the nucleus is unzipped and exactly copied to create a perfectly functioning replica. However, on some occasions the genetic duplication isn't exact – some information is left behind or replaced, and a mutation occurs.

The effects of a mutation are wide-ranging. Tiny-point mutations, which occur at a single nucleotide base pair, occur trillions of times among the trillions of cells that make up an organism's body. The majority of these will be silent mutations that have no notable effect on the organism. However, there are occasions when these mutations can have implications to the physical appearance of an organism, how it behaves or cause a myriad of health issues. As an example, polymelia is an uncommon condition caused by a genetic mutation that leads to the development of additional limbs. The condition is rarely seen in humans but is occasionally reported in domestic animals such as chickens and sheep.

As to why mutations occur, scientists still don't have a complete picture. There isn't much scientific rhyme or reason when it comes to spontaneous mutations. Sometimes, during the process of cell division, errors are made in the replication of DNA, which results in a mutation. There are also active agents in the world that can tip the scales of genetic probability and cause a mutation. Active agents that cause a mutation are called mutagens and are either chemical or radioactive. Chemical mutagens are toxins that can alter DNA and lead to a whole host of health issues and congenital abnormalities. For example, the inhalation of asbestos can cause mutations that lead to the development of lung cancer.

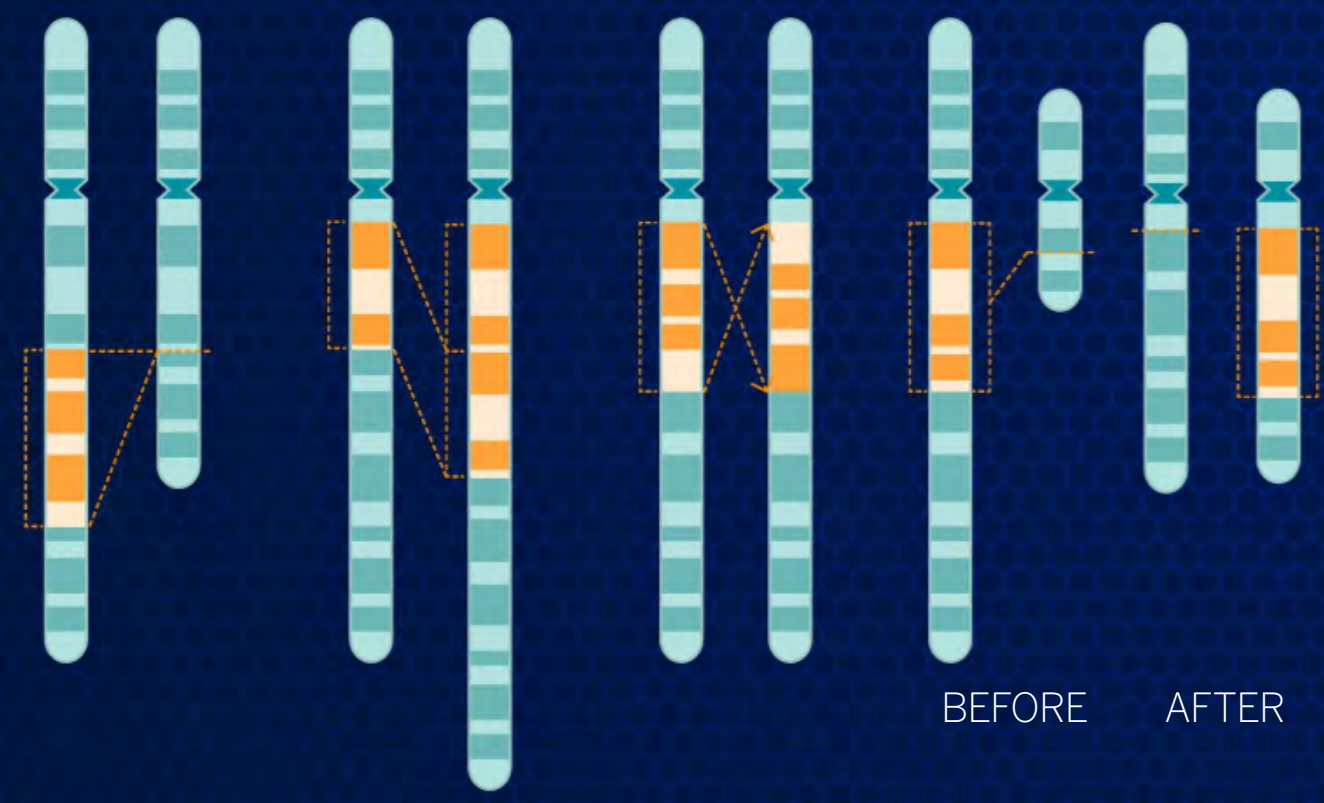
One of the most striking physical mutations seen in the animal kingdom is known as bicephaly, or axial bifurcation, whereby an organism develops a two-headed otherwise-normal body. The most commonly reported organisms to experience this rare condition are reptiles, typically snakes. However, the condition has been seen in species across the animal kingdom and with some human examples. Scientists aren't completely sure why the developing embryo

People in Tibet have evolved to live thousands of metres above sea level

Did you know?

On average, parents pass 60 new mutations to their children

TYPES OF MUTATIONS



1 DELETION
This type of mutation occurs when one or more nucleotides from a portion of a DNA strand are lost. Deletion can lead to many genetic diseases, such as cystic fibrosis.

2 DUPLICATION
This form of genetic mutation involves copying a DNA segment and repeating the same segment again before moving onto the next new segment.

3 INSERTION
Rather than losing or repeating segments, this involves new nucleotide base pairs being added into a sequence. This type of mutation interprets the creation of vital proteins and leads to different birth defects.

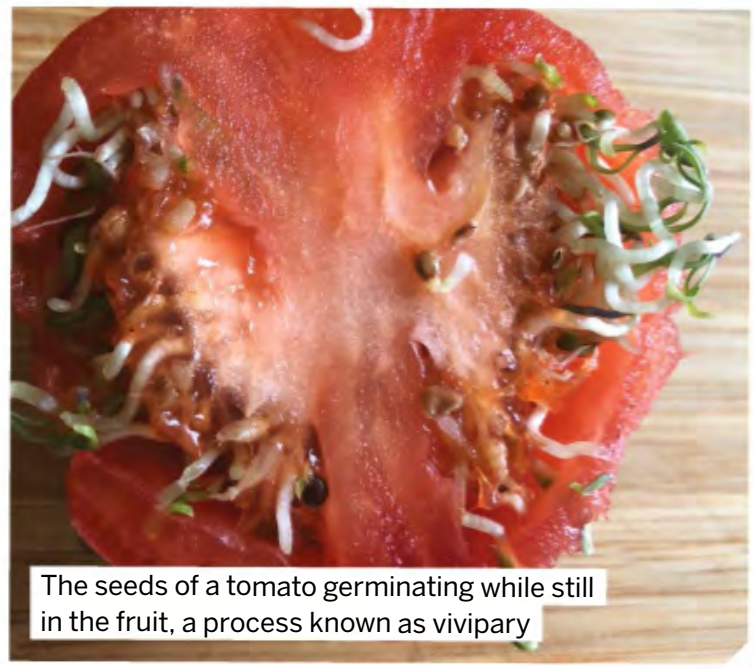
4 SUBSTITUTION
When one nucleotide is incorrectly swapped out for a different one. This replacement has an effect on the production of a protein, such as disrupting and altering its function or rendering it useless.

doesn't completely split and instead continues to grow. Possible explanations for cases in reptiles in particular are fluctuations in external temperature during incubation, pollution or exposure to chemical mutagens.

Ionising radiation can be an extremely damaging external mutagens. The exposure of living tissue to high or prolonged levels of radiation – such as X-rays and ultraviolet light (UV) – can break down sequences in DNA, damage the structure of cells and lead to their mutation. The result of mutations caused by radiation are typically the development of cancers and growth of tumours, along with some physical abnormalities – just as it was in the wake of the tragic Fukushima Daiichi Nuclear Power Plant accident. In 2011, scientists discovered that the larvae of pale grass blue butterflies (*Zizeeria maha*), which were exposed to the radioactive fallout of the explosion, developed much smaller wings and irregular eyes. These

MUTANT FRUIT

If you've ever bitten into an apple or cut into a tomato and found that the seeds inside have already begun to germinate, you've discovered a mutant fruit. The phenomenon of 'live birth' in some plants is called vivipary. This is where the seeds of plants start to germinate before they have matured and separated from the parent plant. While still nestled within the flesh of a tomato or sandwiched on an ear of corn, a hormone produced by the plant keeps the seeds from entering into the next stage of growth. However, if that hormone runs out, the seeds are free to germinate. In the case of vivipary plants, a genetic mutation inhibits the production of the germination-preventing hormone and tiny shoots prematurely emerge from the fruit.



The seeds of a tomato germinating while still in the fruit, a process known as vivipary

RADIOACTIVE MUTATION

How exposure to radiation can trigger genetic mutations

1 RADIOACTIVE SOURCE
When radioactive sources such as uranium decay, they release high-energy particles.

2 INFILTRATION
Some radioactive particles can break through the membranes of cells and penetrate the cells' nuclei.

3 INTRUDER
Once inside the nucleus, radioactive particles damage the double-helix structure of DNA.

4 DNA DAMAGE
Once the sequence of nucleotides is damaged, the transcription of the information when the cell divides will be altered.

5 CANCER GROWTH
Mutations can cause the acceleration of cell division without the occurrence of natural cell death.

6 TUMOUR FORMATION
As the mass of cancerous cells increases, tumours begin to form.

AR zone SCAN HERE

Albinism is a genetic condition where an organism doesn't produce melanin for colouring skin, hair and eyes

butterflies showed a mutation rate double that of butterflies found before the incident.

Often referred to as the 'raw materials' for evolution, genetic mutations are the fundamental building blocks for life on Earth. The father of evolution Charles Darwin penned the theory of natural selection in the mid-1800s, offering the first explanations for modern-day life and the biological journey it had undertaken through time to become what we know today. The theory of natural selection proposed that only members of a species that are able to adapt to their environments will survive long enough to reproduce and continue their lineage. However, Darwin remained in the dark about the role genetics played in the evolution of a species. That knowledge came from Dutch botanist Hugo de Vries at the beginning of the 20th century.

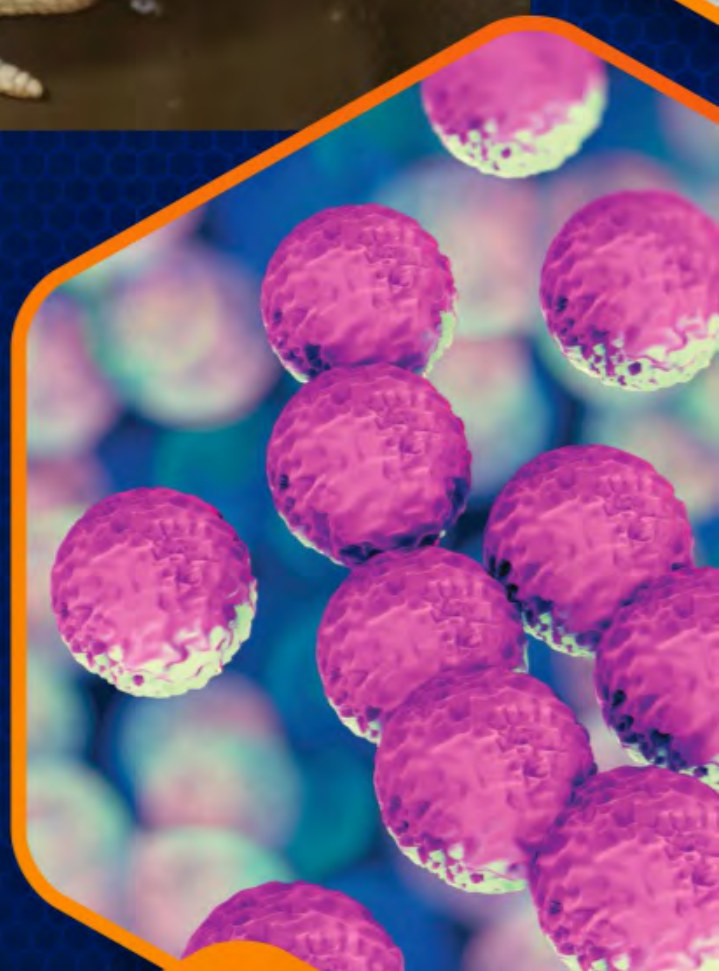
Did you know?

Ribonucleic acid (RNA) genomes can also mutate

Natural selection is driven by mutations in an organism's DNA that cause a beneficial physical or behavioural trait that ensures their survival. Those traits are then passed on to the next generation, and over time the species evolves. Members of the species that don't genetically mutate and adapt often die before they can pass their DNA on to their offspring. For an entire species to evolve, the development and mutation of DNA occurs over thousands of years. For example, over millennia the DNA of some giraffes mutated to allow them to grow long necks and tall legs to reach parts of trees that other shorter giraffes and herbivores struggled to get to. Their long necks gave them an advantage and increased their chance of survival, although natural selection and mutation-driven evolution isn't a thing of the past. There are many examples of modern-day mutants, showing scientists the next potential stages in their evolution, including humans.

Two-headed snakes and poison-protected mice are far from being alone in their mutations. To find one of the most advanced mutants on Earth, you need only look in the mirror. Considering the fact that genetic mutations are the raw materials of evolution, we as humans have undergone countless changes in our genetic makeup over the past 10,000 years to become the apex predators

A giraffe's long neck is both a strange and extremely useful adaptation



MRSA

Staphylococcus aureus

As single-celled organisms, each time bacteria create a copy of themselves through cellular division they run the risk of mutation. In 20 minutes or less, bacteria can double their population. When a mutation occurs it quickly becomes the norm, such as in methicillin-resistant *Staphylococcus aureus* (MRSA): mutations have given it the ability to resist the effects of antibiotics.

DID YOU KNOW? Every living thing on Earth evolved from a bacterium 3.7 billion years ago

MODERN-DAY MUTANTS

Mutations have allowed these species to adapt and survive

EUROPEAN HOUSE MOUSE

Mus musculus

Warfarin is a blood thinner used in pest control. The poison works by reducing vitamin K production, which helps the body form blood clots – an important process that prevents excess bleeding. A mutation in a gene called VKORC1 allows certain mice to produce more vitamin K and combat the blood-thinning ability of warfarin.

GREEN ANOLE

Anolis carolinensis

In only 20 generations, green anole lizards have rapidly evolved to best a group of invasive brown anoles in the US. Within the span of 15 years, these tree-dwelling lizards have evolved larger toepads with more sticky scales that allow them to reach heights that their invasive competitors are unable to access.

TABLE CORAL

Acropora

Warming temperatures cause coral species to 'bleach', where they lose their vital algae and die. Research has shown that table corals have mutated to adapt to warmer waters. Heat-tolerant corals like these are more likely to survive in the face of a warmer climate and may evolve into the dominant type of coral in our oceans.

PEPPERED MOTH

Biston betularia

These moths are naturally speckled white and black. During the rise of the Industrial Revolution, they were able to adapt and survive predation thanks to a mutation that emerged around 1819. It made these moths darker – almost completely black – allowing them to blend in on urban tree trunks that had been coated in soot.

and technological innovators that we are today. Over millennia, both small and large mutations to the human genome have propelled our evolution and created the modern human, from the shedding of our body hair to the development of large brains. One example of a recent human mutation happened between 6,000 and 10,000 years ago, affecting a gene called OCA2 that halted the production of the melanin pigment in the iris that colours the eyes brown, diluting eyes to a shade of blue.

One of the ways humans have evolved – and continue to evolve – relates to our diet. Humans are one of the only mammals that drink milk after infancy. The ability to digest dairy in adulthood is down to a group of genes that allow our bodies to break down the sugar in milk, lactose. In other mammals the genes that codes for proteins that can digest lactose typically switch off after infancy, but a mutation in some humans stops that from happening. "We know there are four independent mutations that we see in various human populations, and they sit in the promotion of this gene," says Laurence Hurst, professor of evolutionary genetics at the University of Bath. "Rather than it being switched off, it gets switched back on again." Over the last 8,000 years, this has led to around 90 per cent of Northwestern Europeans having the ability to digest lactose. It's often thought that humans have jumped off the evolutionary train and have reached their final biological destination, likely due to advancements in medicine reducing the need for natural selection. However, this isn't the case. Adaptive mutations are still prevalent in our species, shaping the way humans evolve.

A royal python with bicephaly, a genetic mutation that causes a single organism to have two heads

Polymelia is a mutation that causes an organism to grow extra limbs, like this four-legged chicken

DID YOU KNOW? Sequencing the human genome began in 1990 and was completed in 2003

THE EVER-EVOLVING HUMAN

HOW SOME MEMBERS OF OUR SPECIES FROM AROUND THE WORLD ARE EVOLVING

Did you know?

Humans have lost over 500 DNA codes through evolution

1 ALTITUDE TOLERANCE

In less than 3,000 years, some Tibetans and Han Chinese people have evolved to live at altitudes most people could not – at altitudes of 4,000 metres where the oxygen levels are around 40 per cent lower than at sea level, Tibetan villages have been thriving in the thin air. Researchers have identified 30 genetic mutations within those that live at these impressive altitudes, half of which are related to the way the human body uses oxygen and helps the individual manage haemoglobin concentrations.

2 DEEP DIVERS

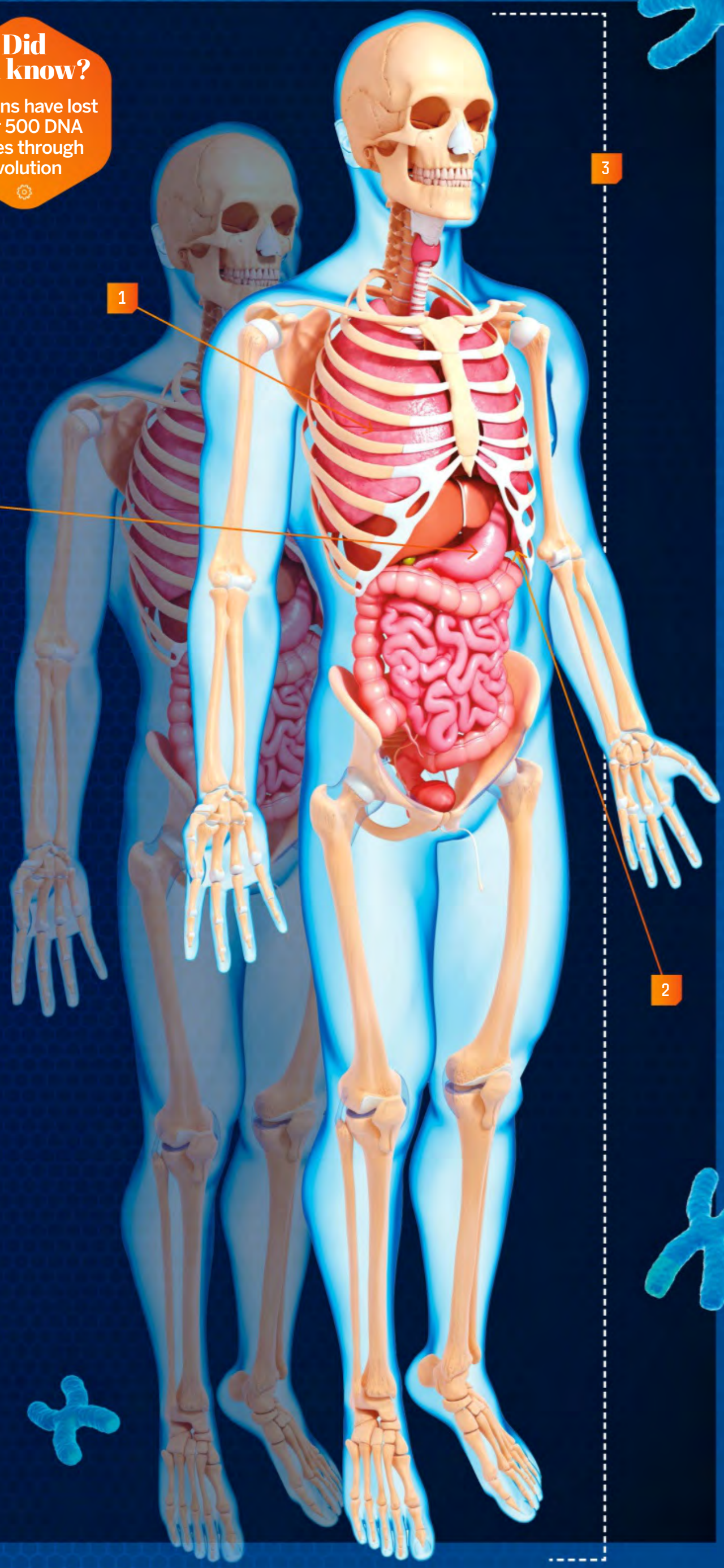
The deep-sea-diving Bajau people of Southeast Asia have shown a remarkable example of human evolution by building the biological equivalent of a scuba tank. The human spleen is typically used to filter blood as part of the body's immune system. Through genetic mutations, the people of Bajau have evolved a larger spleen than most, around 50 per cent bigger on average. A large spleen can act as a reservoir of oxygenated blood while diving, allowing the Bajau people to deep dive up to 70 metres below the surface.

3 GETTING TALLER

In the mid-18th century, the average Dutch soldier was recorded to be 165 centimetres tall. However, the modern-day Dutchman is a towering 182.5 centimetres tall on average. Over the same period, the average American has grown by only six centimetres. It's thought that the 20-centimetre increase is down to natural selection – a preference for tall men among Dutch women.

4 VEGETARIAN NUTRITION

Scientists found that 70 per cent of vegetarians in Pune, India, that they surveyed have a genetic mutation in the FADS2 gene that allows them to produce essential omega-3 and other fatty acids from a non-meat diet. Fatty acids such as omega-3 are abundant in fish and red meat, but sparse in vegetables. The FADS2 mutation is thought to help vegetarians effectively process these fatty acids from alternative sources.



SPECIAL

GENETICS BY NUMBERS

40,000

Thousands of DNA strands can fit into the width of a human hair

6 MILLION YEARS

The estimated time taken for humans to evolve

10 BILLION MILES OF DNA IS FOUND INSIDE EACH PERSON

149 BILLION NUCLEOTIDES

The Japanese plant *Paris japonica* has the largest genome

100 TO 200

Potentially hundreds of new mutations are passed down each generation

4 BILLION YEARS AGO

The earliest date DNA appeared on Earth

50%

The share of DNA between siblings

GENETIC MUTATIONS OCCUR TWICE AS FREQUENTLY IN MALES

DID YOU KNOW? Forensics DNA testing looks at 13 specific segments to identify a suspect

99.9%

You share practically all of the same DNA with every other human

THE DNA IN A SINGLE CELL WOULD STRETCH FOR OVER TWO METRES

521 YEARS

The degradation half-life for DNA

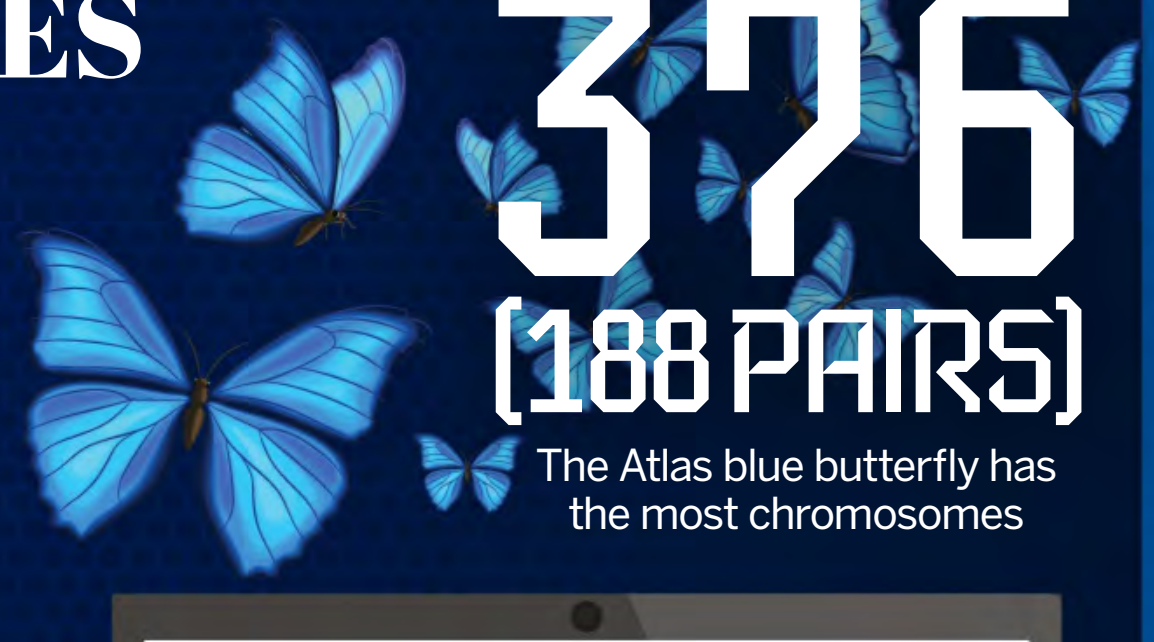
A SINGLE CHROMOSOME HAS 50 TO 250 MILLION BASE PAIRS

HUMANS SHARE 95 PER CENT OF DNA WITH OTHER PRIMATES

20,000 TO 25,000

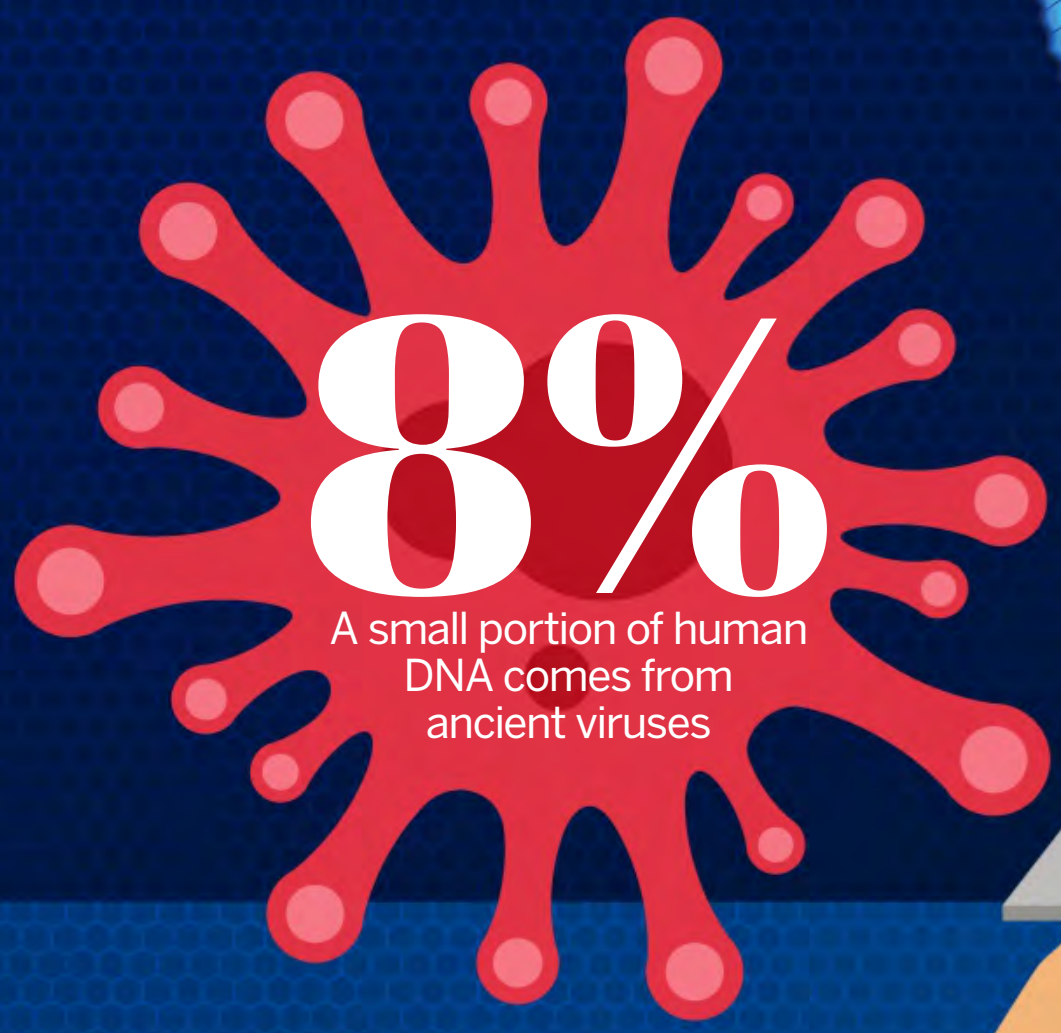
There are thousands of protein-coding genes in the human genome

THE JACK JUMPER ANT ONLY HAS ONE CHROMOSOME



376 (188 PAIRS)

The Atlas blue butterfly has the most chromosomes

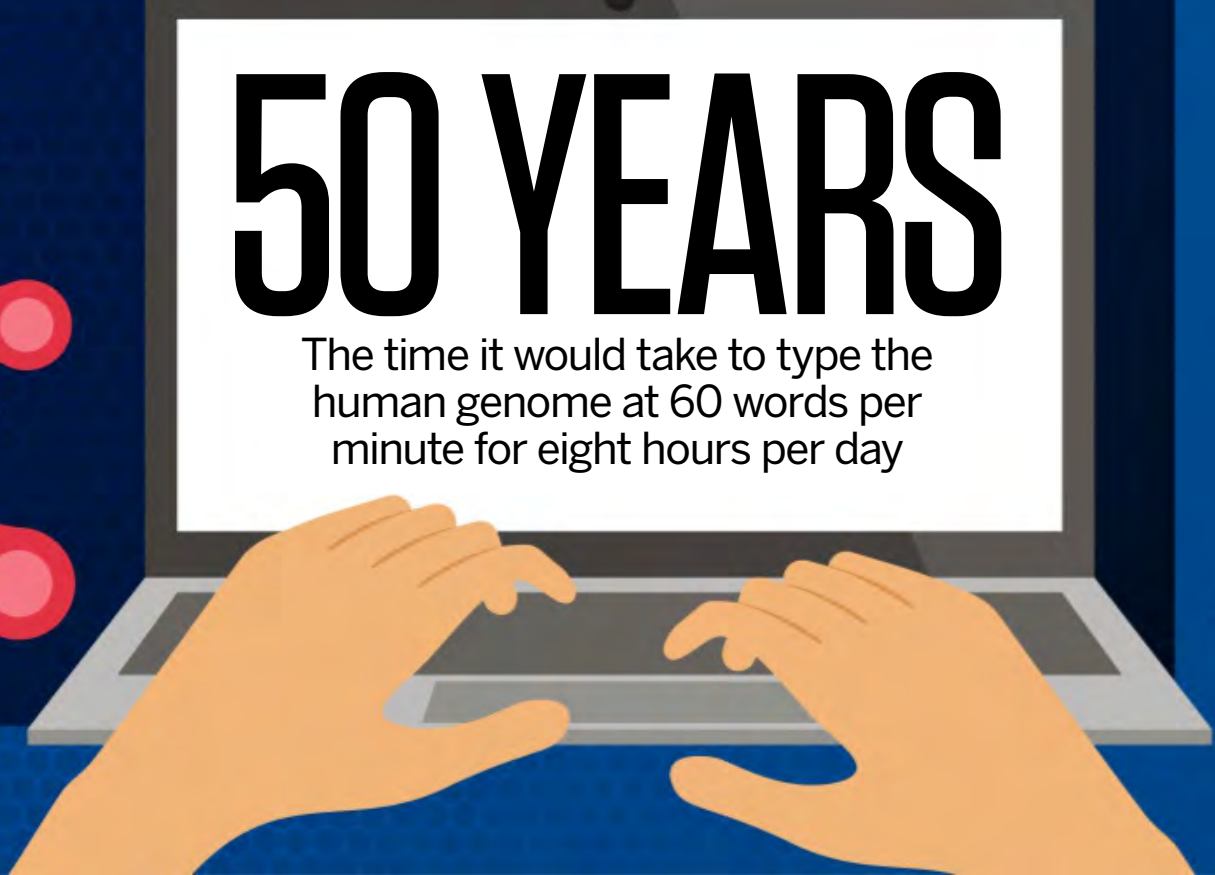


8%

A small portion of human DNA comes from ancient viruses

50 YEARS

The time it would take to type the human genome at 60 words per minute for eight hours per day



SOUND BARRIER SMASHERS

Ever since humanity took to the skies, we've pushed the limits of speed, accelerating past sound to hypersonic speeds and beyond

WORDS **ROBERT LEA**

As the field of aviation grew and planes became faster around the mid-20th century, pilots began to experience strange phenomena when approaching speeds in excess of 700 miles per hour. Almost like hitting a physical barrier, further acceleration for these pilots and their aircraft was prevented by violent effects, sudden changes in temperature and pressure – almost like flying into a wall. Corresponding with the speed at which sound travels, this 'wall' would come to be known as the sound barrier. We now know this isn't an actual physical barrier, but is a sudden increase in aerodynamic drag that occurs as a vehicle approaches the speed of sound, at speeds that are described as 'supersonic'.

Sound propagates through air as a wave at around 761 miles per hour at sea level – a velocity also known as Mach 1, part of a measurement system for speed that takes its name from Ernest Mach, an important figure in the science of shock waves. Because sound waves use air as a medium, the density of air has a significant effect on the speed sound travels. Where the atmosphere is thinner at greater altitudes, sound travels slower. That means that pilots hit the sound barrier at slower speeds. At an altitude of 3.8 miles the sound barrier arrives at 707 miles per hour, while at 11.4 miles it drops to 660 miles per hour. Certain other conditions like temperature also alter the speed at which sound travels, and thus the sound barrier.

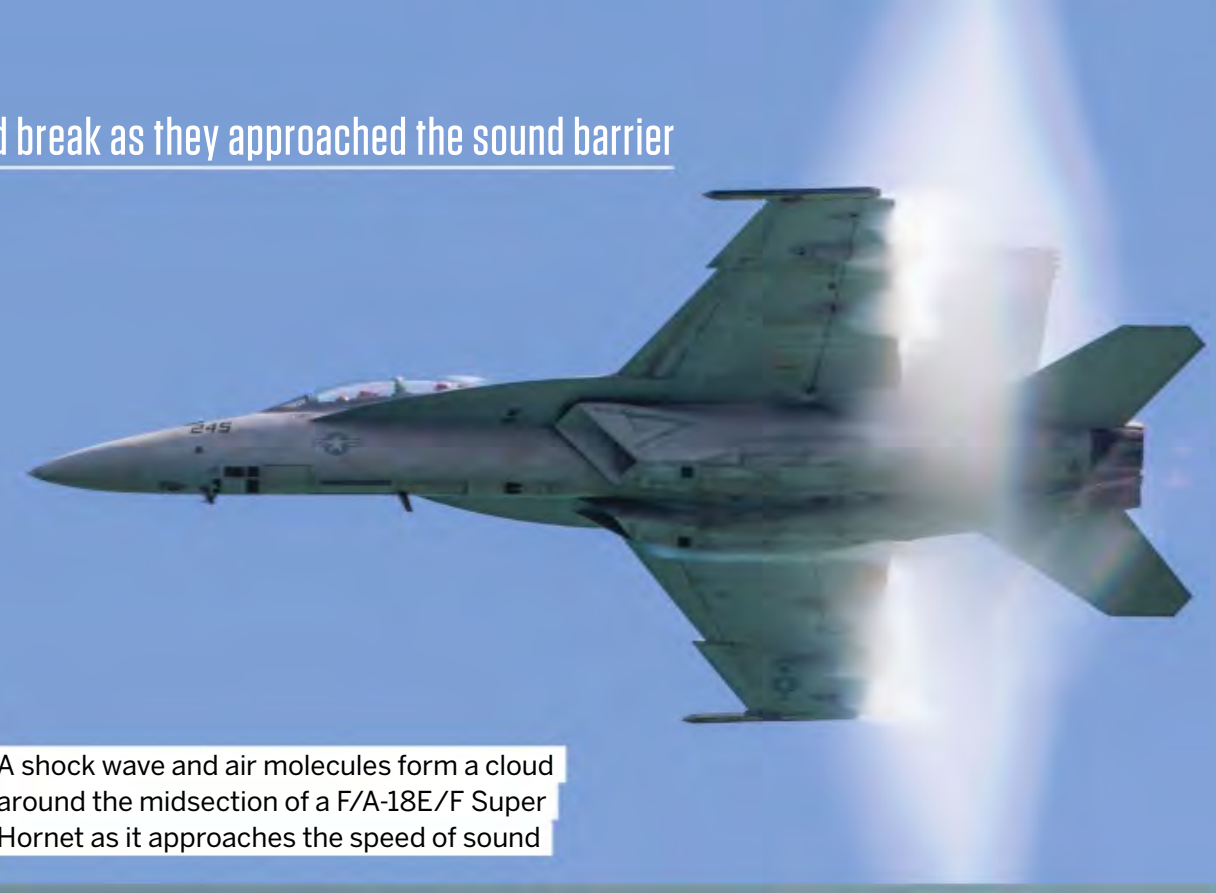
The forces experienced by an aircraft depend strongly on the speed it travels. At

speeds slower than sound – subsonic speeds of up to Mach 0.8 or 614 miles per hour – the air in front of an aircraft moves before the vehicle reaches it. This is because the sound waves – or more precisely pressure waves – created by the plane outrace it and spread out ahead of it. This continues through so-called transonic speeds of between Mach 0.8 and Mach 1, but the situation changes radically at supersonic speeds above Mach 1. The pressure waves no longer race ahead of the jet, shifting air from its path. This results in shock waves building around the aircraft. This also leads to a pressure cone building mostly behind the jet, triggering a famous effect of breaking the sound barrier: the sonic boom.

Sonic booms hit the ground between 2 and 60 seconds after a supersonic flyover, with the area exposed equivalent to roughly one mile for every 0.2 miles of altitude. That means a jet breaking the sound barrier at 5.6 miles causes a sonic boom spread across around 30 miles. The intensity of the sonic boom heard at ground level is determined by a number of factors. This includes how far above the ground the jet is and atmospheric conditions like pressure and temperature.

Did you know?

Swept wings on jets help them go supersonic



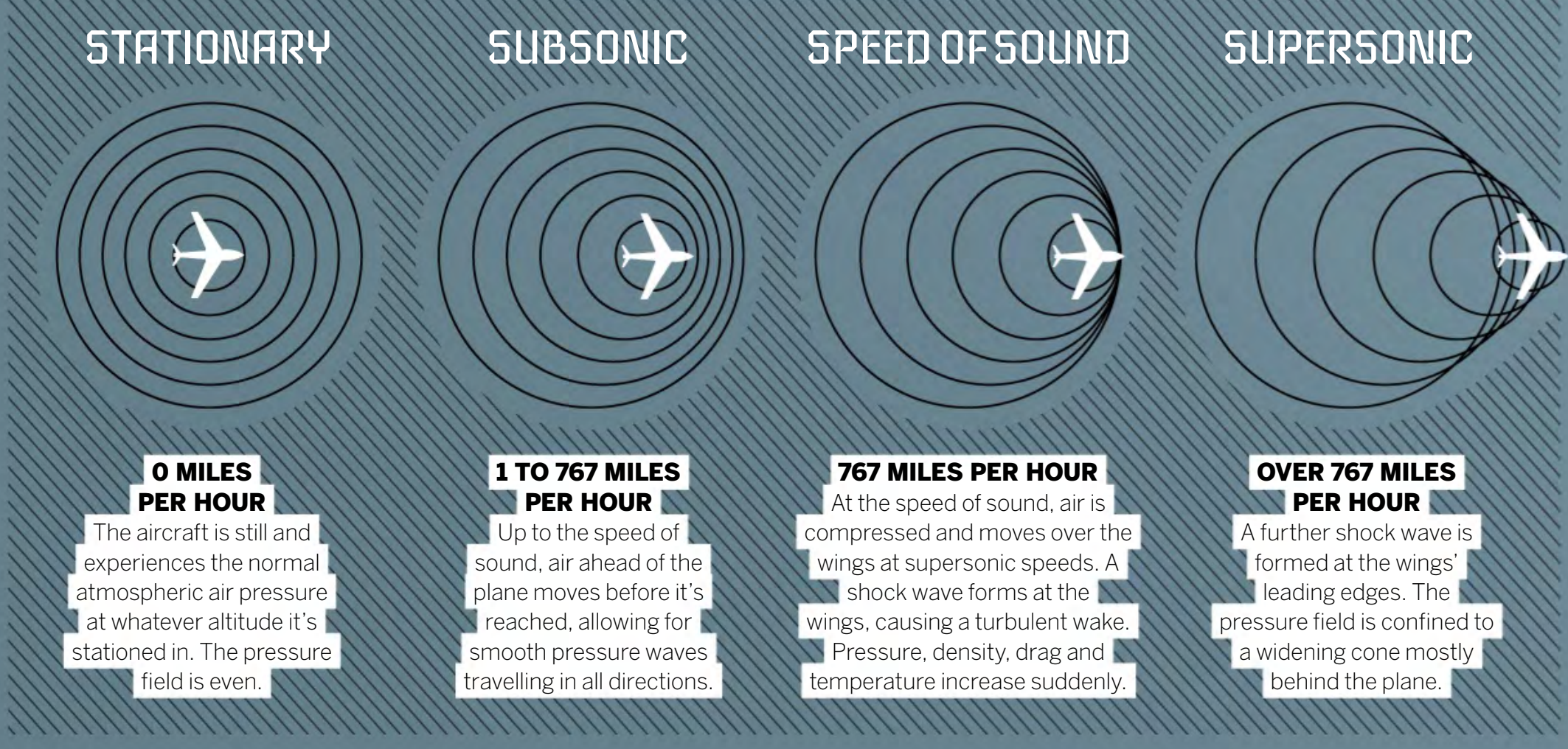
A shock wave and air molecules form a cloud around the midsection of a F/A-18E/F Super Hornet as it approaches the speed of sound

The shape of the jet is also a factor, with longer aircraft capable of causing a double sonic boom – one of which comes from its leading edge, and the other from the trailing edge. There are two types of sonic boom: N-shaped, which are caused by steady flight conditions and an N-shaped pressure wave, and U-shaped that result from jets engaged in flight manoeuvres at supersonic speeds. The strongest sonic boom ever recorded was 6.9 kilonewtons per metre squared and resulted from an McDonnell Douglas F-4 Phantom II flying above the speed of sound at an altitude of 30 metres.

Speeds above Mach 5 – five times the speed of sound or around 3,800 miles per hour – are described as being hypersonic. At hypersonic speeds, molecules of air around an aircraft start to break apart and ionise – they gain electric charge. While this doesn't happen at a set speed, the term 'hypersonic' is used to describe a point at which this phenomenon begins to affect the mechanics of flight. At high-hypersonic speeds above Mach 10 or around 7,700 miles per hour, the ionisation of molecules results in plasma – the same phase of matter that makes up the Sun – forming around the vehicle.

PRESSURE WAVES

As an aircraft approaches the speed of sound, conditions change radically, resulting in a pressure wave that ripples backwards through the air



0 MILES PER HOUR
The aircraft is still and experiences the normal atmospheric air pressure at whatever altitude it's stationed in. The pressure field is even.

1 TO 767 MILES PER HOUR
Up to the speed of sound, air ahead of the plane moves before it's reached, allowing for smooth pressure waves travelling in all directions.

767 MILES PER HOUR
At the speed of sound, air is compressed and moves over the wings at supersonic speeds. A shock wave forms at the wings, causing a turbulent wake. Pressure, density, drag and temperature increase suddenly.

OVER 767 MILES PER HOUR
A further shock wave is formed at the wings' leading edges. The pressure field is confined to a widening cone mostly behind the plane.

BREAKING THE SOUND BARRIER

The Bloodhound supersonic car hasn't quite hit the sound barrier yet

Two main classes of vehicle are capable of breaking the sound barrier, with this feat usually achieved by aircraft and a small number of land vehicles that have in principle been capable of travelling faster than sound – but so far only one has officially done this. It was aircraft pilots that first discovered the existence of the sound barrier during World War II, when their planes began to experience the effects of air being compressed as they approached the speed of sound, giving rise to often severe adverse effects. This included airflow over the wings that made pulling out manoeuvres difficult and shock waves on wings causing 'flutter', costing the life of at least one pilot, Geoffrey de Havilland Jr.

This led to the concept of a physical barrier that restricted the acceleration of aircraft, spurring the quest to smash this barrier. Advances in aircraft design like tiled wings and engine performance led to the sound barrier being broken as a matter of routine in the 1950s, and later to an array of craft that could go supersonic, including one passenger jet: the Concorde. On 15 October 1997, the first vehicle officially achieved the same feat on land. The British-designed and built ThrustSSC, driven by Andy Green, achieved a speed of just over 763 miles per hour – Mach 1.016 – over a mile-long stretch of the Rock Desert of Nevada. The car was powered by two engines, the same as used in F-4 Phantom II jet fighters.

BEYOND MACH 5

This computational image shows air flowing over NASA's X-43A, supersonic combustion ramjet as it travels at Mach 7

THE LOCKHEED MARTIN SR-72

The Lockheed Martin SR-72 is a hypersonic unmanned aerial vehicle (UAV) designed for reconnaissance that could fly by 2025

1 TURBINE POWER
Turbines similar to those used in modified fighters form part of the SR-72's advanced propulsion system. These take the jet to Mach 3.

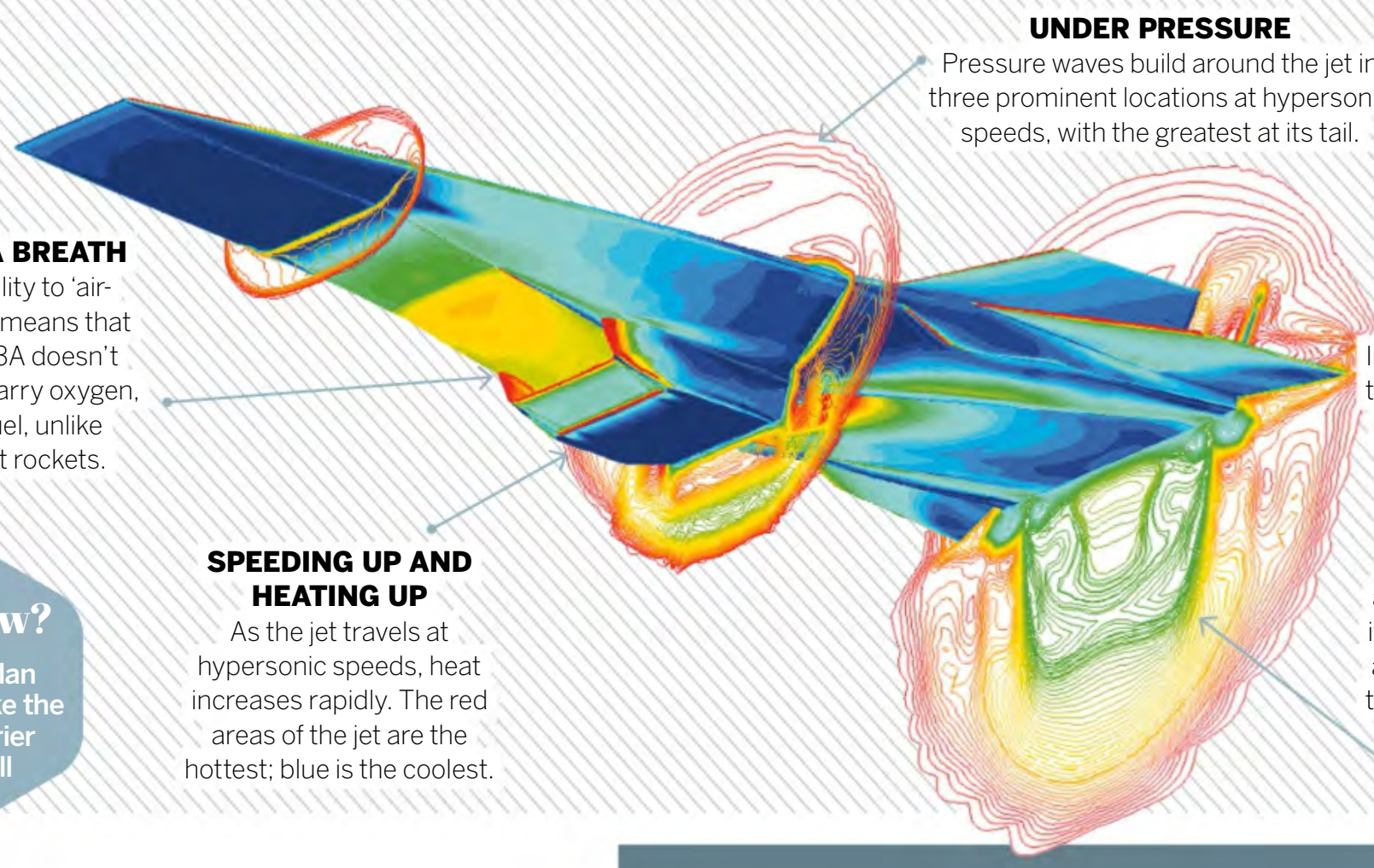
2 DUAL SCRAMJET
The other key component of the jet is a dual-scramjet through which air passes at supersonic speeds. This kicks in to boost it right up to hypersonic speeds.

3 BREATHE IN... AND OUT
An air inlet allows air to pass through to the ramjet engine and the turbines. Air is then released from an outlet at the rear of the jet, with a single inlet and outlet reducing drag.

4 NO DRAG
The jet's design reduces drag and friction, which can heat the body of a hypersonic aircraft enough to melt it.

5 EMPTY COCKPIT
The prototype, which may or may not have already flown, will be unmanned, but a human could take direct control of a similar model in the future.

6 HYPERSONIC EXHAUST
This powerful engine and bodywork combination could push the unmanned SR-72 to reach speeds up to and potentially above Mach 5.



UNDER PRESSURE
Pressure waves build around the jet in three prominent locations at hypersonic speeds, with the greatest at its tail.

TAKE A BREATH
The ability to 'air-breathe' means that the X-43A doesn't need to carry oxygen, only fuel, unlike current rockets.

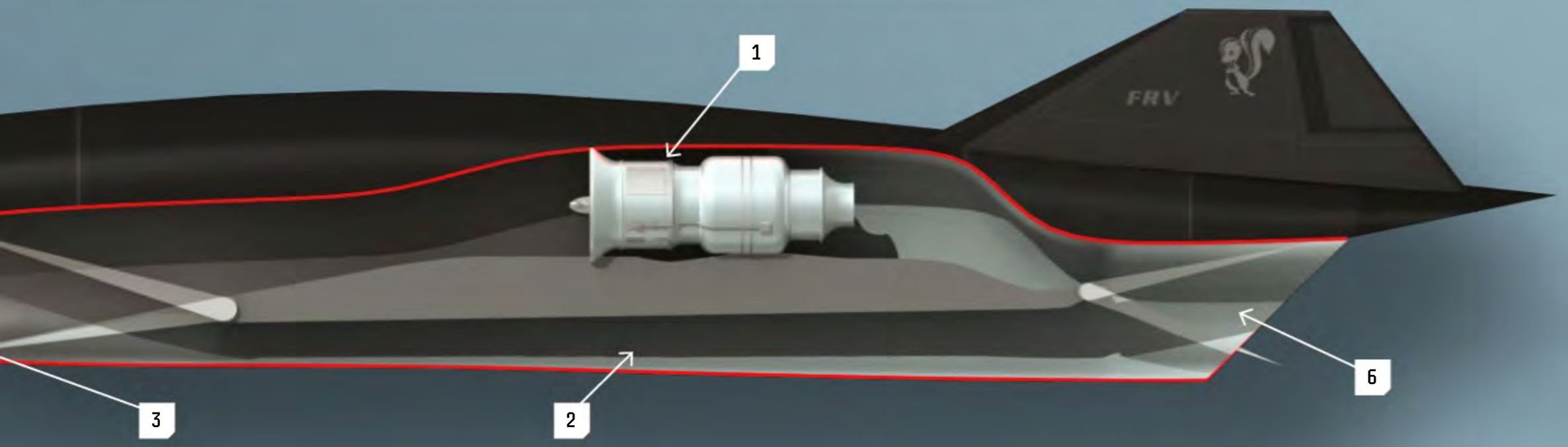
SPEEDING UP AND HEATING UP
As the jet travels at hypersonic speeds, heat increases rapidly. The red areas of the jet are the hottest; blue is the coolest.

THE ENGINE BODYWORK
In these jets, air flows through the engine at supersonic speeds, meaning the body acts as part of the engine. While the X-43A's forebody acts as an air intake, its aft section acts as a nozzle, allowing air to escape. One inflow and outflow of air reduces drag.

Did you know?

Google's Alan Eustace broke the sound barrier in free fall

DID YOU KNOW? In 1953, Jacqueline Cochran piloted a Canadair Sabre to become the first woman to break the sound barrier

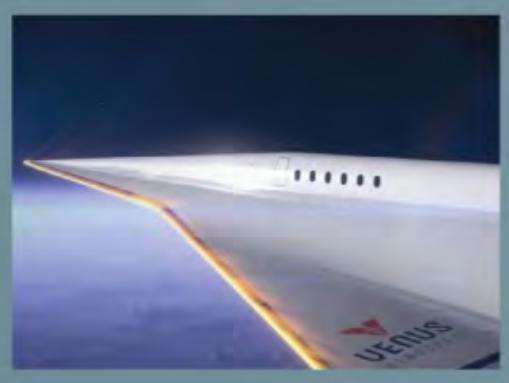


SPEEDING THROUGH THE SKIES

BOOM OVERTURE

TOP SPEED
1,300 miles per hour (Mach 1.7)

Designed by Boom Technology, the aim of the Overture is to bring supersonic jet travel back to the public. In this way, the craft is picking up where Concorde left off in 2003. Supersonic tests of Overture will be conducted in 2025, with the first commercial flight set for 2029.



VENUS AEROSPACE STARGAZER

TOP SPEED
6,905 miles per hour (Mach 9)

In June 2022, Venus Aerospace unveiled its design for a hypersonic space plane known as Stargazer. The craft is designed to launch from a conventional airport and soar to the edge of space, reaching speeds as great as Mach 9, and is also capable of one-hour global travel.

BOEING VALKYRIE

TOP SPEED
3,840 miles per hour (Mach 5)

The Valkyrie is a proposed military vehicle that features a unique flattened design that allows it to reach speeds in excess of Mach 5. The key to the jet's hypersonic velocity could be how its unique design with 2D air inlets handles drag as it hits supersonic speeds.

MAKING HISTORY

On 14 October 1947, American test pilot Charles "Chuck" E. Yeager became the fastest man alive when he broke the sound barrier for the first time. Yeager made history in a Bell X-1 rocket plane, which he nicknamed 'Glamorous Glennis' after his first wife. At an altitude of eight miles, the test pilot relit a third chamber of the plane's engine, causing it to accelerate to Mach 0.98. Yeager climbed another 304 metres, increasing speed and becoming the first man to officially travel faster than sound.

The public was made aware of the feat in 1948 and Yeager was awarded the Collier trophy – a prestigious aviation award – with the awarding body calling his 14 October flight the most important in aviation history since the Wright brothers' in 1903.

Chuck Yeager stands by the Bell X-1 supersonic rocket plane that took him beyond the speed of sound in 1947

5 UNLIKELY SOUND BARRIER SMASHERS

1 WHIP IT
In 1958 it was discovered that the loud crack created by snapping a bullwhip is actually a tiny sonic boom created by the tip of the whip breaking the sound barrier.

2 NO TROUBLE FOR TOWELS
An infamous high school locker room gag, whipping a towel at an unsuspecting teammate and causing a cracking sound is the result of the tip of the towel travelling faster than sound.

3 FLAG THIS ONE
A flag on a flagpole buffeted in a strong wind can cause a sonic boom when its leading edge goes supersonic.

4 A BRUTAL GAME OF PING PONG
In 2018 Mark French and a team from Purdue University created a ping pong bazooka capable of launching these light, hollow plastic balls to speeds exceeding Mach 1.5.

5 FELIX IN FREE FALL
In 2012, Felix Baumgartner leapt from a balloon 24 miles above New Mexico. Not only did he break the then-world-record for a free fall, but travelling at 843.6 miles per hour, or Mach 1.25, he also broke the sound barrier.

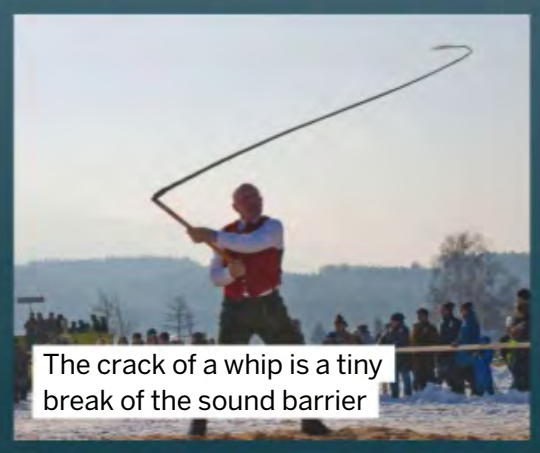
GONE IN 30 MINUTES

Ten of the fastest vehicles ever devised race as far as they can in 30 minutes

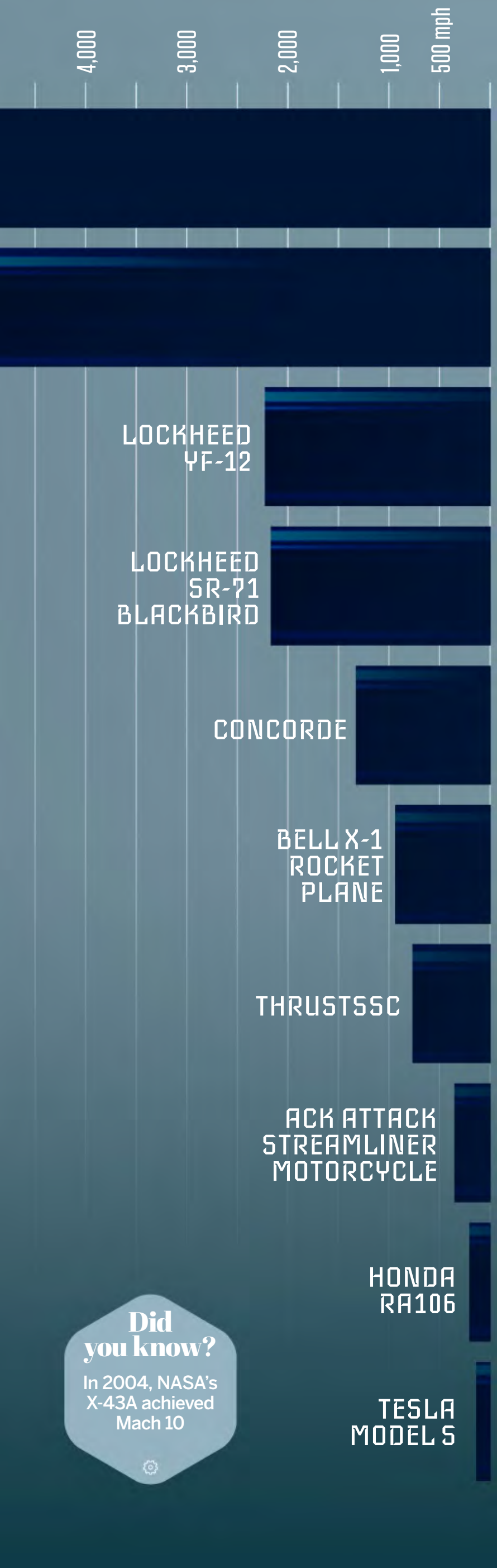

Concorde carried the general public to speeds beyond sound


The ThrustSSC still holds the land speed record

Baumgartner preparing for his barrier-breaking free fall


The crack of a whip is a tiny break of the sound barrier

DID YOU KNOW? An aircraft experiencing a tailwind can have a ground speed faster than sound without breaking the sound barrier



LOCKHEED YF-12
Top speed: **17,500 miles per hour**
Distance travelled in 30 minutes: **8,750 miles**

LOCKHEED SR-71 BLACKBIRD
Top speed: **7,366 miles per hour**
Distance travelled in 30 minutes: **3,683 miles**

CONCORDE
Top speed: **2,275 miles per hour**
Distance travelled in 30 minutes: **1,137.5 miles**

BELL X-1 ROCKET PLANE
Top speed: **2,200 miles per hour**
Distance travelled in 30 minutes: **1,100 miles**

THRUSTSSC
Top speed: **1,354 miles per hour**
Distance travelled in 30 minutes: **677 miles**

ACK ATTACK STREAMLINER MOTORCYCLE
Top speed: **958 miles per hour**
Distance travelled in 30 minutes: **479 miles**

HONDA RA106
Top speed: **763 miles per hour**
Distance travelled in 30 minutes: **381.5 miles**

TESLA MODEL S
Top speed: **394 miles per hour**
Distance travelled in 30 minutes: **197 miles**

Top speed: **247 miles per hour**
Distance travelled in 30 minutes: **128.5 miles**

Top speed: **200 miles per hour**
Distance travelled in 30 minutes: **100 miles**

Did you know?

In 2004, NASA's X-43A achieved Mach 10

The Space Shuttle is one of the fastest human-made vehicles

The SR-71 Blackbird can pass Mach 3

The RA106 raced in the 2006 Formula 1 season

The Tesla Model S is speedy for an all-electric vehicle

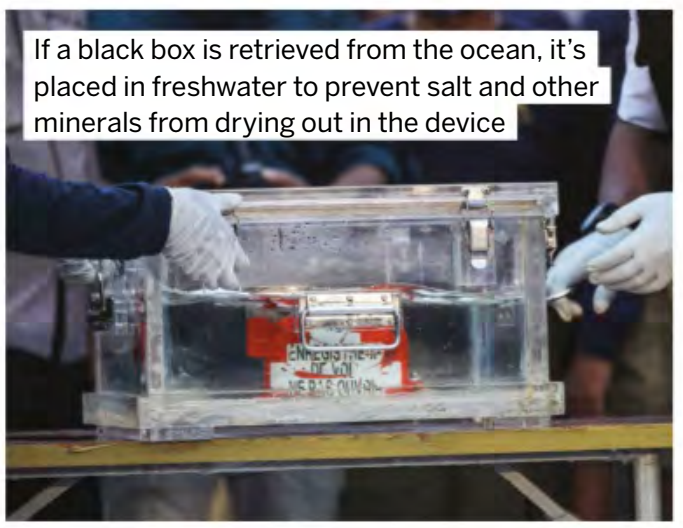
CRASH ANALYSIS: BLACK BOX FLIGHT RECORDERS

What makes these essential devices found on most aircraft virtually indestructible?

WORDS **AILSA HARVEY**

The chances of being in a fatal aeroplane crash are extremely low because of advances in aerospace engineering. One of the devices that helps grow our understanding of how planes crash is the black box flight recorder. This device is made up of two parts: the flight data recorder and the cockpit voice recorder. Combined, these components collect in-depth data about the moments and cockpit communications on board a failing plane. This data includes airspeed, altitude, aircraft positioning, vertical acceleration and environmental conditions. Using this information, investigators can conclude the main fault in plane incidents when key witnesses haven't survived to tell the tale.

Black boxes are most commonly stored at the back of an aircraft because in the event of a crash, this area is less likely to hit the ground first than the nose. Microphones are placed in the cockpit to record sound, but this audio is stored in the black box at the back. Black boxes record all sounds, such as conversations between crew members, background noise and the engine. The recording is made on a loop that overwrites the previous data every two hours so that only the final and most relevant recordings remain after a crash.



If a black box is retrieved from the ocean, it's placed in freshwater to prevent salt and other minerals from drying out in the device

Did you know?

Black boxes are bright orange to make them more visible

IMPRESSIVE STRENGTH

In order to smash a black box to pieces, it needs to suffer an impact at speeds greater than 310 miles per hour. The devices are built to survive in temperatures over 1,000 degrees Celsius for an hour. Black boxes can continue to function in saltwater at depths of up to 6,000 metres for an entire month. With these checks in place, it isn't surprising that they are seldom damaged. In the rare event that one is broken, there's usually some form of useful data still present on the device.

A black box usually looks damaged after a crash, but its data remains intact

DID YOU KNOW? It usually takes between 10 and 15 days to analyse all a black box's information

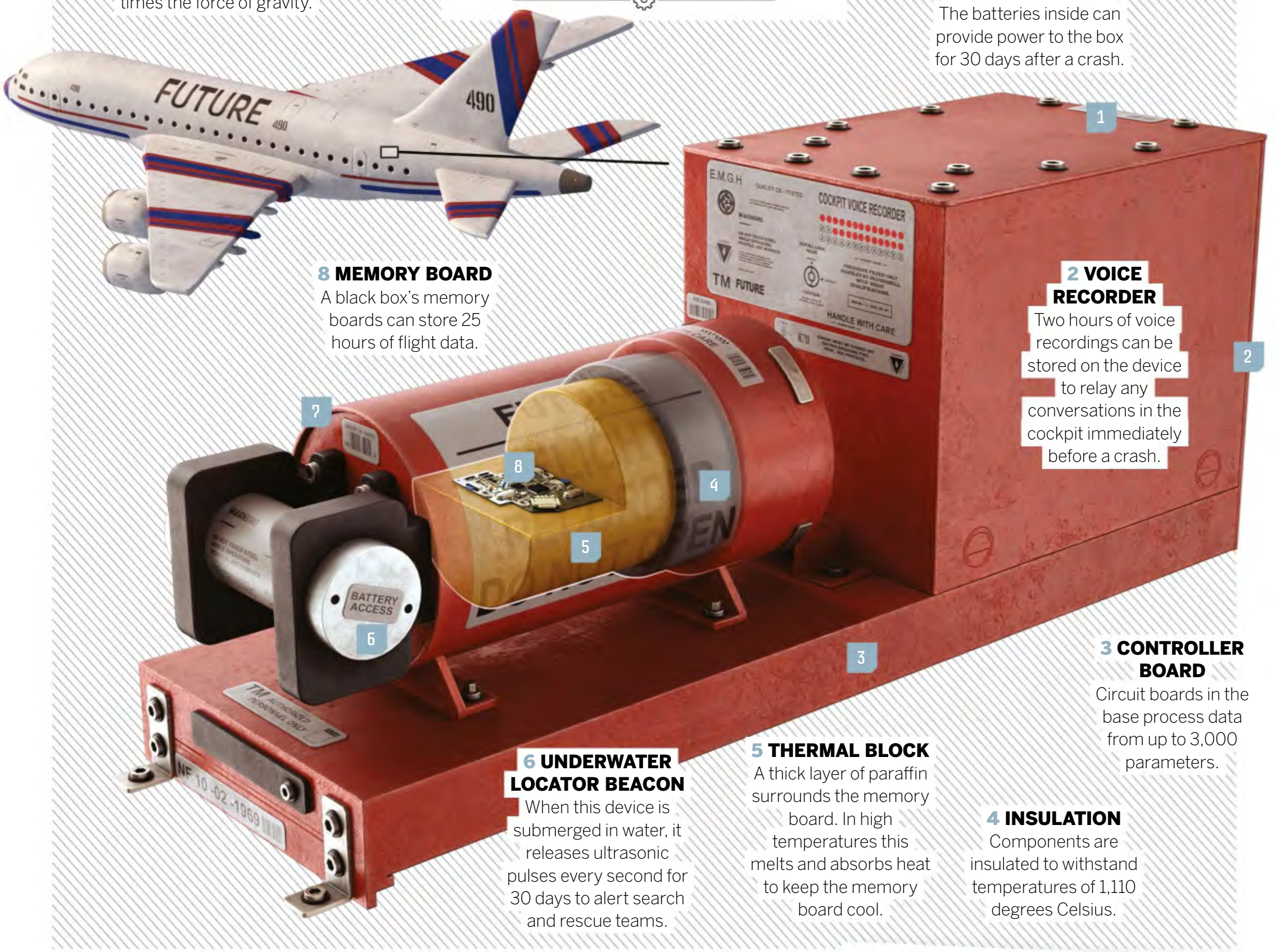
AR zone SCAN HERE

WHAT'S INSIDE?

Black boxes contain vital devices encased in protective layers

7 CRASH-RESISTANT HOUSING
The steel casing is built to withstand an impact 3,400 times the force of gravity.

1 POWER SUPPLY
The batteries inside can provide power to the box for 30 days after a crash.



8 MEMORY BOARD
A black box's memory boards can store 25 hours of flight data.

2 VOICE RECORDER
Two hours of voice recordings can be stored on the device to relay any conversations in the cockpit immediately before a crash.

3 CONTROLLER BOARD
Circuit boards in the base process data from up to 3,000 parameters.

6 UNDERWATER LOCATOR BEACON
When this device is submerged in water, it releases ultrasonic pulses every second for 30 days to alert search and rescue teams.

5 THERMAL BLOCK
A thick layer of paraffin surrounds the memory board. In high temperatures this melts and absorbs heat to keep the memory board cool.

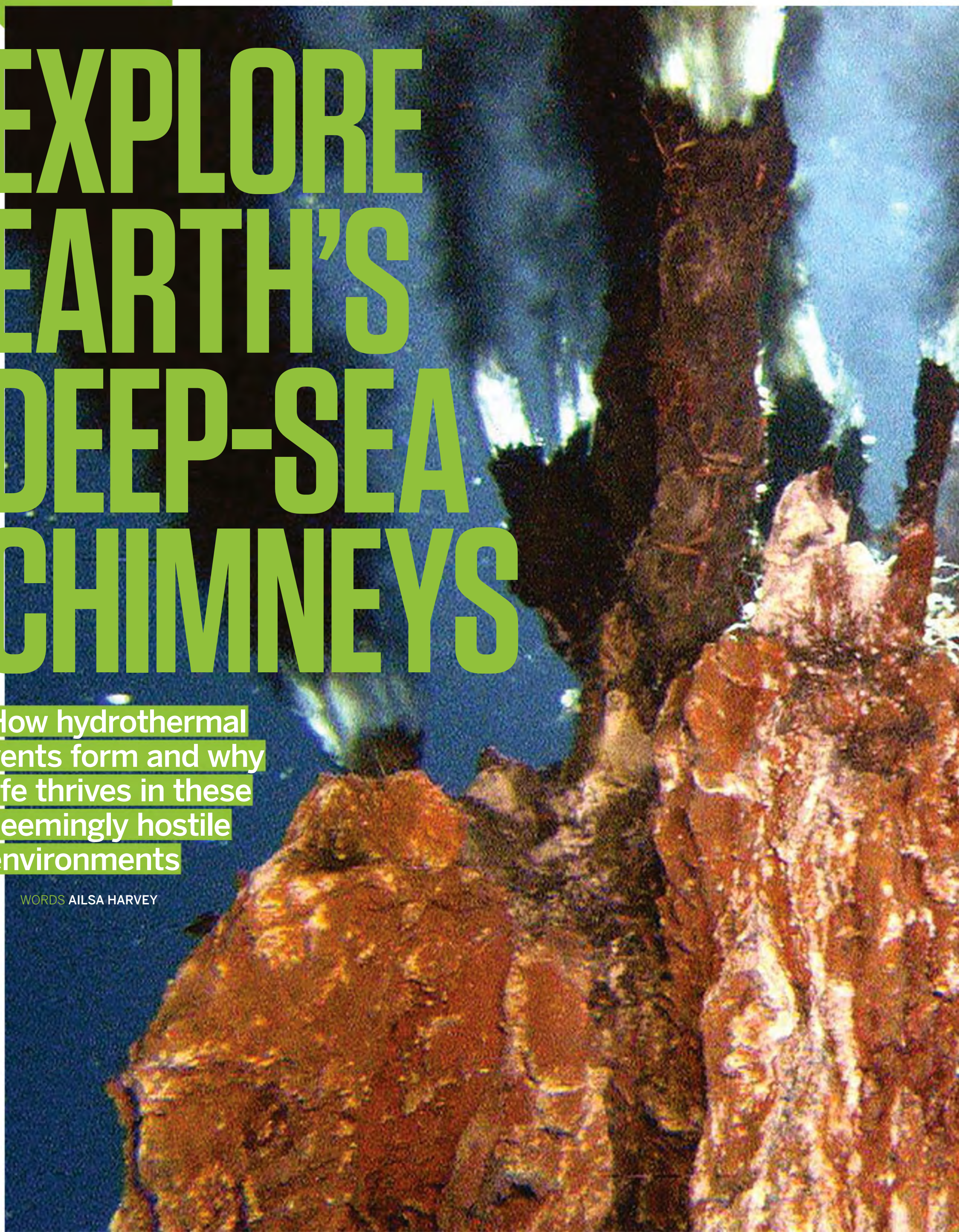
4 INSULATION
Components are insulated to withstand temperatures of 1,110 degrees Celsius.

HOW WAS THE BLACK BOX INVENTED?

Following the launch of the world's first jet airliner, the DH.106 Comet, seven of these planes were involved in crashes between 1952 and 1954, killing 110 people. In order to make air travel safer, experts at Australia's Department of Civil Aviation met to analyse possible causes of the tragedies. One of those at the meeting was a chemist who specialised in aircraft fuels named David Warren. Warren came to the conclusion that one of the main issues was the lack of available data following a devastating crash. With equipment obliterated and witnesses dying, he came up with a plan to invent some sort of recorder as evidence of the final decisions and conversations on board. Due to limited interest from his managers, Warren was forced to produce much of his prototype in his garage at home in his spare time. Once complete, Warren presented his invention to aviation authorities in the UK in 1958, and soon after the black box was a mandatory component in commercial aircraft.

Inventor David Warren pictured with the first black box prototype

EXPLORE EARTH'S DEEP-SEA CHIMNEYS



How hydrothermal vents form and why life thrives in these seemingly hostile environments

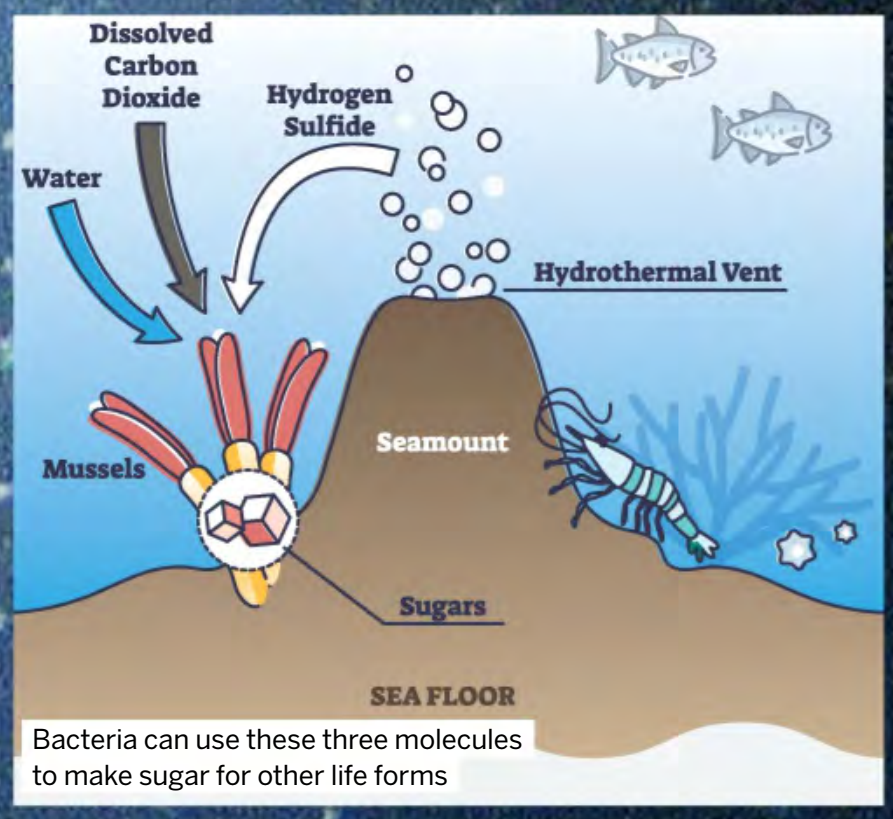
WORDS AILSA HARVEY

DID YOU KNOW? The largest hydrothermal vents, known as the Lost City chimneys, reach 60 metres above the seafloor

Over 2,000 metres below the ocean's surface, Earth's fiery centre is leaking into its crust. As our planet's tectonic plates move, small gaps can appear, providing a passageway for molten rock called magma to pass through. As this happens, minerals are transported into the oceans, cooling upon contact with the cold water to produce impressive, towering chimneys. These chimneys direct the continuous eruption of scalding, mineral-rich water upwards from the dark depths.

Because they're far from the influence of the Sun's rays, deep-sea environments are usually cold, dark and gloomy. But in the areas surrounding hydrothermal vents, temperatures can reach a searing 400 degrees Celsius. Although humans would instantly perish in these hostile conditions, many niche life forms have adapted to survive the extremes and live among the chimneys.

Instead of using photosynthesis, the process by which most plants and some microorganisms convert sunlight into energy, bacteria surrounding hydrothermal vents use an alternative biological process, chemosynthesis. This involves absorbing minerals like hydrogen sulphide from the vents and carbon dioxide from the water to produce sugars.



Bacteria can use these three molecules to make sugar for other life forms

DID LIFE BEGIN IN THE DEEP?

The first life forms could have emerged from the deep sea. About 3.7 billion years ago, single-celled organisms called microbes lived on Earth, but where they first appeared is still debated by scientists. In 1993, before alkaline vents were discovered, a NASA geochemist named Michael Russell proposed a theory about how life could have emerged from hydrothermal vents. When alkaline water from these vents combines with the more acidic water of the ocean, an energy gradient forms. The seas were thought to contain more carbon dioxide billions of years ago compared with today's waters, further increasing this gradient.

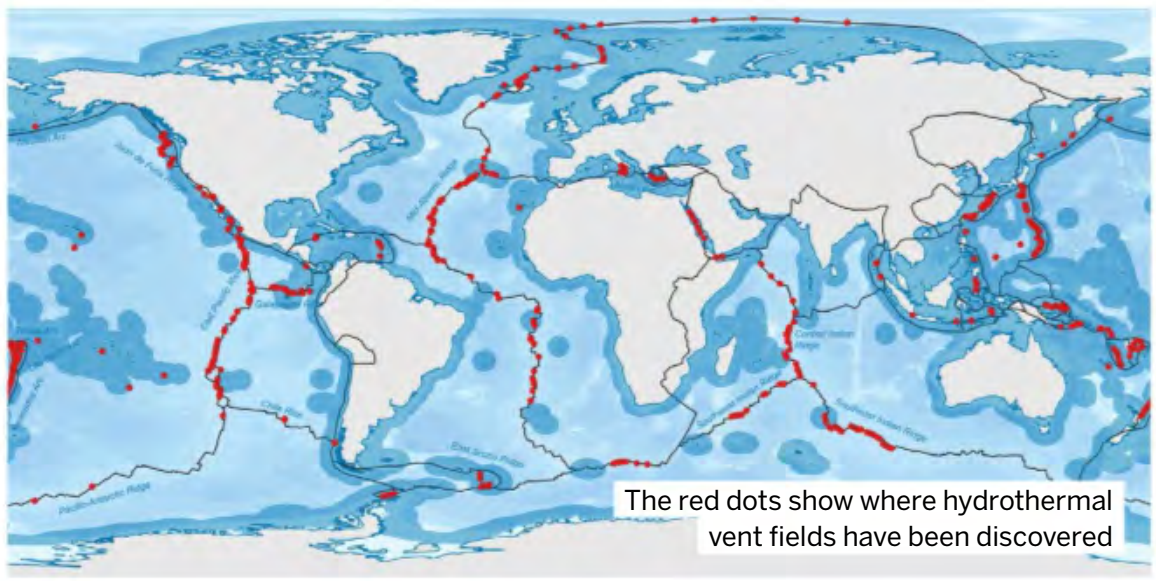
Did you know?

The first hydrothermal vent was discovered in 1977

Cells harness energy by using a proton gradient to determine the electric charge on either side of their membranes. Using this knowledge, Russell proposed that cells of the hydrothermal vents with the same pH difference across their membranes and minerals found at these depths could give way to self-replicating molecules and life forms, each with their own membranes.

WHERE VENTS ARE FOUND

The formation of hydrothermal vents usually follows the same path as the planet's tectonic plates. These plates are large slabs of rock that make up the crust that covers Earth's surface, and they are constantly, slowly moving. As our planet's tectonic plates move apart, Earth's crust is stretched and cracked. Where the ocean floor breaks, seawater fills the crevices. At the same time, the vents release material that has been heated by Earth's core. Hydrothermal vents have formed in oceans and seas across the world. Most vents, including those greatest in size, are found along mid-ocean ridges. These are elevated areas of the seafloor at tectonic boundaries.


The red dots show where hydrothermal vent fields have been discovered

BUBBLING UP

Explore hydrothermal vents above and below the crust

HOT MINERALS
Carrying dissolved chemicals from below ground, water exiting vents can be 700 degrees Celsius.

DIFFUSE VENTING
When seawater mixes with hot output from the Earth before reaching mouth of the vent, it's called a diffuse vent.

Did you know?
Seawater around the vents doesn't boil due to high pressure

METAL-RICH SEDIMENT
Magmatic fluid carries metals and minerals, which are deposited around the vents as they cool above the seabed.

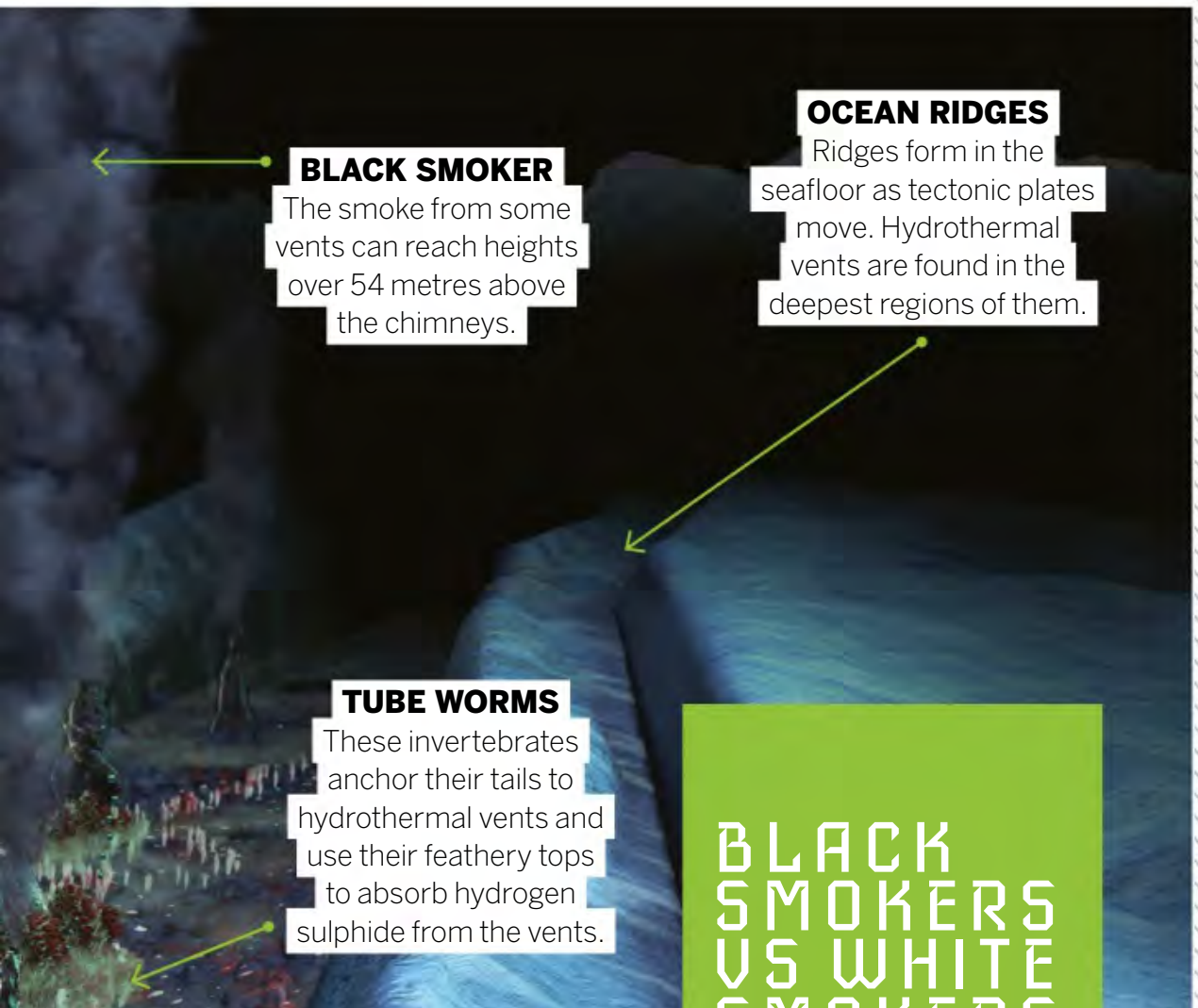
FOCUSED VENTING
Focused vents are well sealed and involve minimal mixing with seawater before the magmatic fluid is released.

MAGMATIC FLUID
Magma from beneath Earth's crust flows upwards through cracks. This is over 1,000 degrees Celsius.

Submarines such as the Chinese Jiaolong have taken samples from deep-sea vents for research


This black chimney fragment from a deep-sea vent displays sulphide minerals

DID YOU KNOW? The Cayman Trough in the Caribbean Sea has the deepest hydrothermal vents



BLACK SMOKER
The smoke from some vents can reach heights over 54 metres above the chimneys.

OCEAN RIDGES
Ridges form in the seafloor as tectonic plates move. Hydrothermal vents are found in the deepest regions of them.

TUBE WORMS
These invertebrates anchor their tails to hydrothermal vents and use their feathery tops to absorb hydrogen sulphide from the vents.

SEEPING SEAWATER
Cold seawater infiltrates the seabed through cracks surrounding the vents and is heated beneath the surface.

"Chimneys direct the eruption of scalding, mineral-rich water upwards from the dark depths"

BLACK SMOKERS VS WHITE SMOKERS

BLACK
400 DEGREES CELSIUS

Black smokers are the more common type of hydrothermal vent. They release the minerals iron and sulphide, which when dissolved in the water create the appearance of black smoke billowing from the top.

WHITE
300 DEGREES CELSIUS

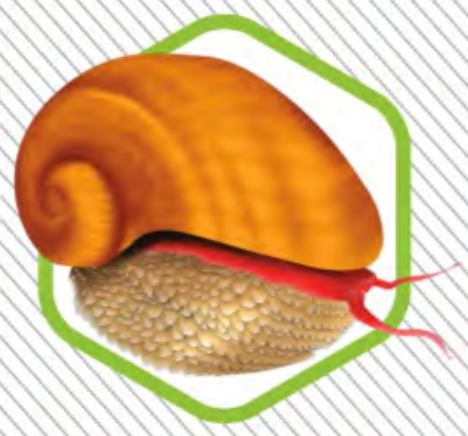
White smokers aren't as hot as black smokers and are generally smaller in size. The mineral composition of these vents includes higher volumes of barium, calcium and silicon, giving the released 'smoke' a white colour.

CREATURES OF THE VENTS

BRISTLE WORM
The deep-sea polychaete is also known as a bristle worm and can live in environments with huge temperature ranges, between 5 and 105 degrees Celsius. These worms can be found living in large colonies on the surfaces of vent chimneys.

YETI CRAB
These crabs are covered in bristles for bacteria to live on. These bacteria convert the inorganic gases that are released from the vents into the water into energy. The bacteria multiply on the crab and the crab survives off the bacteria it harvests.

SCALY-FOOT GASTROPOD
These snails can be found in hydrothermal vents at depths between 2,400 and 2,900 metres. They live near black smokers and use the iron released by these vents to produce hard protective shells.



VENT MUSSEL
Deep-sea mussels have giant gills, with surfaces 20 times larger than regular mussels. Billions of bacteria live on these gills. Some bacteria consume sulphide and oxygen to provide the mussels with carbon for energy.

DEEP-SEA SHRIMP
At the edges of some of the vents, groups of shrimps thrive in volcanic waters. The exoskeletons of deep-sea shrimp are more densely packed than those of shrimps nearer the surface.

WHAT IS SKUNK SPRAY?

How and why these furry critters create such stinky odours

WORDS **SCOTT DUTFIELD**

Cougars are one of many large predators that threaten skunks

Most animals have some sort of natural defence against the many threats found in the wild, such as a potent poison, a pair of sharp claws or the ability to blend into the background. For the skunk, however, it's the emission of a foul-smelling spray that can be ejected over a distance of up to 4.5 metres. There are 12 species of skunks found in the world, ten of which live in the Western Hemisphere – predominantly between North and South America – and two species called stink badgers found throughout Asia. Each species of skunk has the ability to release a noxious cocktail of chemicals called thiols from scent glands positioned next to the animal's rectum. Using coordinated contractions of the surrounding muscles, skunks squeeze the odorous spray through an independently rotating nipple-like opening on each gland, which also gives them a pretty good aim.

Did you know?

A skunk's gestation period is only two months

Once exposed to the spray, the odour can linger for days and has an overwhelming smell of rotten eggs thanks to its high sulphur content. Thiols can cause skin irritation, temporary blindness, nausea and even a loss of consciousness for some of the animals or people that encounter them.

Although thiol is a great deterrent, it's not always a skunk's first line of defence when confronted by a predator. On initial encounter, some species of skunk – such as the striped skunk (*Mephitis mephitis*) – will typically stand their ground, loudly hiss, stamp their feet and even charge at the threat. If these acts of aggression fail to scare predators away then they will turn around, lift their tails and take aim, ready to release their noxious weapon. Aside from this spray standoff, when a skunk is being chased by a hungry predator it will also emit an odorous mist which the pursuing predator will likely have to run through.

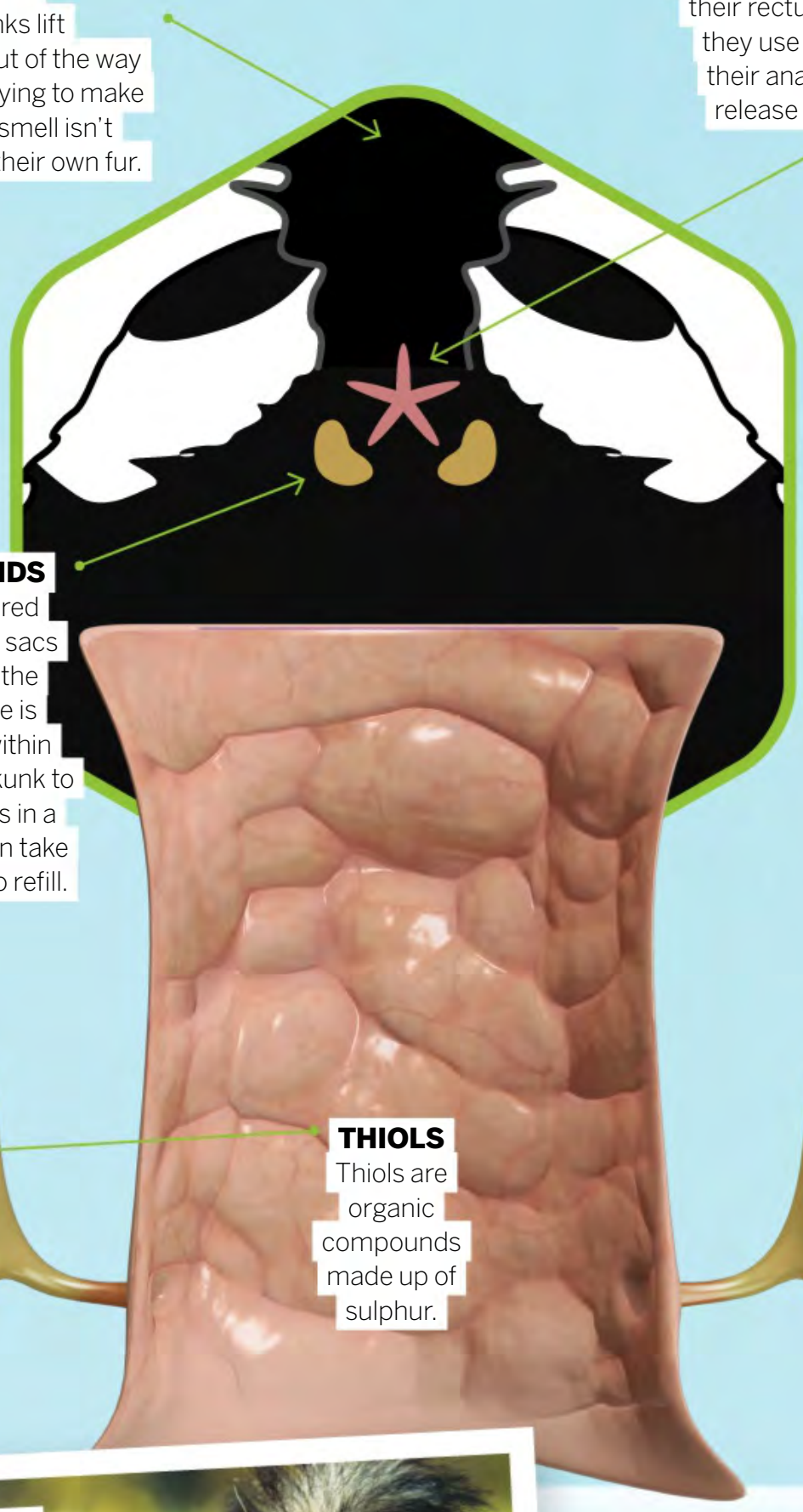
DID YOU KNOW? Humans smell skunk spray at concentrations as low as ten parts per billion

HOW A SKUNK SPRAYS

The science behind the smell

TAIL
Skunks lift their tails out of the way before spraying to make sure the smell isn't trapped in their own fur.

RECTUM
It's a misconception that skunks shoot spray from their rectums. Instead they use tiny jets on their anal glands to release the spray.



ANAL GLANDS
Thiols are stored within two anal sacs either side of the rectum. There is enough thiol within each sac for a skunk to spray five times in a day, but they can take up to ten days to refill.

YOUNG STARTER
At only three months old, young skunks, called kits, are able to spray thiols.

THIOLS
Thiols are organic compounds made up of sulphur.

PERSISTENT
The smell of skunk spray can last up to two to three weeks.

A striped skunk in the US

A western spotted skunk (*Spilogale gracilis*) doing a handstand

SKUNK HANDSTAND

Right before spotted skunks unleash their noxious thiol, they take a final acrobatic stance to signal the countdown to detonation has begun. With their front two paws firmly dug into the ground, these small mammals lift their hind legs into the air and fan out their bushy tails. In a handstand almost perfectly perpendicular to the ground, spotted skunks use their stance to make themselves look larger than they are to some animals before ultimately releasing their spray. These skunks even walk towards any threats on their front two legs while in this pose. Spotted skunks aren't the most intimidating animals in the woods and weigh less than a kilogram on average. However, this doesn't stop them from standing up to much larger predators.

SCENTED SOLUTION

Ridding yourself of the foul stench of skunk spray can be a tricky business, but a chemist named Paul Krebaum has created a home remedy that can successfully combat odorous thiols. The at-home formula calls for 946 millilitres of three per cent hydrogen peroxide, 3.3 tablespoons of baking soda and one to two teaspoons of liquid dish soap. After mixing all the ingredients in a container, use the mixture on hair or pet fur immediately, soak for a few moments and rinse with water. Do not leave the solution in a container as the buildup of pressure in a closed container could make it explode. This solution should oxidise the potent thiols, strip away oils in the spray and neutralise the odour.

HUNTING FOR TRUFFLES

How these culinary treasures grow underground

WORDS **SCOTT DUTFIELD**

Shaved over pasta or blended in a sauce, truffles have become a foodstuff celebrated by chefs all around the world. This small fungus, sometimes referred to as the fragrant diamond or black pearl, is one of the most sought-after ingredients in the world of gastronomy and has built a global market worth billions of dollars. However, while some truffles sit on the kitchen counters of the world's most elegant restaurants, others are nestled beneath the soil of oak woodlands.

The reason why truffles are so desired and expensive – over £1,000 ($1,180) per kilogram for black truffles (*Tuber melanosporum*) – is largely due to their scarcity and the particular requirements needed to cultivate them. Truffles aren't just any kind of mushroom; they are the fruits of a type of fungi called mycorrhizae. Much like the fruits that hang from trees, truffles bear the seeds of the fungus, called spores, which it releases to continue the species' life cycle. Truffles grow underground beneath the first few centimetres of soil, unlike the mushroom species that sprout up on the surface. One of the main differences between mycorrhizae and other fungi is the way they obtain nutrients.

Surface-dwelling mushrooms are referred to as detritivores, meaning they feed on decaying organic matter to gain nutrients. Mycorrhizal fungi, on the other hand, obtain all their nutrition from host plants. Truffle fungi prefer to form this symbiotic relationship with only particular types of trees, such as oak, hazel and birch.

These fungi will grow on the roots of a host plant and absorb nutrients such as sugars. In return for stealing nutrients, mycorrhizal fungi will increase the host plant's ability to absorb water and other nutrients from the soil, and therefore the two exist in a harmonious, symbiotic relationship.

Black truffles are one of the most sought-after culinary ingredients in the world

Did you know?

There are over 40 truffle species

FROM SPORE TO THE CHEF'S DOOR

Beneath the surface are microscopic fungi spores ready to grow into the next generation

1 TREE PREFERENCE
Truffles are typically found in woodlands of hazel or oak trees.

2 ATTACHMENT
Truffle fungi, known as mycorrhizae, attach to the roots of trees.

3 SYMBIOSIS
Long, branching structures called hyphae extend from the fungi to extract nutrients and water from the surrounding soil.

4 GROWING A TRUFFLE
Hyphae become intertwined around fungal spores, and the truffle fruit begins to grow.

5 A LONG WAIT
It can take between five and eight years for a truffle to fruit and be ready to harvest.

6 UNDERGROUND MEAL
Once a truffle fruit has completely formed, burrowing animals and insects feed on the truffle. As a result, the spores within it are released.

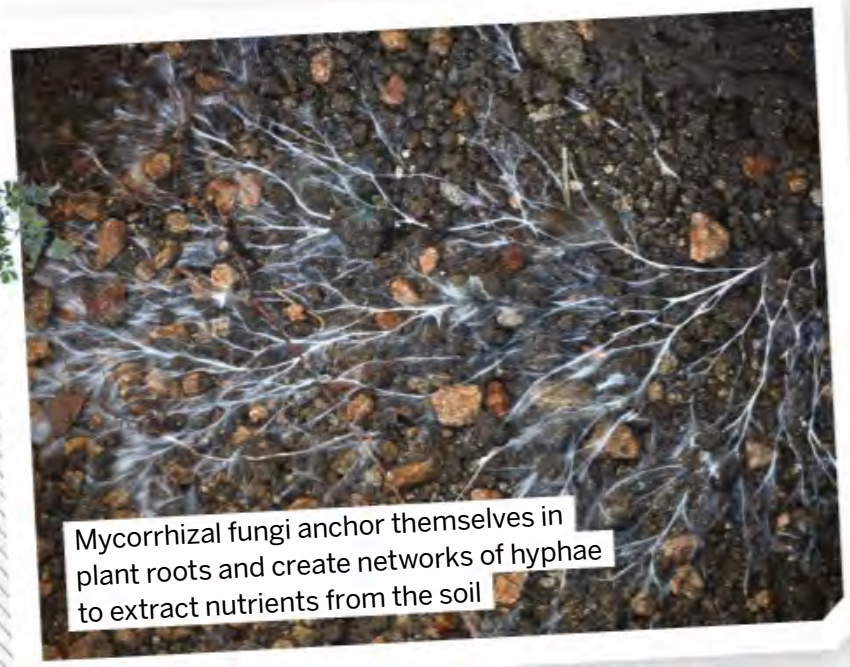
7 FINDING THEIR ROOTS
Spores released into the soil will attach to tree roots and begin a new cycle of symbiosis.

SNIFFING THEM OUT

These fungi are not easy to spot in the wild, so you need to utilise the power of a pig or pooch's nose to find them. Once truffles are ripe and ready to harvest, they release a unique and potent aroma from beneath the soil. Pigs in particular have become the traditional truffle hunters due to the familiarity of the chemical composition of truffle aroma. In hunting truffles, female pigs are the best animals for the job. That's because within the truffle scent is a chemical called androstenol, a sex hormone also found in the salvia of male pigs. The aphrodisiac attraction of the truffles' aroma means that female pigs are quickly drawn to them. Along with an attraction to truffle scents, pigs also enjoy their taste, and so they are quickly removed after finding truffle treasures to avoid them being eaten.

Pig truffle hunters on the prowl through French woodlands

DID YOU KNOW? The world's largest truffle weighed 1,786 grams and was sold for £39,154 ($61,250) in 2014



Mycorrhizal fungi anchor themselves in plant roots and create networks of hyphae to extract nutrients from the soil

COOKING UNDER CLIMATE CHANGE

Like many forms of life on Earth, truffles are also feeling the effects of climate change. They're a tricky fungus to find at the best of times, typically residing in oak forests in Europe. However, since the 1950s farmers have used around 100,000 acres of land to harvest truffles across Spain, France and Italy in an attempt to meet demand. Around 80 per cent of the global supply comes from farms. Cultivating truffles is a difficult business due to their precise environmental requirements, such as soil pH, moisture and host plants. Growing truffles will undoubtedly get even tougher for farmers thanks to the effects of climate change. Some scientists predict that changes in rainfall patterns and droughts could render zones where black truffles are currently harvested unsuitable by 2071.

Domaine de Cordis, the first truffle farm in France

DISTILLING SCIENCE

How evaporating, condensing and filtering alcohol created one of the purest spirits on the planet

WORDS LAURA MEARS

Vodka is the purest spirit. Made almost entirely from pure alcohol and water, it forms the neutral starting point for dozens of cocktails. As liquor goes, it's one of the simplest drinks available, but its production is anything but. Preparing this clear spirit is a complicated, multi-step process. Vodka starts out like any other alcohol. It's a mixture of sugar and water fermented by yeast. The sugar comes from starchy plants like rye, wheat, potatoes or molasses.

When yeast digests sugar in the absence of oxygen, it produces a type of alcohol known as ethanol. It's toxic, so as levels start to rise in the fermenting liquid, the yeast dies. When the alcohol reaches somewhere between 12 and 18 per cent, fermentation stops. Beer and wine manufacturers stop before the mixture reaches this point. They filter and bottle the finished product with a relatively low alcohol content and lots of flavour from the raw ingredients. But for spirit producers, the work is just beginning.

Did you know?

Vodka was first invented in 8th-century Poland

Vodka has a minimum strength of 37.5 per cent ethanol. But how is that possible if the alcohol-producing yeast is dead? The answer is distillation. It is a process of heating and cooling that separates the alcohol from the fermentation liquid – and vodka makers take it to the extreme. They distil their drinks until they are as close to pure ethanol as it's possible to be. Then they dilute them back down again with water to make them safe to drink.

DID YOU KNOW? Russia is the world's top vodka consumer. Russians drink an average of 18 litres every year

Despite often being made from rye, wheat or barley, vodka is gluten free

WHERE DID VODKA COME FROM?

The science of distillation is ancient, but we only started purifying spirits into their cleanest alcoholic form within the last couple of thousand years. The exact origin of vodka is disputed, but it's almost certainly an Eastern European invention. This part of the world is known as the vodka belt. Some say the first vodka came from Moscow, produced by a monk called Isidore. Legend has it that he brewed and distilled a spirit for the aristocracy called 'bread wine'. Others argue it was first distilled in Poland for treating wounds. These early vodkas were nowhere near as concentrated as today. As distillation equipment has improved, so has the purity and strength of alcohol people can produce.

People distilled alcohol in secret during times of prohibition

VODKA IN FOUR STEPS

This pure, clear spirit starts out as a murky mash of water and grain

1 MIX THE INGREDIENTS

The raw materials for vodka are a starchy plant – like rye, wheat, corn or potato – and water.

2 ADD YEAST AND FERMENT

Yeast breaks down the starch and turns the sugars into alcohol.

3 DISTIL AND FILTER

The mixture is heated to evaporate the alcohol. It's collected and filtered, leaving impurities behind.

4 DILUTE WITH WATER

The finished product is mixed with pure water to reach a final alcohol content of up to 40 per cent.

AR ZONE

HOW DISTILLATION WORKS


Turning grain into vodka is a multi-step chemical process

The process of making vodka starts out the same as any other alcohol: a mixture of starchy plant material, water and yeast, heated and left to ferment. But that's where the similarities end. For most other drinks, the by-products of the fermentation process form part of the character. You can taste the grapes in wine, the hops in beer and the grain in whiskey. But with vodka the aim is to strip everything back and get as close to pure alcohol as possible. This happens in the distillery. A distillery takes advantage of the unique boiling points of different chemicals to separate one component of a liquid from another.

Water boils at 100 degrees Celsius, turning from a liquid into a gas. Ethanol – pure alcohol – boils at 78.37 degrees Celsius. When you heat fermented liquid, the alcohol boils first. This means that you can collect that ethanol vapour and leave the water behind. The trouble is, the fermentation process produces lots of other chemicals, and many of them have boiling points similar to alcohol. To remove them, distillers need to boil and condense the liquid over and over again. The easiest way to do this is in a column still. It's hot at the bottom, cool at the top and filled with perforated metal plates. As the vapour rises, it goes through repeated cycles of cooling, condensing, heating and evaporating, leaving many impurities behind.

Did you know?

Smirnoff is the best selling vodka in the world

No matter how many times the vapour passes through the still, it never comes out as 100 per cent pure alcohol. The practical maximum is around 97.2 per cent, and most distillers stop at 96 per cent. The final step in the process is to filter the liquid through activated charcoal, and then there are still trace impurities left behind. They're so distinctive that chemists can pinpoint the country different vodkas were brewed in – and even the brand – just by looking at the molecules.

AR zone

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DANGEROUS BY-PRODUCTS

Distilling does more than just increase the ethanol content of a spirit. It also removes harmful chemicals. Microbes present in the brewing process make an enzyme called pectinase, which breaks down the walls of plant cells and turns them into a chemical called methanol, another type of alcohol that's highly toxic. Methanol poisoning makes people feel sick, sleepy and confused. It can cause permanent damage to the eyes and even death. Methanol is easy to remove during distillation because it boils at a lower temperature than ethanol. Vodka manufacturers ensure there's no more than 100 milligrams per litre.


Care is taken throughout the distilling process to reduce methanol production

COLUMN
The fermented mash enters through the middle of the column and sinks down through the steam.

BUBBLE PLATE
The steam repeatedly vaporises the alcohol. Impurities in the vapour condense on a series of metal plates.

BOILER
A stainless-steel pot boils water to create steam, which passes through the still.

DID YOU KNOW? Countries in the 'vodka belt' in Northern and Eastern Europe have climates too cold to grow grapes

INSIDE A VODKA STILL

The alcohol evaporates, passing through the columns and leaving the impurities behind

America imports around 240 billion bottles of vodka a year

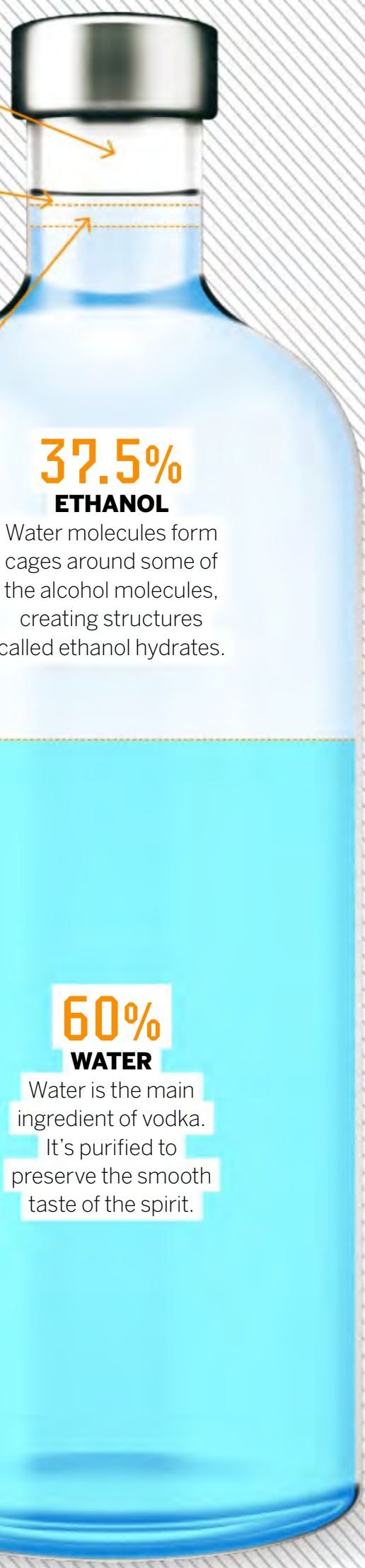
DEPHLEGMATOR
The top of the column condenses the pure evaporated alcohol, allowing it to flow away.

DRAIN VALVE
Valves can be opened or closed to change the flavour or the proof of the finished product.

FLAVOURING
Some vodkas have added flavours, replacing a portion of the alcohol with aromatic chemicals.

WHAT'S IN A SHOT?

Vodka is more than just alcohol and water – there's complex chemistry in every shot



0.3%
ADDITIVES
Many manufacturers add taste enhancers like citric acid, glycerol or sugar to make the vodka 'smoother'.

1.6%
IMPURITIES
Traces of chemicals left over from the fermentation process give different brands of vodka their unique taste.

37.5%
ETHANOL
Water molecules form cages around some of the alcohol molecules, creating structures called ethanol hydrates.

60%
WATER
Water is the main ingredient of vodka. It's purified to preserve the smooth taste of the spirit.

WHY DO WE SHIVER?

This heat-generating technique employed by your body isn't always triggered by the cold

WORDS **AILSA HARVEY**

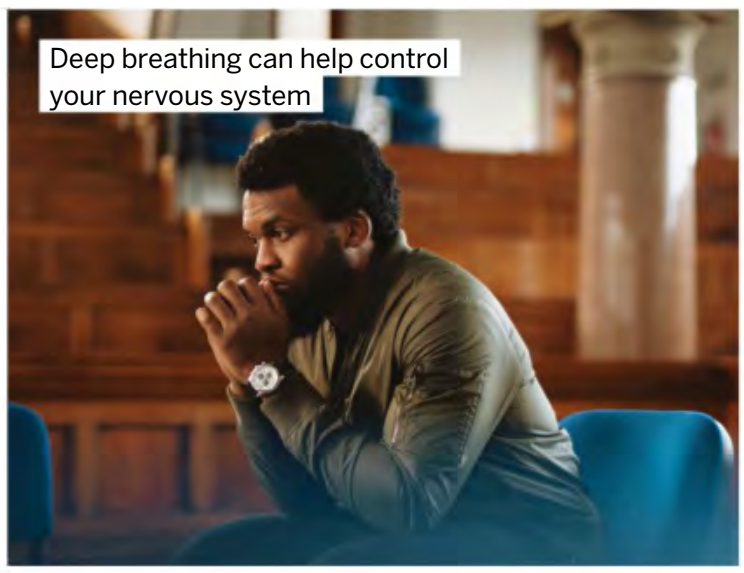
There are many things you can do to combat the cold, from layering your clothes to short bursts of exercise. But shivering is a process that's beyond your control. When you shiver, your body automatically works to regulate your temperature. But what happens when you experience these teeth-chattering shakes, and why is this action largely out of your control?

The spasms are caused by your muscles – usually those in your limbs and jaw – contracting and relaxing rapidly in a short space of time. Most often it's a sign that your temperature has dropped too low and is the body's emergency intervention before you lose dangerous amounts of heat.

The brain is constantly monitoring your body and might trigger this response when you're cold, if you're suffering from a bacterial or viral infection, panic attacks, low blood sugar, drug withdrawal or following general anaesthesia. If your body didn't shiver, it could eventually enter hypothermia – a state whereby your body is losing heat faster than it is produced. Normally, your body is at a temperature of 37 degrees Celsius. Hypothermia occurs at 35 degrees Celsius. Shivering is a life-saving natural response, but it isn't an instant fix. In most cases, shivering raises the body's temperature by one degree Celsius an hour.

COLD OR SCARED?

Have you ever felt nervous and begun to shiver, even though it isn't cold and you aren't unwell? This is because increases in adrenaline can cause shivering. When you feel anxious or scared, part of the brain called the amygdala releases the fight-or-flight hormone adrenaline. This causes contractions in the muscles by increasing their energy levels in preparation for a physical fight or to move away from danger. As adrenaline levels increase, muscles can shake uncontrollably. Usually this is because the built-up extra energy wasn't required by the muscles.

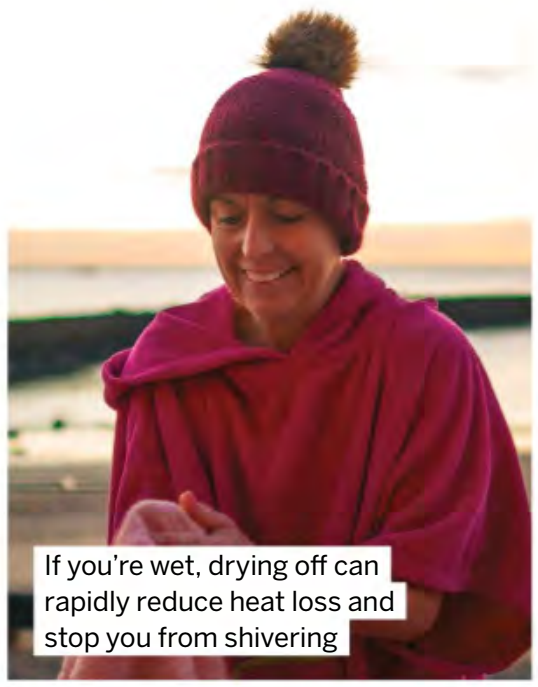


Deep breathing can help control your nervous system

DID YOU KNOW? Shivering can increase your body surface heat production by 500 per cent

HOW DO YOU STOP YOURSELF SHIVERING?

To know the best way to stop shivering, you need to consider the cause. For example, if it's as simple as the weather getting colder, wrap up warm and dry any wet areas of your skin. If you are suffering from a fever and feel unwell, take some time to rest and wait for your body to naturally fight the illness. You may feel cold due to the shivering, but your body is very hot internally in order to fight disease. Wearing too many layers can create a risk of overheating. For those suffering from low blood sugar, eating foods that are high in carbohydrates can help reduce shivering, while fear-induced shakes can usually be stopped by deep breathing and making a conscious effort to stay calm.



If you're wet, drying off can rapidly reduce heat loss and stop you from shivering

Postanaesthetic shivering is shivering that occurs shortly after general anaesthesia due to the anaesthetic stopping the body from regulating its temperature properly

CAUSING CONTRACTIONS

How your brain triggers the shiver reflex

1 DECREASED TEMPERATURE
Your blood or skin experiences a lowering in temperature.

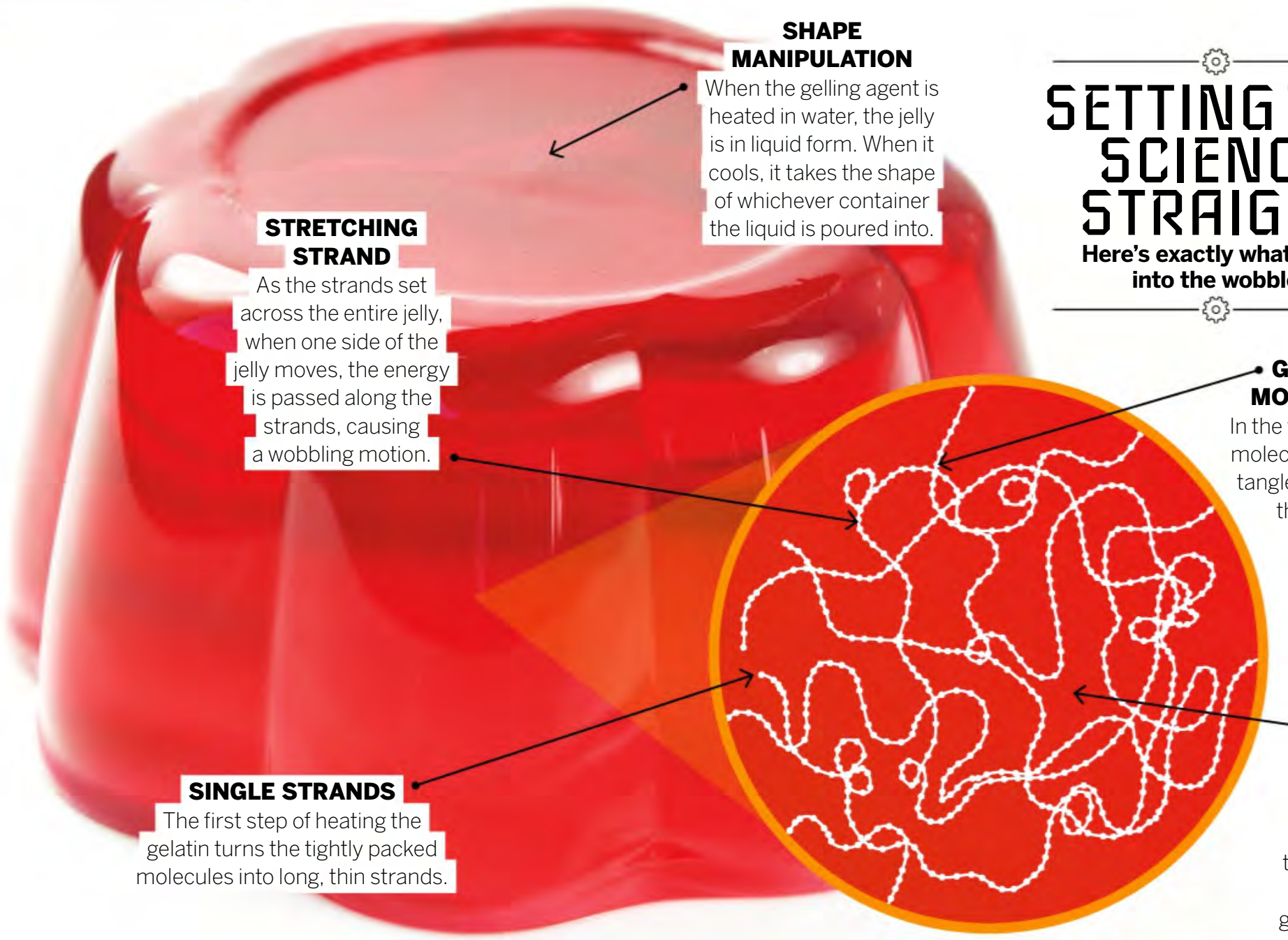
2 BRAIN SIGNALLING
Part of the brain called the hypothalamus reacts to the temperature drop by sending nerve signals to the muscles.

3 SKIN RESPONSE
Blood vessels near the skin's surface narrow so that less heat can be lost from the blood.

4 MUSCLE ACTIVITY
Upon receiving the nerve signals, the skeletal muscles tighten and loosen rapidly.

5 TEMPERATURE RETURN
The shivering movements of the muscles generate heat, returning your body temperature to normal levels.

Did you know?
Shivering stops at a core temperature of 30 to 32 degrees Celsius



SETTING THE SCIENCE STRAIGHT

Here's exactly what goes into the wobble

WHAT MAKES JELLY WOBBLY?

Explore the molecular science responsible for this entertaining dessert

WORDS **AILSA HARVEY**

When you touch a piece of jelly – or jello if you're in the US – on a plate, you'll notice that the consistency is unlike many other foods. It doesn't move as one solid body, but it still remains in one piece unlike a liquid. This is because jelly is a semi-solid structure. The cause of this wobbling comes from strands of proteins or fibre throughout jelly. Defined as a colloid gel, jelly contains solid strands with liquid water trapped between them. The solid strands are called 'gelling agents', and these are the crucial ingredients needed to give jelly its consistency. Most often jelly is made using gelatin, a protein extracted from animal bones, or a starch called pectin from fruits and vegetables. These ingredients are solid at room temperature, but as they are heated and dissolved in water, the molecules disperse. After this, the cooling of jelly causes the gelling agents to reform as separated, long strands. These extend throughout the substance, providing jelly with elasticity and keeping its shape. If you were to hit one side of a piece of jelly, a chain reaction causes this movement to pass through the entire jelly like a wobbly wave. But because jelly is held together by the solid gelling agent, as long as it isn't broken or heated the jelly will bounce back to its original shape.

Did you know?

Kiwi and pineapple enzymes cut up the strands of gelling agents

JELLY OR JAM

Using gelatin jelly as a dessert became popular during the 18th century. In 1747, an English cookery writer named Hannah Glasse wrote about the use of jelly in trifles. This text, in her book *The Art of Cookery*, is the first record of gelatin being used in this dessert form. Jam, known as jelly in countries such as the US, is made in a similar way to jelly. While jelly combines a gelling agent and sugar with fruit juice, jam is made from the fruit pulp instead. As a result, jam is thicker and clear jelly is easier to spread.

Jelly is usually the base layer of a trifle so that it can set first

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		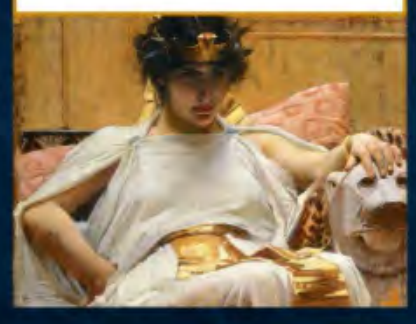	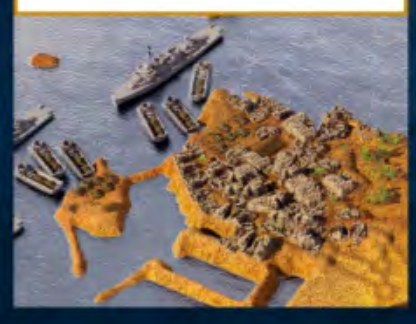	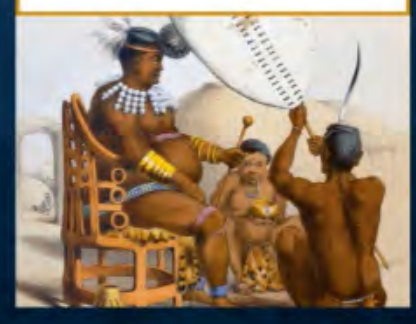

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There's nothing more spectacular in the night sky than a really bright comet, so when can we expect the next one?

WHEN IS THE NEXT COMET?

WORDS ANDREW MAY

It's always exciting to see a comet in the sky, and they're few and far between, so when is the next one due? The surprising answer is that comets aren't really that rare at all. During July 2022, no fewer than 15 comets are potentially visible in the night sky in the Northern Hemisphere, and a similar figure in any other average month. However, while many of these comets can be viewed by an amateur astronomer using binoculars or a telescope, they are rarely bright enough to be seen without optical aids. And even with them, the typical comet is far from being the spectacular sight you might expect.

When someone asks when the next comet is coming, they're usually talking about a very bright naked-eye object. But before we can answer that question, we need to look in more detail at just what is meant by a comet in the first place. Sometimes described as 'dirty snowballs', comets are small objects orbiting the Sun that are composed of rock and dust mixed with frozen water, carbon dioxide, ammonia and methane. As the comet's orbit takes it closer to the Sun, the frozen materials start to warm up and vaporise, creating the long tail which is a comet's most distinctive feature.

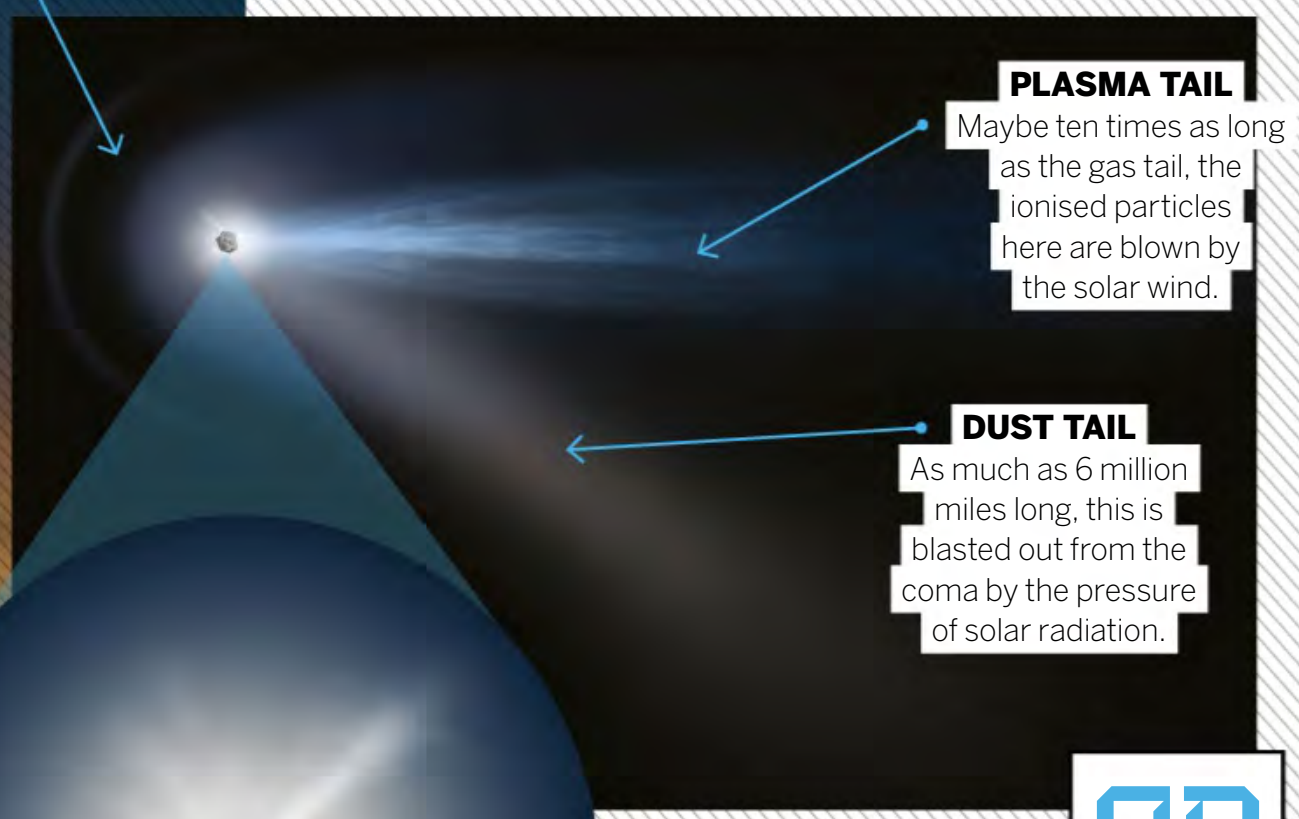
The natural home of comets is the outer Solar System beyond Neptune, but some of them travel on highly elongated orbits that periodically bring them through the inner Solar System, where they may potentially be visible from Earth. For example, the most famous comet of all, Halley's Comet, makes an appearance in our skies every 75 years or so. Halley's most recent visit to the inner Solar System occurred in 1986 – recently enough that we were able to study it from close range with an armada of space probes. That's good news because it means we know a lot about it, but the downside is that it won't be back again until around 2061. Fortunately, there's a good chance we'll see several other really bright comets before then, because on average one turns up every decade. The most recent comet that was easily visible to the naked eye was C/2020 F3 NEOWISE, which graced the night sky in the Northern Hemisphere in July 2020.

The question of when the next bright comet will turn up is frustratingly difficult to answer. Although they travel on predictable orbits, they're so small and unremarkable – until they get close enough to the Sun to develop a tail, at least – that they're usually only detected a few months before they arrive. Their appearance also depends on their size and composition and on how close they get to

DID YOU KNOW? Edmond Halley didn't discover Halley's comet, but he showed that several previous sightings were the same object

ANATOMY OF A COMET

Four basic components give a comet its characteristic appearance



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Earth. The largest comet ever discovered, Bernardinelli-Bernstein, is an amazing 85 miles across, yet it's never going to be visible to the naked eye. That's because its closest approach, due in 2031, will be outside the orbit of Saturn. Other comets that look promising at first may end up being a disappointment. A recent example was C/2021 O3, which was expected to be a naked-eye comet in April 2022, but it disintegrated before it got here. It's far from easy to answer the question of when the next comet will be. A best guess at the moment is probably C/2022 E3, which will make its closest approach in early February 2023. With any luck this will be easily visible with binoculars, and possibly also to the unaided eye against a really dark sky.

Did you know?

Over 4,400 comets have been discovered to date

A close-up image of Comet 67P/Churyumov-Gerasimenko, taken by the European Space Agency's Rosetta spacecraft

WHERE DO COMETS COME FROM?

Comets obey the same laws of motion as the planets do, which means they travel around the Sun in elliptical orbits. The difference is that while the ellipses followed by the planets are roughly circular, the orbits of comets are far more elongated. As a consequence, while their closest approach to the Sun – called perihelion – may lie here in the inner Solar System, their most distant extreme, or aphelion, is much further away.

Unsurprisingly, the further out a comet's aphelion is, the longer it takes to complete a single orbit around the Sun. Among the well-studied comets, the one with the shortest period is Comet 2P/Encke, which completes an orbit in just under 3.3 years. It has its perihelion at 0.34 AU – where one AU, or astronomical unit, is the distance between Earth and the Sun – and an aphelion at 4.09 AU, inside the orbit of Jupiter.

Did you know?

The full Moon has a magnitude of -13.0

A more typical cometary orbit is that of Halley's Comet. With a period of around 75 years, this has an aphelion of just over 35 AU, which is beyond the orbit of Neptune. This puts it in a region of the Solar System known as the Kuiper Belt, which is filled with small, icy comet-like objects – though only a minority of them have orbits that bring them anywhere near Earth. Those that do – together with closer-in comets like Encke – are known as 'short-period comets'.

While Halley's 75 years may not sound that short, it's the blink of an eye compared with a genuine 'long-period comet', which may take thousands or even millions of years to complete an orbit. These long-period comets – such as Hale-Bopp with an aphelion of 363 AU and period of around 2,450 years – originate not in the Kuiper Belt but in an even more distant region of the Solar System called the Oort Cloud.

SPACE OBJECT BRIGHTNESS

The magnitude scale is a handy way of gauging the brightness of a celestial object, including comets

-4.5 The planet Venus at its brightest, which can even be seen in daylight.

-1.4 Sirius, the brightest star, which is visible even to casual observers.

+2.0 Typical of many of the brighter stars, such as Polaris, the Pole Star.

+6.0 The faintest magnitude visible to the naked eye, and even then against a dark sky.

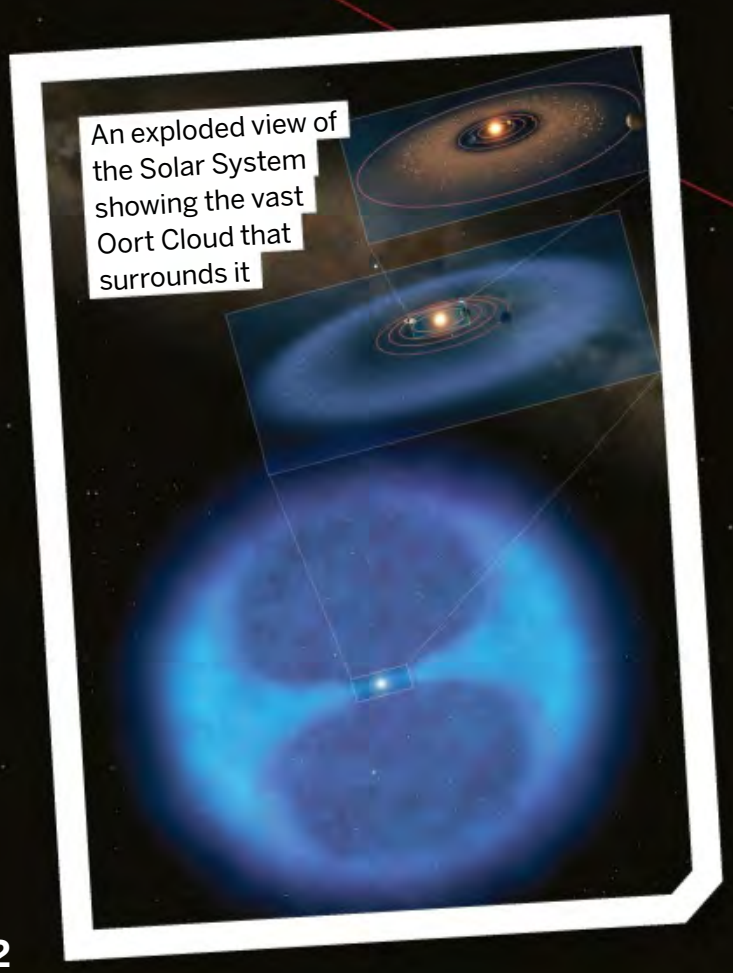
+9.0 Objects down to this magnitude should be visible through 10x50 binoculars.

The Solar System (not to scale) with some cometary orbits in relation to the planets

Comet Hyakutake ~17,000 years

Comet Halley ~76 years

Comet Tempel 1 ~5.5 years



An exploded view of the Solar System showing the vast Oort Cloud that surrounds it

DID YOU KNOW? Astronomers estimate that the Oort Cloud contains around a trillion comet-like objects

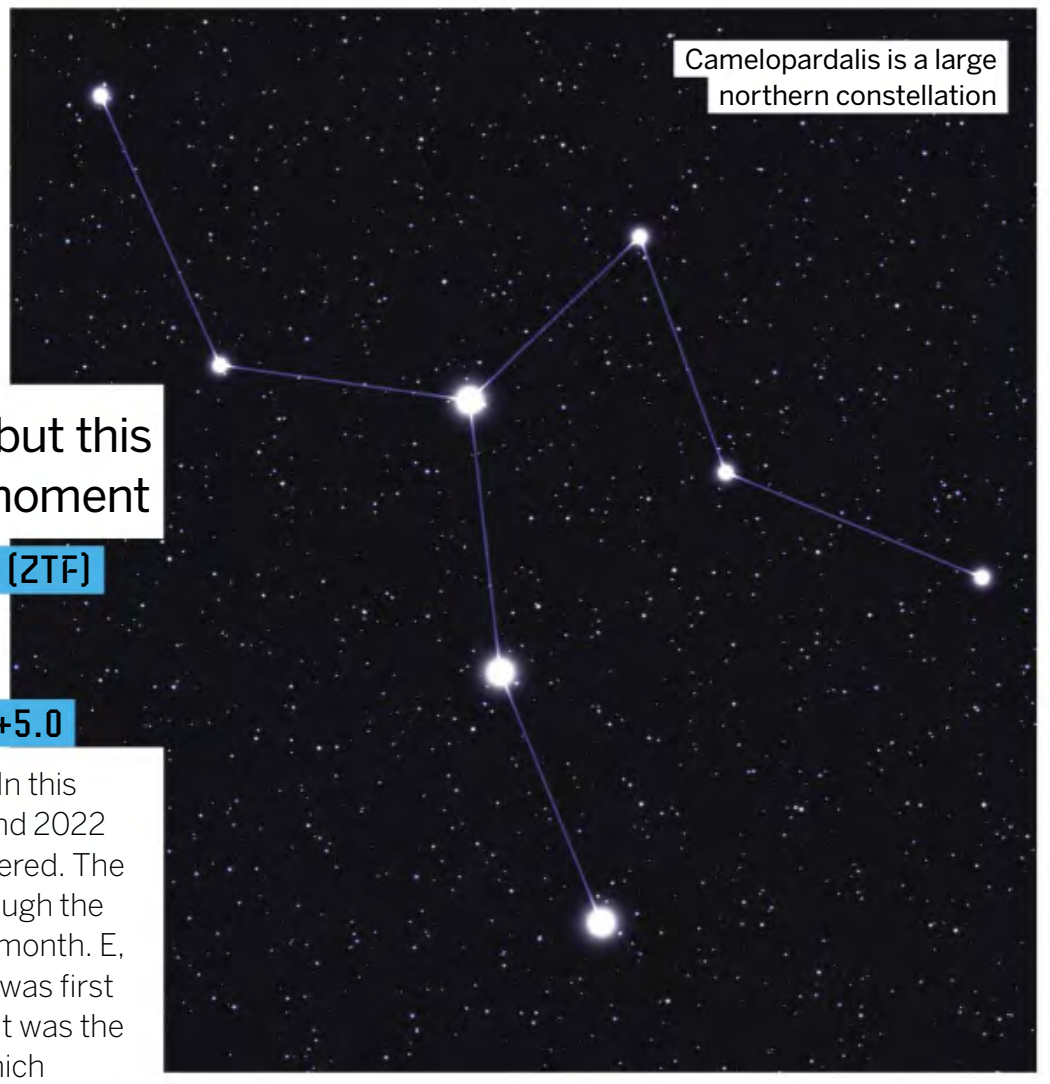
THE NEXT BRIGHT COMET?

It's always a difficult call, but this is our best guess at the moment

COMET NAME: COMET C/2022 E3 (ZTF)

ESTIMATION WHEN VISIBLE: JANUARY TO FEBRUARY 2023

ESTIMATED PEAK MAGNITUDE: +5.0


Camelopardalis is a large northern constellation

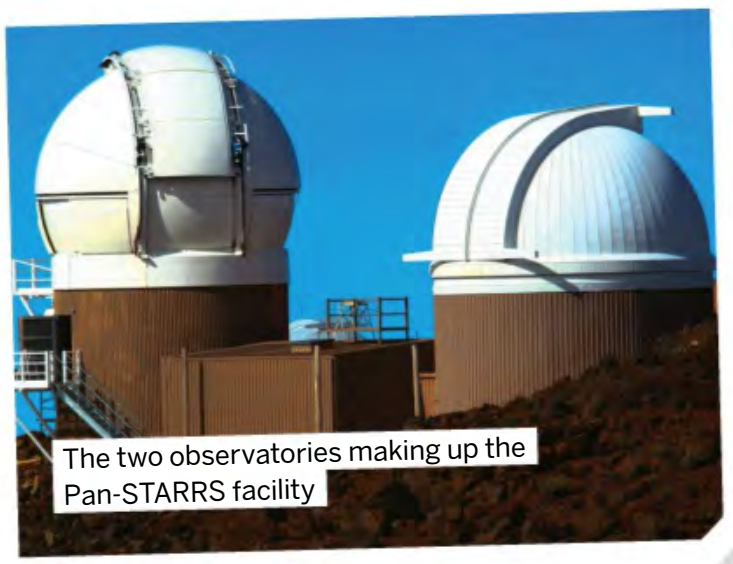
Comet names are reassuringly logical. In this case the C simply stands for 'comet', and 2022 refers to the year in which it was discovered. The letter code that follows progresses through the alphabet at a rate of one letter per half-month. E, being the fifth letter, means this comet was first spotted in the first half of March 2022. It was the third to be discovered in that period, which explains why it's E3. The final part of the name, in brackets, is reserved for the discoverer, which is often an individual, but in this case refers to an ongoing sky survey. Specifically, ZTF is the Zwicky Transient Facility at the Palomar Observatory in California.

C/2022 E3 will make its closest approach to Earth – at just 0.3 AU away from us – on 2 February 2023. At that time it should be visible in the constellation of Camelopardalis (the Giraffe), not far from the celestial north pole. Estimates of its peak brightness vary, but the most optimistic is around magnitude +5.0. Technically this would make it a naked-eye object, though for a good view of it you are really going to need binoculars.


A close-up view of Halley's Comet, as seen by the Giotto spacecraft in 1986

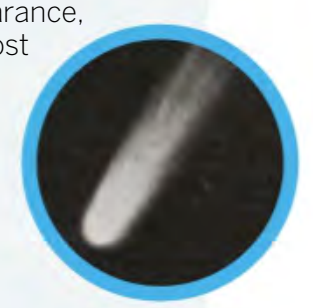
COMET HUNTERS

Astronomers discover new comets by searching for faint objects that change position relative to the more distant stars over a period of a few hours or days that haven't previously been catalogued. Most such objects turn out to be asteroids, but if one shows a telltale fuzzy coma then it must be a comet. At one time comets were commonly discovered by dedicated amateur astronomers, who would patiently scour the skies looking through the eyepiece of a telescope. But these days the process has become automated, with even amateurs using digital cameras and computer programs to do the hard work for them. The majority of new comets are now discovered by professional surveys, largely as an offshoot of the search for potentially hazardous near-Earth objects. Major surveys include the Asteroid Terrestrial-impact Last Alert System (ATLAS) and Panoramic Survey Telescope and Rapid Response System (Pan-STARRS), both located in Hawaii and funded by NASA.

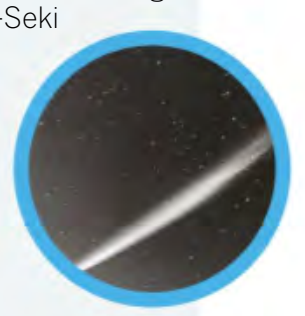

The two observatories making up the Pan-STARRS facility

4 GREAT COMETS

1 AREND-ROLAND
Visible from Earth: 1957
Peak magnitude: +1.0
This comet had a distinctive dart-like appearance, but may be most notable for its starring role in the very first *Sky At Night* TV show, broadcast in April 1957.



2 IKEYA-SEKI
Visible from Earth: 1965
Peak magnitude: -10.0
The brightest comet in living memory, Ikeya-Seki peaked at an amazing -10.0 on the magnitude scale, making it easily visible in broad daylight.



3 WEST
Visible from Earth: 1976
Peak magnitude: -3.0
Another very bright object, West was remarkable for having an aphelion distance of no less than 70,000 AU or more than a light year.

4 HALE-BOPP
Visible from Earth: 1996 to 1997
Peak magnitude: 0.0
The most famous comet of the last 30 years, Hale-Bopp remained visible to the naked eye for a record-breaking 569 days, from May 1996 to December 1997.

WHY IS THE SKY BLUE?

Blue skies are such a familiar sight, it's easy to overlook the science behind them

Even looking to the Sun, the sky is black at the altitude of the International Space Station

A 'blood Moon' occurs when sunlight passes through Earth's atmosphere before reaching the Moon

THE SKY ON MARS

Since the first NASA landers arrived on Mars, it's been known that the sky on that planet has a predominantly red tint. This is also due to atmospheric scattering, but not of the Rayleigh kind. Rayleigh scattering is produced by air molecules, which are smaller than the wavelength of light, and these are less important in the thin atmosphere of Mars than wind-blown dust. The latter is made up of much larger particles, and for these a different scattering mechanism comes into play, resulting in the distinctive reddish-orange colour of the Martian sky.

This photograph from Opportunity shows the characteristic orange-red colour of the Martian sky

Ancient philosophers puzzled over why the sky is blue – now we know it's all down to something called Rayleigh scattering

WORDS **ANDREW MAY**

Everyone loves a blue sky, but why does it take on that particular colour when it isn't obscured by clouds? The answer lies in the physics of what happens when sunlight passes through the atmosphere. The light rays are scattered in all directions as they hit air molecules, and light at the blue end of the spectrum is scattered more strongly than other colours. That's why the sky usually appears blue when we look in any direction away from the Sun itself.

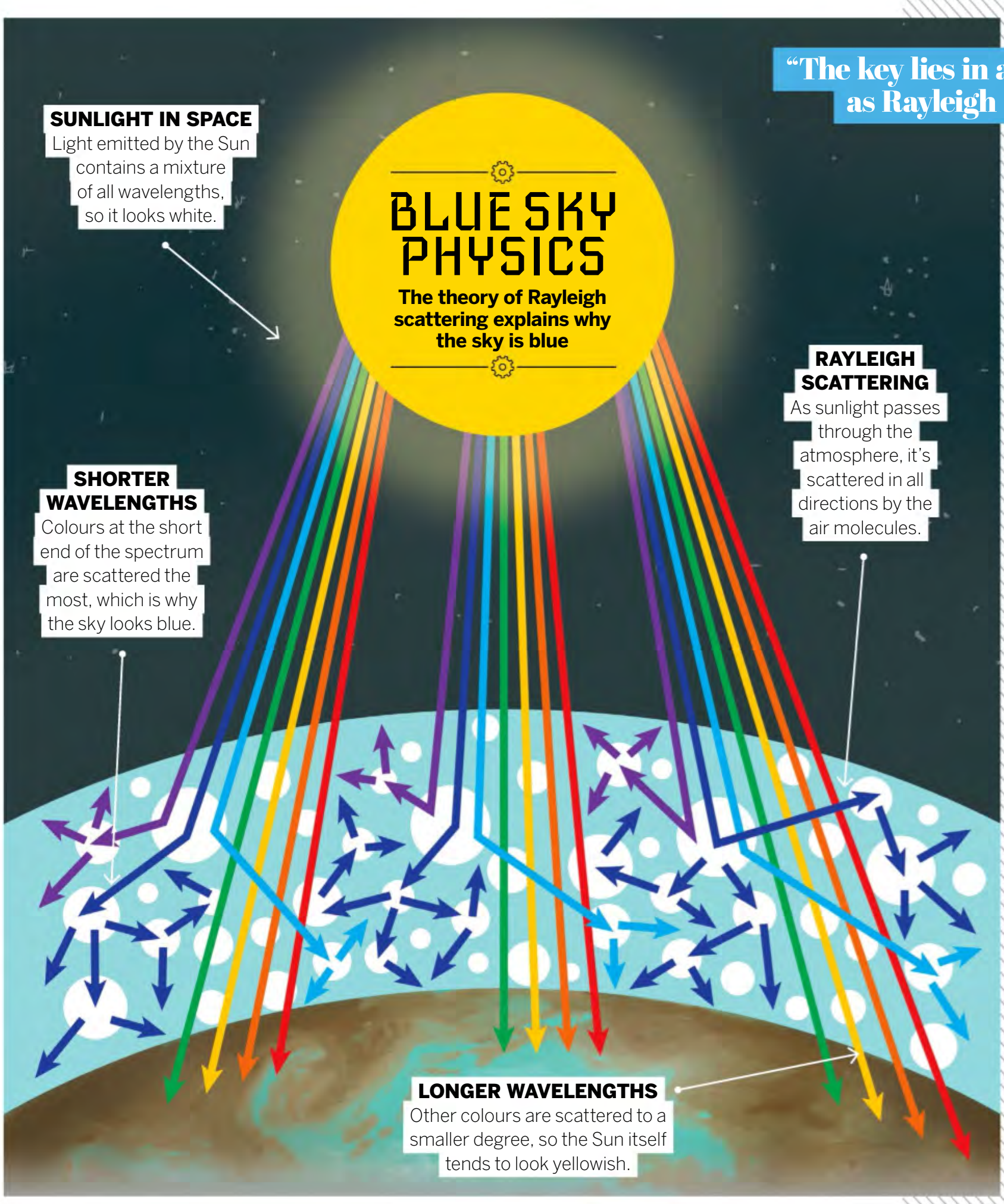
Above Earth's atmosphere, in space the sky looks black even in sunlight. That's one of the most striking phenomena experienced by travellers on Blue Origin's suborbital flights: "To see the blue colour whip by you, and now you're staring into blackness," as William Shatner put it after his flight. This blackness is easy enough to understand. Unless you're looking directly at the Sun, there's no reason for the sky to be illuminated at all. The real puzzle is why it's illuminated down here on the surface of the planet – a long-standing mystery that wasn't fully explained until the end of the 19th century.

Did you know?

Blue light has a wavelength of 450 to 495 nanometres

The key lies in an effect known as Rayleigh scattering, after its discoverer Lord Rayleigh. This refers to the way light bounces off small particles – up to about one-tenth the wavelength of the light itself – which includes the molecules making up Earth's atmosphere. Rayleigh showed that longer wavelengths, corresponding to the red end of the spectrum, aren't scattered as strongly as short wavelengths like blue and violet. Of those two colours it's the blue that dominates, partly because our eyes are more sensitive to it and also because the Sun emits less violet light to begin with.

DID YOU KNOW? Lord Rayleigh won the Nobel Prize in Physics in 1904 for discovering argon gas



"The key lies in an effect known as Rayleigh scattering"

WHY ARE SUNSETS RED?

The sky isn't always blue. When the Sun is low in the sky, at sunrise or sunset, it can take on a red hue. This is explained by the same physics – Rayleigh scattering – as the blueness of the sky at other times. When we look towards the Sun at sunset, we're seeing light that has travelled further through the atmosphere than when the Sun is high in the sky. Most of the shorter wavelengths have been scattered away, and we just see what's left. The dramatic phenomenon of a blood Moon, when the Moon turns red during a lunar eclipse, is also caused by sunlight passing through a large thickness of Earth's atmosphere. It happens when Earth blocks direct sunlight from reaching the Moon – its only source of illumination is light that has already travelled all the way through Earth's atmosphere.


A deep-red sunset seen over Tower Bridge in London

5 FACTS ABOUT BLUE SKIES

1 THE SEA IS ALSO BLUE
The sea's blue colour is unrelated to the blue sky. Water molecules absorb red light, so a large body of water only reflects the bluer portions of light illuminating it.

2 CLOUDS ARE WHITE
Unlike air molecules, the water droplets in clouds are much larger than the wavelength of light, so they reflect all colours equally.

3 FOG-LIGHT FALLACY
The water droplets in fog also reflect all wavelengths equally, so it's a misconception that yellow fog lights penetrate through it better than white ones.

4 A RECORD-BREAKING PROBLEM
The question of the sky's blue colour, dating back at least 2,300 years, was the longest standing unanswered question in physics until Lord Rayleigh finally solved it in the 19th century.

5 A PROLIFIC SCIENTIST
As well as Rayleigh scattering, Lord Rayleigh has several other scientific principles named after him, including Rayleigh distribution, Rayleigh-Jeans law and Rayleigh-Schrödinger perturbation theory.

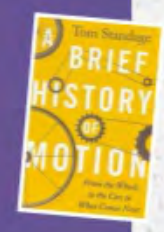
HOW CARS CONQUERED THE WORLD

Discover the evolution of the motor car, from its disjointed steam and bicycle origins to the Ford Model T

WORDS **TOM GARNER**

EXPERT BIO

TOM STANDAGE
As well as his work for *The Economist*, Tom Standage has also written for the *New York Times*, *The Guardian*, *Wired* and other publications. He has a degree in engineering and computer science from the University of Oxford and has written several bestselling history books. To purchase a copy of *A Brief History of Motion* visit: **www.bloomsbury.com**



DID YOU KNOW? There are around 1.45 billion cars currently in use worldwide

The car is an inescapable fact of modern life. Along with other motorised road vehicles, it can be used for personal journeys, as a means of income, can power economies and move entire armies. In transportation terms, it has completely changed the way humanity has administered, laid out and policed itself since it was invented in the 1880s.

The car's ubiquity has been revolutionary, transforming the human experience in just over 100 years. Its presence has had both a significantly positive and – as climate change makes increasingly clear – negative impact on the world. Today the relationship between people and cars is under ever-increasing scrutiny. However, compared to the current debate the car's origins are less well known, and its early history is intriguing and often surprising.

Tom Standage, the author of the recently published *A Brief History of Motion*, is an expert on historical engineering and technology. His book explores the confusing and bumpy road that led to the invention of the car and how it became an essential part of the modern world's development. He discusses steam-powered road vehicles; why the inventions of cars, bicycles and railways are inextricably linked and how smartphones could shape the future of transport.

How old is the concept of the car?

The word 'car' has meant different things at different times. At the end of the 19th century a car was a 'streetcar', or a tram. Before streetcars there were 'horse cars', which were omnibuses pulled by horses on rails. The word 'car' became applicable to what was previously called a 'horseless carriage' or possibly a motor car. The 'automobile', as they call it in America, was itself an import from the French.

The history of this is deep and has a very tortuous path with lots of detours that gets us to the car. Steam engines, buses and various kinds of carriages played important parts, but the car is really descended from the bicycle and not the steam train.

We generally think of the 1886 Benz Patent-Motorwagen as the first proper car. Carl Benz built an entirely new vehicle around an internal combustion engine and used bicycle parts to do it. It was really a motorised bicycle, so this is what makes the car interesting. Its innovation required lots of people to try different things, and although this seems obvious in retrospect, it wasn't at the time.

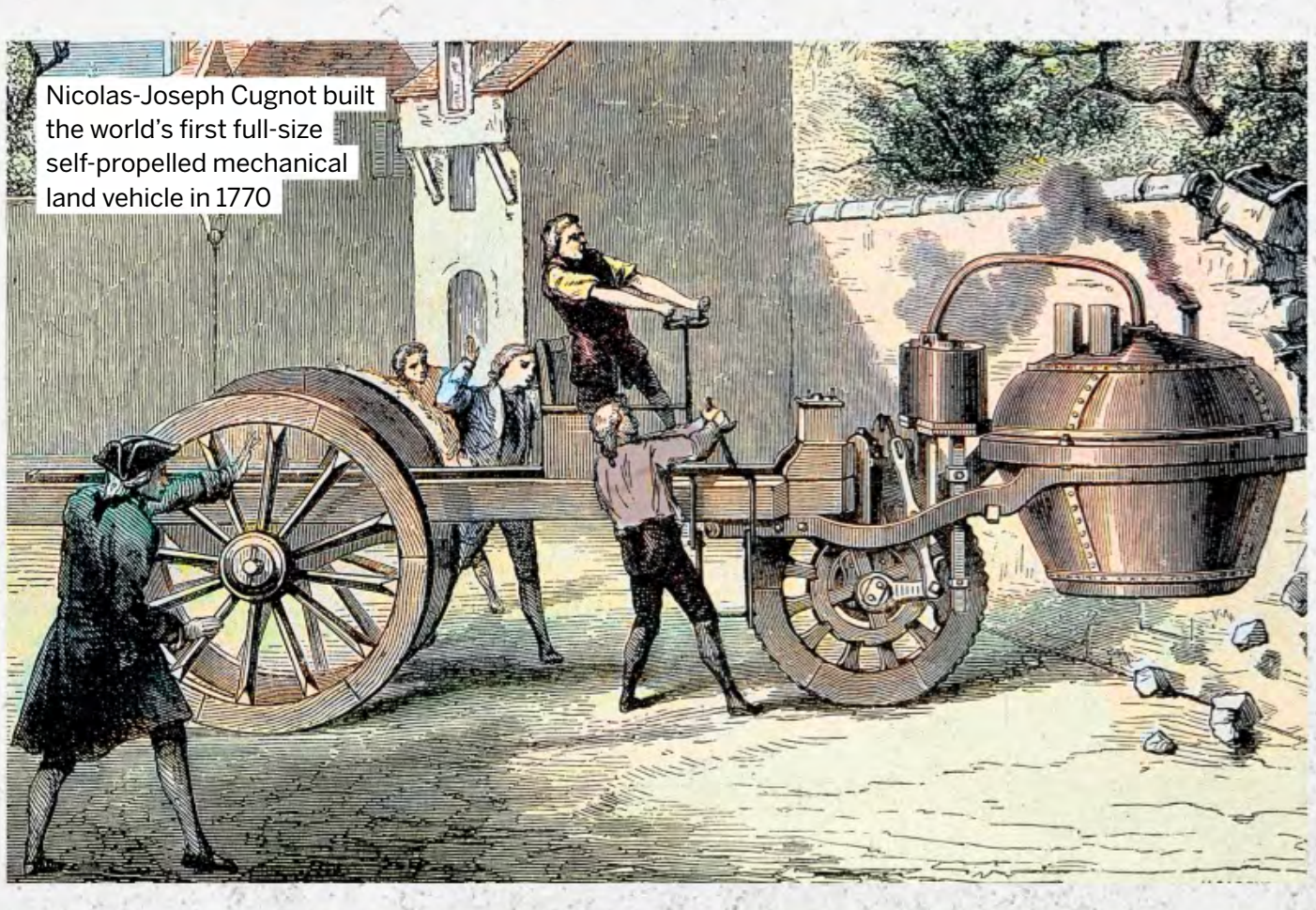
When were the first steam-powered road vehicles developed?

The first steam engines were large, fixed and used to pump water out of coal mines. Scottish inventor James Watt figured out a way to make them a lot smaller in the 1760s, and then you had the first attempt by a Frenchman called Nicolas-Joseph Cugnot to build a self-powered steam vehicle. You could say that it was the first car, but it didn't go very fast. It only travelled at about three miles per hour and the problem was that its steam engine was the size of a modern Fiat 500. It was a huge thing stuck to the front wheel of this vehicle, and when you wanted to steer you had to swing the entire steam engine. It was very big, slow, heavy, hard to steer and trashed the roads it went on. It actually crashed almost immediately into a wall.

The French Army was funding this because it thought it would be an easier way to pull cannons than horses. However, the idea was given up, and not much happened until 1801 when Richard Trevithick built the 'Puffing Devil', which was much smaller. It was basically a steam engine on wheels, but it had similar problems. It caught fire, and so he built another one called the 'London Steam Carriage' to carry people. He trialled it in London in 1803, but like Cugnot's vehicle it carved up the roads. It was really heavy, hard to steer and also crashed.

What Trevithick then said was: "We can fix the steering and road problem if we just put the vehicles on rails." There were rail systems in mines already, but they were pulled by horses. Mine owners said: "Perhaps we can use steam power instead?" So Trevithick built a steam engine for one of those people and proved that it worked. This ultimately led to steam railways.

Steam vehicles like Cugnot's and Trevithick's weren't reliable, but during the 1820s two interesting things happened. Steam engines became more reliable and the 'omnibus' was



Nicolas-Joseph Cugnot built the world's first full-size self-propelled mechanical land vehicle in 1770

Above: More than any other vehicle before it, the car owes its existence to the bicycle

Above inset: Richard Trevithick built the 'Puffing Devil', a steam engine on wheels, in 1801

invented. The omnibus was a horse-drawn vehicle that could seat about a dozen people. It started to become popular, and soon people realised you could make omnibuses more efficient if you put them on rails.

At that point people had given up on 'land locomotives', and they didn't like the idea of putting one on an omnibus. They were noisy, smelly, carved up roads and could explode. However, if you took the idea of the horse-drawn rail omnibus then you had a faster, more efficient service. In America these 'horse cars' were electrified, and so you had trams.

Meanwhile, there was the railway and bicycle boom. By the 1890s there were trams, fast trains and bicycles for personal transport. The big question was, could you have a form of transport that was personal but also fast? The answer ultimately became the car.

German engineer Carl Benz patented the first car in 1886. What was the importance of his wife Bertha to the car's development?

Benz' first car was a three-wheeler, and he wanted to perfect it because it wasn't very good going uphill and the brakes were rubbish. Bertha stole the prototype and went on the first-ever road trip to visit her mother. She didn't tell her husband but took her sons to help her push it uphill.

This trip has been mythologised, but there's a kernel of truth to it. During this trip, Bertha figured out various things, such as that the brakes needed to be better and a better lower gear was required to get up hills. She actually stopped at a cobbler's and had him put leather on the brake pads to improve them. Carl then adopted that approach.

The fact that Bertha showed you could use this car for a road trip – she travelled 40 miles in the prototype – gave Carl the confidence that he actually had a sellable product. He put it on sale at a trade fair and people were amazed. He started selling them, along with the rights, to other people around Europe so they could manufacture them.

What were early cars like?

Early cars were internal combustion engines fitted to carriages, which is why they were called 'horseless carriages'. They didn't have doors, roofs, windows, weren't lockable and had carriage lamps. You steered them with a tiller and you wouldn't want to go out in the rain with them, so they weren't very practical.

At the beginning of the 20th century there were two kinds of cars. There were big, expensive 'touring cars' that were sometimes called 'road locomotives'. They had a big engine at the front, could go very fast and far and get over bumpy roads. Then there were smaller vehicles called 'runabouts', which were lightweight wooden carriages that would have been pulled by horses

CARL BENZ' REVOLUTIONARY VEHICLE

In January 1886, transport history changed forever when Carl Benz patented the world's first true car

AVAILABILITY

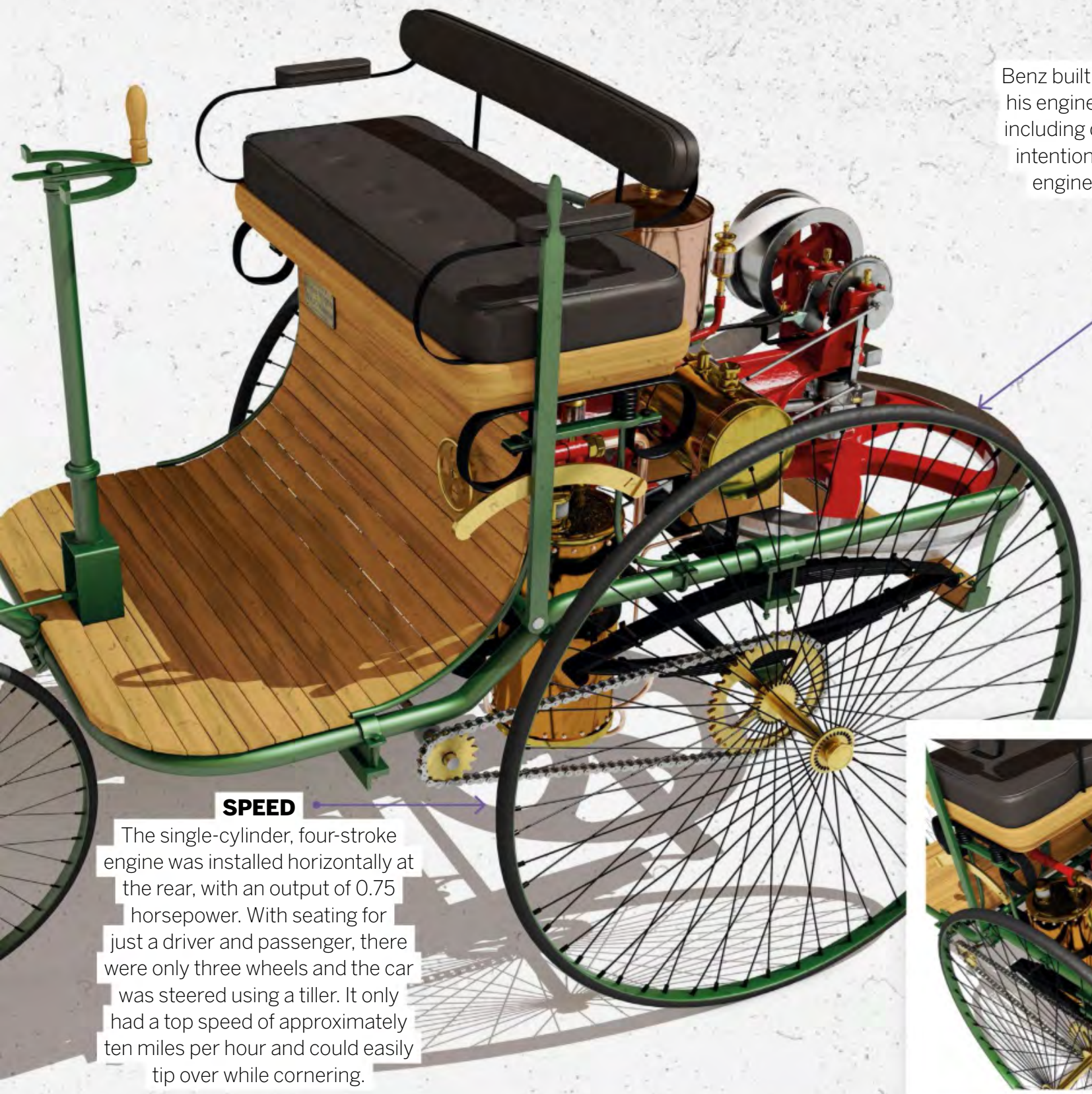
Once it went on the market, buyers could purchase a Patent-Motorwagen for 600 Imperial German marks, although only around 25 were manufactured during 1886 to 1893 by Benz's company .

Left inset: As well as being the first female car driver, Bertha Benz was the first driver of an automobile over a long distance, inventing brake lining in the process

Left: Carl Benz and a companion driving the Benz Patent-Motorwagen

Right: By the time Ford built his first British factory in 1911, thousands of cars were being sold in the UK every year

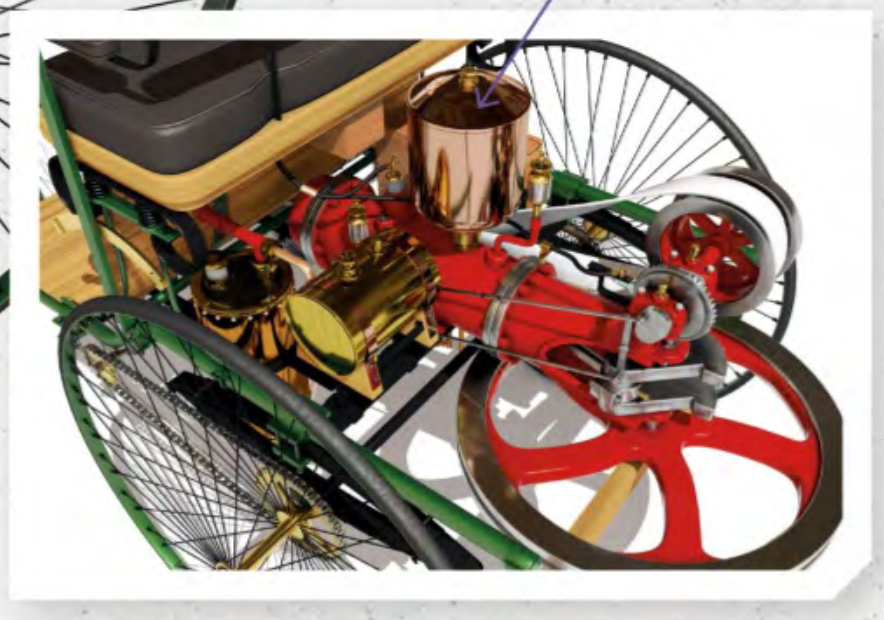
DID YOU KNOW? Peugeot sold the first convertible in 1935, featuring a hard-top retractable roof



FRAME
Benz built a large tubular steel tricycle frame around his engine and used bicycle parts within the design, including drive chains and wire-spoked wheels. This intentional design around an internal combustion engine made the Patent-Motorwagen unique.

ENGINE
Benz invented the car hot on the heels of two other German automotive engineers: Gottlieb Daimler and Wilhelm Maybach. In November 1885, Daimler and Maybach had designed a small, light internal combustion engine, which they attached to a bicycle. This was the first motorcycle, but Benz went further by developing his own engine.

SPEED
The single-cylinder, four-stroke engine was installed horizontally at the rear, with an output of 0.75 horsepower. With seating for just a driver and passenger, there were only three wheels and the car was steered using a tiller. It only had a top speed of approximately ten miles per hour and could easily tip over while cornering.



"The numbers are amazing. America went from having 800 cars in 1900 to 8 million in 1920"

but were modified to have an engine. You could use them for short trips on good roads, but you wouldn't want to go on a long trip with them because they had a tiny fuel capacity. However, they were relatively cheap, so you could buy one for driving around town.

How quickly did the car replace horse-drawn and steam vehicles?
It wasn't really directly competing with steam. As steam trains became more popular, they increased the demand for horses to move stuff within cities. Rail companies often ran the biggest stables in a city, and there were fleets of horse-drawn carriages that were used for delivery or as taxis. More horses meant people were looking for alternatives by the 1890s because of the mess and pollution. It was a very similar situation to today, where we recognise car pollution is unsustainable. Department stores were actually some of the earliest adopters of steam or electric automobiles because they needed transport that moved around within cities quite easily.

Did you know?
The world's first speeding ticket was issued in 1902

The number of horses dropped extremely quickly in America. Although it's an outlier, America was the perfect place for cars to take off. Cars initially had no roofs, and places like California had warm weather, rich people and cheap gas. You also had big, wide roads, whereas adapting cars to medieval street plans in Europe was a lot harder.

© Alamy / Getty / Illustrations by: Adrian Mann

The numbers are amazing. America went from having 800 cars in 1900 to 8 million in 1920. That's a thousand-fold increase, which is the same as doubling every two years. We associate that rate of growth with computers, but it also happened with cars at the beginning of the 20th century. It was a bit slower in other parts of the world, but during the first decades of the 20th century people switched to cars. They took up less space, weren't producing horse manure and were cheaper to run.

Why is the Ford Model T so important for car history?

Henry Ford's idea was: "What if you had a car that was as reliable and powerful as a touring car but as cheap as a runabout?" That's what the Model T ended up being because he used vanadium steel to build a very light, small but powerful engine. It wasn't quite the cheapest car when it came out in 1908, but it had this amazing engine that could get it over rough country roads. It became really popular and people customised them, such as farmers hooking them up to machinery.

This new kind of car was cheaper, powerful and more versatile. Ford then drove down the price by optimising manufacturing. The Model T came out in 1908, but Ford didn't establish a moving production line until 1913, and that was just for the car's magneto ignition. However, the moving production was so efficient that he eventually moved the whole car production onto that. This caused an incredible collapse in the price of the car and an explosion in volume. By 1921, Model Ts were 57 per cent of the cars manufactured in the world. However, if you look at a Model T now, it's a very weird car. It has three pedals – none of which is the clutch, accelerator or brake. If you put a modern driver in a Model T, it would end in tears.

Nevertheless, it was the first successful car 'product'. There were hundreds of carmakers at the beginning of the 20th century, but the Model T found a formula that you could mass produce. It's the combination of the product itself being extremely desirable and that the method that was used to make it could be copied by other carmakers. It was the 'iPhone moment' of car production.

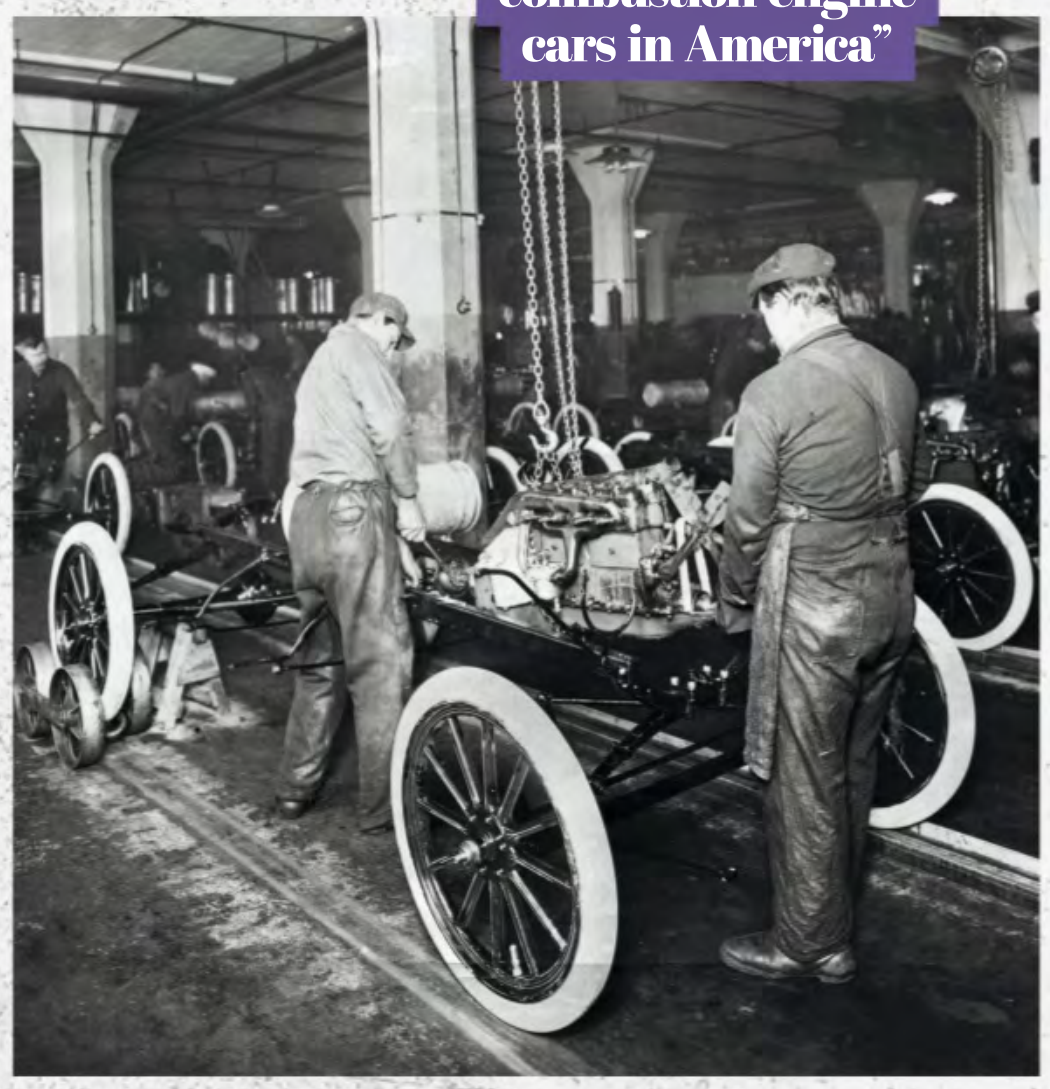
The history of electric cars is surprisingly old. Why did they fail to compete with petrol cars at the beginning of automotive history?

At the beginning of the 20th century, electric cars were very briefly more popular than internal combustion engine cars in America. However, they had very bad batteries. Electric cars are only good today because of batteries that were initially developed for laptops and camcorders.

Because of their bad batteries, they were initially marketed as 'women's cars'. This is because you didn't have to be 'strong' to throw the starter handle and electric cars weren't messy. It was assumed that 'real men' – who were all supposedly mechanics – would put up with a slightly less reliable petrol car in return for better performance. In those days when you bought a car, you had a set of tools that came with it because you were expected to look after it yourself.

> "Electric cars were very briefly more popular than internal combustion engine cars in America"

The other 'girly' thing about electric cars was that men liked buying them for their wives. It meant that they couldn't get very far because the battery would run out. This is why some people think that Henry Ford – despite building the most successful car in history – didn't give his wife a Model T and instead bought her an electric car, because that's what women were expected to drive. There is sexism in the history of the car, but Bertha Benz is the original example of why this is wrong.



Above: Early electric cars were specifically marketed towards women as runabout town vehicles

Left: Workers assemble a Ford Model T on the assembly line at the Highland Park Ford Plant in Michigan

What do you think the future of the car will be?

There are a lot of problems with cars. Electric cars fix some problems, but we need to avoid falling into a historical trap. The mistake that people made in the 1890s was that a horseless carriage was going to fix all the problems to do with horse-drawn vehicles. They thought cars would take up less space, reduce traffic and pollution and stop road accidents like horses kicking people. All these predictions turned out to be wrong, and cars turned out to be something completely different. The mistake we could be making with electric cars is if people say we'll replace the petrol engine with an electric one and everything will be the way it was before.

Getting rid of the petrol engine does stop greenhouse gases to some extent, but you still have to charge the car from sustainably produced electricity. We're still not using 100 per

DID YOU KNOW? A car driving 60 miles per hour could reach the Moon in under a month

Cars were considered a solution to ease traffic problems created by horse-drawn vehicles in cities

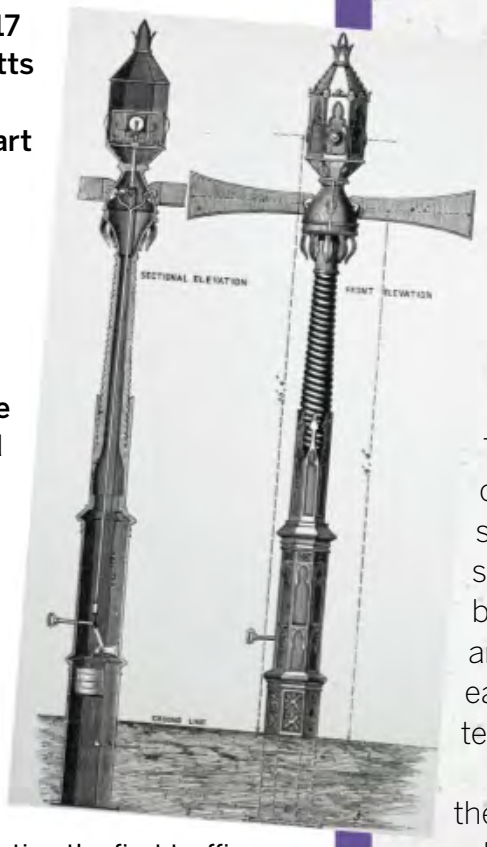
RED, AMBER AND GREEN

An integral part of road infrastructure worldwide, traffic lights are inextricably linked with cars to control flows of traffic. However, their invention actually preceded the automobile by several decades. The very first traffic lights were installed outside the Houses of Parliament in London in 1868 on Westminster Bridge by a railway engineer called John Peake Knight. Using a system that was based on railway signalling, semaphore arms were mounted on a tall post that could be manually raised by a policeman. Raised arms stopped horse-drawn vehicles and allowed pedestrians to cross the road, while lowered arms performed the opposite function.

What made Peake's traffic system unique was that the arms were accompanied by coloured gaslights at night. This included red for 'stop' and green for 'caution'. The lights did improve traffic flow, but on the night of 2 to 3 January 1868, sadly the gaslight exploded and killed the operating policeman.

Traffic lights were revived in the United States during the early 20th century. The first electric traffic light system was invented in 1912 with red and green lights. This was quickly followed by the first electric traffic signal system in Cleveland, Ohio, in 1914. Modern traffic lights as we know them today were introduced in 1917 when William Potts introduced the amber light as part of the first four-way, three-colour system.

Despite the American innovations, traffic lights were not reintroduced to their country of origin, Britain, until 1926, when three-colour lights were installed in Piccadilly, London.



An engraving depicting the first traffic lights by the Houses of Parliament

cent renewable energy, but it doesn't address the main problem. We only use cars four per cent of the time – they mostly just sit around, so they're a waste of space and money. We pay for them, but it's becoming more and more inconvenient to own a car, and rightly so. What's interesting is that we've seen this flowering of alternatives to cars during the last ten years. It has become more feasible for more people to not have cars, except for those who live in rural areas.

Most who live in cities in particular can live without them. They can use public transport, car-sharing clubs, ride-hailing, scooters and electric bicycles. You can stick together all these modes of transport by using your smartphone. This is what I call an 'internet of motion', because it's much easier to use buses when your smartphone tells you when the next one is leaving.

We're seeing more attempts to knit together these various non-car forms of transport into a coherent alternative. We're not there yet, but it's definitely getting better. It's really telling that young people are learning to drive less and doing it later because these days owning a car is more hassle than it's worth for a lot of people. I think that's good and ultimately we do want fewer cars on the roads. We're going to look back at car ownership and think that was very weird. We're also going to be astonished at the level of car accidents and deaths that we were prepared to put up with.

Did you know?

The Lamborghini Miura of 1966 is thought to be the first 'supercar'

What has the car's overall impact been on the world?

It has influenced all sorts of things, but I think it imprisoned us while making us feel free. There are aspects of owning a car that do give you freedom. If you pay to own a car, you have the freedom to jump in and go places. However, in practice you'll get stuck in traffic and you have also tied yourself down for that freedom.

A quote says that "the car freed us in the 20th century, but in the 21st century we're going to free ourselves from the car". The car is still a symbol of freedom and liberation, but that's an echo from the 1920s, and I wonder whether young people still think that. It's very contradictory and hard to encapsulate, but I think that's what it is. It's that paradox of a technology that both liberates and imprisons us.

HISTORY

WHO INVENTED CHESS?

How this challenging game has captivated minds for centuries

WORDS **AILSA HARVEY**

Chess is a sport, board game and a battle of brains. Although the core concept is simple – capture the opponent's king and declare 'checkmate' – the strategy and planning that take place as a game unfolds make for an intense, cognitive challenge. Nobody knows exactly who invented chess, but the earliest origins of the game can be traced back to India, China and Persia over the course of 15 centuries. Chess was eventually introduced to Europe some time before 1,000 CE, partly due to the travelling of merchants. As people voyaged over long distances for trade, many would take chess sets with them to occupy themselves. Some impressive carved chess pieces produced in different regions of the world were transported overseas, and thus interest in and knowledge of the game grew.

In Europe during the Middle Ages, chess became so popular that individuals regarded as upper class were expected to know the rules of chess, with techniques being passed down to new generations. Meanwhile, Arabic countries still played a similar game called Shatranj, parts of which chess evolved from. The organised international chess competitions that are popular today only started in the 19th century. Of the many varieties of the game, a single set of rules was decided upon. These continue to change slightly over time, with the latest rule change taking place in 2014. The International Chess Federation works to make this lasting, cultural game a fair and modern sport.

DID YOU KNOW? The 'knight's tour' challenge involves the knight visiting every square once without repeating any

MIXED ORIGINS

Chess wasn't born in a day. Being a complex and tactical affair, the rules evolved over time. The earliest predecessor of chess was a game called Chaturanga, which was invented in India over 1,500 years ago. Like chess, the object of Chaturanga is to 'checkmate' your opponent's king. Instead of the two-sided game that is displayed in chess, Chaturanga included four different 'armies', each beginning play in one of the four corners of the board. Each player represented one of the divisions of the Indian military: infantry, cavalry, elephantry and chariotry.

Taking away some of the choice of tactics, the earliest versions used a dice to determine which piece could be moved. While similarly designed with horses, rooks and pawns, some of the pieces used in Chaturanga were different to today's chess pieces. Instead of a bishop, an elephant was used, while a minister took the place of the queen. The king took a similar position on the board, but unlike in chess, where the king's position depends on its colour, in Chaturanga the king remains on the right of its advisor for all players.

AN ANCIENT GAME

EARLIEST SURVIVORS

The earliest surviving chess pieces consist of seven ivory ornaments that were dated to 760 CE. These pieces were abstract in design due to Islamic law preventing figurative art. These were also made using bone or wood in some instances.

CHRISTIAN INFLUENCE

Chess pieces carved from Walrus tusk and whale teeth in the 12th century were found on the Scottish Isle of Lewis in 1831. The chunky chess set is thought to have originated in Iceland and includes the oldest known Christian bishop in chess.

DARK AGES

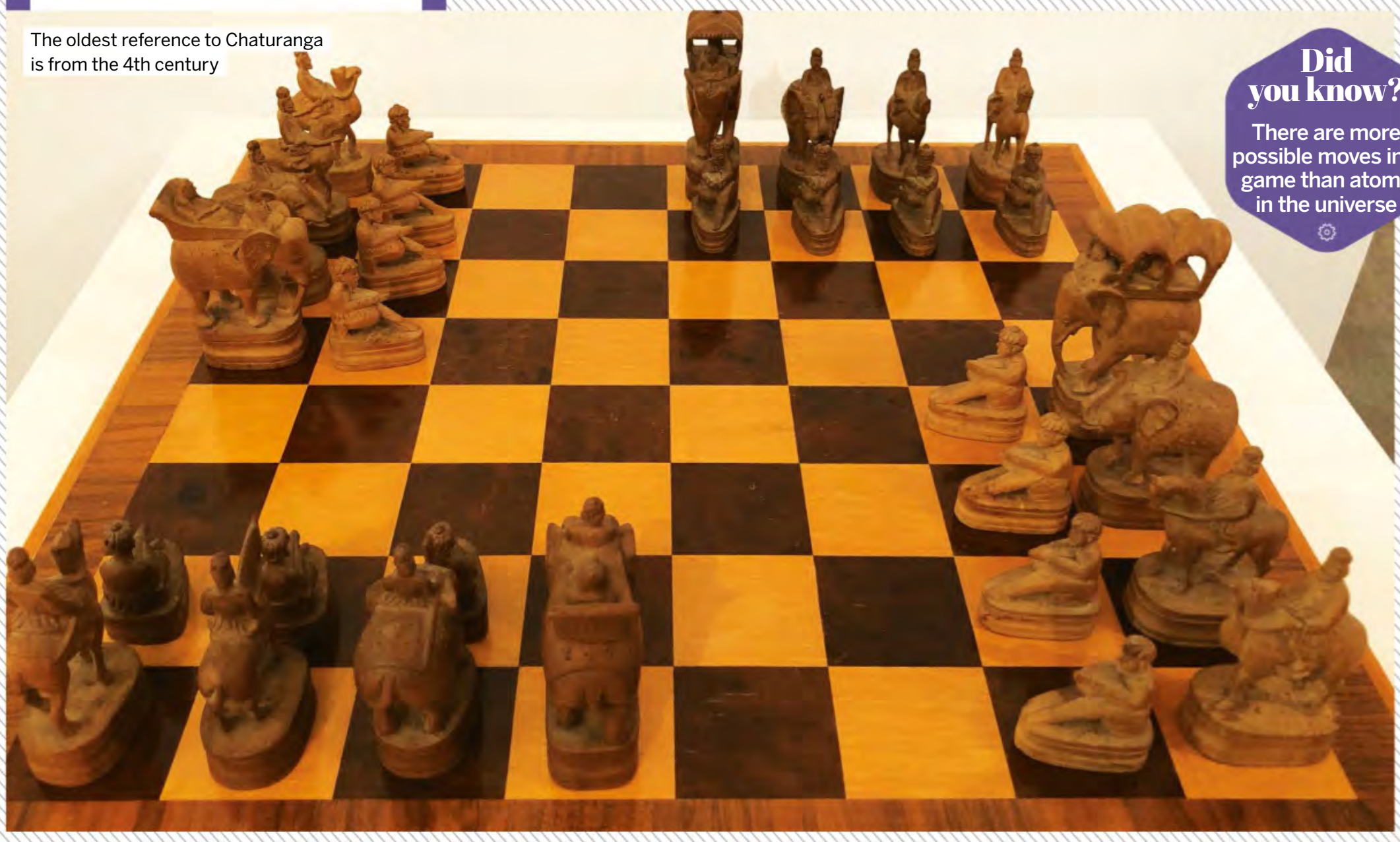
Small ivory pieces less than five centimetres in height were uncovered in the ancient Mediterranean city of Butrint, Albania, in July 2002. Some historians believe that this set could date to 465 CE. If this is correct, then these pieces are the oldest known physical evidence of the game.

OLDEST EUROPEAN

In 1958, the oldest known European chess pieces were discovered. The four Mozarab pieces were made using deer antlers and were preserved in the Mozarabic monastery of Santiago de Penalba, Spain.

Some of the oldest chess pieces were carved from ivory and painted

93 medieval chess pieces were discovered on a Scottish island



The oldest reference to Chaturanga is from the 4th century

Did you know?

There are more possible moves in a game than atoms in the universe

5 CHESS LUMINARIES

1 SISSA IBN DAHIR
According to Indian legend, Sissa invented Chaturanga as a gift for King Shirham of India and taught many of the king's ministers the game. Sissa described chess as a game for intelligent people with good memory.

2 HAN XIN
Chinese military leader Han Xin is credited with inventing the Chinese version of chess in 200 BCE to represent a battle he was involved in. The rules of this variation quickly spread around the world.

3 KING XERXES OF PERSIA
Portuguese chess player and author Pedro Damiano named King Xerxes the inventor of chess in one of the oldest comprehensive chess books available. The terms 'check' and 'checkmate' also originated in Persia.

4 RUY LÓPEZ DE SEGURA
In the late 1500s, this Spanish priest demonstrated a new opening move which proved successful in international tournaments. These moves have shaped modern strategies, with many people choosing the 'Ruy López Opening' as the best way for White to gain quick control.

5 FRANÇOIS-ANDRÉ DANICAN PHILIDOR
This French musician was regarded as one of the best chess players of the 18th century. A checkmate method and unique chess opening were his strategies, and are both named after him today.

AN EVOLVING GAME

These events took the next move in the evolution towards today's game

TIMELINE FACTS

600 CE
An Arabic game named Shatranj emerged from the Indian game Chaturanga, more closely resembling chess.

5,949
The longest chess match possible has thousands of moves

800 CE
Chess began to spread to the rest of the world, with the first iteration of Chinese chess introduced by Buddhists from India.

Chinese chess is also known as Xiangqi

26 YEARS, 337 DAYS
Emanuel Lasker remained World Chess Champion longer than any other player

1561
The term 'gambit' was first used to describe tactical sacrifices of pieces.

1575
The first informal chess tournament took place between Spanish and Italian chess players.

Giovanna Leonardo di Bona and Ruy López took part in the first chess tournament

1744
18-year-old François-André Danican Philidor played two simultaneous games while blindfolded.

1849
The official chess pieces – today's Staunton style – were designed, named after English chess player Howard Staunton.

1861
The first chess timers were used in chess matches, with three hours of sand inside.

1886
An Austrian-American player named William Steinitz became the first world chess champion.

ORIGINALLY, THE QUEEN COULD ONLY MOVE DIAGONALLY AND JUST ONE SQUARE PER MOVE

169,518,829,100,544,000,000,000,000,000
The number of ways to play the first ten moves of a chess match is in the octillions.

1997
A computer beat a chess champion, Garry Kasparov, for the first time.

CHECKMATE COMES FROM THE PERSIAN PHRASE 'SHAH MAT', MEANING 'THE KING IS DEAD'

2013
Norwegian chess player Magnus Carlsen became World Champion in 2013 and remains the world's top player.

DID YOU KNOW? Chess rules changed in 1280 to allow the pawn to move two squares on its first move

THE SECOND BOOK EVER PRINTED IN THE ENGLISH LANGUAGE WAS WRITTEN ABOUT CHESS

900 CE
In the late 900s, light and dark squares were added to chess boards.

20 HOURS
The longest official game was 269 moves

1450
To speed up the game, a rule change called 'mad queen' allowed the queen to move as many spaces as the player wished.


The queen is now considered the most powerful chess piece.

100
The record number of moves with no pieces captured

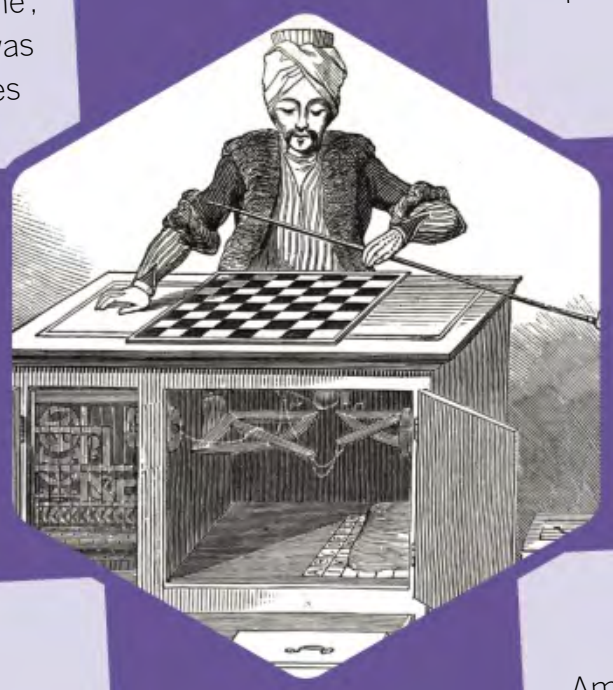
1690
Different chess opening strategies were analysed and systematically classified.

1769
Hungarian inventor Wolfgang von Kempelen demonstrated a magic 'chess-playing machine', but a hidden player was controlling the pieces with magnets.

600,000,000
Around 600 million people know how to play chess

1830
The earliest evidence of a female chess player was published in the US

IN 1936, ALBERT EINSTEIN SAID "I DO NOT PLAY ANY GAMES. THERE IS NO TIME FOR IT." BUT HE TOOK UP CHESS LATER IN LIFE



FOLDING CHESS BOARDS WERE INVENTED IN 1125 BECAUSE A PRIEST WAS FORBIDDEN FROM PLAYING CHESS

1924
The World Chess Federation, also called the Fédération Internationale des Échecs (FIDE), was established.

1958
American chess player Bobby Fischer became the youngest Grandmaster at the age of 14. This record remained for over three decades.

CHEATING AND CONTROVERSY

Chess comes with complex rules and extensive possibilities. The sport represents tactical skill and intelligence, and so there are many precise elements that can be disagreed on. Throughout history, competitions have caused moments of speculation and even represented the power of whole countries. In 2006, Vladimir Kramnik and Veselin Topalov went head to head, with Kramnik winning. However, his frequent toilet trips led to Topalov and his team accusing him of cheating in these breaks. In every chess match that followed between them, this hostility remained, and the two players refused to shake hands.

Cheating has been suspected in many other matches. In 1978, Anatoly Karpov had a hypnotist on his team, causing opponent Viktor Korchnoi to start wearing reflective glasses during play to avoid entering a trance. Korchnoi also accused Karpov of receiving coded messages written in his yoghurt during the game. In 1972, while the Cold War continued, a chess match between US player Bobby Fischer and Russia's Boris Spassky served as a metaphor for the conflict. Fischer won the intellectual battle between countries, ending 24 years of Russia's dominance on the chess board. During a match of particularly high tension, the Russian side thought that Fischer was poisoning Spassky and releasing low-frequency sound waves in his chair to distract him. Fischer's chair was X-rayed and cleared.

Did you know?

Many top World War II codebreakers were chess players


Bobby Fischer (right) playing against Boris Spassky (left)

INSIDE A VACUUM CLEANER

How do these household cleaning machines suck up dirt and dust?

WORDS **AILSA HARVEY**

Whether your vacuum cleaner plugs into the wall, is a handheld device or performs its job automatically as a robot, the science behind these appliances is largely the same. Vacuum cleaners efficiently collect small particles through suction, which involves manipulating the movement of air particles by altering the pressure near them. When the pressure of the air inside a vacuum cleaner is lower than the air outside, particles rush towards the lower pressure.

This process falls under a scientific idea called Bernoulli's principle, which dictates how vacuum cleaners control air flow. To create a lower air pressure inside the vacuum cleaner, air particles need to be moving faster. The speed of particles inside the vacuum is increased by an internal fan. As the difference in air pressure increases, external air rushes with speed towards the fan to balance this, carrying light particles of dust and dirt from nearby surfaces through the vacuum's small opening.

Carpets full of crumbs are easy to clean

Did you know?

Vacuum cleaner parties were held for the first vacuums

THIS DEVICE SUCKS

The principles of vacuum cleaner technology haven't changed for years

7 DUST BAG

Tiny holes in this bag are large enough for air particles to pass through, but not dust and dirt. As the air flows through, dust is collected inside the bag and later removed.

HOUSEHOLD FIRST

In 1901, British engineer Hubert Cecil Booth invented a machine that could suck up dirt in homes. This early version wasn't as accessible as the one you likely have stored in a cupboard at home. The first vacuum cleaners were large horse-drawn units that required around six people to operate. When the vacuum cleaner reached the house where its wealthy occupants had paid to hire it, its hoses were fed through the windows and used to remove any dust. It wasn't until 1908 that the smaller, handheld appliances we know today were invented by William Henry Hoover.

Early vacuum cleaners were hand-powered

Dirty filters reduce the ability of air to flow through vacuum cleaners

DID YOU KNOW? Dyson controls over one-fifth of the vacuum cleaner market in the US

The first cordless vacuum cleaner was manufactured in 1979

1 POWER CORD
Electricity is required to keep the motor in the vacuum cleaner powered.

2 EXHAUST
Air flows out of the vacuum cleaner through these holes to keep a constant stream of air moving when the appliance is turned on.

3 FAN
As the fan rotates, it pulls air through the vacuum cleaner at high speed.

4 MOTOR
The motor converts electrical power into mechanical power to turn the fan.

5 INTAKE HOSE
A partial vacuum is created in the hose as the air pressure inside the vacuum cleaner falls below that outside the device.

6 PRE-MOTOR FILTER
A pre-motor filter is an additional filter that prevents larger particles from reaching and damaging the motor.

ROBOT UPRISING

Wireless robots can navigate rooms automatically, with no human input until they need to be emptied. With a series of rotating brushes and infrared lasers, these circular devices sense the boundaries of the room and sweep any dirt into their dust compartment. Robots can carry out multiple vacuuming sessions before needing to be emptied, and are charged at a docking station. Some people preprogram these vacuums so that they clean up on schedule, while others start the process manually. Most robot vacuum cleaners come with a remote control, allowing the user to direct it to specific areas or return the vacuum to its dock before it has carried out its full routine.

Robotic vacuum cleaners scan the floor and navigate it methodically

HOW ELEVATORS WORK

Take a look at the lift technology that provides an alternative to stairs

WORDS **AILSA HARVEY**

Did you know?

The first buildings with elevators were hotels

Electric elevators, also known as lifts, have been in development since the 1800s. Serving as vertical transport for people and heavy freight, the technology typically involves a contained box, called a cab or car, connected to strong cables, an electric motor and a counterweight. As the motor turns, the cable is fed through the system, causing the car to rise and fall. The counterweight is essential for stabilising the elevator at specific level points, and both the car and counterweight utilise gravity as the elevator moves both up and down to save significant electrical energy.

The counterweight and car of an elevator won't always be the same weight, because a lift is seldom empty. Usually counterweights weigh the same as a car when it is holding 40 to 45 per cent of its maximum load. When the heavier of the two drops under the influence of gravity, resistors kick in. These devices serve as electric brakes, converting the excess kinetic energy into heat energy and maintaining a steady falling speed.

Replacing friction brakes, which clamp onto an elevator's cables, dynamic braking resistors are part of a temporary circuit connected to the motor. These resistors slow the motor to control the elevator's speed. In some systems this excess kinetic energy is converted into electricity for the building so that it doesn't go to waste.

SHAPING THE WORLD'S CITIES

The invention and evolution of elevators has revolutionised urban architecture around the world. Before elevators became common, houses and other buildings were limited to just a few floors and the most desirable homes were on the easy-to-access lower floors. Today apartment buildings can be 20 to 40 floors high, with multiple flats on each floor. With elevators connecting every floor, the higher settlements have become much more popular because there's less street noise, more light and impressive aerial views on these floors.

New York has 300 skyscrapers over 150 metres tall

DID YOU KNOW? The elevator in the world's tallest building covers 504 metres

There are multiple cables attached to each elevator car, but each one can safely hold the car and its passengers alone

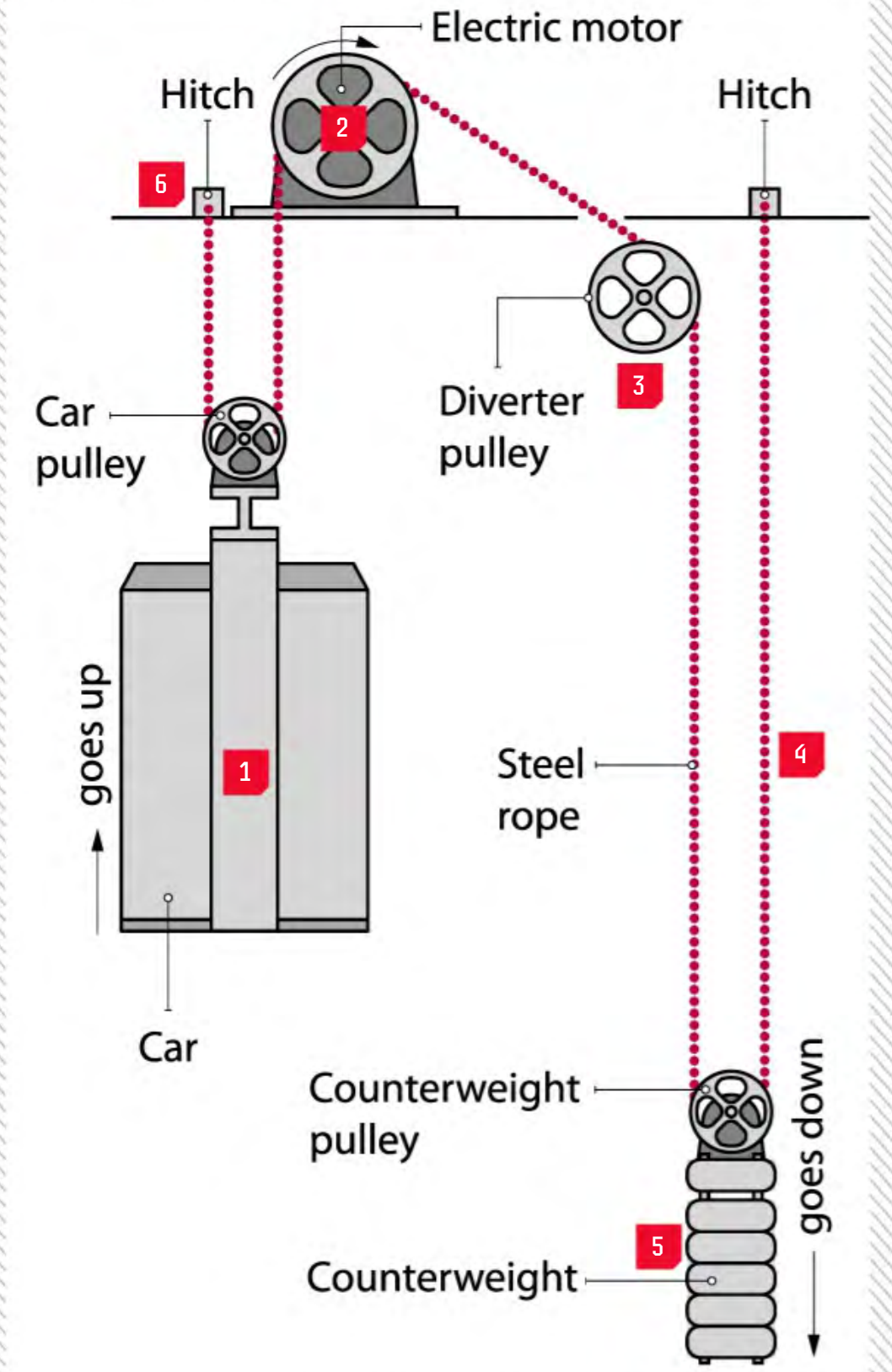
NON-STOP ELEVATORS

When you ride in an elevator, you need to press a button, wait for the lift to arrive and come to a stop before its doors open to let you in. But one type of elevator, known as a paternoster, is a non-stop stream of elevator cars circling a doorless shaft. This technology is older than that found in modern elevators, but because there are so few of them left, they have become a novelty. Since the 1990s, paternosters haven't been installed for safety reasons, but those still circling have been altered to make them safer. Lasers can detect if someone hasn't left a car before it circles over the top, or when someone is entering the elevator too late and is about to become trapped. If this happens, they come to an emergency stop. The tallest paternoster in Europe operates in the Arts Tower at the University of Sheffield.

A man steps onto a moving paternoster as it travels upwards. The right side is moving downwards

FLOOR TO FLOOR

How elevator mechanisms are controlled



1 STEP INSIDE
The doors of elevator cars are unlocked only when they are level with a building's floor.

2 POWER UP
The motor turns, transmitting the force of this movement to the cable's pulleys.

3 BIG BOOST
Multiple pulleys increase the mechanical force to lift the elevator.

4 JOINING FORCES
Strong cables connect the car and counterweight, balancing them over a central motor and pulley.

5 GRAVITY ASSIST
Heavy iron counterweights reduce the energy needed to move the car.

6 SECURE TETHER
This holds the end of the cable, keeping the system stable.

HOW NOISE CANCELLING WORKS

Active noise cancelling helps stop ambient noise from ruining the listening experience

From the cockpits of airliners to something you wear on your daily commute, noise-cancelling technology has revolutionised how we work, listen and play

WORDS **MARK SMITH**

Is there anything worse than trying to listen to your favourite tunes or watch a YouTube video and you can't hear properly even with your headphones on? You're getting to your favourite part and suddenly the dog barks, a car drives by outside or even worse – someone turns their own music up. Or what about when you're out and about jogging, on the bus to school or work and all you can hear is traffic? Noise-cancelling headphones are the solution. They reduce what's called ambient sound – background noise that can drown out what you're listening to – by using something called active noise cancellation (ANC).

A sound is a wave that must reach your eardrum for you to hear it, so an ANC system, such as that found in noise-cancelling headphones, uses tiny microphones to listen to ambient noise. Then a chip inside the headphones generates a sound wave that essentially cancels out the incoming sound wave from outside and neutralises it in a process called 'destructive interference'. Think of two waves crashing into each other until there's nothing left but calm blue sea. There are different types of noise cancellation that don't all use ANC, while some use a super-advanced version of it. This includes passive cancellation, which just uses sealed ear cups over the headphones or earphones to act as a physical barrier to the incoming sound waves.

Did you know?

Nathaniel Baldwin first created headphones in 1910

Adaptive noise cancellation is a more sophisticated type of ANC that digitally adjusts automatically to the sound levels around you. Adjustable active noise cancellation lets you choose how much background noise you can hear by adjusting the controls, and adjustable own voice allows you to control how much of your own voice you want to hear, so you can hear yourself talking to friends.

Bose turned a problem into a best-selling piece of technology during a flight to Boston

LAUNCHING AN INDUSTRY

Bose is one of the biggest sound companies on the planet, owing the name to Dr Amar Bose, a true pioneer of noise-cancelling equipment. He was an engineer at the Massachusetts Institute of Technology (MIT) in the late 1950s and founded the company in 1964. In 1978 he was on a flight from Zurich to Boston when he put on a pair of headphones and everything was drowned out by the engine noise. He got out his notepad, and by the time he landed he already had a rudimentary design for what would become noise-cancelling headphones. It wasn't until 1989 that the Bose aviation headset was launched. It allowed pilots to hear more clearly over the din of the aircraft. The tech has since gone on to be used by the military, in sport and by the public too.

DID YOU KNOW? Headphones became portable when Sony released the Walkman in 1979

HEADPHONES EXPLODED

These may look like ordinary headphones, but they're crammed with noise-cancelling tech

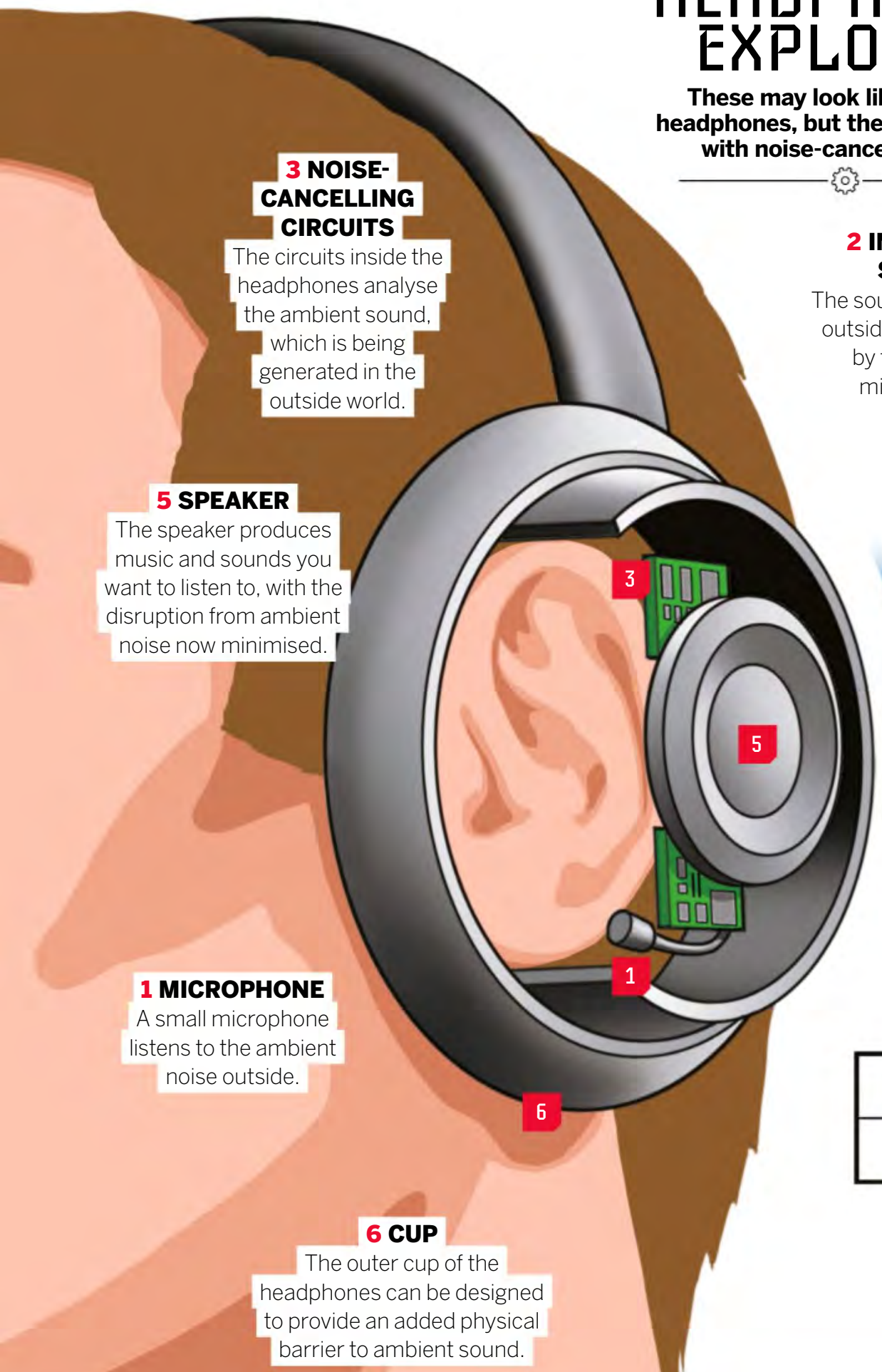
High-end noise-cancelling tech is used in the headsets of commercial and military pilots

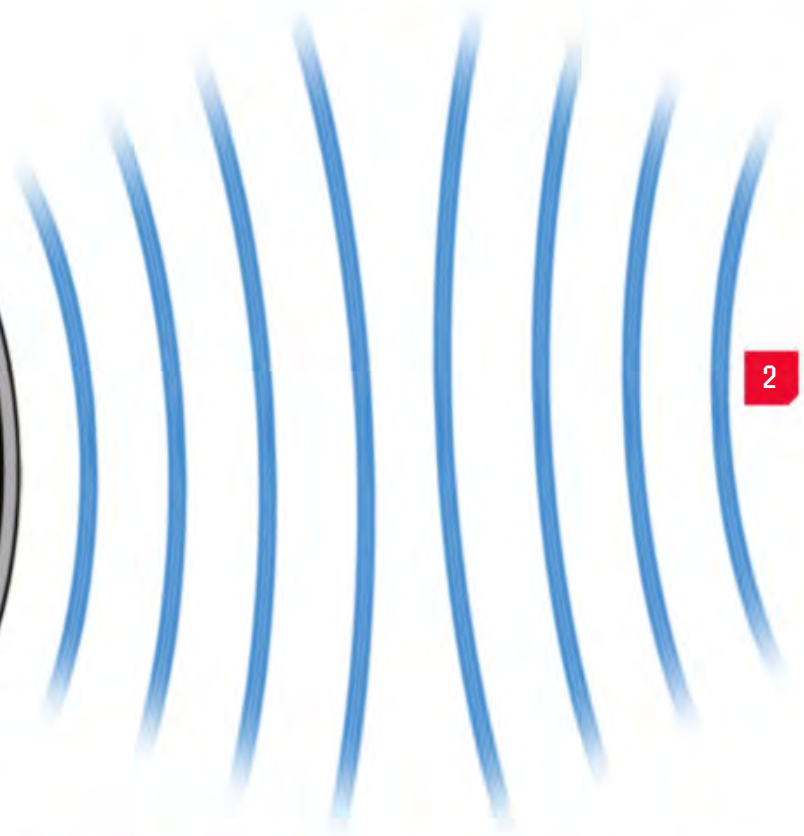
"Think of two waves crashing into each other until there's nothing left"

3 NOISE-CANCELLING CIRCUITS
The circuits inside the headphones analyse the ambient sound, which is being generated in the outside world.

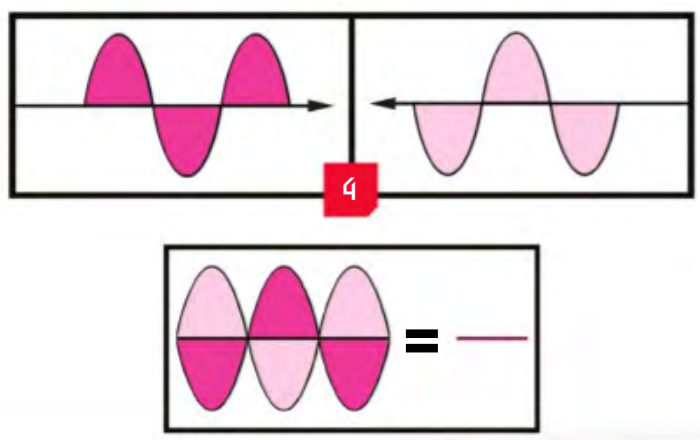
2 INCOMING SOUND
The sound waves from outside are detected by the internal microphone.

5 SPEAKER
The speaker produces music and sounds you want to listen to, with the disruption from ambient noise now minimised.





1 MICROPHONE
A small microphone listens to the ambient noise outside.



4 NEW SOUND WAVES
The ANC produces sound waves that have been inverted and are out of phase, cancelling out the incoming ambient waves.

6 CUP
The outer cup of the headphones can be designed to provide an added physical barrier to ambient sound.

SILENT FILM

Such is the demand for better and clearer sound technology that research continues to take place all over the world. One of the newest developments in audio is MIT's research into a loudspeaker which is quite literally paper thin. The technology consists of a thin film that can be used to cover surfaces like a plane cockpit, which can then generate noise-cancelling sound waves to reduce the ambient noise so that pilots can communicate more easily with each other. The hand-sized prototype the team created weighs less than a penny and uses a much smaller amount of energy than a traditional speaker.

MIT's paper-thin loudspeaker could be used to cover the interiors of cockpits

Win!

A HEALTH GADGET BUNDLE

WORTH

£400

This month we're giving you the chance to win a bundle of amazing health gadgets from Withings. The bundle includes the intelligent Sleep Analyzer; Thermo, a smart temporal thermometer; BPM Connect, a sleek blood pressure monitor, and Body+ Wi-Fi connected scales

For your chance to win, answer the following question:

Which of these is *not* one of the four bases of DNA?

A: ADENINE B: JASMINE C: CYTOSINE

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Terms and Conditions: Competition closes at 00:00 BST on 25 August 2022. 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 BST on 25/08/2022. 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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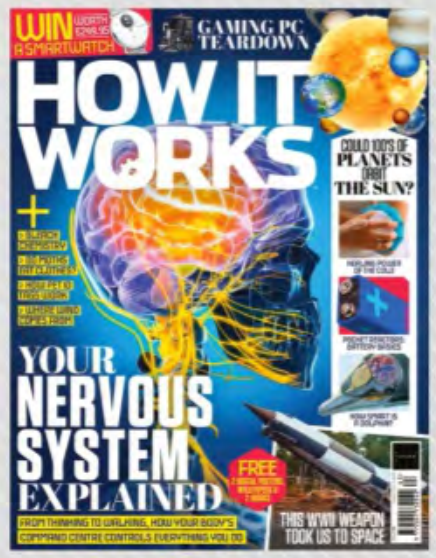

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BRAINDUMP

Amazing answers to your curious questions

What keeps submarines underwater?

James Pilkington

In order to understand what allows submarines to stay underwater, it's important to first look into why things float on water in the first place. Archimedes showed that an object will float if the weight of that object is less than the weight of the water it displaces. As you may be aware, when you get in a bath you are displacing the water – this causes the water level to rise. The effect is known as buoyancy and accounts for why big steel ships don't sink.

Submarines fall into two different categories: static divers and dynamic divers. Static diving uses differences in weight to affect the buoyancy, whereas dynamic diving uses speed and power to submerge, a little bit like how aeroplanes fly. Static diving submarines can submerge by taking on more water through the use of ballast tanks. To return to the surface they can dump this extra weight to regain their buoyancy. The mechanism by which these ballast tanks work may involve an electric motor or compressed gas. Dynamic divers use fins or hydroplanes along with speed to force themselves underwater. This means if they slow down they return to the surface.

The important thing to remember is that a submarine isn't just air inside – it has some, but it's the overall weight with respect to the amount of displaced water which causes something to float or sink.

WHY DOES WATER FLOW DOWN PLUGHOLES IN DIFFERENT DIRECTIONS?

Chris Wise

The rotation of Earth gives rise to an inertial force experienced by liquids and gases on Earth. This is called the Coriolis effect, and it accounts for why cyclones rotate clockwise in the Southern Hemisphere and anticlockwise in the Northern Hemisphere. The Coriolis effect is dominant in large quantities of gas and liquid under the right conditions. But in a sink or bath there are many other more dominant factors that will affect which way the water goes down the plughole. The shape of the container, the direction in which the water was added, the movement of the water molecules and any outside disturbances all have an impact. Studies have tried to eliminate the dominance of these other factors and test whether the Coriolis effect has any bearing whatsoever on the direction in which water chooses to rotate down a plughole, but it is too weak a force on a small body of liquid to have any noticeable effect.

THEY SAY THAT FOR EVERY HUMAN YEAR A DOG HAS SEVEN. WHY IS THIS?

Tom Barnes

The equivalence of dog years to human years varies depending on the size and breed of dog. Larger breeds tend to mature quicker and live shorter lives than smaller breeds. Also, humans develop relatively slowly compared to other mammals. For example, many breeds of dog will have reached full growth and sexual maturity by one year, which is roughly equivalent to 12 to 15 in human years. The second year for a dog can range from three to eight human years, with each year thereafter being roughly equivalent to four to five human years, but even this is inaccurate and can only ever be an approximation.

WHY DO WE HAVE EYEBROWS?

David Davies

Eyebrows are very important for diverting moisture, such as salty sweat, away from our eyes due to their distinctive arch shape. This is useful for allowing us to see clearly if it is raining or if we are sweating a lot. It is quite easy to see how this could have had an evolutionary advantage in terms of escaping predators. Sweat also causes irritation in the eyes, making them sting.

Did you know?
There are around 160,000 species of moths

Do insects feel pain?

Lyn Dowdall

All animals respond to stimuli that cause them discomfort. For instance, insects will move away from heat that is likely to damage them. All insects have senses that are triggered by stimuli and a nervous system that translates stimuli into a response. The complication is whether this can be described as pain or if it is just an automatic response. To feel pain, do you have to be conscious of the sensation and able to decide how to react? The British legal system does not recognise pain in invertebrates, except in cephalopods and decapods – which include octopuses, crabs and lobsters. It accepts the argument that as there is no evidence that other invertebrates are conscious of their predicament, they are unable to be conscious of pain and therefore do not feel pain. This is reassuring because the numbers of insects and other invertebrates that we maim and kill on the front of vehicles and on the leading edge of ploughs is staggering.

BRAINDUMP

WHY ARE WE TOLD NOT TO PUT WHOLE EGGS IN A MICROWAVE?

Steven Tilson

When things heat up they expand. The yolk of an egg contains lots of water, and this starts to expand upon getting hot. In boiling water this is fine, but in a microwave the yolk can reach temperatures so high that the water vaporises. Eggs have a shell, and within that there's also a membrane. If the pressure of the rapidly heating yolk exceeds the breaking pressure of the shell and membrane, the egg will explode.

Why are a duck's feathers waterproof?

Leanne Morris

Ducks have a special gland positioned near their tails called the preen gland. This gland produces an oil that ducks rub over their feathers with their beaks to maintain their waterproof effect. This oil creates a protective barrier that stops feathers becoming waterlogged. These waterproof feathers insulate ducks from water and cold temperatures. Beneath the waterproof outer feathers is a fluffy, soft layer of down feathers which keep ducks warm. This protective barrier of waterproof feathers is a very effective system, but it requires constant maintenance, therefore wildfowl spend a lot of time preening and washing.

WHO DECIDES WHICH BEE IS GOING TO BE THE QUEEN WITHIN A BEE COLONY?

Greg Sewel

The workers decide which eggs will develop into queen bees. There can only ever be one queen in a beehive. When a hive becomes overcrowded, the worker bees prepare queen brood cells and the queen lays an egg in each cell. The workers then cover the eggs with royal jelly. It's the jelly that makes the difference between the larvae developing into a queen bee or a worker. Following this the queen and about half of the worker bees leave the hive and look for a new place to form a hive. Back in the old hive, one of the queen cells breaks open and a new queen bee emerges. The new queen then searches out the other queen cells and stings them, killing the remaining developing queens. If two queens emerge at the same time, a fight ensues until one is dead.

WILL THE ANIMALS AT THE BOTTOM OF THE FOOD CHAIN SOME DAY BECOME EXTINCT?

Nina Ramone

Biological systems are difficult to predict, but even species low down the food chain can get into difficulties when the system is unbalanced. Take Australia, for example; in the 1950s the number of rabbits exploded. In similar circumstances, this boom can easily be followed by a bust through an animal population eating all its own food supply.

Also in Australia, cattle introduction led to such a buildup of cowpats that they were destroying the habitat through the buildup of their own waste – at least until a suitable dung beetle was introduced. Generally speaking, predator species help provide balance, keeping animals lower down the food chain in check, therefore allowing plants to provide the resources on which the rest of the system depends. Meanwhile, other contributors to the system, such as decomposers, also help the system stay in shape.

How do bioluminescent creatures produce light?

Mel Collins

Bioluminescence is light emitted by living organisms. Yellow-green light is produced by various insects, including glowworms and fireflies, but it's in the oceans where we see most animal lights. The light is produced in a chemical reaction in which an enzyme, luciferase, stimulates a reaction between molecules called luciferins and oxygen, resulting in the emission of light as well as oxyluciferin. It's in effect a cold light source. Some creatures use their own luciferins to produce light, either from many small sites or in special light organs with reflectors, lenses and even colour filters.

In some deep-sea anglerfish the light is produced by bacteria living within special bulbous light organs. Marine bioluminescence is usually blue or green, but there are variations, and a few predatory fishes have the ability both to transmit and to see red light, providing them with a private visual system for detecting prey. Light organs on the undersides of fishes and squids camouflage their owners against downwelling light from the surface, but some organisms' flashing displays and spark-like luminous discharges are designed to confuse predators.

Did you know?
Jellyfish are over 600 million years old

It's much easier to spot jellyfish thanks to their glow

How can animals survive in the deepest parts of the sea?

Alex Duvell

Organisms that live in the perpetual darkness and extreme pressures of the deep sea have a variety of bizarre and ingenious adaptations to enable them to survive. In the twilight zone, between 200 and 1,000 metres, animals are often equipped with huge eyes to find food and mates and to evade predators – the giant squid (*Architeuthis dux*) has eyes the size of dinner plates. In the total darkness found past 1,000 metres, many deep-sea animals have evolved light-producing organs that are used either for recognition or as lures to catch prey. With no phytoplankton available as a primary food source, the inhabitants of the deep must rely on a slow, steady rain of waste food particles from above or hunt and scavenge in the darkness. Sometimes a shipwreck, the carcass of a large organism such as a whale or the trunk of a tree will arrive on the seabed and the slow pace of life is transformed as a range of animals take advantage of the nutritional bonanza, which can last a number of years.

Did you know?
Most scuba divers don't go deeper than 40 metres

Shipwrecks can form small biomes deep in the ocean

WHAT IS PINS AND NEEDLES?

Margie Keel

Most people have experienced the prickly, stinging sensation known as pins and needles, or paraesthesia to be medically accurate. It usually occurs when pressure is applied to the affected area, which restricts the blood supply to the nerves in that area. The limb may feel numb while the pressure is still applied, but the tingling generally starts when the blood flow resumes and the nerves start to send signals back to the brain again. They should disappear once the blood flow returns to normal. If pins and needles are a recurring problem over a long period of time, they are referred to as chronic pins and needles. In these circumstances advice should be sought from a medical professional, as this could mean there is an underlying serious condition such as multiple sclerosis or diabetes.

WHY DOES GIN LOOK BLUE IN CERTAIN LIGHTS?

Heather Brooking

We assume the effect you're talking about here is when certain drinks glow in the presence of ultraviolet light. Gin is commonly mixed with tonic water, and it's the tonic water, not the gin, which will glow in ultraviolet light. This is due to a component of the tonic water called quinine. When ultraviolet light falls upon quinine, electrons in the quinine molecules absorb some of this energy and jump up to a higher energy level. The electrons then lose energy, giving it off in the form of photons as they jump back down to a lower energy level. The photons given off are of lower energy than the ultraviolet light and correspond to blue light in the visible spectrum. This effect can be quite common in clubs or bars where ultraviolet lights are used.

WHAT IS EARWAX?

Phil Carsby

Earwax is a substance that can be found in the ear canals of humans and other mammals. Medically it's referred to as cerumen and consists of dead skin, hair and water-soluble secretions from the outer ear canal. It serves several functions – one of which is as an antibacterial, self-cleaning lubricant. Excess cerumen usually finds its way out of the ear canal through the washing of hair and jaw movement. Occasionally it can collect and become compacted, which can lead to tinnitus and slight hearing loss.

A clever way to protect itself from predators

I've heard there's a plant that's sensitive to touch; what is it called and how does it work?

Richard Fishlock

Some plants in the pea family have a rather unusual ability that sets them apart from the rest of the plant world. They can collapse their leaves and stems when touched or disturbed in some way. The best known of these 'sensitive plants' is *Mimosa pudica*, a tropical weed that comes from South and Central America. It's a complex process that happens within the plant's cells that provide support to the leaves and stems. The cells are filled with water, which keeps them turgid and firm. When the plant is touched the cells release the water, deflating them and resulting in the leaves and stems collapsing and folding inwards. If you watch closely, a few minutes later the water will be pumped back and they will return to normal.

But why do they do it? Plants have to come up with many clever ways to stop themselves being munched on by animals and insects, as they can't run away and hide. The drooping leaves will deter hungry animals and hopefully shake off insects. The sensitive plant also comes in quite useful if you get bitten by a monocled cobra – the extracts from the roots can be used to counteract the venom.

THE LIBRARY

The latest book releases for curious minds

TRANSPORTED: 50 VEHICLES THAT CHANGED THE WORLD

VIVA LA VEHICLE REVOLUTION

AUTHOR **MATT RALPHS**
ILLUSTRATOR **RUI RICARDO**
PUBLISHER **NOSY CROW**
PRICE **£18.99 (APPROX $22.80)**
RELEASE **1 SEPTEMBER**

A long time ago, our primate ancestors stood up, walked and then realised that getting to places was literally the way to get by in life. Ever since we've sought out more efficient ways of travelling by inventing vehicles that could quickly take us to our destinations, or even take us to places that would otherwise be completely inaccessible to us. Author Matt Ralphs celebrates the ingenious ways we've discovered to better get around with *Transported: 50 Vehicles That Changed the World*, which cherry-picks a wide range of driving, floating and flying vehicles from the last 10,000 years or so. We're reliably informed that Matt lives on a canal boat called Nostromo, which seems entirely suitable for someone writing about some very unconventional modes of transport.

It begins over 7,000 years ago with the Bronze Age invention of the wheel and the canoe – two very different vehicles used by two civilisations on opposite sides of the world – the Sumerians and the ancient Polynesian islanders. They harnessed the power of animals and the wind respectively to take them to new places for trading and for warfare. From there, *Transported* takes us quickly into the Industrial era and beyond, where vehicles developed rapidly, and we begin to see steam-driven boats, trains, aircraft, deep-sea submersibles, rockets and finally extraterrestrial robotic explorers.

Each vehicle gets a full spread to itself plus one of Rui Ricardo's stunning illustrations conveying an appropriate scene: a farmer happily ploughing his field on a tractor, a masked tank commander on a grim World War I battlefield, the glinting brass of the first fire engine as it speeds to an emergency and many more. Along with some history, facts, stats and details of its technology, there's a box about how each vehicle changed the world, in case that wasn't already obvious. Even when it is obvious, like with the Wright brothers' first flight, Matt Ralphs always has some pithy insight into exactly what made it so revolutionary.

"A wide range of driving, floating and flying vehicles"

It's a fun coffee table book just to look at, let alone to pore over and carefully digest. So despite being pitched at ages seven and upwards, we can easily imagine younger children enjoying *Transported* as much as adults.

POWERED BY PLANTS

BOTANY THAT INSPIRES EVERYDAY TECHNOLOGY

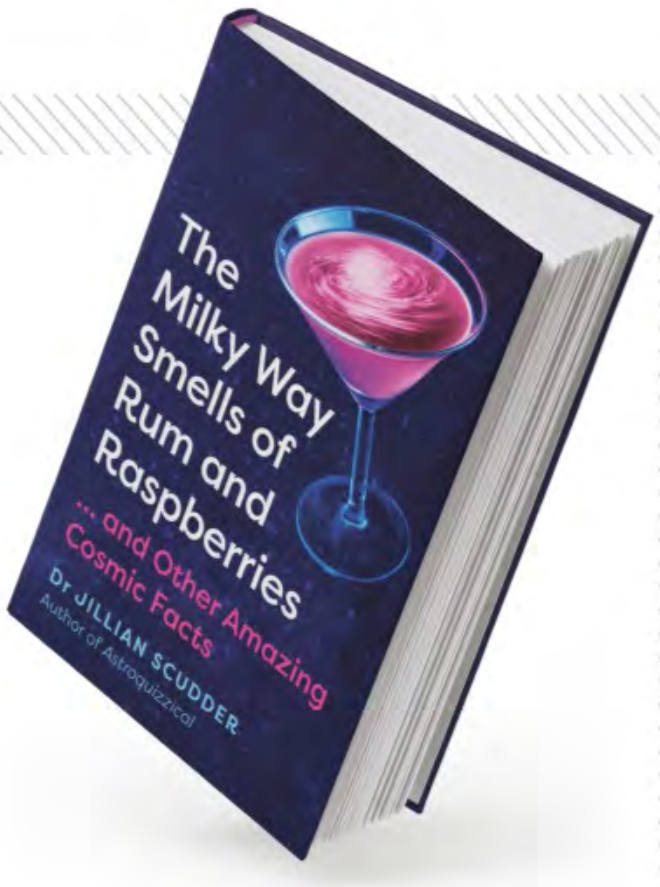
AUTHOR **CLIVE GIFFORD**
ILLUSTRATOR **GOSIA HERBA**
PUBLISHER **WIDE EYED EDITIONS**
PRICE **£14.99 / $24**
RELEASE **2 AUGUST**

Did you know that sycamore seeds inspired scientists to develop air-quality-monitoring robots or that coconuts are teaching researchers about earthquake-proofing buildings? These are just some of the fascinating examples of how plants have not only helped the human race throughout history but how they continue to supply answers to questions that scientists and engineers are asking. Although *Powered by Plants* is targeted at a younger audience, it covers a broad range of scientific topics – some more complex than others. It's a great example of how you can inform a young audience about innovations in science without completely dumbing down the principles or explanation of how things work. A good STEAM children's book isn't complete without fun illustrations to sit alongside the science – and this one certainly doesn't disappoint. This is a light-hearted and informative children's book to inspire the next generation of scientists and engineers alike.

THE MILKY WAY SMELLS OF RUM AND RASPBERRIES

AND OTHER AMAZING COSMIC FACTS

AUTHOR **JILLIAN SCUDDER**
PUBLISHER **ICON BOOKS**
PRICE **£12.99 / $22.95**
RELEASE **3 NOVEMBER**



Space is full of things that humankind still doesn't understand or hasn't discovered yet, and what we do understand can seem downright weird. For example, black holes sing at a super-low B-flat, it rains iron on some brown dwarf stars and the centre of our galaxy smells like rum and raspberries. It's these oddities in space that astrophysicist Dr Jilian Scudder has revealed in this humorous, witty and fascinating book. Short and concise chapters make this book a great read for anyone interested in science or someone intrigued about the universe who doesn't want to take too deep a dive into the world of astrophysics.

A particularly amusing feature of this book are the footnotes. Scudder uses the traditional bibliography to inject some welcome humour, witty commentary and fun facts to the format. This book is both a pleasure to read and is guaranteed to improve your knowledge of space, whatever level that is. If you only pick up one book about space this year, then it

NEIL ARMSTRONG

THE BOY WHO WENT TO THE MOON

AUTHOR **MARIA ISABEL SANCHEZ VEGARA**
ILLUSTRATOR **CHRISTOPHE JACQUES**
PUBLISHER **FRANCES LINCOLN**
PRICE **£9.99/ $15.99**
RELEASE **OUT NOW**

The most famous images of Neil Armstrong are the photographs of him stepping onto the Moon – the first person in history to do so. His name will remain in the history books forever, but how did Armstrong come to be this famous figure? This book, as part of Vegara's Little People, Big Dreams series, helps young children view Armstrong as a young person with big ambitions and wasn't too different from themselves. As a young boy in Ohio, Armstrong was fascinated with flight after an early experience at the Air Races. From that ignition of inspiration to the moment he earned his pilot licence and took his dreams to new heights, this book demonstrates to young readers how far interest and ambition can take you.

Not many good stories come without overcoming trials, and Armstrong earned his fame through persistence and bravery. During both his time working as a pilot in the Korean War and through his most scary moments in spaceflight, the story of Armstrong is one of courage and dedication.

Each of these key moments in Armstrong's life is beautifully depicted in educational, cartoon-style illustrations, while the latter pages present real photographic depiction of the man himself. Armstrong's footprints on the Moon are illustrated as the final image in the story. These remain in place there today, as a symbol of his long-standing achievement. After reading this gripping true story, readers may be filled with inspiration to follow their own dreams and leave their own footprints.

SUPER ANIMALS: THE LOUDEST

GREATEST SOUNDS IN THE ANIMAL KINGDOM

AUTHOR **REINA OLLIVIER AND KAREL CLAES**
ILLUSTRATOR **STEFFIE PADMOS**
PUBLISHER **CLAVIS PUBLISHING**
PRICE **£14.99 / $19.95**
RELEASE **OUT NOW**

These nine animals are all different shapes and sizes and have a range of habitats and groups, but all of them share one thing in common: they all know how to make a racket. So what's the difference between these noises? How are these sounds produced and why are they made in the first place? This book in the Super Animals series provides fascinating facts about some of the planet's loudest animals. They include the African lion, rooster, cicada, donkey, common frog, black howler monkey, European green woodpecker, pistol shrimp and tawny owl.

Most will be familiar with the noises of some of these, but did you know that pistol shrimp can create bubbles as hot as the Sun that explode with a deafening boom? Or that donkeys make a braying sound for up to 20 seconds at a time? Each animal has a double page filled with detailed illustrations of their body parts and key facts and stats. This helps the reader fully understand the lives of the animals before learning about their sounds. Each loud sound is explained from the animal's point of view, personifying the animals and helping the reader relate to them. The lion explains that it roars to establish who is boss, while the rooster describes its warning 'cackle'.

BRAIN GYM

Give your brain a puzzle workout

Sudoku

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

EASY

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

MEDIUM

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

HARD

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

Word search

Find the following words

STINK
KING
ASCEND
GAME
AUTOMOBILE
COMET
ETHANOL
WOBBLE
DNA
BOX
VENT
SOUND

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

What is it?

Hint: Most people have ten of these

A

Spot the difference

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

Answers

Find the solutions to last issue's puzzle pages

Q1 850 MILLION
Q2 LOVELINESS
Q3 400 BCE
Q4 NUCLEUS
Q5 105,700 LY
Q6 20

What is it?

LIGHT BULB

Spot the difference

QUICKFIRE QUESTIONS

Q1 How far is red supergiant Betelgeuse from Earth?

- 600 billion miles
- 600 light years
- 6 million light years
- 600 million light years

Q2 What part of the body do dogs mainly sweat from?

- Tongue
- Back
- Paw pads
- Anus

Q3 Which structure can be seen from space?

- Burj Khalifa
- Great Wall of China
- Great Pyramid of Giza
- None of them

Q4 How many years separate dinosaurs from humans?

- 42
- 1 million
- 64 million
- 1 billion

Q5 How long is the average memory of a goldfish?

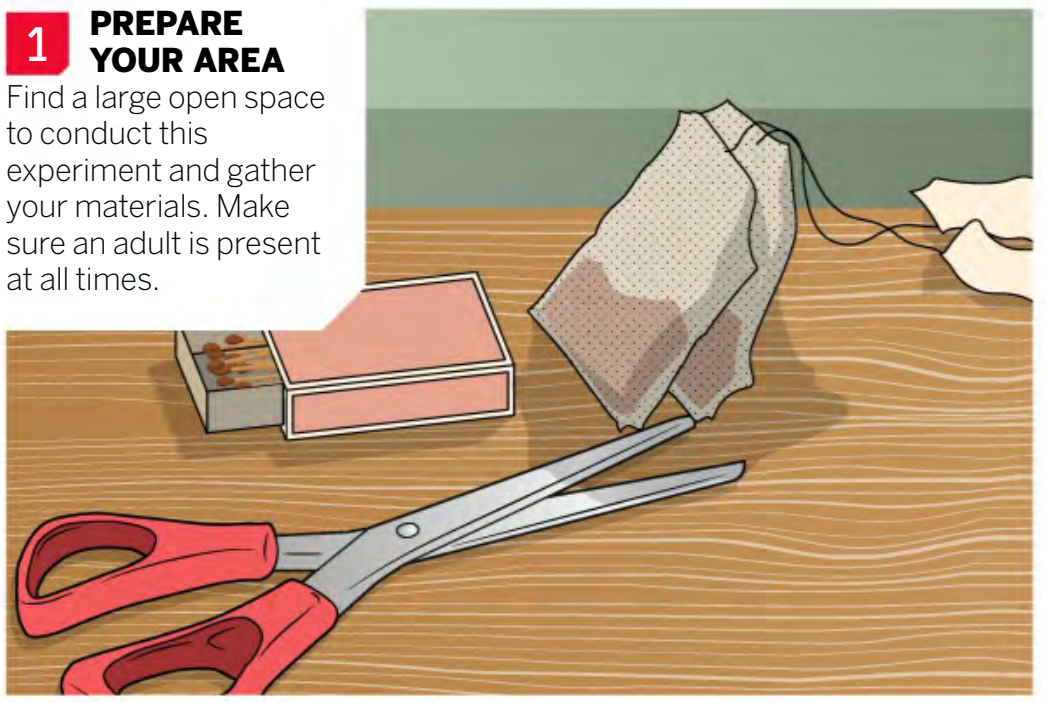
- 3 seconds
- 20 seconds
- 20 hours
- 3 months

Q6 Which letter doesn't exist in the periodic table?

- X
- J
- Z
- Q

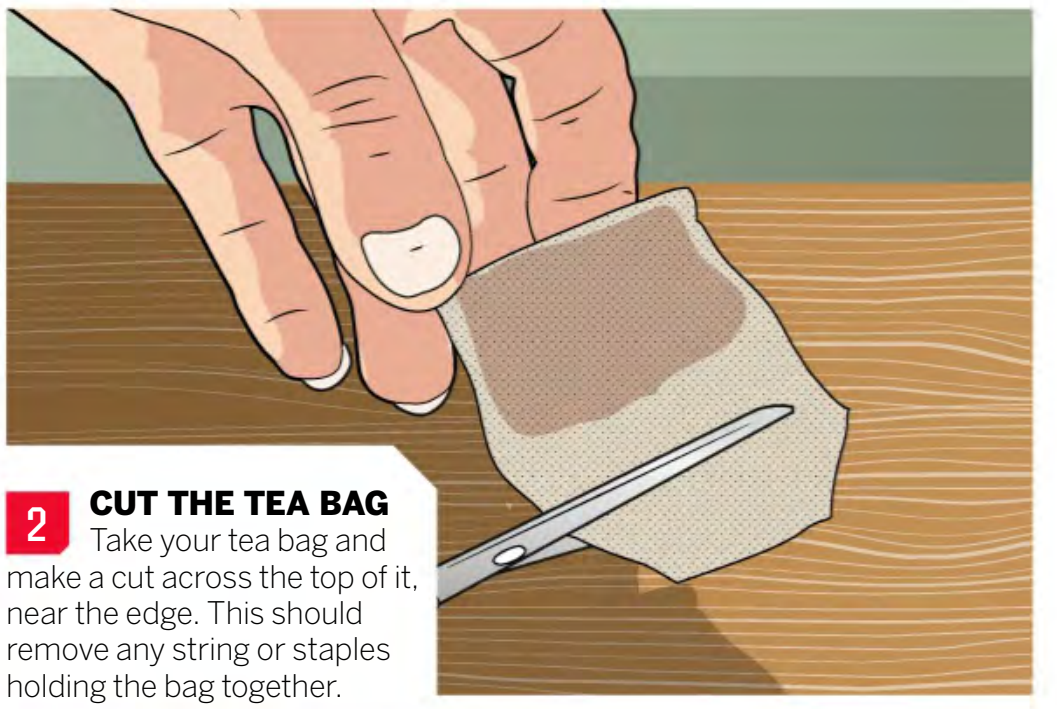
MAKE A TEA BAG ROCKET

Learn about thermodynamics as you watch the tea bag fly



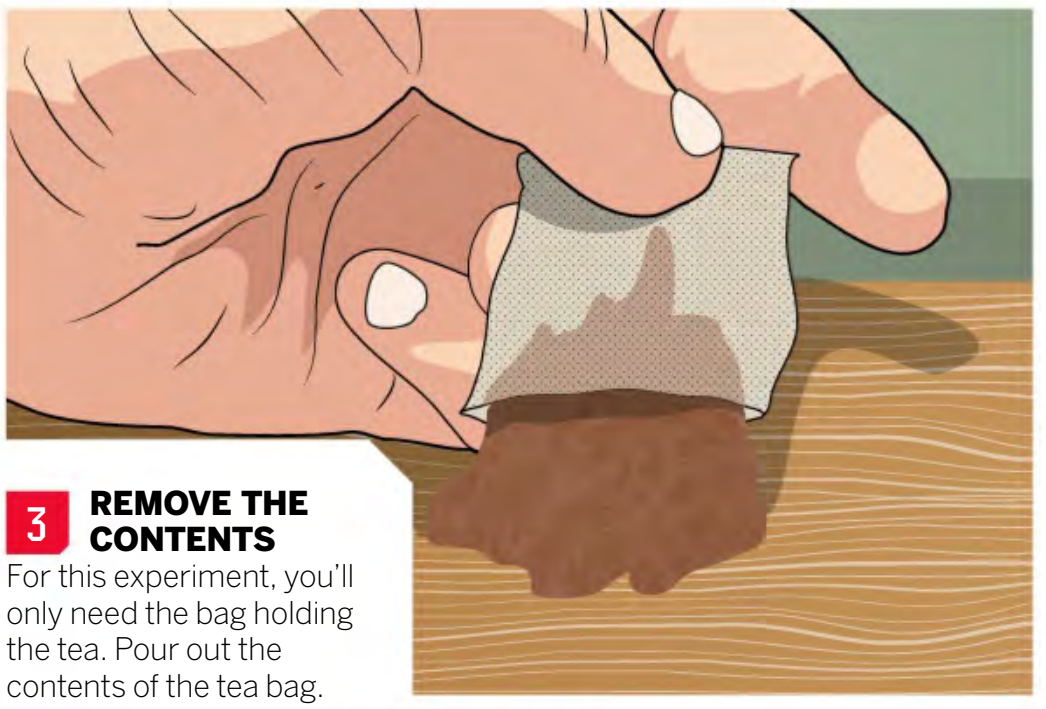
1 PREPARE YOUR AREA

Find a large open space to conduct this experiment and gather your materials. Make sure an adult is present at all times.



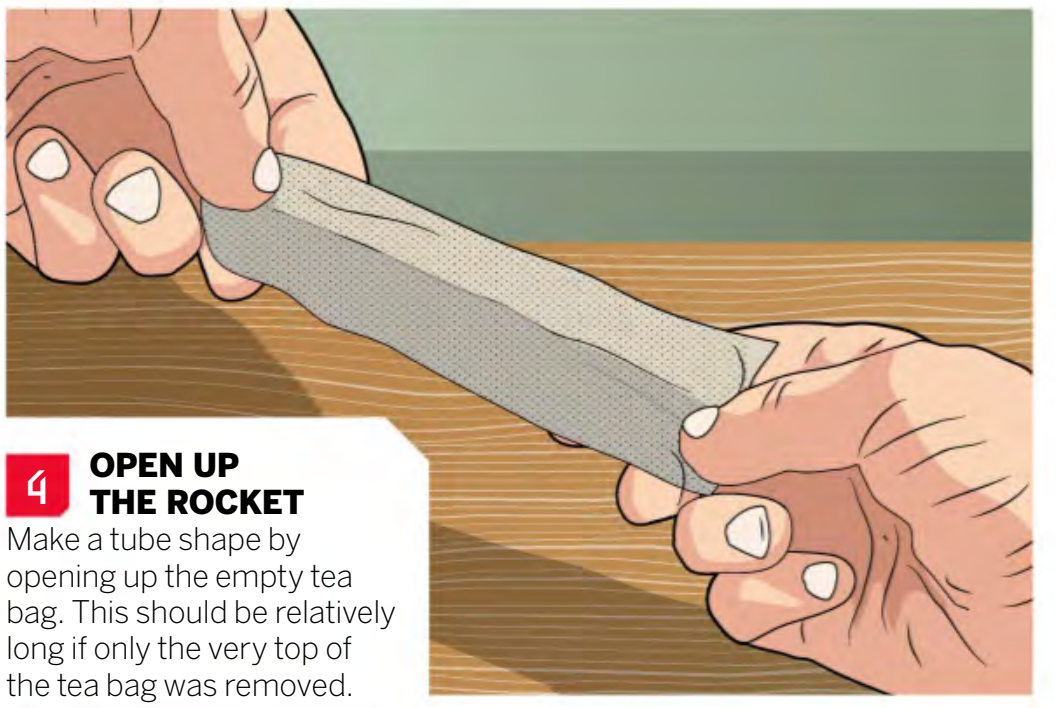
2 CUT THE TEA BAG

Take your tea bag and make a cut across the top of it, near the edge. This should remove any string or staples holding the bag together.



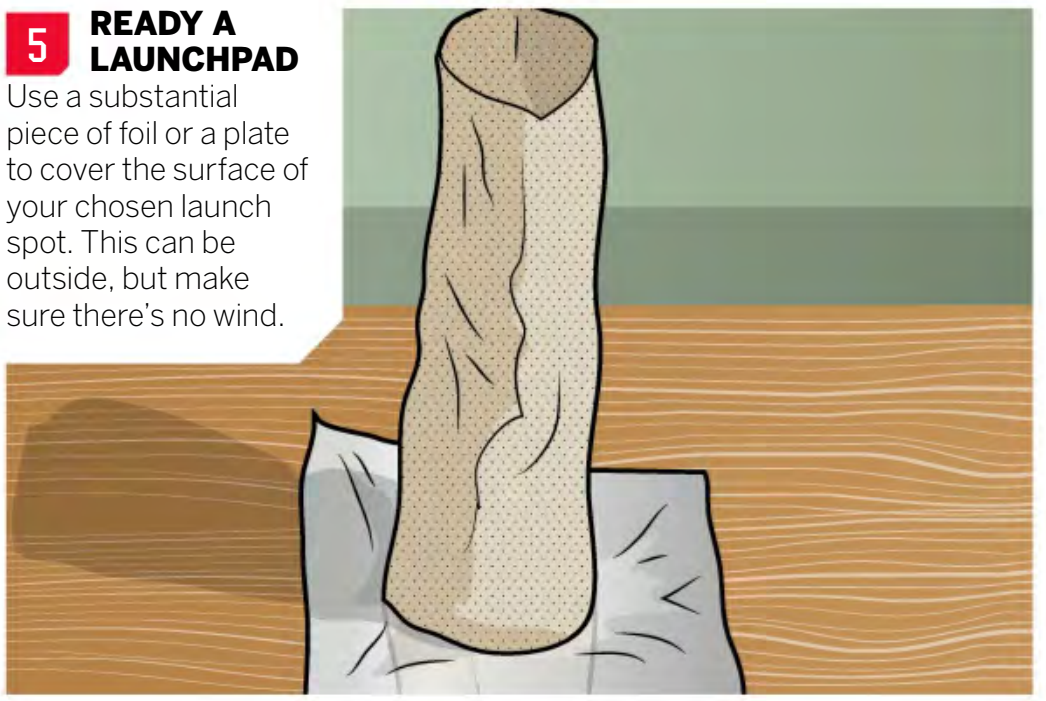
3 REMOVE THE CONTENTS

For this experiment, you'll only need the bag holding the tea. Pour out the contents of the tea bag.



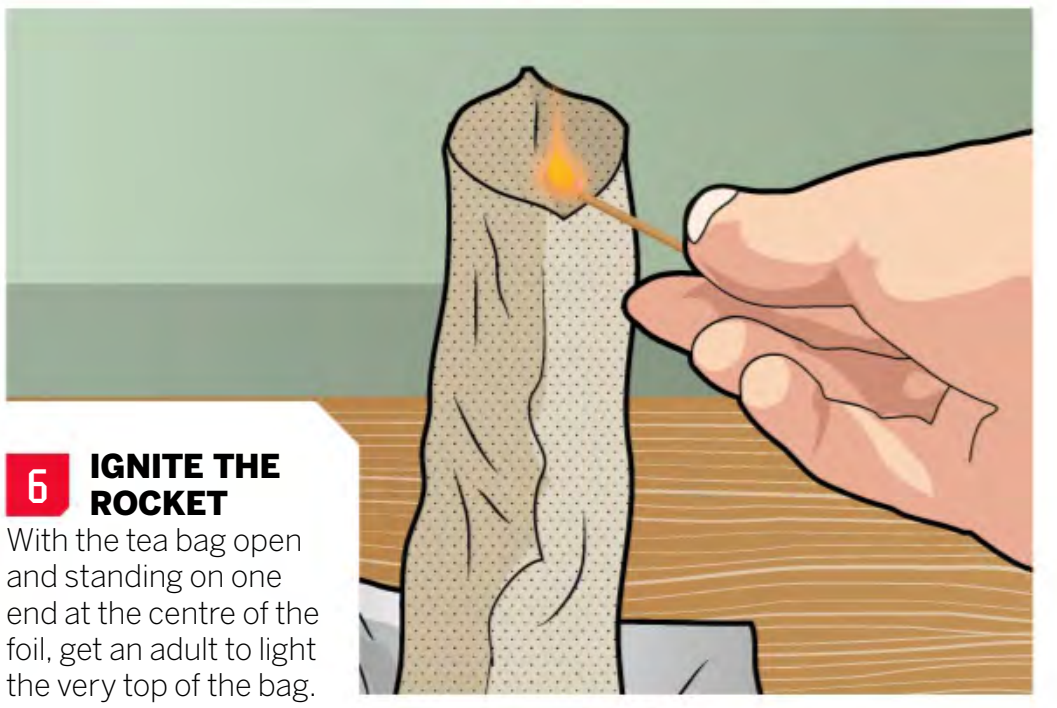
4 OPEN UP THE ROCKET

Make a tube shape by opening up the empty tea bag. This should be relatively long if only the very top of the tea bag was removed.



5 READY A LAUNCHPAD

Use a substantial piece of foil or a plate to cover the surface of your chosen launch spot. This can be outside, but make sure there's no wind.



6 IGNITE THE ROCKET

With the tea bag open and standing on one end at the centre of the foil, get an adult to light the very top of the bag.

KIT LIST

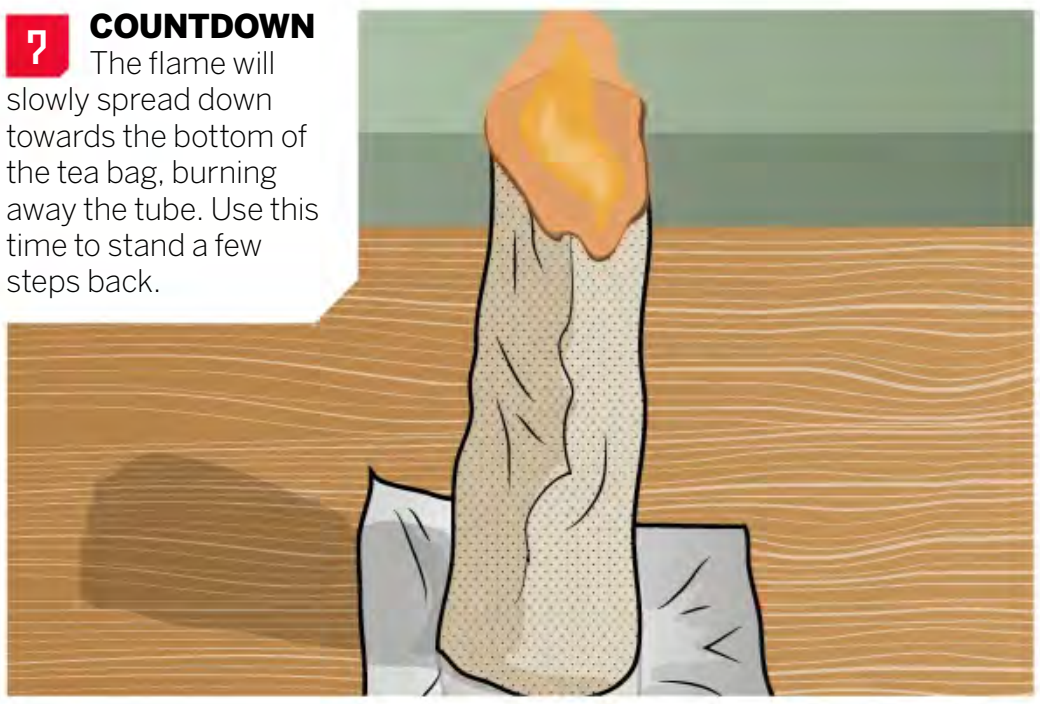
- Tea bag
- Scissors
- Metal foil or a large metal or ceramic plate
- Matches or lighter

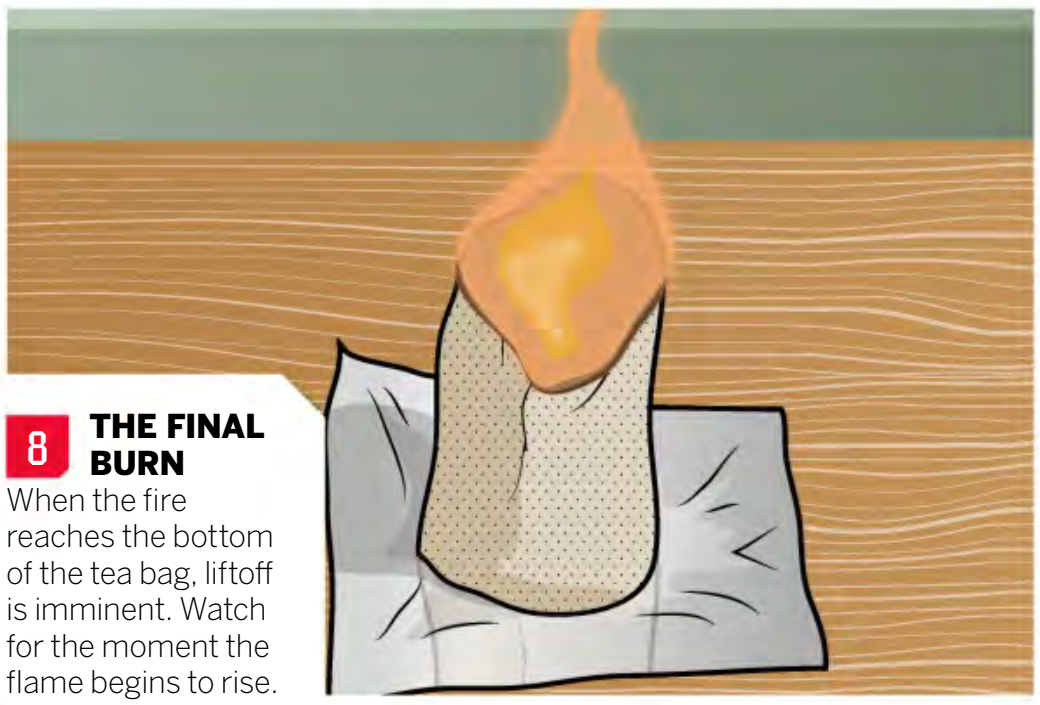
DON'T DO IT ALONE!

If you're under 16, make sure you have an adult with you

7 COUNTDOWN

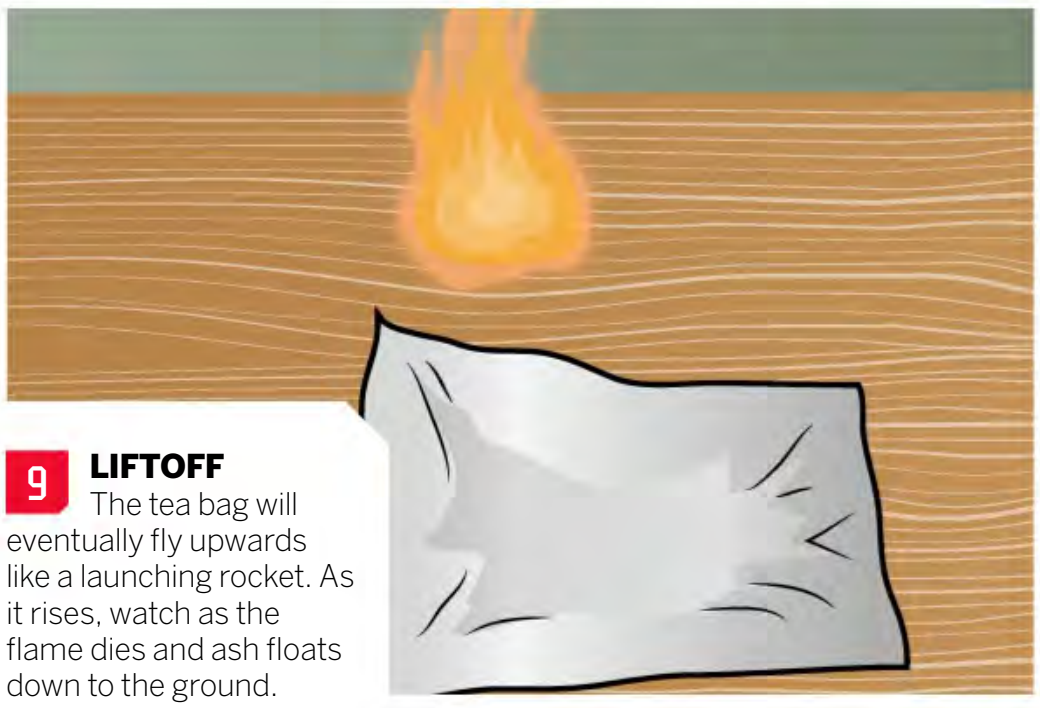
The flame will slowly spread down towards the bottom of the tea bag, burning away the tube. Use this time to stand a few steps back.





8 THE FINAL BURN

When the fire reaches the bottom of the tea bag, liftoff is imminent. Watch for the moment the flame begins to rise.



9 LIFTOFF

The tea bag will eventually fly upwards like a launching rocket. As it rises, watch as the flame dies and ash floats down to the ground.

SUMMARY

How does setting a tea bag alight propel it upwards? It's all due to how heat impacts the surrounding air. As the flame heats the air molecules inside the tea bag, they become more energised and move around faster. As they move, they spread apart and move up and out of the tea bag. Because the air molecules are being lost from inside the bag, the density of the air is reduced.

Relative to the denser air surrounding the tea bag, the tea bag itself becomes lighter. The air inside the bag starts to rise above the cooler air outside of it, carrying the tea bag with it. The tea bag continues to burn, producing lightweight ash. Eventually the bag will be completely burnt and the fire will run out of fuel. With little to no wind, the ash should fall back onto the tinfoil launchpad mat you prepared beforehand.

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.

INBOX

Speak your mind

CAMERA MAGIC

Dear **HIW**,
We can't see infrared rays with our naked eyes, but when we use a phone camera we can see the infrared coming out of the TV's remote control. Why is it so?
Xiuping

The infrared light from a TV remote can't be seen with the naked eye

Our phones' cameras can make the invisible visible when it comes to the light spectrum. We often think of light as just what our eyes can see, as this is the visible light we experience daily. But there is so much more in the spectrum of light that our eyes are unable to detect. This is because only certain wavelengths can excite our eyes' light receptors and create an image. Infrared light and other invisible wavelengths have uses in technology, and as you mention, infrared light is used in television remotes for wireless communication with the device. Different pulses of infrared light are emitted when different buttons are pressed as instructions for the television. This light can be picked up by sensors in our phone cameras and digital cameras – try pointing your camera at the top of the remote as you press a button.

Cameras are able to display this light because their sensors are more sensitive than the human eye and can detect wavelengths outside of the visible spectrum. However, some phones have an infrared filter over the lens. If you are unable to see flashing lights when you film your remote control's diode, this is because the phone manufacturer has added a filter to block out infrared wavelengths. This feature helps to cancel out interfering wavelengths and make images clearer to better resemble what we are used to seeing with our eyes.

LETTER of the MONTH

WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

TRANSPORTED: 50 VEHICLES THAT CHANGED THE WORLD

Read about some of the most iconic vehicles in history and the impact they had

SPACE TRAVEL DAMAGE

Dear **HIW**,
Isn't conducting space research coming at a huge cost to the environment? And shouldn't people who unnecessarily go into space for pleasure be seen as environmental abusers?
Stephen

It's no secret that space launches have a high carbon footprint due to the burning of rocket fuel. However, aerospace companies are working to make space exploration damage as minimal as possible through reusable rockets and liquid hydrogen fuel. The latter produces a less detrimental water vapour exhaust. Rocket engines also release gases into Earth's upper atmosphere which can contribute to damage in the ozone layer. This being said, it's worth remembering the many other contributing factors to environmental damage that occur every day. Launches for space exploration and tourism occur much less frequently than the 100,000 aeroplane flights which depart daily, with many of these carrying passengers who are travelling for pleasure.

A trip into space currently costs upwards of hundreds of thousands of dollars

SACRED SPECIES

Dear **HIW**,
When I went to India I noticed that there were many monkey temples. I found out monkeys were a sacred animal there, but how did different animals become sacred in different religions or countries?
Nienke Hoebeek

Sacred animals date back to very ancient civilisations and usually relate to animals that are native to a particular country. Many religions with sacred animals believe that a god is represented as the animal. This can sometimes arise due to behavioural traits that have been observed in the wild. Hinduism, Buddhism and Christianity are just some of the modern religions that have sacred animals.

Monkeys at a temple in Jaipur, India

NEXT ISSUE ISSUE 168 ON SALE 1 SEP 2022

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One tree can be used to make over 60 books

TREES TO BOOKS

Dear **HIW**,
I am an avid reader and always think about how the pages I'm reading were once trees. How are trees turned into books?
Elis Gorman

The process of making paper from trees is a relatively long one. First trees are cut into transportable lengths to be taken to a factory for processing. Machines strip the bark off the trees first, before wood chippers reduce the logs into thin pieces. Next, the wood is boiled to make a thick paste and chemicals are added for extra strength. This is flattened by rolling machines, and any remaining water is squeezed out. Small lumps are also smashed to maintain an even consistency. Finally, this smooth wood mixture is dried and cut into thin sheets to make paper.

Reader Ian Baird shared his copy of **How It Works** with his daughter

YOUNG FAN

Dear **HIW**,
Starting her early on issue 162
@IanBaird475

Thank you to Ian for sending this adorable photo to the team. We always love to receive images of our readers enjoying the magazine and were happy to see one of our youngest readers so engrossed in Formula 1 tech. It's never too young to start learning!

WE ASKED YOU

This month on social media, we asked you: If you could travel to any point in time or space, when and where would it be?

@DARYA.7.7.1991
When Einstein was alive so I could be his student

@VIKRAMLOVESFITNESS
I would travel to 65 million years ago to see what really happened to the dinosaurs

@TIRA.__.MISU
When Mozart was alive so I could listen to him perform to better understand his music

@SAMMY.GLANFIELD
1,000 years ahead

@HEATHER_BIRCH16
The UK, 20 years from now

@M.CAMM
Big Bang or when the pyramids were built

@JOSHDIXON2806
The Big Bang

HOW IT WORKS

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FAST FACTS

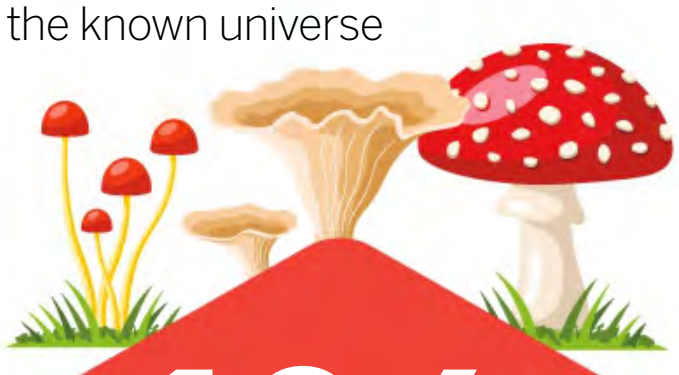
Amazing trivia that will blow your mind

F

All house flies buzz in the same musical key

50 BILLION

There are billions of galaxies in the known universe



1%

A small part of our genetic makeup comes from plants or fungi

1922

It's 100 years this November since King Tutankhamun's tomb was discovered

$200 BILLION

What natural disasters cost the US in 2021

KILLER WHALES ARE ESSENTIALLY VERY BIG DOLPHINS

6,363 MILES PER HOUR

NASA's X-43A scramjet set a record when it achieved Mach 9.6 in 2004

1.2 billion

The estimated number of computer viruses circulating in 2021

HOT WATER FREEZES FASTER THAN COLD WATER

FOUR KILOGRAMS

An elephant tooth can weigh as much as a newborn human

Google's name is a spelling error – it was supposed to be named Googol

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Honor Miles,
Apprentice Agricultural Service Technician

9001

9000